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16th South-East Asia Congress of Medical Physics

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A Sustainable Future for Medical Physics

Book of Abstracts

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PREFACE

AOCMP and SEACOMP are both important annual events in medical physics in the region. The objective of the congress is to gather the medical physics and allied health professionals in the region for the sharing of knowledge, expertise, scientific discussions, cultural exchange and medical technologies updates. This is the second time Malaysia is given the honour to host this event after year 2004. The congress is expected to attract more than 400 participants from the professions of medical physics, biomedical engineering, radiology, radiotherapy, nuclear medicine, radiation protection, biophysics, radiobiology and the related fields.

The theme for this congress is "A Sustainable Future for Medical Physics". We have put forward a comprehensive scientific programme including orations, talks by eminent speakers, oral paper presentations, poster presentations, lunch symposiums, panel discussions and some pre-congress workshops that cover most of the disciplines in medical physics, i.e. diagnostic and interventional radiology, nuclear medicine, radiotherapy, radiation protection, radiobiology and new emerging techniques. We also look forward to promote collaboration between the various disciplines and our regional partners.

This book of abstracts is divided into four sections, I) plenary/invited speakers' abstract - 81 abstracts, II) presenters' abstract (Therapy) - 139 abstracts, III) presenters' abstract (Imaging) - 99 abstracts and IV) presenters' abstract (Radiobiology, Radiation Protection and Others) - 65 abstracts. A total of 384 abstracts are published in this 398-page book of abstracts. To ease all participants to search for abstract, an index of first authors with the respective page number and arranged in alphabatical order is provided at the end of the book.

SECTION I

PLENARY/INVITED SPEAKERS ABSTRACT

Establishment of DRL in Pediatric CT in Saudi Arabia: Lessons Learned

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The establishment of a national diagnostic reference level (DRL) for different diagnostic imaging procedures has been recommended to evaluate the practices and to optimize radiation safety of patients. The presentation will show how the study in establishing the DRL for pediatric CT procedures in Saudi Arabia was undertaken in the five regions namely: North, South, East, West and Central regions. The study covered age groups 0, 1, 5 and 10 years old both males and females. The DLP values taken from patient records were used and analyzed for dose variation and in establishing the DRL. The DRL value was calculated using the third quartile of all the DLP values. The aim of the study is to recommend a national diagnostic reference level for four age groups in common pediatric CT procedures as an approach for dose optimization. The presentation will also deal with the difficulties and problems encountered that affected the DRL values and the recommendations to improve safety of patients.

DRL in Diagnostic Radiology in Middle East Countries

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The Middle East region has 12 countries that are members of the Middle East Federation of Organizations in Medical Physics with Saudi Arabia having the greatest number of medical physicists. There are more than 20,000 diagnostic radiology procedures being performed annually in middle east countries. Radiation safety practices in these countries follow the IAEA and other international recommendations including establishment of diagnostic reference dose levels. National authorities of each country adhere to the recommendations regarding the establishment of diagnostic reference levels in diagnostic radiology. However national regulations enforcement on establishing DRL in diagnostic radiology is in the neophyte stage. Efforts are being exerted by local medical physicists to establish local DRL in their institutions which are being recommended to national authorities consider for establishing a national DRL. In Saudi Arabia alone, studies are being undertaken with the support of the national regulatory agency to establish a national DRL. The presentation will show the developments in developing DRLs in diagnostic radiology in middle east countries from local to national level.

Women in Medical Physics in the Republic of the Philippines

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Women medical physicists in the Republic of the Philippines are employed in both government and private institutions. They work mainly in radiation oncology and radiology departments of hospitals and in the two national radiation regulatory agencies of the government. They are treated equally as their male counterparts and occupy professional level positions such as medical physicists, health physicists, and science research specialists. The highest government position ever held by a Filipino medical physicist, who happens to be a woman, is Assistant Secretary of the Department of Health. Except for three women medical physicists who studied in other countries, all the women medical physicists received their graduate education in medical physics at the University of Santo Tomas in Manila, the only university in the country offering the master's degree course in medical physics. Most of their undergraduate degrees are BS Physics, BS Applied Physics, and BS Physics for Teachers. This paper presents relevant information about women medical physicists working in the Republic of the Philippines. Data on those who work overseas are not included in this paper.

Resting State Functional Magnetic Resonance Imaging (rsfMRI): Theory and Data Analysis

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Resting-state functional magnetic resonance imaging (rsfMRI) is an fMRI experiment conducted on subject who is at rest. It does not require stimulus presentation to, or task performance by the subject. Instead, subject remains calm with eyes fixed at fixation point or closed. It is commonly used in studying default mode network (DMN), a distinct brain system that is activated when an individual is at rest. Most rsfMRI studies focused particularly on the effective connectivity between the DMN regions or nodes. This can then be extended to group studies. One example is characterizing connectivity differences between normal and experimental/interventional groups. This presentation provides the theory and data analysis for modelling the effective connectivity between the DMN nodes using rsfMRI data. The pre-determined nodes were the posterior cingulate cortex (PCC), middle pre-frontal cortex (mPFC) and bilateral inferior parietal lobes (IPL). The extent of activation of the DMN nodes was obtained using statistical parametric mapping (SPM) while the effective connectivity among the coupled nodes was estimated using spectral dynamic causal modelling (spDCM). The aim of spDCM is to model the random neuronal fluctuations that cause the resting state activity in each node. The outcome of the modelling is the optimum connectivity among nodes that explains the observed data.

From Radium to Radium

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In 1902 Pierre and Marie Curie isolated 0.1g of pure radium chloride from almost 3 tons of pitchblende mineral ore. This led to a diverse range of uses for radioactivity. Whilst some early industrial and medical applications seem unbelievable today, leading to disasterous human consequences, further scientific studies led to the medical speciality of radiotherapy. Over 100 years later Ra-233 in the form of radium dichloride (Alphardin or XofigoR) is having a major impact on the treatment of metastatic carcinoma of the prostate. This presentation will outline the events that occurred in this remarkable medical story.

Development and Future Prospect of Hand-held Gamma Camera

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Since the development of the Anger gamma camera in the 1950s the scientific basis for clinical gamma imaging remained the same for over 50 years. More recently, advances in technology and instrumentation have allowed the production of a new generation of clinical cameras based on new detector technologies. These advances have enabled the development small field of view (FoV) gamma cameras offering new possibilities for small organ, bedside and intraoperative imaging. Whilst the major equipment manufacturers have concentrated on the development of large hybrid imaging systems such as PET-CT and SPECT-CT a small number of academic institutions have produced compact SoV systems. A collaboration in the UK between Professor John Lees at the University of Leicester and Prof Alan Perkins at the University of Nottingham has resulted in the development of a hand-held hybrid gamma-optical camera of weight approximately 1kg. This comprises a 0.5mm thick CsI(Tl) columnar scintillator coupled to an electron multiplying CCD. A pinhole collimator produces a 40x40mm nominal FoV with optical camera providing coaligned images with the same FoV as the gamma camera. Images are taken simultaneously and presented in a fused display. Clinical trials have demonstrated that the compact size and fused display makes these compact systems ideal for surgical use, where optical information can aid the physical localisation of radiopharmaceutical uptake, such as in sentinel node detection. The development and future prospects for these systems will be reviewed.

Moly Meltdown: Worldwide Supplies of Mo-99

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The speciality of nuclear medicine involves the daily production of radiolabelled molecular tracers for medical diagnosis and treatment. Approximately 80% of diagnostic nuclear medicine procedures are carried out using Tc-99m radiopharmaceuticals. To undertake this work clinical services rely on the secure supply of Mo-99 in the form of the Mo-99m/Tc-99m generator. Mo-99 is a thermal fission product of Uranium-235. The majority of the global supplies of Mo-99 for nuclear medicine is produced by the irradiation of uranium target plates in a small number of nuclear research reactors mainly in Europe, South Africa and Australia. Most of the reactors used to produce medical grade Mo-99 are over 40 years old and supplies have been disrupted due to reactor faults and material processing problems. The closure of one of the largest production sites at Chalk River in Canada in 2017 placed additional pressure on global the supply chain. The issues around the ongoing security of supplies including changing to low enriched uranium targets, the economics of the supply chain and the development of alternative production technologies will be reviewed. Alan Perkins is the UK representative on the High-Level Group for Medical Radioisotopes (HLG-MR) which is organised by the Nuclear Energy Agency of the OECD in Paris.

Principle of Internal Dosimetry Measurement

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The ultimate goal of radiopharmaceutical internal dosimetry is to develop a method whereby the radiation doses to the organs of a specific patient may be estimated, rather than those of a standard phantom. As more and more therapeutic applications of radiopharmaceuticals are developed, patient-specific dosimetry will be needed to estimate both the probabilities of tumor control and of complications arising in normal tissue, as is standard practice in external beam radiation therapy. Patient-specific radiopharmaceutical dosimetry requires two sets of information: patient-specific biokinetic data for the radiopharmaceutical of interest and a three-dimensional voxel phantom conforming to the individual patient to derive S factors by means of the usual Monte Carlo approach. The former is easily obtained by administering a tracer dose to the patient and by using normal imaging and excretion data to develop an individual biokinetic model. The latter must be obtained by digitizing magnetic resonance or computed tomographic (CT) images of the patient. The MIRD schema has provided an effective, uniform approach to the traditional issues of radiopharmaceutical dosimetry, and it will continue to form the foundation for enhanced dosimetry applications.

Medical Physics Education and Clinical Training in Thailand

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In Thailand, the education and clinical training had been established since 1972 until now for the 2 year graduated program, M.Sc. in medical physics and related fields. In 2018, there will be 5 M.Sc. programs and one Ph.D. program in Medical Physics. The two year clinical training in medical physics for sub specialty in radiation oncology, diagnostic radiology and nuclear medicine was started one by one in 2007 and completed all in 2014. E-Learning in clinical training of medical physics started in Feb 2016 using IAEA Curriculum for ROMP, DRMP and NMMP simultaneously. The program is progressing as planned at the orientation. Residents are competence in several topics they had no experienced earlier. The final assessment consists of the written examination, oral and practical assessments. Residents submit 6 month progress report, 3 assignments at 8 month period. All residents conduct a small research and present the research work at the scientific meeting of professional society. The abstract and full paper of the should be submitted. At the end of clinical training, the successful residents will work as clinically qualified medical physicists independently. They can train other young medical physicists and be able to strengthen medical physics in Thailand.

Woman in Medical Physics in Thailand

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Medical physics is established in 1959 at Siriraj Hospital, Mahidol University, Bangkok, Thailand. The first medical physicist was Associate Professor Ms. Pradab Atthakorn at Section of Radiotherapy. The number of woman in medical physics was increasing when Section of Radioisotopes was started at Siriraj Hospital. Women graduated Bachelor of Sciences in Physics with major in nuclear physics, solid state physics or electronics were selected to work at the university hospital with radiotherapy and nuclear medicine. In general, there were more women working in the hospital, the opportunity of women working in many department is a little higher than man. In 2002, Thai Medical Physicist Society is established. Currently, the ratio of woman to man member is 56 to 44. Number of woman with Ph.D in Medical Physics equal to man in all tracks but the number of woman with M.Sc. in Medical Physics is higher than man. Number of male medical physicists is high in the field of radiation safety and in section of regulators. In conclusion, woman in medical physics has the good opportunity to work in radiation oncology, nuclear medicine and diagnostic radiology in Thailand.

Choices of SF Detectors

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Small static photon fields is challenging due to a number of challenges such as lack of lateral electronic equilibrium, source occlusion, high dose gradients, and detector volume averaging. This has become more apparent with a rapid increase in the number of treatment machines that deliver static photon fields which such as stereotactic radiotherapy (SRT), stereotactic body radiotherapy (SBRT), stereotactic radiosurgery (SRS) and intensity modulated radiation therapy (IMRT). The new IAEA-AAPM dosimetry of small static fields Code of Practice (CoP) provides recommendations for measurements and updates on recent commercial detectors on the market. It is recommended that detectors with a small volume and tissue equivalent are best suited for small field dosimetry. Field output factors were measured with ionization chambers and diode detectors for small photon beams and corrected for volume averaging and detector density perturbation effects using new CoP formalism. It is demonstrated for small field dosimetry ionization chambers will show underresponse due to detector cavity density perturbation effect and volume averaging of measured signal. The same density perturbation effect will cause over-response of diode detectors in small photon fields due to detector density which is higher than water. Volume averaging of measured signal prove to be significant effect leading to under-response depending on the size of detector active volume. Geometrical uncertainties associated with adjustment of detector may be critical for accurate dosimetry when measuring clinical output factors for small photon beams. Even for smallest and nearly tissue equivalent detectors readings need to be corrected for effects inherent to small photon beams when used for dosimetry of small fields. New IAEA/AAPM CoP provides machine specific beam quality correction factors and formalism for clinical output factors which includes field output correction factors. Correction factors for small photon fields are due to differences in electron density between detector active volume and water and due to volume averaging of measured signal over the detector volume. Other detectors are recommend for small fields such as diamond detectors, plastic and organic scintillators, also radiochromic film.

E-learning for Medical Physics Training in Asia: IAEA Ample

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The number of radiation medicine facilities in many Asian countries is significantly less than the required number. Recognition of this problem by governments has resulted in a rapid expansion of radiotherapy, nuclear medicine and diagnostic radiology services across the region. But in many cases, there are not enough qualified medical physicists to support the new facilities. There is an urgent need to train more medical physicists. The IAEA has supported a number of projects in Asia to strengthen the recognition of medical physicists and to support training, education and certification programs. One initiative was the development of three clinical training guides for nuclear medicine, diagnostic radiology and radiation therapy physicists. Another initiative was the creation of AMPLE – the Advanced Medical Physics Learning Environment. AMPLE is an online version of the three clinical training guides, designed to help residents and supervisors manage clinical training. AMPLE contains a number of modules for each discipline, sub-divided into competencies. Residents can submit their training evidence for each competency online where it can be reviewed and assessed by their supervisors. Each competency contains links to a variety of learning resources to help residents gain the necessary skills and knowledge. Because all the information is available online, AMPLE can help residents in regional and remote locations where there may not be a suitably qualified local physicist to provide training. AMPLE also provides communication tools to allow remote residents and supervisors to make contact with colleagues. AMPLE has been trialled in Thailand, Philippines, Bangladesh, Singapore and Indonesia and the IAEA hopes it will be adopted by other Asian countries in future. Using the IAEA framework for training will help to ensure a strong, well-educated medical physics workforce to support the ongoing expansion of healthcare services in Asia.

Data-Science-Based Radiomics

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Medicine including cancer treatment is moving toward "precision medicine," in which health care is personalized on a basis of patients' data (e.g. genes and health care records) to take into account individual variability (patient or tumor heterogeneity). However, there are several issues in the precision medicine of the cancer treatment such as invasive biopsy and slow throughput for examination of gene mutations from sampled specimens. Besides, since tumors are heterogeneous, a small part of a tumor obtained by a single biopsy could be unreliable for the precision medicine. Consequently, it could not be reasonable to practically perform the precision medicine of the cancer treatment. Therefore, the idea of radiomics has come out from radiation therapy for solving the issues and performing the "practical" precision medicine. Radiomics is a field based on data science that massively and comprehensively analyzes a huge amount of the medical images to extract a large number of phenotypic features reflecting disease traits, and to discover signatures that can predict patients' prognoses. The signatures are considered imaging biomarkers, and they are defined as vectors capsulating significant selected features as vector elements. Data science is an interdisciplinary field among statistics, pattern recognition, machine learning, data mining, data processing, data visualization, etc., to inductively discover features or hidden meaningful patterns of natural, human, and social phenomena with the vast amount of multidimensional data using computer science and domain knowledge. The purpose of data science is "learning from data" by extracting important patterns and trends, and understand "what the data says". Since the speaker believes that the data science is the key to the success of the radiomics for statistically delving into the 'dark' big medical data including the huge amounts of medical images, he will describe the basics of radiomics and data science.

Overview of Radiomics with Artificial Intelligence

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Medical doctors including radiation oncologists are keen on artificial intelligence (AI) that can support decision making in diagnosis and treatment in human-like manners. AI approaches are the computational algorithms or systems that can accurately perform high inference based on a huge number of knowledge data. At around the same time as the third large wave of AI, an idea of radiomics has come out from radiation oncology as one of feasible approaches for solving the issues in precision medicine and practically performing it based on multimodality medical images in a non-invasive, fast, and low-cost way. Radiomics is a field based on data science that massively and comprehensively analyzes a huge amount of the medical images to extract a large number of phenotypic features reflecting disease traits, and to discover signatures (radiomic biomarkers) that can predict patients' prognoses. Machine learning algorithms of AI are boosting radiomics powers for prediction or estimation of what are associated with treatment strategies such as survival time, recurrence, adverse events, and subtypes. Since a number of machine learning software are open-sourced and easy-to-use for radiation oncology staffs, this third boom of AI could be a practical phase of AI in radiation oncology. Radiomics with AI are considered "specialized AI", which may potentially provide one of practical ways for precision medicine in radiation therapy by emphasizing outcomes and reducing toxicity for individual patients.

NSD to BED-Evaluation of Radiological Models

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All the tumors are not treated with same time dose fractionation schedule and all radiotherapists do not treat similar tumors with schedules followed by others. Many fractionation schedules encounter gaps, planned or unplanned and many tumors are treated by altered fractionation schedules, combination of brachytherapy and teletherapy. Since treatment schedules are numerous and different from each other it is rather difficult to intercompare them unless they can be reduced to preferably a single number. Various concepts of time, dose and fractionation were introduced in 1950's to correlate the biological effectiveness of different time, dose factors. Many empirical models such as NSD, CRE, TDF and TSD were put forth and were used despite of their many drawbacks. The main limitation of all these time dose models is that they are too simple, so that they could never be expected to accurately represent the highly complex effects occurring in irradiated tissues. The result is that all these empirical models that have been proposed have severely limited applicability. Serious doubts have been raised concerning the validity of the NSD and relation with respect to the type of tissue involved. Abundant evidence is now available indicating that for different tissues the dependence of tolerance doses of fractionation schedules is not the same. Therefore the need for reliable dose effect relationship has increased significantly with the advent of a variety of innovative fractionation techniques. Today the most commonly used radiobiological model for quantitative prediction of time - dose dependence is linear quadratic [LQ] model and has gained popularity because it describes a mechanistically based model, with tumor control and normal tissue complications attributed specifically to cell killing. As LQ model is based on the recent radiobiological data, it is claimed to be able to predict the biological responses of tumor as well as normal tissues (early & late) more accurately. However the accuracy of prediction depends on the precise values of various parameters such as α/β, Υ/α (repopulation constant) and μ (repair constant) that are involved in the LQ model. The present communication elaborates about the limitations of empirical model and advantages of the LQ model.

Australian Radiotherapy Provider Experience in Demonstrating Compliance to Radiotherapy Practice Standards for Safety and Quality

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The professional societies representing the major staff groups in radiotherapy have developed Radiation Oncology Practice Standards (ROPS) with the support of the Australian government. These standards are freely available online at the RANZCR website https://www.ranzcr.com. The ROPS standards cover all technical and clinical aspects of radiotherapy in areas such as workforce, data management, infrastructure, safety and quality management, audits and clinical trials participation. In the state jurisdiction of Queensland, the ionizing radiation regulator called Radiation Health has adopted these practice standards and integrated these standards into conditions for a possession licence. Radiotherapy service providers must submit to the regulator documentary evidence of compliance with each of 16 standards incorporating 41 criteria in ROPS. For Icon Group, with 10 operational radiotherapy centres across Queensland, this gathering and submission of evidence is a large undertaking on top of the other radiation regulatory requirements in obtaining approved radiation management plans, independent dosimetry audits and use licences. However, the benefits to the organization of the process of demonstrating compliance to agreed practice standards outweigh the effort in terms of the resources required to develop processes and complete the work. The benefits include firstly to the patient in terms of expectation of safe and high-quality care, reputationally to Icon Group, and in job satisfaction for staff. One point that Icon Group faces in regulatory compliance is that for new radiotherapy centres that have not yet built up a record of, for example, patient treatment records, patient follow-up and incident reports, it is difficult to demonstrate documentary evidence of compliance with particular standards. Radiation Health has been accommodating in recognising these limitations.

Survey Results on Postgraduate Education in Medical Physics

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Access to radiation medicine services in nuclear medicine, radiology and radiotherapy continues to expand in the Asia region, hence the need for growing medical physics services to support continued safe and high-quality practice. According to the IAEA, one of the requirements for a clinically qualified medical physicist is a post-graduate degree in medical physics at an accredited academic institution (IAEA HHS No. 25) and the IAEA has also published a recommend syllabus for academic programmes in medical physics (IAEA TCS No. 56). However, in some Asian countries, lack of access to medical physics academic programmes hinders the development of the medical physics profession in reaching the standards recommended by the IAEA. In 2018, the IAEA initiated a regional technical cooperation project RAS6088 on strengthening medical physics services including academic programmes. Importantly, this regional project covers not just Asia-Pacific countries but also the West Asia countries. In supporting academic programmes, the RAS6088 project has firstly, through survey, captured a snapshot of academic programmes as a baseline for refining activities in the project. The current survey builds on previous surveys of medical physics capacity in the Asia region by Kron et al (APESM 38, 493-501, 2015) and by the IAEA under a previous regional project RAS6077, with more depth as to the strength of the academic programmes including their resources and structure. The comprehensive survey covers infrastructure, staffing, entry requirements, programme framework and accreditation.

From Conventional Nuclear Medicine to Thera(g)nostics

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Thera(g)nostics is a new emerging term in medical dictionary. The pioneer of the term is attributed to John Funkhouser, that the term "theranostic" was coined to define ongoing efforts in medicine to develop more specific, individualised therapies for various diseases, and to combine diagnostic and therapeutic capabilities into a single agent thus leading to a promising therapeutic paradigm involving diagnosis, drug delivery and monitoring of treatment response. With a key focus on patient-centred case, thera(g)nostics provides a transition from conventional medicine to a contemporary personalised and precision medicine approach. Thera(g)nostics is in reality, 75 years old, with the use of radioiodine (I-131) for diagnosis and treatment of thyroid cancer. In the last decade, a similar paradigm has been developed for neuroendocrine tumours and radiopeptide therapy. This type of therapy has also been used in combination with radiosensitive chemotherapy. This lecture will discuss about the current development and future prospects in thera(g)nostics, which is an exciting area that marks the future of nuclear medicine.

Medical Imaging in Radiation Therapy

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In recent years, steady progress has been made towards the implementation of MRI and other medical imaging modalities in external beam radiation therapy for processes ranging from treatment simulation to in-room guidance. This session will review the commonly used medical images and their roles in current radiation therapy. However, understand the limitations of each imaging modality is also the paramount of importance in preventing geometrical miss in radiation therapy. Special discussions will also be given to MRI in intracranial SRS, and in-room imaging guidance, IGRT for moving targets. The later will include imaging guided alignment for lung cancer SBRT, MRI guided radiotherapy, IGRT with gating and tumor tracking.

Motion Management in Radiation Therapy

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Motion management in stereotactic body radiation therapy (SBRT) is an essential component for a successful SBRT program, and still an on-going challenging task. The commonly used measures include a. the tumor motion control to reduce the magnitude of the motion; b. the radiation beam control to synchronize the irradiation with the tumor motion. If adopted correctly, the motion management can effectively reduce the size of PTV and increase the radiation dose conformity to the tumor in the hypofractionated treatments while more surrounding normal tissue can be effectively spared. Successful implementation of such requires one to 1. understand basic roles of commonly used imaging modalities for moving structures, including those in diagnostics, simulation, and treatment guidance; 2. familiarize the major advantages and limitations of gated radiation delivery techniques; 3. familiarize the major advantages and limitations of tumor tracking techniques. All of these will also define the creation of internal tumor volume (ITV) and defining the margins of planning tumor volume (PTV) in daily practice. However, in current lung SBRT practice, effective motion management still posts ongoing challenges. This session of presentations is intended to provide an overview of the current techniques used in directing radiation delivery to a moving target and discussions on the limitations in each technique as essential references in forming an effective strategy for lung SBRT.

Radiation Biology and Biologically Effective Dose

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With the advances of high precision in radiation therapy, dose escalation and hypofractionation have led the recent trend. With those changes, the need of understanding the fundamentals of radiation biology has also become increasingly important. According to classic theory, radiation induced cell death through a number of established pathways, which includes Mitotic Death, Apoptotic Death (Apoptosis step I), Autophagic Cell Death (Apoptosis step II), Autophagy, and Cell Senescence. Autophagy is a self-digestive process that uses lysosomal degradation to eradicate damaged cell organelles or unused proteins, regulated by autophagy-related genes, which triggered interests of biologists in discovery of radiosensitizing method or promotors for tumor killing. In the process, the abscopal effect refers or by stander effect may potentially play some role in overall tumor control, that is the ability of localized radiation to trigger systemic antitumor effects. To describe cell killing process by different radiation doses, alpha and betta ratio is also used in distinguishing the radiation sensitivities of different cells or tissues. In addition, diversity of modern therapeutic radiations, such as high-energy photons, electrons, protons, and other particals showed different biological effectiveness. Estimation of biologically effective dose is essential in guiding a good clinical practice, which will also be discussed in this session.

SRS/SBRT Principles

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Both stereotactic radiosurgery (SRS) and stereotactic body radiation therapy (SBRT), also called stereotactic ablative radiation therapy (SABR) are widely used in modern radiation oncology facilities. Stereotactic radiosurgery (SRS) refers to a specialized dose delivery technique used in the treatment of brain lesions. In this irradiation technique, multiple narrow radiation beams are directed at focal points resulting in the formation of very small but concentrated dose regions for the treatment of small lesions. The initial application of this treatment technique was the irradiation of intracranial lesions in single fractions without regard to the radiobiological impact of the treatment, and hence the irradiation technique was coined radiosurgery by Lars Leksell, a Swedish neurosurgeon. Because of the small field sizes and very high doses, the target must be precisely positioned within the radiation beams. The positioning was performed with the aid of the stereotactic frame system. The stereotactic frame system provides the external coordinate system for identifying the location of the lesions within the brain. Advances in imaging technology in particular the availability of helical CT scanners and image-guided radiation therapy have transformed SRS to the use of frameless system. An extension to this irradiation technique outside the brain is called stereotactic body radiation therapy (SBRT). Because SBRT is a recent application, much of the technical issues such as motion, immobilization, localization, and dose constraints on organs at risk are being addressed. The advances in accelerator technology and imaging technology have produced specialized dose delivery systems designed for SRS and SBRT and also dose delivery systems with tighter tolerances that are consistent to the requirements for SRS and SBRT irradiation techniques. This presentation will review briefly the principles of SRS and SBRT, several dose delivery systems for use with this irradiation technique, and discussion on the technical issues of localization using image-guided radiation therapy and radiation dose toxicities.

3D Treatment Planning Principles

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Computerized 3D treatment planning is an integral process in modern radiation therapy. It involves the use of large image datasets obtained using imaging modalities in particular from helical CT scanners. The advantage of 3D treatment planning has been the exquisite images, the ability to construct virtual patients, and the ability to visualize the tumors relative to the patient anatomy in three dimensions. This image-based treatment planning has additional inherent benefits including the auto-extraction of external body contours and tissue electron densities for radiation dose calculations. The tumor identification is further aided with the use of other imaging modalities such as MRI and PET through image fusion for those cases where the tumors are ill-defined on CT images. The tumors and organs at risk must be delineated and defined in accordance to the definition as specified in the ICRU Report No. 50 and Report No. 62 for treatment planning purposes. With these definitions, multi-leaf collimation systems which are integrated into modern radiation therapy dose delivery systems are used to shape the treatment fields. Treatment planning performed using computers has facilitated the process of comparing different treatment plans to arrive at an optimized treatment plan for a patient to undergo radiation therapy at faster speed. Computers have also facilitated the implementation of new treatment techniques such as conformal radiation therapy, and intensity-modulated radiation therapy which were deemed not possible previously. The focus of this presentation is to demonstrate the delineation of target volume and organs at risk processes, the shaping of treatment field processes, arrangement of treatment fields, computation of radiation doses, and the display and evaluation of dose distributions and dose-volume histograms in modern treatment planning.

Treatment Planning Strategies – CRT, IMRT and VMAT

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Computerized 3D treatment planning systems are essential components of modern radiation therapy equipment. These systems are used to generate complex treatment plans and have led to the implementation of new treatment techniques, namely conformal radiation therapy (CRT), intensity-modulated radiation therapy (IMRT), and volumetric modulated arc radiation therapy in modern radiation therapy. CRT requires the use of multiple shaped treatment fields that cross-fired to produce isodoses that conform to the 3D shape of the target volumes. The shaping of the treatment fields is aided with the use of the beam's eye view tool. The beam's eye view is a visualization tool of the field edge projected onto the target volume as seen by the observer from the radiation source. This tool is used to define the field outline relative to the target volume for block fabrication or to configure multileaf collimation (MLC) system. This shaped treatment fields are strategically placed manually around the patient to create the conformal dose distributions. Beam weights and wedges are often used in the optimization of the dose distribution. This treatment planning process is called forward planning. On the other hand, inverse-planning process is used in IMRT and VMAT. In inverse-planning, the optimization process is performed automatically by the computer dose algorithm to satisfy the dose constraints on the target volume and critical structures. The "goodness" of a treatment plan or the ability to satisfy the dose constraints is based on lowering the cost function. Because the optimization can results in multiple solutions, priorities must be assigned to improve the selection of the appropriate solution. The interest in this presentation is the discussion of the treatment planning processes both forward planning and inverse planning and the strategies in the processes of selecting the appropriate treatment techniques.

SBRT Using Tomotherapy – Way Forward

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The TomoTherapy is a technologically advanced dose delivery system and is well suited to perform stereotactic body radiation therapy (SBRT). The system is unique in the mechanical design based on a small 6 MV linear accelerator mounted on a ring gantry that rotates around the patient while the patient moves through a bore, ultimately yielding a helical path of radiation dose delivery. While it looks like a helical CT scanner on the outside, the beam intensity is modulated using a binary collimator on the inside. The specially designed binary collimator has two banks and each bank has 64 leaves with a beamlet size of 0.626 cm giving a total field width of 40 cm. The binary collimator is computer controlled with the leaves sliding in and out of the slit aperture to provide temporal beam modulation. The unit has the tight tolerances required of SBRT. In addition, the use of multiple beams spread around the patient is the needed requirements for the performance of SBRT. The helical pattern of dose delivery differentiates TomoTherapy from other contemporary radiation therapy systems at the time of its inception. Frameless systems are used for immobilization and compression system is commercially available for implementation on the TomoTherapy unit. The integrated image-guided radiation therapy system on the unit is used for patient localization. Because of the inherent properties of the unit, the tight tolerances, the use of many radiation beams, and the use of IGRT make TomoTherapy well suited to perform SBRT. The treatment time is relatively short compared to other dose delivery systems. The interests in this presentation are to briefly review the operational principles of TomoTherapy, the requirements of SBRT, the treatment planning processes, and the patient specific quality assurance for this unique dose delivery system.

The Role of the ICRP in Medicine: Past, Present and Future

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The International Commission on Radiological Protection (ICRP) is a body made up of experts in radiological protection from around the world. The Commission makes recommendations on protection in the application of radiation in a variety of fields, prepares guidelines for users of radiation, and has developed a system of dosimetry for evaluation of radiation hazards, including the recommendation of dose limits. The International X-ray and Radium Protection Committee, the forerunner of ICRP, was established in 1928 to address concerns about effects observed in radiologists and the committee produced the first recommendations on occupational protection in medicine in July 1928. As other applications of radiation developed, the field of radiological protection broadened and the commission was renamed the ICRP in 1950. Several committees were established within ICRP at this time, dealing with different types of radiation, routes of exposure, and radioactive waste, and the first official ICRP report was published in 1958. During the 1960s the potential for reducing doses to patients began to be recognised, culminating in Publication 16 entitled "Protection of the patient in X-ray diagnosis" in 1970. ICRP Committee 3 "Protection in medicine" was established in 1977 and a series of reports on protection of the patient in different areas were prepared during the 1980s. Facilitating the understanding of radiation dose and the link to potential harm by non-specialists has always been a problem, and ICRP have attempted to address this through the introduction of protection quantities such as effective dose. Committee 2 "Doses from radiation exposure" works with Committee 3 to derive coefficients that allow organ and effective doses to be calculated for a wide range of radiopharmaceuticals for use by the medical community. ICRP felt that early reports produced by Committee 3 giving practical guidance were not reaching the medical community, so their impact was limited, and the emphasis has been changed to production of shorter concise reports on specific topics. Since 2000, 24 reports have been prepared giving guidance and recommendations on areas relevant to medicine. However, a major source of ICRP income is from purchase of reports and this places a barrier to many potential users. Therefore, to mark the 90th anniversary of the founding of ICRP, the commission has launched a funding campaign with the aim of making reports available free through the internet. ICRP hope that if this step can be achieved, it will make a major difference in implementation of good radiological practice across the world.

The UK Nuclear Medicine Regulatory Framework

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UK national regulations relating to the use of radioactive materials in medicine are produced under the auspices of several government departments, each of which covers a different aspect. Requirements for radiation safety are set out in the European Commission Basic Safety Standard Directive, with which the UK must comply. The Ionising Radiations Regulations 2017 (IRR17) produced through the Health and Safety Executive cover radiation protection and dose limitation of people who are occupationally exposed, radiation protection of members of the public, and the safe use of radioactive materials. IRR17 also covers transport of radioactive materials, but this is policed by the Office for Nuclear Regulation. Radioactive Substances Regulation dealing with requirements for maintaining control over the keeping, use and security of radioactive materials, and the accumulation and disposal of radioactive wastes is overseen by the Environment Agency. It also includes the need for operators to make financial provisions for re-use, recycle or disposal of high activity sealed sources. Requirements involve obtaining permits for holding and disposal in England and Wales, with a slightly different licencing system in Scotland. The Ionising Radiation (Medical Exposure) Regulations 2017 under the Department of Health and Social Care cover medical exposures including licencing of practitioners and hospital facilities. The regulations contain requirements to set and comply with diagnostic reference levels, but do not include formal values as these are perceived to be quantities that will need to change periodically as techniques evolve. A continuing awareness of radiation protection needs and a desire to be involved with the legislative process has grown up over the years as the system moved from voluntary codes of practice to specific requirements set out in legislation. Professional groups are consulted on specific aspects of draft regulations and guidance before they are issued formally for public consultation, so that UK legislation will already have undergone discussion and debate to ensure its practicability before being enacted by parliament. Guidance notes on compliance with regulations are prepared by associated professional societies such as the IPEM with input from regulatory bodies, but the guidance, setting out methods for compliance with legislation, remains voluntary.

ICRP Proposals for Use of Effective Dose in Medicine

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Effective dose is a radiological protection quantity constructed by ICRP to provide a risk-adjusted measure of total body dose from external and internal sources. It is calculated from the weighted average of organ equivalent doses, where the weighting factors provide a simplified representation of contributions to the stochastic detriment from cancer and hereditary effects. It is based on dose-risk data from epidemiological studies of exposed populations, primarily the Japanese survivors of the atomic bombs, and assumes that the risk per unit dose is linear down to low doses. Effective dose is calculated for sex-averaged reference persons of specified ages, so while exposures may relate to individuals or population groups, effective dose only applies to reference persons exposed in the same way. Nevertheless effective dose has provided a valuable and robust quantity for use in optimisation of protection and setting of control criteria (limits, constraints and reference levels). Estimates of effective dose in medical applications are used for comparing doses from different diagnostic and interventional imaging modalities (e.g. CT and nuclear medicine) and exposure techniques that give different spatial distributions of radiation within the body tissues. However, it should not be used for medical procedures in which a single radiosensitive organ receives the majority of the dose, such as the breast in mammography, or the thyroid from administration of radioactive iodine. Effective dose provides a generic indicator for classifying medical procedures into broad risk categories. It can be used not only prospectively to inform decisions on justification of patient diagnostic and interventional procedures and planning requirements in research studies, but also retrospectively in initial assessments of unintended exposures of patients. It can also be used for communicating relative risks to clinicians and patients. However, there has been a tendency to extend the use beyond the intended purpose. The uncertainties in the relation to risk are large, even for a reference person. This must be borne in mind when it is used in any application, and in the publication now being prepared ICRP sets out purposes for which it should be used and constraints that should be applied.

Development of High Spatial and Temporal Resolution Dosimeters in Radiotherapy and Radiodiagnosis QA

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We discuss development of Ge-and P-doped silica for luminescence-based dosimetry. The defects giving rise to electron trapping are of particular interest, readout of the radiation sensitive signal being obtained through use of one or other of the related stimulated luminescence phenomenon, thermoluminescnce (TL) and radioluminescence (RL). During the course of our studies, various manipulations of the media have been made in an attempt to improve their radiation sensitivity, as an example in TL studies starting from simple use of standard Ge-doped silica telecommunication fibres (SMF), through to tailor-made Ge-doped flat fibres (FFs) as well as Ge-doped photonic crystal fibres (PCF) co-doped with boron. Currently in use of such glassy media, we have made successful measurements of terrestrial natural radiation dose (eg 1 or 2 mGy per year), the very low doses of dental radiography (~ 10s μGy) through to the sub mGy doses of chest radiography, both delivered in a few ms, the tens of Gy doses of radiotherapy, through to 10s of kGy used in radiation processing. In use of RL, we have compared the signal originating from Ge- and P-doped silica optical fibres and commercial nanoDot Al_2O_3:C dosimeters, the RL signal being guided through PMMA optical fibre cables to obtain real-time measurements. For the doped fibres the manifest absence of an appreciable memory effect or afterglow favours their preferential use in real-time evaluations.

Molecular Biology in the Age of Modern Medicine

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The cell is one of the most complex systems that can often be perceived as an elegant machine with thousands if not millions of molecules working in concerted effort to give and sustain life. The genesis of many diseases can often be traced to aberrations in one or many molecules whilst human's relentless effort to reverse the effects of these diseases depends on our understanding of how these molecules function. This session will focus on three fundamental areas of molecular biology – 1) the flow of information from DNA to cellular functions, 2) the molecular basis of diseases and 3) the application of molecular biology in medicine.

IAEA/RCA RAS 6087 Project

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Medical physics support of radiation medicine is critical for the appropriate, effective and safe use of radiation in radiation medicine. However specific surveys of the Asia Pacific region indicate there is a critical shortage of medical physicists that would compromise the effectiveness of the irrepressible role out of radiation medicine in the region. Through previous RCA projects clinical training, guidelines have been developed for all three specialities of medical physics (radiation oncology, diagnostic radiology and nuclear medicine) and have been implemented in a number of pilot programs. Importantly an e-learning platform (called AMPLE) has been recently developed and is under testing by the IAEA. This platform is designed to allow easier administration of clinical training, presentation of resources and easier communication and thus allow new strategies in clinical education including applications in developing countries through remote supervision of residents. Clinical training in developing countries is difficult as local expertise in medial physics is limited. Strategies adopted include training blocks at an identified Regional Resource using AMPLE to define and monitor training. Upon return to their home country the link with the host institution can be maintained through AMPLE with supervision supplied by the hosting GP. Within the Asia Pacific region, good progress has been made in clinical training. Improvements will include implementation of accreditation processes, for academic and clinical facilities, the adoption of IAEA recommended staffing levels and guidance on supervision and assessment to promote long term sustainability.

Image-Guided Radiation Therapy Accuracy

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Modern Radiation Therapy is highly conformal. It treats just the target volume with a small margin for possible positioning uncertainty. It is very much different from early techniques of radiotherapy such as a whole brain treatment where the patient's scull is uniformly irradiated by a uniform large open field. In addition to that, most of modern radiation treatments use some type of intensity modulation, such as field-in-field, sliding window, step-and-shoot or rapid arc. All this makes it critically important to properly align the target with the radiation fields. This task was much less important for old traditional treatments with wide open fields. To achieve the goal of proper positioning, modern Radiation Therapy is image-guided. In addition to traditional portal imaging, where the image is taken using the treatment beam and an imager, we are now using more advanced methods. The first of these methods is conventional diagnostic x-ray imaging, so called "On-Board Imaging" (OBI). It is performed using a conventional kilovoltage x-ray unit which is solidly attached to the treatment gantry. Use of kilovoltage imaging significantly increases the contrast of the radiograph making it much more useful for the patient positioning. The image is registered using the same amorpho-silicon imager as one being used for the portal imaging. The second method allows to further improve the contrast resolution and create cross-sectional image. This method is called Cone-Beam CT (CBCT) imaging which is much easier to match the simulation scan. This match could be even performed automatically, suggesting necessary couch shifts for the precise alignment. Precision of the image-guided radiotherapy is defined by: Coincidence of the kV and MV isocenters, proper patient alignment and system resolution.

Assessing Criteria on Patient-Specific Quality Assurance

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Sophisticated systems used for modern radiotherapy require extensive Quality Assurance (QA) procedures. These procedures could be divided into equipment QA and patient-specific QA. Equipment QA ensures the quality of equipment used, including accuracy of calculation, precision of the imaging and positioning as well as correctness of the output. The patient-specific QA addresses individual patient's plan. In practice, for a conventional treatment, the patient-specific QA includes thorough check of the plan and contouring together with the independent monitor unit calculation. For the intensity-modulated treatment including step-and-shoot, sliding window and Volumetric Modulated Arc Therapy (VMAT) techniques, the same tests are supplemented by direct measurement of the spatial dose distribution, performed prior to the first treatment. Since the measurement cannot be performed on the patient, the treatment plan is projected and calculated on a phantom that is subsequently used for the dose measurements. There are many commercial types of such phantoms, e.g. Octavius from PTW, Matrixx from IBA, MapCheck and ArcCheck from SunNuclear, Delta from Scandidos and others. We are not giving recommendations for any of these products but just mentioning them as a reference. Some of these devices use diodes, some of them utilize ion chambers. The measurement arrays could have flat or cylindrical forms for static beam or volumetric treatments, respectively. In addition to all these devices, one can use a plain radiographic film, either conventional or radiochromic. The film is usually sandwiched between the slabs of build-up material and gets exposed to the treatment prepared for a patient. At the end, the dose measured is compared with the dose calculated. Possible errors include the dose deviations or positional deviation of the measured dose map. In practice, the dose acceptance criteria usually vary from 3%/3mm to 5%/5mm. More detailed analysis could be performed using so-called gamma-factor which combines the dose and positional uncertainties.

New Technologies in Radiotherapy

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Radiotherapy is a technology driven field. There is a constant process of innovation. There are few directions of constant innovation: 1) Use of Volumetric Modulated Arc Therapy (VMAT), as opposed to a few stationary x-ray beams, has already become a standard of care, due to a better dose distribution control and reduced amount of radiation. 2) Proton radiotherapy. It was shown that protons have important advantages with respect to photons. Most importantly, they can stop in the tissue forming the Bragg peak. Because of that, there is a constant process of innovation in the proton radiotherapy. 3) Use of heavy ions. For the same reason, heavy ions are even better than the protons, however, their production is even more sophisticated then the proton production. 4) MRI Cobalt unit. It enables rotational delivery, like tomotherapy, and also MRI imaging just before the treatment. MRI imaging is better for showing soft tissues than the photon imaging. 5) MRI Linear accelerator. The same considerations as for the MRI Cobalt unit but linear accelerator allows more intense and better controlled radiation. Special attention should be paid to the operation of the linac in the magnetic field of the MRI. 6) Cyberknife with the MLC. Use of Cyberknife allows more intense radiation than Gamma-Knife, and also does not need radioactive isotopes. Addition of the MLC allows more controllable radiation with intensity modulation. All new modalities have certain advantages and limitations that will be discussed.

The Role of Clonogenic Stem Cells in Head and Neck Cancer as a Function of HPV Status

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The role played by cancer stem cells (CSCs) is fundamental to tumour progression, metastases and recurrence. These are the most treatment resistant of tumour cells and are irresponsive to therapy, accelerating their replication and tumour repopulation. The human papillomavirus (HPV) has emerged as a discrete aetiology in head and neck cancers (HNC). They demonstrate consistently better responses to radiotherapy initiating several clinical trials to de-escalate treatment. This study investigates in vitro differences in CSC responses to radiation in terms of their HPV aetiology. Methods: UM-SCC-47 (HPV+) and UM-SCC-1 (HPV-) cells were irradiated with 4 Gy using a 6 MV X-ray beam. Sham-irradiated flasks were used as controls. CSC proportions of cell populations were measured at 24, 48 and 72 hours, and 10 days post irradiation. CSCs were identified by cellular markers CD44 and aldehyde dehydrogenase (ALDH), using flow cytometry. In the next step, parallel cultures surviving 4 Gy irradiation were re-cultured and passaged to develop subsequent generations which were re-irradiated and analysed for generational change in radiation response. MTT assays were used to determine surviving metabolic activity as a function of dose following 6 MV X-ray irradiation. Results: Triplicate analysis of non-irradiated UM-SCC-47 cell cultures showed a mean population of CD44+/ALDH+ cells to be 2.87%+0.219, 5-fold that of the UM-SCC-1 population which was 0.57%+0.077. UM-SCC-47 and UM-SCC-1 showed increased ALDH+/CD44+ CSC proportions following 4 Gy irradiation. The proportional increase for UM-SCC-47 was 3 to 4 times the control within 72 hrs post irradiation. After 10 days these cultures no longer presented significant differences in CSC population against the control. UM-SCC-1 showed the most significant increase in CSC proportion 24 hrs post irradiation and a persisting elevation in CSCs 10 days after irradiation. Second and third generations of UM-SCC-1 showed decreasing metabolic activity with dose but little difference was evident in surviving fractions between these generations. Significantly lower metabolic activity in the 3rd generation at <6 Gy, compared to the 2nd generation, showed UM-SCC-47 becoming progressively more radiosensitive. Conclusions: CSCs display significant heterogeneity between cell lines warranting investigation of the effect aetiology has on intrinsic population numbers and treatment responsiveness.

How to Improve Engagement of Women in Science and Medicine

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The Women in Medical Physics and Biomedical Engineering (WiMPBME) task group was established in 2014 under the International Union of Physical and Engineering Scientists in Medicine (IUPESM) with the aim to develop, implement and coordinate tasks and projects related to roles and needs of women in medical physics and biomedical engineering around the world. Our task group is committed to advancing women in science and health and has been very proactive in a number of aspects. The aim of this presentation is to provide brief background on the current status of women in medical physics and biomedical engineering, while focusing on the solutions and providing examples of current activities conducted nationally and internationally. A number of proposed strategies include: a) identification and development of role models that actively model successful work-life balance and flexibility in gender roles in addition to professional conduct; b) establishment of programs on leadership development c) development of opportunities for females to present their work, represent their organizations and network, and d) development of archives and databases of women in STEM.

The contribution of Medical Physics to Women's Health

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The discovery of X-rays, natural radioactivity and ionizing radiation has played an important role in numerous fields in modern scientific and technological developments radically influencing the entire modern civilization spanning fields like atomic and nuclear physics, agriculture, industry and in medicine providing an impetus for development of radiology and radiotherapy as medical specialties and medical physics. In this article contributions of medical physics for the occupational workers especially for women, s health in terms of radiation safety have been described. Continuous technological advancements in all areas of medical physics are significantly increasing the risk of potential exposure to ionizing radiation. General acceptance of risks of radiation is a matter of consensus and therefore, international safety standards are needed to provide the justification of the use of any radiation with standardization, optimization and limitation of exposure. International consensus was achieved for the IAEA safety standards (BSS) through the IAEA SAFETY SERIES, which adopted and documented for medical public and occupational exposures as well as the special needs for the safety of women medical physicists with child bearing incidence. Six major relevant international organizations: FAO, IAEA, ILO, the OECD Nuclear Energy Agency (OECD/NEA), Pan American Health Organization (PAHO) and WHO are the initiator for these activities. The purpose of the standards is to establish basic requirements for protection against the risks associated with exposure to ionizing radiation and for the safety from the radiation sources. A safety culture should be developed that governs the attitudes and behavior in relation to protection and safety of all individuals and organizations dealing with sources of radiation with special consideration to pregnant women. In-depth defensive measures should be incorporated into the design and operating procedures for radiation sources to compensate for potential failures in protection or safety measures; and also protection and safety should be ensured by sound management and good engineering, quality assurance, training and qualification of personnel, comprehensive safety assessments and attention to lessons learned from experience and research.

Quality Control Program for Digital Mammography in Japan

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Mammography is the only method that has proved to be effective and cost-effective for breast cancer screening. In Japan, most of mammographic systems have changed to digital systems, and about half of them are interpreted by soft-copy. Mammographic quality control has been done by the Japan Central Organization on Quality Assurance of Breast Cancer Screening. A digital mammography quality control manual has been prepared by the organization, it is explained about acceptance tests and quality control tests for mammographic equipment and display. In order to ensure the quality control and maintain the high image quality and low radiation dose, the organization has hold technical training courses for technicians in two steps. The first course consists of lectures and practical training about Basics of mammography, evaluating quality control tests, interpretation, and positioning according to the guideline in two days. To evaluate mammographic equipment, quality control tests are defined in the guidelines. At the training course, practical training will be conducted on these QC tests. The technicians who are approved in the training course then receive certification can attend a training course for digital mammography quality control. In the training course for digital mammography, we are teaching about the QC tests divided into detector and display in practical training. In particular, it also explains Image analysis of the acquisition data.

Medical Physics Support to Nuclear & Radiological Emergencies

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The IAEA International Nuclear and Radiological Event Scale (INES) is a useful tool for communicating the safety significance of nuclear and radiological events to the public. It can be used to differentiate between major accidents, such as at Chernobyl and Fukushima, and progressively less serious incidents. Whilst most medical physicists can expect to go through their entire career without involvement in major accidents, they have skills and experience which make them a potentially valuable resource when radiation-related events occur beyond the medical sphere. Communication is a crucial aspect of Nuclear and Radiological Emergency (NRE) response. Few people have a good understanding of radiation risks to human health, yet it is vital that those who have to make important decisions when NRE events occur are well-informed. Clinically qualified medical physicists working in nuclear medicine, diagnostic/interventional radiology or radiation therapy have a highly-relevant combination of scientific knowledge, technical skills and experience. They have a good understanding of radiological science and are used to working with radiation detection equipment. They are able to place radiation risks in perspective, and are familiar with questions and concerns which frequently arise when people are exposed to ionising radiation. Circumstances involving accidental or malicious exposure to ionising radiation are clearly different from deliberate medical exposures, but nevertheless knowledge and experience in dealing with workers and members of the public exposed to ionising radiation is readily transferable to NRE situations, where such skills are likely to be in short supply. Medical physicists may be asked to provide advice to a range of stakeholders and be expected to play leading roles in personal monitoring and decontamination programmes, potentially involving large numbers of members of the public. Recognizing the need to provide emergency preparedness training for medical physicists who may be asked to provide support in NRE situations, the IAEA, in conjunction with the Japanese government, has devised a training package which aims to better equip medical physicists to undertake such roles. This talk will describe the creation and development of this training package.

Introduction to Additive Manufacturing

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Additive manufacturing, also colloquially known as 3D printing, is a layered manufacturing process where materials are deposited layer-by-layer to form a 3D part. This technology dates back to 1981, when Hideo Kodama from Nagoya Municipal Industrial Research Institute created the first rapid prototyping system using photopolymers. However, it was not until two decades ago that additive manufacturing becomes increasingly popular. This presentation will provide a background to different types of additive manufacturing, with a focus on medical applications. Finally, some of the current research by the speaker will also be presented.

Absolute Dose Rate Measurement for a Gamma Knife: TRS-483 and Small Field Dosimetry

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Gamma Knife Perfexion® (GKP) is a typical example of devices for which conventional standard protocols such as TRS-398 and TG-51 to measure absolute dose absorbed to water cannot be applied. The irradiation beam is composed by accumulating beams from 192 cobalt 60 sources located in a conical section such that the source to center distance cannot be defined as a single number. The shape of the iso-dose surface around the center is an ellipsoid and it cannot be a square of 10 x 10 cm^2 as requested in the standard protocols. Typical phantoms used in GKP dosimetry are made of water equivalent plastics and their shapes are either spherical or cylindrical with a hemi-spherical top of 8 cm radius. In order to provide standard conditions for measurement of absorbed dose to water of small field radiotherapy machines, IAEA and AAPM published an international code of practice for reference and relative dose determination, TRS-483, in 2017. It suggested to use water equivalent plastic phantoms of radius 8 cm. Beam quality correction factors for several sets of ion chambers and phantoms were provided based on Monte Carlo simulations. It also recommended to apply a phantom dose correction factor determined by the electron density of the phantom material to convert measured values to the absorbed doses at 8 g/cm^2 of water depth. Contents of TRS-483 on GKP dosimetry were reviewed and some of the beam quality factors were verified using independent Monte Carlo simulations. The new protocol was applied to measure dose rates absorbed to water of a GKP and compared with those measured with previous standard protocols. Two PTW 31010 ion chambers and an Exradin A16 chamber were used to measure dose rates at the center of a solid water phantom provided by the Gamma Knife vendor and an in-house phantom made of polystyrene. When the new beam quality correction factors were applied, the deviations of the dose rates measured by different chambers were significantly reduced.

Pilot Study of Patient Doses from Conventional Diagnostic Radiology in Lebanon

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The widespread use of x-ray examination and the increased utilization of recent development of remarkable x-ray equipment have improved the lives of patients in Lebanon; however, this evolution of imaging has also resulted in a significant increase in the population's cumulative exposure to ionizing radiation. The objective of this study is to assess the patient doses for most frequent x-ray examinations in Lebanon by measuring the entrance skin dose for patients within the weight range of 65 to 70 kg taken in some of the Lebanese hospitals. This study gives preliminary results of a pilot project on "improvement in x-ray image quality and reduction in patient dose in radiology" launched by the IAEA and Lebanon –LAEC as a first step towards the standardization of medical imaging procedures in Lebanon. Quality control checks on the x-ray machines used for the study should be performed prior to the experimental investigations. The results will be compared between involved hospitals and compared to the International Guidance Levels of patient dose; this study will help to provide a more unified diagnostic radiology practice and help to reduce patient exposure levels to those comparable to IAEA standards. We hope through this effort to establish in the near future a National Reference Dose Levels in Lebanon.

Clinical Value of Patient-specific Three-dimensional Printing of Congenital Heart Disease: Quantitative and Qualitative Assessment

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Introduction: Current diagnostic assessment tools remain suboptimal in demonstrating complex morphology of congenital heart disease (CHD). This limitation has posed challenges in preoperative planning, communication in medical practice, and medical education. This study aims to investigate the dimensional accuracy, as well as the clinical value of three-dimensional (3D) printing of CHD in the areas mentioned above. Methods: Ethical approval was obtained from Human Research Ethics Committee. Using cardiac computed tomography angiogram (CTA) data, a 3D model of a 20-months-old heart with double outlet right ventricle was printed in TangoPlus material. Pearson correlation coefficient was used to evaluate correlation of the measurements taken at analogous anatomical locations between the CTA and 3D printed model. Surveys were also conducted with 6 health professionals (2 radiologists, 2 cardiologists and 2 cardiac surgeons) and 3 medical academics to assess the clinical value of the 3D printed model. Results: Excellent correlation (0.99) was noted in the measurements between CTA and 3D printed model. Four out of six health professionals found the model to be useful in facilitating preoperative planning, while all of them thought that the model would be invaluable in enhancing patient-doctor communication. All three medical academics found the model to be helpful in teaching, and thought that the students will be able to learn the pathology quicker with better understanding. Conclusion: The patients' heart anatomy can be accurately replicated using 3D printing technology. 3D printed heart models could serve as excellent tool in facilitating preoperative planning, communication in medical practice, and medical education.

The Role of SEAFOMP in Growing Medical Physics in ASEAN Countries

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The healthcare sector of ASEAN countries will continue to grow in conjunction with population growth and economic progress. The role of medical physicists is important in radiation medicine and its growth must follow the expansion of healthcare. There is a continuing need to meet various challenges to train and build a new generation of medical physicists, both in quantity and quality. This is because the number of ASEAN medical physicists is still in shortfall and the advancement of radiation medicine challenges our medical physicists to have strong fundamentals and to continuously acquire new knowledge to handle advanced technologies and new developments. SEAFOMP therefore has an important role to play in building up medical physics for the region. The congress theme of "A Sustainable Future for Medical Physics" clearly sums up an appropriate and relevant focus for SEAFOMP in the coming years.

Patient Dosimetry Methods in Mammography

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Mammography is a common imaging modality used for screening and diagnosing patients who are at risk of having breast cancer. Radiation dosimetry is crucial in order to control the dose to be no higher than necessary, but high enough to ensure adequate image quality. Mammographic radiation dose is also used to compare equipment performance, either between different mammographic units, conventional mammography, full field digital mammography or tomosynthesis. There is also a need to provide information for patient to compare the risk and benefits of mammography screening. Patient dosimetry for mammography, also known as mean glandular dose (MGD) has a long history, starting from the 1970s. The focus on the glandular tissues is because of the higher risks of cancer. Since 1987, ICRP has recommended the use of MGD for patient dose determination. There are a variety of streams/schools in deriving MGD. This talk will outline the different streams, the assumptions and highlight the current guidelines that for performing patient dosimetry for mammography.

Medical Physics Education and Clinical Training in Philippines

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The Philippines is an archipelago in Southeast Asia with more than 7,100 islands. The capital city Manila is also the center of learning and healthcare. Recent regulatory changes have driven the need for medical physicists in radiation oncology and nuclear medicine. Increased government spending to improve healthcare facilities, medical equipment (CT, mammography, SPECT/CT, PET/CT, cyclotron, and linear accelerators) and expanding access to these services outside Manila have driven the demand for new medical physicists and experienced medical physicists. The country's first medical physicists with formal education in medical physics came from those sent by the government for studies in the United Kingdom and the United State between 1969 and 1981. Through an IAEA technical assistance project proposed in 1978, a Masters in Science in Applied Physics, major in Medical Physics was established in 1981 at the University of Santo Tomas Graduate School in Manila. By 1986 the first batch of students of the IAEA-supported local medical physics program successfully graduated. The period between 1986 to the early 2000 saw small enrolments in the program with most students working as health physicists with regulatory bodies or in the few but increasing radiotherapy facilities mostly in the private sector. While the medical physics academic program was already established, self-supporting and producing graduates, the clinical training of medical physicists in the health physics, radiotherapy, radiology and nuclear medicine fields were mostly on-the-job and unstructured. Several workshops were conducted in the country during 1990's and mid-2000 that served to enhance the clinical training of medical physicists in the fields of medical imaging, radiation safety and protection, radiation dosimetry and quality assurance and control in diagnostic radiology, radiotherapy, and nuclear medicine. Structured clinical training of medical physicists started in 2009 for radiation oncology medical physics with the piloting of the IAEA/RCA Clinical Radiation Oncology Medical Physics Program. This was soon followed by DRIMP in 2011 and NMMP in 2016; all follow the IAEA-developed clinical residency programs and enrolled in the AMPLE learning management system. Certification of ROMPs was established in 2010 and will be expanded to DRIMP and NMMP in the future.

Medical Physics Education and Clinical Training in Bangladesh

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The number of medical physicists working in Bangladesh in different areas of radiation medicine are still relatively low. There are around 32 hospitals that have radiotherapy departments and 20 hospitals having nuclear medicine departments. The number of medical physicists in radiation oncology are 35 and 14 in nuclear medicine. Two universities, one public and the other private, have medical physics degree program. These degree programs include B.Sc., M.Sc. and Ph.D. Besides these, Bangladesh Atomic Energy Commission has established an Institute of Medical Physics to implement medical physics best practices in Bangladesh. However, none of the University or Institute's programs are coupled with adequate clinical training. Clinical training in Bangladesh started first in 2011, introduced by an IAEA/RCA project following IAEA guide book TCS-50 in nuclear medicine. The 2 years structured clinical training program was completed successfully. The medical physicists who qualified in the clinical training program were evaluated by IAEA expert. These qualified medical physicists were subsequently tested and certified by the Bangladesh Medical Physics Association (BMPA). Clinical training program for medical physicists commenced for the 2nd time in 2016 supported by another IAEA/RCA project through the e-learning AMPLE platform with medical physicists for both radiotherapy and nuclear medicine discipline. The radiotherapy residents are following IAEA guide book TCS-37 while the nuclear medicine residents are following the IAEA guide book TCS-50. BMPA, in association with Bangladesh Atomic Energy Commission and Bangladesh Atomic Energy Regulatory Authority, is going to form a national accreditation and certification board for medical physicists for their clinical training program according to the IAEA's recommendation. It is expected that in future accreditation and certification for medical physicists will become a basic requirement for all medical physicist operating in a clinical environment.

Education and Research of CT Technology

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From past to present, and to the future, CT has been developing wonderfully. What is the foundation power for these CT developments. I believe that power is based on clinical demands and the efforts of companies and developers who respond to it. Clinicians have many demands for medical effect. It is for patient diagnosis and treatment. However, they will not be familiar with detailed technical problems. Developers make efforts to meet their demands. The result will be the development of CT equipment. What kind of education and knowledge are necessary for developers? They are required to have knowledge about X-rays and machinery, and medical science. Therefore, medical physicists and radiological technologists are important for the development of CT. At the beginning of this workshop, I will introduce the idea of CT development and the knowledge to complete it. By participating in this workshop you will be able to know the fun of CT development.

Ultra High Resolution CT: Performance and Clinical Use

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We are interested in recent CT technology. You will have many expectations for Dual Energy CT and Photon Counting CT. However, the development of CT devices is not limited to Dual Energy CT or Photon Counting CT. Though they are new technology, CT should advance more. That is Ultra High Resolution CT (UHR - CT). Extensive effort is required to realize UHR-CT. And to understand that effort it is important to solve the fundamental phenomenon of X-rays. In this lecture, I will introduce what has been done to realize UHR-CT by organizing the X-ray effect in CT. After experiencing the development of UHR-CT, we noticed important problems of CT. It is image reconstruction kernel. You might understand that it is very useful. However, it contains dangerous elements. For example, is an image reconstruction kernel for displaying a sharp CT image a correct CT image? We would like to advocate undershoot as an important artifact. By using UHR-CT you can display images with high spatial resolution and no undershoot. Conventional evaluation methods cannot be used for performance evaluation of UHR-CT. This lecture will also introduce the new performance evaluation method for UHR-CT. How will CT change with UHR-CT? It is very interesting. The accuracy of 3D CT improves. The accuracy of Dual Energy CT and Photon Counting CT will improve. The accuracy of CT fractional flow reserve (CT - FFR) will also improve. We understand that UHR-CT is a technology expected in clinical examinations.

Dosimetry in Radiopharmaceutical Therapy for Personalised Patient Treatment

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Precision medicine is the selection of a treatment approach that is specifically tailored to the genetic and characteristics of a particular patient's disease. In cancer, the objective is to treat with agents that inhibit cell signaling pathways that drive uncontrolled proliferation and dissemination of the disease. Radiopharmaceutical therapy (RPT) involves the use of radionuclides that are either conjugated to tumor-targeting agents or concentrated in tissue through natural physiological mechanisms that occur predominantly in targeted cells. Classically, the level of radioactivity administered is primarily fixed, sometimes adjusted by body weight, body surface area, or clinical factors. In order to improve the outcome treatment of cancer patients, however, the patient-specific biodistribution can be determined by in vivo nuclear medicine imaging of the radiopharmaceutical. As the ability to collect pharmacokinetic data by imaging and use this to perform dosimetry calculations for radionuclide treatment planning, this can distinguish RPT from other treatment systems. The weakest links in both diagnostic and therapeutic dosimetry are the accuracy of the input and the reliability of the radiobiological models used to convert dosimetric data to the relevant biologic end points. Dosimetry for RPT places a greater demand on both of these weak links. As a result, RPT offers the possibility of evaluating radiopharmaceutical distributions, calculating tumor and normal tissue absorbed doses, and devising a treatment plan that is optimal for a specific patient. Furthermore, personalized dosimetry based on molecular imaging is an interesting field that will become more important in the near future as well.

Clinical Use of Volumetric CT

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Developed following a request from clinical practice, the volume CT was hailed as 'a global breakthrough in CT' when it was first introduced in 2007. With the area detector (160 mm coverage in the body axis direction), the new system brought radiologists and technologists new opportunities in volume- and dynamic scanning and opened the doors to a new way of medical imaging. The area detector CT remarkable journey over the last 10 years has resulted in unique software- and hardware developments that have changed the direction of CT. Examples of utilization with the volume CT in clinical setting include finding endoleaks of after endovascular aortic repair (EVER) or thoracic-EVER, observing the cerebral blood-flow, and observing joint movement, and so on. In this lecture, I would like to introduce how to use the volume CT in clinical setting with our hospital.

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Patient Dosimetry in Computed Tomography

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When considering patient dosimetry in computed tomography (CT) examinations, it is important to understand that the absorbed dose distribution within each patient differs from that of other X-ray examinations. Hence, specific methods must be used for evaluation of radiation doses in CT scans. The CT dose index (CTDI) is basically used for describing the doses delivered by CT scans. CTDI is based on measuring the air kerma in cylindrical polymethyl methacrylate phantoms of 16 cm (for adult head and child) and 32 cm (for adult body) in diameter. Although CTDI is not the absorbed dose of an actual patient, the American Association of Physicists in Medicine (AAPM) released report 204, which provided conversion factors as a function of geometric patient size to translate volume CTDI (CTDIvol) to size-specific dose estimates (SSDE). The AAPM also released report 220, which provided conversion factors as a function of X-ray attenuation to calculate SSDE for all patients. The dose-length product (DLP) represents the total dose over a whole scan. DLP is also used as an indicator of radiation output of a CT system. The patient effective dose can be estimated from DLP by multiplying the conversion factor that depends on patient age and scanning regions. Obtaining the organ dose from point measurements is another effective method for patient dosimetry in CT. Sectioned and drilled anthropomorphic phantoms, which accept small dosimeters, are used for this purpose. The energy dependency of small dosimeters within the energy range generally used in CT is relatively high; hence, their dose values must be corrected with the X-ray energy used by comparing their dose values with those of an ionizing chamber. Without using anthropomorphic phantoms and small dosimeters, the absorbed dose for each organ or tissue for typical clinical CT scanner models and scan protocols can be calculated on the basis of Monte Carlo (MC) simulation software. In addition, there are several types of MC packages that are used for CT dosimetry. When the MC packages are used, source models of the CT scanner and human models need to be set manually for calculating absorbed doses in CT.

Radiomics: Walkthrough of a Sample Workflow

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Radiomics is defined as the collection and conversion of large numbers of standard clinical images and associated clinical information, into derived quantitative features, which can then be mined and analysed for the development of clinical decision supportapplications. The full process of radiomics involves image data acquisition, segmentation, feature extraction, and analysis. The majority of available literature focuses on the segmentation and feature extraction sub-processes, most often focusing on oncology tumour management. In this talk, the target audience is assumed to be relatively inexperienced in radiomics; a practical workflow for the acquisition and management of image data is introduced, from the perspective of a smaller scale, single department approach. An appropriate computing environment setup, as well as tools for image data acquisition and management are introduced. For image processing and analysis, existing tools for segmentation and feature extraction are introduced, especially with regard to magnetic resonance brain imaging.

Extracting Imaging Biomarkers for Radiological Applications: A Treasure Hunt in Biomedical Imaging

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Imaging parameters/biomarkers in the form of extracted features are critical for the challenging task of object recognition in the biomedical imaging field. Feature extraction is a critical step in image processing solutions as it marks the transition from pictorial to non-pictorial (usually quantitative) data representation. The main challenge is to extract good or relevant descriptors that only contain information about what makes an object unique or different from other objects. An important characteristic of good descriptors is that they should be invariant to rotation, scaling, and translation. This is particularly desirable/important in the biomedical imaging field, whereby a machine vision or classification system should still be able to recognize objects even when they appear at different sizes and positions within the image due to a shift in the patient's position, e.g., during image capture. Another important characteristic of good descriptors is that the quantity of information used to describe the object should be less than the information required to have a complete description of the object itself. Furthermore, a good descriptor should be robust against noise and distortion, which are common characteristics in biomedical images. Good descriptors should also be computationally efficient or have low computational complexity. Many descriptors are proposed in the literature for different applications including shape, texture, and histogram based or statistical features. The descriptors that are useful are dependent on the application/task at hand. The relevance of individual features can usually be determined/derived using good feature selection methods available in the literature. The feature extraction stage also precedes the classification and modeling stage, whereby selected features are given as inputs to a machine learning algorithm, e.g., an artificial neural network or a logistic regression classifier. Using relevant features selected by the feature selection method, the machine learning algorithm combines different features in the learning task to improve the overall performance of combined features over the individually extracted features. The performance of the machine learning algorithm is mainly determined by the usefulness of selected features, thus underlining the importance of extracting features that are relevant to the application at hand.

Diagnostic Reference Levels (DRL) for Nuclear Medicine in the State of Kuwait

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The objective of a diagnostic reference level is the need for standardization of dose to the patient (avoid unnecessary radiation) without compromising the clinical purpose of each examination or procedures in Nuclear medicine departments in the state of Kuwait. Introduction: DRLs provided good tools in previous years when the spread of doses were by a large order of magnitude and the shape of dose distribution curve was right-skewed asymmetric. Another concept of "achievable dose" propagated in 1999 by the National Radiological Protection Board (now Public Health England) and recently adopted by the National Council on Radiological Protection and Measurements also suffers from some of the limitations of DRL and has thus not picked up much in preceding years. Recently, Acceptable quality dose (AQD) was introduced. Furthermore, it is questionable if one should use dose value for lower range as that can imply ignoring better technology that may exist in many centres in which diagnostic quality can be obtained at lower doses. The patient administered activity (MBq) was compared to the image quality in this study. The patient activity was recorded (e.g. 25 mCi) and if applicable the displayed values of CTDIvol and DLP for samples of 10 or more patients of for common clinical indications. The dose was estimated for each type of examination in (mSv). Reduction of the activity by 20% (e.g. to 20 mCi) for each procedure mentioned in the previous step was done. Compare the image quality with different activities. Further reduction of activity by 20% for each procedure was done. The image quality with different activities was compared by nuclear medicine consultants and based on their evaluation the optimum dose vs. the image quality was proposed. The consultant is provided with image quality guideline on what information should be available in the specified image and to what extent and how to be aware about image of higher than necessary quality. The dose used for nuclear medicine procedures was optimized based on the patient weight (mci/kg) and the image quality. The National DRLs for NM was established and compared to internationally published values.

Predictive Models in Radiotherapy-related Toxicities using Machine Learning and Radiomic Features

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Radiotherapy-related toxicities reduce the ability to maximise dose to the target volume to improve tumour control. The risk of toxicity is commonly quantified using normal tissue complication probability (NTCP) models based on dose-volume and dose-surface histograms. An obvious limitation of models using such histograms is the lack of information on the spatial distribution of the dose. The models derived from such information might not be optimal. Recently, there are suggestions that radiomic features beyond the histograms may offer improvements in the predictive power of the models. Features including spatial locations and shapes have been shown to relate to toxicities. Furthermore, the relationship between these features and toxicity has been suggested to be non-linear. Thus, machine learning strategies including support vector machines and random forest which are capable to efficiently learn more complex relationships have been implemented reasonably successfully. In this presentation, I will review recent proofs of the improvement made in NTCP models including the addition clinical and dose features, derivation of novel radiomic features and utilisation of machine learning strategies that allow modelling of non-linear relationships. Special focus will be given to my recent works on predictive models in bladder toxicities including the use of multiple machine learning methods and development of dose surface maps of the bladder which allow spatially-specific NTCP models to be constructed.

Comparison of ACR and EU Protocols for the Quality Control of Full-Field Digital Mammography Systems with Digital Breast Tomosynthesis Capability

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Digital breast tomosynthesis (DBT) is an advanced technique of breast imaging that uses low radiation dose X-ray and data reconstruction algorithms to create three-dimensional images of the breasts. It contributes to the early detection and diagnosis of breast diseases. Although housed in a single unit, due to the differences in technology between full-field digital mammography (FFDM) and DBT, the FFDM and DBT components of a mammography system need to undergo quality control (QC) tests as two separate units. Even if a facility uses only the DBT component of a mammography system, both the FFDM and DBT components must undergo QC tests of the DBT modality that relies on documenting the proper functioning of certain aspects of the FFDM system. QC is an important part of the quality assurance (QA) program that deals with techniques used in monitoring and maintenance of the systems that may affect the quality of the image produced hence diagnostic outcomes. Several guidance documents have been developed nationally and internationally to promote quality in mammography. Most of the existing guidelines are derived from key documents (American College of Radiology (ACR) and European Union (EU) protocols) and propose similar tests despite the variations in detail and methodologies. This lecture aims at presenting the comparison of ACR and EU protocols for the QC of the physical and technical aspects of FFDM systems with DBT capability. The differences in techniques and phantoms used in assessing radiation dose and image quality will be emphasized.

Application of Dosimetry in Nuclear Medicine

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The administration of radiopharmaceutical into the human body in Nuclear Medicine procedure will cause the human organs receiving amount of internal radiation dose. For this reason, the internal radiation dose needs to be assessed for considering the risk and benefit to the patients. Hence, conducting a dosimetry assessment will be important to perform a better radiation safety in the nuclear medicine. In a diagnostic procedure, dosimetry study could be useful for evaluating an option between two radiopharmaceuticals for the same procedure and reviewing the dose estimation between different groups. Few references also state that establishing a dosimetry protocol in radionuclide development will be useful for supporting the production of a new radiopharmaceutical by estimating the human dose from preclinical and clinical studies. Moreover, in the therapeutical procedure, dosimetry assessment plays an important role in predicting the organ at risk for the patients. Hence, in the therapeutical procedure, administered radiopharmaceuticals, will deliver the maximum dose to cancer cells but spare the healthy tissue. In recent few years, a dosimetry study in radionuclide therapy has played a role as a treatment planning. Regarding this issue, there is one statement in Bonn Call Action in 2012 which has emphasized the importance of performing dosimetry in nuclear medicine therapy (radionuclide therapy), so that it will be developed as well as an external radiation therapy . By the development in digital imaging technology and computer code, some computer codes are practically useful in implementing the use of dosimetry in Nuclear Medicine, both for diagnostic and therapy purposes. In the past, computer codes for dosimetry calculation has been built separately from the nuclear medicine equipment, but some of installed new equipments has been attributed by the dosimetry calculation features. Nevertheless, the dosimetry study is not the part of routine protocols, however, performing the dosimetry assessment will raise the implementation of radiation safety aspect in the nuclear medicine department.

Safety Learning and Safety Management to Prevent Radiotherapy Incidents

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Radiotherapy has long been an effective way of treating cancer and it is estimated that more than 50% of patients with cancer would benefit from radiotherapy. More than five million patients undergo radiotherapy each year around the world. In many developing countries there is, however, no access at all to this treatment modality. Expanding radiotherapy into countries and areas without current access has the potential to save a great number of lives, but it is mandatory that the expansion is done with safety in mind, considering the complexity of this high-technology treatment modality and the potential for serious consequences when something goes wrong. It is worth considering that radiation accidents involving medical uses have accounted for more deaths and early acute health effects than any other type of accident, including accidents at nuclear facilities. Voluntary safety reporting and learning systems are often confidential and focus on events and outcomes, instead of regulatory sanctions, capturing also near miss events with the purpose being to share knowledge on safety-related events and conditions and on lessons learned to improve the safety environment and patient outcomes. An incident in another hospital can lead to identification of the hazard before a similar incident is realized locally. The IAEA has developed a voluntary safety reporting and learning system for radiotherapy. This is called Safety in Radiation Oncology (SAFRON). This system has incorporated data from other international, national and local reporting systems, and data directly from SAFRON participants, in order to make radiotherapy safety information more accessible. In addition, this database also provides links to publications of interest in the evaluation of incidents, lessons learned, and corrective actions, as well as to prospective risk management elements. The system is designed to educate facilities about incidents and corrective actions, promoting safety learning and safety management to prevent radiotherapy incidents.

Establishment of National Quality Control Program for Digital Mammography in Thailand

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Establishment of National Quality Assurance standards for Digital Mammography Systems for Thailand based on IAEA Human Health Series Report No.17: Quality Assurance Programme for Digital Mammography. A National Workshop relevant to Breast Imaging was conducted in Bangkok, Thailand during October 2017 to: 1. Give lectures on digital mammography systems, digital detectors, radiation dose and image quality; 2. Conduct hands on practicum on quality control procedures for medical physicists and mammography technologists; 3. Demonstrate the use of imaging informatics including DICOM standard in quality improvement of digital mammography; 4. Demonstrate the use of Integrating Healthcare Enterprise (IHE) mammography image integration profile actors (Acquisition Modality, Image Archive/Manager and Image Display) in digital mammography; 5. Assist participants in developing local QA procedures for mammography focusing on the medical physics, clinical aspects and radiological technology. A total of 25 participants including 17 medical physicists, 6 mammography technologists and 2 scientists attended the workshop. A hands on practical session was conducted with Fuji Amulet Innovality digital mammography system, Fuji FDR-3000AWS acquisition workstation and Fuji Synapse radiologist review workstation. A task group consisting of 6 medical physicists representing 4 hospitals was established to draft a national quality control manual for digital mammography systems to be used nationally within Thailand. A successful IAEA Technical Corporation Expert Mission on the establishment of National QA standards for Digital Mammography Systems was conducted for Thailand in October 2017.

Medical Physics Practice in the Era of AI: Is There a Medical Physicist in the Room?

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Medical physicists' roles in radiation therapy will be transformed by the introduction of AI in medical practice. Various AI technologies such as machine learning and deep learning are not emerging, they have already arrived in radiotherapy suites. These technologies will deeply transform treatment planning, chart checking, brachytherapy procedures and quality assurance of relevant equipments. Repetitive and complex processes that usually conducted are being automated by AI planning softwares. What is left to physicists then? Would machine and deep learning send highly trained physicists to retirement? Probably not soon, as the human and professional interactions between medical physicists and radiation oncologists remain at the core of proper cancer treatment. Shared decision on treatment protocols based on clinical judgement of the tandem radiation oncologist-medical physicist is still needed to determine optimal image combinations, to delineate the tumor volume. Yet AI is useful in empowering the medical physicist in its daily practices. In sum, this session open the floor for a debate to discuss whether AI would enable medical physicists to better perform in clinical practices or to push them out of the radiotherapy suite.

Physics and Concepts of Small Fields (SF) in Radiotherapy

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Small field dosimetry is particularly relevant to precision radiotherapy treatment techniques such as stereotactic radiosurgery (SRS) and stereotactic body radiation therapy (SBRT), as well as radiotherapy treatment using specialized equipment like CyberKnife, Gamma Knife, tomotherapy, and high-resolution multi-leaf collimating systems. However, small field x-ray beam dosimetry is difficult due to a number of challenges that include lateral electronic disequilibrium, source occlusion, high dose gradients, and detector volume averaging. It can be further complicated in the presence of low-density inhomogeneous media. Furthermore, the introduction of radiation detectors into small fields for dosimetry usually perturbs the level of electronic disequilibrium. Compared to the traditional radiotherapy with fields, this can result in significant uncertainty in the accuracy of clinical dosimetry. Hence, the small field dosimetric accuracy can be uncertain for both absolute and relative dose determination. This has become evident with the increase in the number of treatment machines that deliver small x-ray fields which are used for stereotactic radiotherapy. The recent release of Technical Report Series No. 483 is the first international code of practice dedicated to the dosimetry of small static fields used in radiotherapy. This talk introduces an overview of small field radiotherapy physics, followed by a general formalism for reference dosimetry in small fields, which will give an insight on how to handle small field radiation dosimetry.

Heavy Ion/Particle Therapy

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The particle therapy including proton therapy and carbon ion therapy is expected to be a promising method for offering the superior quality of life to patients. The high energy ion beams such as protos and carbon ions, which are used for particle therapy, have good physical property such as Bragg peak. This physical feature leads to realize relatively easily the rationale of the radiotherapy, that is, the delivery of a high dose of energy to the tumor while sparing normal tissue around it. Recent scanning irradiation technology development permits more concentration of high dose to the tumor than the convention passive irradiation method. Furthermore, the complex distribution of dose to the tumor such as IMPT (Intensity Modulated Particle Therapy) can be performed. One of the advantages of the scanning irradiation technique is high beam use efficiency of almost 100% while that of conventional passive method is less than 30%. This results in reduction of unwanted neutron production. Another is the optimization of inhomogeneous dose distribution according to the difference of the biological response of parts of the tissue, which is usually that the inner part of the tissue has radio-resistance nature. The superconducting technology has been also applied to the particle therapy system. Using superconducting magnets enables to reduce the size of irradiation system, especially, that of the gantry for carbon beams. We developed the superconducting gantry irradiation system and has started to use it clinically since May 2017. In the lecture, the knowledge relevant to the above-mentioned techniques and the ongoing developments will be provided with the most recent status of particle therapy including facilities in Japan, to medical physicists who are familiar with the radiation therapy using X-rays, electrons, but unfamiliar with particle therapy.

Advances in Detector Technology in Nuclear Medicine and Hybrid Imaging

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A review of Nuclear Medicine and PET detectors will be initially undertaken to give participants an idea of the advancement and historical development of these detectors. The replacement of scintillation/ PMT detector system will be discussed in detail with reasons for their change, developments and current trends in detector technology would be covered. A review of solid-state detector technology that was approved by the FDA in 1997 will be provided. The high cost and sporadic ability of CZT crystals with limited adoption by the majority of companies & use in large FOV scanners will be discussed besides the long replacement cycles and substantial cuts in reimbursement that may have had a stronger adverse impact on technology adoption than previously expected will be delved into. The strong driver for solid-state technology being its ability to be coupled with other imaging modalities, such as MRI and in addition, solid-state detectors that have good low-energy resolution and are sensitive to a wider range of energies will be looked at as well. Results: What is in the market now for hybrid SPECT-CT, PET-MR & PET-CT scanners would be discussed before summarising.

IAEA Quality Audits in Radiotherapy: From Dosimetry to Comprehensive Audit, QUATRO

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The International Atomic Energy Agency (IAEA) has a long history of providing assistance and support to Member States through radiotherapy dosimetry audits such as the TLD (thermoluminescent dosimetry) and RPLD (radiophotoluminescent dosimetry) dosimetry service for beam output, non-reference dosimetry audits, treatment planning system audits, IMRT end-to-end audits and QUATRO (Quality Assurance Team for Radiation Oncology). Quality audits have several levels of complexity and are an integral part of quality management. QUATRO is a comprehensive audit methodology developed by the IAEA to review and evaluate all components of the radiotherapy practice with the aim to improve quality and safety. Radiotherapy dosimetry audits are available to eligible Member States on request and are cost free for the participating hospital. The audit findings reflect the different dimensions of radiotherapy practices in Member States. Throughout the time, several discrepancies in radiotherapy dosimetry have been discovered and rectified but the general trend is that radiotherapy centres improve their ability to deliver the dose accurately. It proves that using a regular and committed audit system brings continuous improvement through assessment and implementation of audit recommendations and provides adequate confidence that the radiation treatment satisfies the requirements for quality and safety.

IAEA Activities in Medical Physics Education and Training

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Purpose: In the pursuit of safe, effective and quality applications in radiation medicine for diagnosis and treatment, the IAEA supports academic education, clinical training and continuing professional development for clinical medical physicists working in diagnostic radiology, nuclear medicine and radiotherapy. Methods: The IAEA has published over the years guidelines and training material to support academic education and clinical training in the different sub-areas of medicalphysics. Publications are also produced to support best practices in clinical medical physics. Furthermore, the IAEA directly delivers support to Member States through the IAEA Technical Cooperation programme. In the Region of Asia and Pacific, specific projects focus on support to medical physics postgraduate education and clinical training also through specific on-line based tools. These projects also provide regional training courses, expert missions, consultant meetings and fellowships. Results: The support delivered by the IAEA to medical physics in the Asia and Pacific Region has resulted in providing education and training opportunities in the field of clinical medical physics. During the last 4 years the IAEA has supported medical physics in the Asia and Pacific Region through various activities under more than 60 projects, including mostly National but also Regional and Interregional Technical Cooperation projects. About 150 residents are enrolled in the Advanced Medical Physics Learning Environment (AMPLE). Conclusions: Considering the increasing need of clinical medical physicists in the Region, more actions and support are foreseen for the future, with the goal of creating adequate medical physics capacities to support safe, quality and effective healthcare for patients.

Testing of the IAEA/AAPM TRS483 Code of Practice in SF Dosimetry

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IAEA has proposed the project of RCM of CRP E2.40.21 on testing of IAEA/AAPM code of practice for small field dosimetry since 2015. This project aimed to assess the clinical implementation of the determination of machine specific reference dosimetry and relative dosimetry according to IAEA small field code of practice. There are four agreement holders and nine contract holders from different countries joining to test this code of practice. Chulalongkorn University is one of the groups in this project. The purpose of this work is to present the testing results of the IAEA/AAPM TRS483 code of practice in small field dosimetry from Thailand. The measurements were carried out on 6 and 10 MV photon beams both with and without flattening filter from Varian TrueBEAM. The testing of the IAEA/AAPM code of practice for small field dosimetry were separated into six sections: the beam quality index determination in machine specific reference field and the "Palmans equations" testing for machine specific reference field, cross-calibration of compact chamber against farmer chamber, field output factors measurement with and without field output correction factor of four types of detectors (ionization chamber, shielded diode, unshielded diode and diamond detectors), overall uncertainty budget determination, field output factors calculation in treatment planning system, and small field audit using glass dosimeter. The project will be completed in 2019.

Medical Physics Education and Clinical Training in India

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Foreseeing the requirements of medical physicists and radiation safety officers (RSOs) well in advance, the Radiological Physics & Advisory Division (erstwhile Division of Radiological Protection), Bhabha Atomic Research Centre (BARC) started a regular training programme in Radiological Physics in 1962, in collaboration with World Health Organization. This course was later converted as Diploma in Radiological Physics (DipRP). The DipRP course of BARC is a prestigious multidisciplinary education and training programme which is well recognised both in India and abroad. Because of increased demand of medical physicists/RSOs in the country, a few universities/institutions also started education and training programme in medical physics. Currently, twenty two universities/institutions are conducting courses in medical physics in India. The medical physics courses conducted in India are of two different types: (i) Post MSc Diploma in Radiological/Medical Physics (DipRP/DipMP), and (ii) MSc Degree in Medical Physics [MSc (Medical Physics)]. In DipRP/DipMP course, the entry level qualification of the candidate is MSc Degree in Physics whereas in MSc (Medical Physics) course the entry level qualification is Bachelor of Science Degree majoring in physics. As most of the medical physicists trained in India work in the discipline of radiation oncology medical physics (ROMP). Due to the complexity of recent radiotherapy equipment and clinical techniques and to ensure the effective and safe treatment for the patient, medical physics internship at a well-equipped radiotherapy centre for at least one year duration on successful completion of academic component has recently been incorporated in the medical physics education in India. A structured competency based medical physics internship programme was developed and implemented from July 2013. As on today, more than 130 radiotherapy centers are conducting medical physics internship in India. In addition, competency certification process of clinical medical physicists has also been started way back in 2009 and by now more than 50 candidates have been certified by the College of Medical Physics of India. In summary, both academic and clinical part of medical physics education in India is well-structured. We are also initiating the process of re-validation of certification both for clinical competency and radiological safety.

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The characteristics and Challenges of Radiation Dosimetry with Gafchromic Film

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The Gafchromic Film has been widely used for radiation dosimetry in Diagnostic Radiology and Radiotherapy. In radiotherapy practice, Gafchromic film are used as one of tool to verify the Treatment Planning dose calculation. The point dose and gamma index analysis of plannar dose are common techniques used in dose verification in radiotherapy. Number of authors have published their works on characteristics of gafchromic film in radiotherapy dosimetry. some factors which influence to the accuracy of dose calculation such as the scanner, environment etc have been investigated by many authors. In this paper, we would like to share the result of our study of characteristics of gafchromic film and compare with the result of others investigators. We also want to explain our experience of the implementation and challenges dose verification in radiotherapy. According to our result, film dosimety are much influenced by the enviroment of film storage, time of reading, and also scanner characteristic. The accuracy of film dosimetry in dose verification in radiotherapy is higher in small field dosimetry compared to some ionization chambers. The optical apparatus of scanner are also important factor has to be considered in radiation dosimetry.

The Role and Vision in Development of Medical Physics in AFOMP

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The Asia–Oceania Federation of Organizations for Medical Physics (AFOMP) was formed to act as one of the regional organization of the International Organization of Medical Physics (IOMP), and was announced in July 2000 during the Chicago World Congress on Medical Physics and Biomedical Engineering (WC 2000). The formation of the AFOMP aims to provide a solid platform for close collaboration and mutual support among its members, particularly in the promotion of education and training, standard of practice, and professional status of medical physicists in its affiliated regions. Furthermore, the AFOMP aims to facilitate and encourage cross-regional collaboration and interaction on every aspect of medical physics. There are 19 countries associated with the AFOMP. The Middle East Federation of Organizations for Medical Physics (MEFOMP) countries also became members of AFOMP in 2018. The AFOMP is involved in several activities. The main activities are annual official congress (AOCMP), publication of Policy statement, AFOMP newsletter, AFOMP website, and the AFOMP official journal. One major role of the AFOMP is to hold the AOCMP every year. It has been held 17 times since the first one, which was held in Bangkok, Thailand, in 2001. One of the main activities of the AFOMP has been to develop the AFOMP policy statement. Five AFOMP policy statements and one AFOMP code of ethics have been developed thus far. The first issue of the AFOMP newsletter was published as an e-version in December 2007. The format and contents of the AFOMP newsletter have been improved since 2013. The AFOMP website was initially developed in 2007, improved several times, and, recently, newly designed by a professional company, making it ready for use. Three journals have been officially endorsed by the AFOMP: the Biomedical Imaging and Interventional Journal (BIIJ), Australasian Physics & Engineering Science in Medicine (APESM), and Radiological Physics and Technology (RPT). The role and challenges of medical physicists in the AFOMP region have gradually improved and are being recognized by related societies. However, the importance of medical physics and necessity of accreditation have not been recognized by the governments or general public yet. A well-prepared strategy and strong visions are crucial for the AFOMP to move forward.

Current Status of Personalised Radiopharmaceutical Therapy

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Radioactive Iodine, I-131, is generally known to be the first radiopharmaceutical therapy. Recently, several radiopharmaceuticals such as Lutetium-177, Yttium-90, Rhenium-186, Samarium-153, and Actinium-225 have been developed and used in clinical practice. Lu-177 and Y-90 DOTA-peptide have now been used as second line therapy in treating metastatic neuroendocrine tumour. Whereas, Lu-177 and Ac-225 PSMA has shown promising results in treating metastatic prostate cancer. Although calculated dose technique has long been proposed when treating thyroid cancer with Iodine-131, majority of centres still practice fixed dose regime. Recently, European Society of Nuclear Medicine has proposed to adopt internal dosimetry to all radiopharmaceutical therapies. However, there are pros- and cons, as well as feasibility and practicality in adopting internal dosimetry in clinical practice. These issues will be highlighted and discussed in this session.

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Paediatric Radiation Oncology: Can We Translate the Technological Advances from Adults to Kids?

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Fortunately, cancer in children is rare. However, when it occurs it is devastating and small patients unfortunately does not necessarily translate into small tumours. It is also important to note that childhood cancers and their prevalence is different from adults with leukemias and brain cancers being most common. Over the years, radiotherapy has often been discouraged because of the potential late effects such as the induction of secondary cancers through radiation. However, as techniques improve and new modalities become available it is worthwhile to assess what radiotherapy can offer in times of IMRT, IGRT and protons. In addition to the emotional drain there are several issues that make paediatric radiation oncology more challenging: 1) As paediatric cancers are rare clinical trials are difficult to conduct and as a consequence clinical evidence is difficult to obtain. 2) The need for anaesthetics in young patients as well as the common use of chemotherapy and treatment of a growing body, pose additional challenges. 3) The effects of concern are often very late such as cardiac toxicity or secondary cancer induction, which can occur several decades after tie initial irradiation. As low doses to non-targeted tissues become important for these late effects there is often reluctance to employ advanced radiotherapy techniques such as VMAT and IMRT due to the increased leakage and low dose bath associated with these techniques. The same applies to gated CT and image guidance techniques such as cone beam CT which are often not optimised in radiotherapy departments in respect to dose minimisation in adults let alone children. The presentation explores how technology and techniques have changed over the last 20 years making paediatric radiation oncology safer and the use of modern approaches more effective. Objectives in paediatric radiotherapy are often different than in adults where growth retardation or IQ reduction are less frequently taken into consideration. This will be highlighted in the context of an emerging stereotactic ablative body radiotherapy (SABR) program for children at Peter MacCallum Cancer Centre. Overall it is argued that children can benefit from many technological advances as long as the particular needs of these patients are considered.

Clinical use of Ultra High Resolution CT (UHR-C)(UHR-CT can Perform Innovative Imaging Diagnosis)

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In Ultra-High Resolution CT (UHR-CT), a research project was started in 2001 by National Cancer Center Japan and TOSHIBA Medical Systems Corporation (CANON Medical Systems Corporation). Beginning with the first specimen microscope CT capable of taking only small subjects, Aquilion Precision was released as UHR-CT in the spring of 2017. Aquilion Precision has a detector of 0.25 mm X160 data acquisition system (DAS), 1792 channels. Furthermore, the reconstruction is a CT apparatus which realized 2048 matrix and the resolution characteristic was greatly improved. Since UHR-CT can obtain an image with less blurring, strut constituting stent can be recognized. Furthermore, in multiple stents cases for multiple biliary stenosis in the hepatic portal region, it was possible to evaluate lumen embolism, which had heretofore been difficult to visualize. In addition, staging in biliary and pancreatic tumor, effect judgment is done by CT and it is stated that multi detector CT (MDCT) is also used for guidelines in Japan but MDCT diagnosis of pancreas cancer of 2 cm or less No is as low as 43 to 65%. Especially the diagnostic capability such as vascular invasion and lymph node metastasis which is necessary information for the determination of surgical indication in pancreas cancer and bile duct cancer is not enough and it is a standard diagnostic imaging method, there is a limit to Noh. It is considered that this is due to the fact that the diagnostic target part is small and the contrast between the property part and the abnormal part is low. In UHR-CT, it is possible to evaluate the microstructure compared with MDCT, and the possibility of high diagnostic ability in staging is sufficiently expected. Furthermore, the artifact from stent is also alleviated, and it is considered that clinical significance is significant in judging the effect of staging of indwelling cases and chemotherapy that image evaluation after stent indwelling is possible.

Dose Management Systems

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The medical use of radiation is characterized by rapid introduction into practice of new radiation-based techniques and technologies, often without enough knowledge of their radiation protection implications. This makes many of the issues in this area hard to resolve through 'simple' changes of practice and points to the need of research underpinning practical radiation protection. Medical professionals referring to or applying ionising radiation have a very important role in ensuring that their patients and they are adequately protected. This is particularly important in the case of CT and other high radiation dose procedures. Specifically for CT, depending on clinical needs and technical protocols, patient radiation dose differs, even for the same anatomical region, clinical indication, technical protocol and sometimes even for the same CT unit. Due to the aforementioned reasons, the urge to standardize, to monitor, optimize and generally review medical practices has risen significantly. At the same time, this can be an extremely time consuming, complex and compound task. Nowadays, sophisticated software with friendly interface can assist to this task, resulting in a much easier and quicker way to monitor all data included in the Digital Imaging and Communication in Medicine (DICOM) header of the X-ray machines or data recorded in the Picture Archiving and Communication System (PACS) of the hospital. Manufacturers assert these dose tracking softwares form an efficient tool to the user in his attempt to manage imaging examinations. The related lecture will provide an overview of dose tracking systems developed by different vendors and how these systems can help in radiation protection of patients, optimization and organ dose evaluation.

Women in Medical Physics: A Global Perspective

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Introduction: According to the survey of the International Organization for Medical Physics (IOMP) published in 2015, women medical physicists (MPs) account for 28 % of the total workforce around the world. The survey was triggered by the need to find out about the gender composition of MPs around the world. The survey could provide an opportunity for countries and IOMP for more in-depth analysis. Due to the large variation between regions of the world, a more in depth investigation on the reason of this dissimilarity was decided and results will be presented below. Material and Methods: An online questionnaire was created, prepared as a Google Forms survey with a number of simple questions relating not only on the total number of MPs and women MPs, but also on issues related to leadership or high level professional or scientific roles. The questionnaire was sent to all national member organizations of IOMP. In the attempt to have as much data as possible, even non-IOMP member countries were included in the survey. Results: The results of the survey included data from 92 countries in total. Total number of MPs were 29086, 20421 being men and 8665 women (30%). The percentage of women is slightly better than the 28% found in an earlier IOMP survey in 2015. The percentage is lower than the European target set at 40% and the United Nations 50% target for 2030. The representatives of the countries provided various reasons for explaining the data provided. There are a number of countries, in which women do not take higher responsibility roles or leadership positions whereas in others women account for 100 % of the total workforce of the country. Conclusion: The IOMP survey showed slight progress in women presence in the MP field the last years. Representation of women in leadership positions is currently very low.

Reference Dosimetry for SF – Machine Specific Reference Assessment

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Introduction: Current diagnostic assessment tools remain suboptimal in demonstrating complex morphology of congenital heart disease (CHD). This limitation has posed challenges in preoperative planning, communication in medical practice, and medical education. This study aims to investigate the dimensional accuracy, as well as the clinical value of three-dimensional (3D) printing of CHD in the areas mentioned above. Methods: Ethical approval was obtained from Human Research Ethics Committee. Using cardiac computed tomography angiogram (CTA) data, a 3D model of a 20-months-old heart with double outlet right ventricle was printed in TangoPlus material. Pearson correlation coefficient was used to evaluate correlation of the measurements taken at analogous anatomical locations between the CTA and 3D printed model. Surveys were also conducted with 6 health professionals (2 radiologists, 2 cardiologists and 2 cardiac surgeons) and 3 medical academics to assess the clinical value of the 3D printed model. Results: Excellent correlation (0.99) was noted in the measurements between CTA and 3D printed model. Four out of six health professionals found the model to be useful in facilitating preoperative planning, while all of them thought that the model would be invaluable in enhancing patient-doctor communication. All three medical academics found the model to be helpful in teaching, and thought that the students will be able to learn the pathology quicker with better understanding. Conclusion: The patients' heart anatomy can be accurately replicated using 3D printing technology. 3D printed heart models could serve as excellent tool in facilitating preoperative planning, communication in medical practice, and medical education.

CT Dose and X-ray Beam Profile Measurements

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The purpose of this study was to measurement computed tomography (CT) dose, half-value layer (HVL) and CT beam profiles (CTBP) for several X-ray beam widths on 64-slice, and dual source multi detector-row CT (MDCT) using recent X-ray analyzer. We measured the CT dose and CTBP, CT-HVL using recent X-ray analyzer (Accu-Gold+, Radcal, Monrovia, CA) with an ion chamber (10X6-3CT or 10X6-0.6CT, Radcal, Monrovia, CA) and a solid-state multisensor (AGMS-D+, Radcal, Monrovia, CA). An ion chamber placed in the center hole of the single CT dose phantom, and solid-state multisenser placed on the CT gantry. we performed three helical scans of phantom length. Then two, and three coupled CT dose phantoms were placed together to simulate a 300-mm-long, and 450-mm-long phantom. We acquired several helical scans. Next, we performed convenient method of measuring the CT-HVL using a solid-state multisensor and hand-made Pb slit. We put the solid-state multisensor in the hand-made Pb slit and placed on the CT table. We performed several axial scans for measuring the CT-HVL. The cumulative CT dose were increased with extended length from 150 mm to 300 mm of the CT dose phantom. CT dose were greatly increased toward peripheral area of the CTBP. With extended length from 300 mm to 450 mm of CT dose phantom, the observed percent increase of the CT dose was slightly increased. There was no difference in the form of the CTBP between 300-mm-long phantom and 450-mm-long phantom. The results of the CT-HVL were compared with those of conventional non-rotating method. There was no difference in the CT-HVLs between conventional method and our convenient methodin clinical practice. These issues will be highlighted and discussed in this session.

Clinical Value of Patient-Specific 3D Printed Models in Medicine

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3D printing has been increasingly used in medicine with applications in many different fields ranging from orthopaedics to cardiovascular disease and tumours. Physical 3D models can be printed with different materials to replicate anatomical structures and pathologies with high accuracy. 3D printed models based on medical imaging data acquired with CT, MRI or Ultrasound have been shown to improve understanding of complex anatomy, assist preoperative planning, simulate surgical or interventional procedures, training young or junior doctors and providing medical education to medical students or health professionals. This presentation will provide an overview of clinical value of patient-specific 3D printed models in medicine with a focus on the following applications: 3D printed models in cardiovascular disease including congenital heart disease, coronary artery disease, pulmonary embolism, aortic aneurysm and aortic dissection; 3D printed models in liver and biliary disease including hepatocellular carcinoma; and 3D printed models in tumours including brain glioma and renal cell carcinoma. Dimensional accuracy and clinical value of the patient-specific 3D printed models in these applications will be presented, while limitations and future research will be highlighted.

SECTION II

PRESENTERS ABSTRACT (THERAPY)

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A006

Preliminary Study of In-House Phantom as Verification Tools for Brachytherapy Treatment using 2D Gamma Analysis Method

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Purpose: This study presents a potential of in-house pre-treatment verification phantom as verification tools to evaluate the isodose distribution calculated by brachytherapy treatment planning (TPS) for high dose rate (HDR) interstitial brachytherapy treatment. The isodose distribution calculated by TPS based on the pre-treatment verification phantom was compared with measured Gafchromic EBT3 films and were analysed in term of two-dimensional (2D) Gamma analysis using a patient plan verification software (Verisoft®, PTW, Freiburg, Germany). Methods: Pre-treatment verification phantom was customised in-house. Twelve of 6F plastic catheters were placed firmly on the surface of bolus with 1 cm distance between each catheter and sandwiched with another bolus on top of the catheters. The phantom was scanned using computed tomography (CT) scan and the CT data were exported to the Oncentra Version 4.5 brachytherapy treatment planning (TPS). On the TPS, the catheters were reconstructed and source was activated on the different catheters in order to create three different plans which are plan A (Rectangle shape), plan B (Box shape) and plan C (Pear shape). Those plans were executed and Gafchromic EBT3 film was placed 1 cm beneath the catheters. The comparison of isodose distribution from measurement and TPS was evaluated based on 2D Gamma analysis using Verisoft software. Results: From the results, those 3 plans passed the criteria of acceptability (3% delta dose and 3mm distance) which are more than 90% of 2D Gamma analysis. Plan C demonstrated the highest pass rate of gamma analysis which is 99.9% compared to plan A and plan B which showed 99.4 % and 90.2 % respectively. Conclusions: The in-house verification phantom could be utilized for the QA procedure of HDR brachytherapy remote after loading system to confirm accuracy of dose distribution in interstitial implants.

Keywords: Verification; gafchromic film; gamma analysis

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A008

Utilizing Virtual Bolus in Dose Optimization (Tomotherapy) for Head and Neck Cancers

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Purpose: To evaluate the radiation dosimetry effects of using virtual-bolus (VB) in Tomotherapy treatment planning for Planning-Target-Volume (PTV) that extends to skin/body-surface. Methods: PTV is drawn on phantom that extended to the phantom surface, virtual bolus of various thickness (2mm/4mm/6mm) and densities (0.5g/cc or 1.0g/cc) combinations are drawn to provide build-up region and then optimized with Tomotherapy TPS. EBT3 Gafchromic Film is calibrated and used to analyze the dose profiles across PTV and the phantom surface, and to perform gamma analysis with Distance-to-Agreement (DTA) 3mm and Dose Difference (DD) 3% criteria. Tomotherapy Planned-Adaptive software is used to analyze the delivered Dose-Volume-Histograms (DVHs) reconstructed from mega-voltage computed tomography (MVCT) acquisition. Results: Without VB, the control set (without VB) optimization showed maximum dose close to 110% at the phantom edge/surface due to lack of build-up region. VB of 2mm is unable to provide adequate build-up area. VBs of 4mm and 6mm are able to control the maximum dose. However, VB of 6mm exhibits significant reduction in dose coverage (95%) in actual radiation delivery. Conclusions: VB of 4mm is observed to provide satisfactory dose coverage even in actual radiation delivery. Virtual bolus of thickness 4mm and density 1.0g/cc combination provides the most robust model to account for lack of build-up region. It exhibits the least difference in maximum dose from TPS planning and actual radiation delivery; where the maximum dose is kept below 105% and the dose coverage is clinically acceptable.

Keywords: Tomotherapy; IMRT; virtual bolus; superficial PTV; dosimetry

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A009

Dosimetric Verification of IMRT and 3DCRT Radiotherapy Techniques of Localised Prostate Cancer Treatment using Custom-made Pelvic Phantom

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Purpose: Verification of dose delivery is a basic necessity of quality assurance in radiotherapy treatment. The entire treatment process was replicated with a constructed male pelvic phantom. Intensity modulated radiation therapy (IMRT) and three-dimensional conformal radiotherapy (3DCRT) treatment planning techniques were used for localised prostate cancer treatment using 6MV photon energy. Methods: A CT image of male pelvic region was used to contour the prostate, rectum, bladder and both femoral head from custom made phantom. Dose measurements to the target and organs at risk (OARs) were obtained from the thermoluminescent dosimeters (TLDs) and Gafchromic external beam therapy (EBT3) film. Points of interest were identified in phantom for TLDs placement with seventeen (17) holes to the prostate and eighty-three (83) holes distributed among the OARs. A piece of EBT3 film was located at the center of 31 pieces of perspex where the target was located. Teflon was used to construct both femoral head. Results: The pelvic phantom has been successfully constructed to replicate male pelvic region. All calibrated TLD generated standard deviation in range 0.04 to 0.38. The EBT3 film displayed a linear response (R^2=0.9229) from dose range 0cGy to 400cGy. The percentage different between the TLD and 3DCRT plan at the PTV resulted in range 0.24% to 4.61%. The standard error bar of 5% value on PTV and OARs showed no significant differences. The gamma evaluation at PTV using IMRT technique was 95% using EBT3 film. Conclusions: The new handmade pelvic phantom fulfilled the basic criteria for dosimetric verification of IMRT and 3DCRT techniques.

Keywords: Prostate cancer; verification phantom; treatment planning system

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A012

Optimal Treatment Planning Conditions for SBRT of Spinal and Lung Tumours

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Purpose: Use of SBRT techniques is now a relatively common recourse for spinal and lung metastases due to good local control rates and durable pain control. However, the technique has not yet reached maturity for gantry-based systems so work is still required in finding planning approaches that produce optimum conformity and delivery while also minimizing skin toxicity. Methods: 90 clinical SBRT VMAT lung and spine plans, varying in modality, arc length and control points, were created in Pinnacle. These plans were assessed according to complexity metrics and planning objectives as well as undergoing treatment delivery QA on an Elekta VersaHD through multiple methods. Skin dose was assessed by considering the National Cancer Institute skin reaction grades. Results: Plan complexity and delivery accuracy were found to be independent of MUs but improved with the number of control points. The fraction of small apertures utilized also had no impact on plan quality or accuracy but rather more complexly modulated plans showed poorer results due to MLC leaf position inaccuracies. The skin volumes predicted to exhibit low grade reactions decreased with arc length, while high grade reactions were found to increase at smaller arcs as well as at full arcs where a superposition of entrance and exit doses would occur. Conclusions: The most impactful parameter at the disposal of the planner to determine plan delivery accuracy is the number of control points utilized while skin dose effects are mostly predicted by arc length.

Keywords: SBRT; accuracy; skin dose; planning

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A019

The Investigation of the Polymer Gel Dosimetry in Patch-Field Proton Therapy using Beam Current Modulation

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Purpose: In Proton Beam Therapy Center of the University of Tsukuba, we use imaging plates (IP) for a dose verification of patch field irradiation method. Although a polymer gel dosimeter is a chemical dosimeter that can perform three-dimensional dose distribution measurement, there are few reports in proton beam therapy. In this study, a polymer gel dosimeter was used as a tool for a verification of the patch field irradiation method corresponding to the rectangular irradiation of the esophagus. Methods: Measurements were carried out with a polymer gel dosimeter irradiated with to patch field of two to 8x4 cm^2 rectangular fields which was created with the treatment planning system beforehand.The results were compared with The IP in radiation profile near the field. Joint. Results: The dose measured with the gel dosimeter was 21% higher compared to that measured with the IP. In addition, the differences plans designed to make the joint dose hot and cold, respectively. Conclusions: We found that the gel dosimeter was in a better agreement with the existing verification method with higher dose. The gel dosimeter is an easy-to-use three-dimensional dose verification, and it is easy to compare with a treatment plan from an arbitrary profile. In the future, it is necessary to develop a dosimeter with improved stability in the lower and higher dose range.

Keywords: PAGAT; patch field irradiation method; proton therapy

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A020

An Investigation on Impacts of Anisotropic Planning-Risk Volume Margins for Rectum in Prostate Cancer Radiation Therapy

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Purpose: To investigate the impacts of the application of anisotropic safety margin to the organs at risk (OAR) (referred to as planning-risk volume (PRV) margins) for the rectum on the dose distributions to the rectum and the clinical target volumes (CTVs) in prostate cancer radiation treatment. Methods: The population standard deviations (SDs) of systematic and random errors were calculated by using a statistical point distribution model (PDM) for rectum regions in planning computed tomography (CT) and cone-beam CT (CBCT) images at 80 fractions of 11 patients. The anisotropic PRV margins were determined by combining the population SDs of systematic and random errors of a group of patients, as formulated in the PRV margin recipe, and were applied to additional 4 test patients. The comparisons between the original and the PRV-based plans were conducted by calculating dose evaluation indices of the CTV and the rectum (CTV V_{98},rectum V_{75},V_{70},V_{65}, V_{60} and V_{40}). A Wilcoxon signed-rank test was employed to compute the statistical differences between the dose evaluation indices in original and PRV-based plans. Results: The V_{75} of the rectum in the PRV-based plans was significantly smaller than that in the original plans ($p < .001$). However, the V_{40} of the rectum in the PRV-based plans was significantly larger than that in the original plans ($p < .001$). On the other hand, the D_{98} to the CTV showed no statistical significant differences between original and PRV-based plans ($p > .001$). Conclusions: The anisotropic PRV margin should be considered to reduce high doses to the rectum in prostate cancer radiation therapy.

Keywords: Prostate cancer; radiation therapy; PRV margins; rectum; dose indices

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A021

Calibration of Ionization Chambers and Quality Audit Intercomparison for High Energy Photon Beam Dosimetry of Radiotherapy Centers in Bangladesh

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Purpose: The outcome of the radiotherapy is highly dependent on how precisely dose is delivered to the tumor that should not be exceeded ± 5% of the prescribed dose including all types of uncertainties involved in the treatment procedure. The main objectives of this research program is to ensure dose delivering to the patients and traceability of radiotherapy dosimetry that performed by the radiotherapy centers. Methods: A total number of 26 ionization chambers of different oncology centers in Bangladesh have been calibrated in terms of absorbed dose to water at ^{60}Co against the reference system at SSDL, Bangladesh. On the other hand, the best available process of quality assurance of radiotherapy dosimetry by participating IAEA/WHO TLD intercomparison program for oncology centers has been initiated for fifty number of photon beams. Results: The maximum variation of calibration factors of the chambers between the manufacturer and SSDL values have been observed within ± 2.2 % with an uncertainty of ± 1.5% (k=1). The deviation of stated dose to measured dose of photon radiotherapy beams lies between 0.1-4.5% for linac photon and 0.6-4.0% for cobalt with an uncertainty of ± 1.8% (k=1) . Seven out of fifty photon beams were exceeded the tolerance level set-forth by IAEA (smaller or equal ± 5%). The reason of discrepancies was determined and corrected by onsite visit at the radiotherapy centers. Conclusions: The intercomparison performed is a successful step from the point of view in improving the dosimetry situations in hospitals. Hence, a regular quality assurance program of radiotherapy dosimetry should be emphasized worldwide.

Keywords: Radiotherapy; calibration; ionization chamber; intercomparison

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A023

Determination of the Half Beam Block Factor using Breast Treatment Device and its Effect on Treatment Time Calculation for Breast Cancer Radiotherapy in Cobalt-60 Machine

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Purpose: During the treatment of the breast cancer in cobalt-60 machine there is high probability of irradiation of organ at risk (OAR). The breast treatment device is used to treat patient with optimal accuracy at low or no risk to the OAR. The half beam block factor (HBBF) is determined to account for the change in dose delivery observed due to the use of breast treatment device compared to that without using it. Methods: The chamber FC-65G was fixed at 10cm depth in PMMA solid phantom on the couch of cobalt-60 machine. The chamber was connected with electrometer. Electrometer reading with and without breast treatment device for different recurring field size used during the treatment of breast cancer patient in BP Koirala Memorial Cancer Hospital was taken. Results: The calculated value of HBBF varies from minimum value 0.8989 to maximum value 0.9412. The mean and standard deviation of these calculated HBBF are 0.9125 and 0.0107 respectively. It was found that the treatment time calculated without considering HBBF is less compared to the treatment time calculated with considering HBBF by minimum 0.057 to maximum 1.687 minutes. In average 59.07cGy dose was insufficient to the patient. Conclusions: The difference in treatment time calculated with and without using HBBF corresponds to insufficient dose delivery of 59.07cGy which is not too high but is against the principle of radiotherapy. Small insufficiency of prescribed dose may cause recurrence of cancer. Therefore HBBF should be taken in account while planning treatment in cobalt-60 machine using the breast treatment device.

Keywords: Irradiation; phantom; half beam block factor

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A025

Comparison of the Jaws Only IMRT and 3D-CRT for Head-and-Neck Cancer using Physical and Radiobiological Evaluation Method

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Purpose: Jaws-Only IMRT (JO-IMRT) is a technique which use the integrated jaws of the linear accelerator to deliver IMRT plan. Our previous studies have demonstrated that the dose distributions planned using our JO-IMRT treatment planning system for H&N patients were superior to the corresponding 3D-CRT plans and those JO-IMRT plans were also verified by an ionization chamber, Mapcheck 2, and Octavius 4D. In this study, we performed the radiobiological method of evaluations along with the routine physical dose evaluation for JO-IMRT and 3D-CRT plan. Methods: The physical index including conformity indexes (CI), homogeneity indexes (HI) and radiobiological indexes like Niemierko's EUD-based tumor control probability (TCP), normal tissue complication probability (NTCP) and biologically effective dose (BED) was calculated to compare between two plans for the same patient using Prowess Panther. Results: JO-IMRT had a better tumor coverage and conformity index compared to 3D-CRT plans. The mean dose to the PTV for the 3D-CRT plan and JO-IMRT plan was 72.1 ± 0.8 Gy and 72.5 ± 0.6 Gy ($p > 0.05$). In addition, the mean dose to parotid grand were 56.7 ± 0.7 and 26.8 ± 0.3 ($p < 0.05$) for the 3D-CRT plan and JO-IMRT plan, respectively. The CI, HI, BED values were 0.14 ± 0.05 and 0.13 ± 0.01 ($p > 0.05$); 0.73 ± 0.10 and 0.83 ± 0.05 ($p < 0.05$); 72.76 ± 5.63 and 79.78 ± 5.51 ($p < 0.05$) with 3D-CRT and IMRT plans, respectively. The TCP and NTCP for 3D-CRT and JO-IMRT were 0.37 ± 0.15 and 0.42 ± 0.06; 0.76 ± 0.29 and 0.04 ± 0.20. Conclusions: Our result shows the JO-IMRT technique was clearly able to increase the dose delivery to PTV, improve CI, HI and spare the parotid glands in comparison to 3D-CRT technique. Furthermore, the TCP and NTCP should be performed to provides additional information for the treatment planning selection process.

Keywords: Intensity-modulated radiation therapy (IMRT); jaws only IMRT (JO-IMRT); quality assurance (QA); physical and radiobiological evaluation

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A026

Monte Carlo Evaluation of Dose Calculations Accuracy of Prowess Panther System for Lung Case

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Purpose: The dose calculation algorithm is an important factor to accuracy of the dose calculation in the treatment planning systems (TPS). The fast photon effective (FPE) and the collapsed cone convolution (CCC) algorithm have been used for Prowess Panther systems. The aim of this study was to evaluate the accuracy of the FPE and CCC algorithms using Monte Carlo (MC). Methods: A set treatment plans of test cases including the acrylic phantom, the QUASAR multi- purpose body phantom, and lung cancer patient was designed using Prowess Panther version 5.1 to assess the accuracy of prediction algorithms. The DICOM-RT files of the treatment plans were exported to the Monte Carlo system to recalculate. The simulated dose distributions were then compared with the ones calculated by Prowess Panther TPS, using relative dose error comparison and 3D gamma index using global methods implemented in PTW-VeriSoft with (3%/3 mm, 2%/2 mm, 1%/1 mm criteria. Results: We compared the Monte Carlo algorithm with two algorithms (CCC and FPE) for phantom and lung cancer patients. The gamma index (3%/3 mm, 2%/2 mm, 1%/1 mm) is good agreement between the simulated and calculated dose for both the QUASAR multi-purpose body phantom and lung cancer patient (in form of CT images). However, the discrepancies are found to be 10% in inhomogeneous medium. It is extremely important not to go beyond the maximum doses tolerated by sensitive. Therefore, the dose calculation accuracy of TPS should be adequate. Conclusions: According to the results of this study, it is concluded that the CCC and FPE algorithm may not accurately predict the dose distributions in and near inhomogeneous structures. Monte Carlo method will be more accurate and possibly more efficient than them.

Keywords: Radiotherapy; dose calculation accuracy; algorithm; treatment planning system

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A027

Characterisation of the Secondary Fragmentation Field Produced by Carbon and Oxygen Ion Beams of Therapeutic Energy: A Monte Carlo Simulation Study

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Purpose: The main advantages of charged particle radiotherapy compared to conventional X-ray external beam radiotherapy are a better tumor conformality coupled with the capability of treating deep seated radio-resistant tumours. This work investigates the possibility to use oxygen beams for hadrontherapy, as alternative to protons and carbon ions. Oxygen ions have the advantage of a higher relative biological effectiveness (RBE) and better conformality to the tumour target. This work describes the radiation field produced by an oxygen beam in water and compares it to the one produced by a therapeutic carbon ion beam. Methods: This work is performed by means of Geant4 simulations. The dose is calculated for incident carbon ions with energies of 162 MeV/u and 290 MeV/u, and oxygen ions with energies of 192 MeV/u and 245 MeV/u, so that the range of the primary oxygen ions projectiles in water were located at the same depth as the carbon ions. The incident beam has a lateral size of 5 cm. The dose contribution due to the incident beam and secondary fragments was scored and analysed. Results: The results show that oxygen ions provide a higher peak-to-entrance ratio than carbon ions at lower energy, the lateral dose distributions for secondary fragments generated by both primary carbon ions and oxygen ions were similar. The benefits of oxygen ions are more pronounced when using lower energies. Conclusions: This work concluded that oxygen ions are the most suitable heavy ions for hadron therapy in addition to carbon ions due to a higher peak-to-entrance ratio and higher energy deposition at the Bragg peak.

Keywords: Charged particle therapy; Monte Carlo simulation; Geant4; carbon ions; oxygen ions; lateral dose distribution

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A028

Quality Assurance of External Beam Radiotherapy at Khwaja Yunus Ali Medical College & Hospital (KYAMCH)in Bangladesh

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Purpose: The outcome of the radiotherapy is highly dependent on how precisely dose is delivered to the tumor that should not be exceeded ± 5% of the prescribed dose including all types of uncertainties involved in the treatment procedure. The main objectives of this research program is for comprehensive Quality Assurance program for two linear accelerator, Elekta Synergy at our Center. Methods: The comprehensive Quality Assurance (QA) program was conducted with the measurement Percentage Depth Dose (PDD), Quality Index (QI), Beam Flatness and Symmetry, and Output Factor (OF) for two linear accelerators Elekta Synergy at our Center. The program is designed according to the policy of the center as well as followed by the guideline of Regulatory Authority of Bangladesh. The chambers were calibrated once a year from SSDL, Bangladesh. The results of the study showed reproducibility in all QA procedures with an average photon for monthly OF of 0.988 ± 0.011, 0.989 ± 0.010 and 1.005 ± 0.006 for 4 MV, 6 MV and 15 MV respectively. Results: The maximum variation of calibration factors of the chambers for last six consecutive years between the manufacturer values and new calibration coefficient lies within ± 0.56 to ± 0.94% with an uncertainty of ± 1.1% (k=1). The result shows an excellent agreement of calibration coefficient of ionization chamber which have a good consistency. Conclusions: Under the QA program, reproducibility of all other parameters over the 24-month period for both the Linacs, as well as the accuracy and repeatability of the treatment plans generation and dose delivery were excellent.

Keywords: Radiotherapy; quality qssurance (QA); intercomparison

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A029

Dose Evaluation Indices for Total Body Irradiation using Tomodirect with Different Numbers of Ports: A Comparison with the Tomohelical Method

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Purpose: To investigate the relationships between the number of ports and dose evaluation indices in low-dose total body irradiation (TBI) using 2 to 12 ports of TomoDirect and to compare with TomoHelical in a simulation study. Methods: Thirteen patients underwent low-dose TBI with TomoHelical from June 2015 to June 2016. We used same data sets of these patients to create new treatment plans of upper body part using TomoDirect with 2 to 12 ports and TomoHelical. The prescription was 4 Gy in 2 equal fractions. For TomoDirect plans, we generated plans with 2 to 12 ports with approximately equally spaced angles, and the parameters of modulation factor, field width, and pitch were 2.0, 5.0 cm, and 0.500, respectively. For TomoHelical plans, the parameters of modulation factor, field width, and pitch were 2.0, 5.0 cm, and 0.430, respectively. D2, D98, D50, and homogeneity index (HI) were evaluated to compare each plan of TomoDirect with 2 to 12 ports with TomoHelical plan. Results: D2 of 5-port and less, D98 of 3-port and less, D50 of 7-port and less, and HI of 3-port and less in TomoDirect plans showed significant worsening compared with TomoHelical plan. D98 of 6-port and more, D50 of 12-port, and HI of 8-port and more in TomoDirect plans showed significant improvement compared with TomoHelical plan. Conclusions: TomoDirect plans showed significant improvement of D98, D50, and HI compared with TomoHelical plan. Our finding suggest that TomoDirect would provide better dose distribution in low-dose TBI with Tomotherapy.

Keywords: TomoTherapy; TomoDirect; total body irradiation (TBI)

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A030

Validation of 4D CBCT with 4D CT for Respiratory Gated Radiotherapy: A Phantom Study

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Purpose: The purpose of our study is to validate the 4D CBCT generated on Edge linear accelerator using advanced imaging with 4DCT used for planning purpose. Methods: 3DCT scan of Quasar motion phantom, containing single target was acquired in static ,and 4DCT using Varian RPM and Siemens 4DCT scanner . Images were retrospectively sorted into six phase bins from 0% to 100% inhalation in increment of 20%. The target was delineated in each of the eight CT datasets using Eclipse treatment planning system(v13.6). The same phantom was set up on Edge linac and 4D CBCT was acquired for same condition and the images were reconstructed using CBCT Basic and CBCT Advanced modes in the advanced imaging workspace on the console of Linac.The changes in volume of target at different phases were compared with that of 3DCT and 4DCT acquired. Results: Variation of target volume for CBCT and CT was less than ±1%. Of the two reconstruction methods used for CBCT, CBCT Advanced showed a deviation of ±8 % in terms of volume delineation as compared to CBCT Basic it was ±12% for all the phases when compared with 4DCT. Conclusion : The 4D CBCT images generated on Linac with CBCT advanced reconstruction mode correlated well with the 4D CT generated on the CT scanner. These results may be relevant to respiratory gated treatments for target volume definition, verification imaging with the gating signal during treatment.

Keywords: 4DCT; 4D CBCT; motion phantom; phase binning

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A031

Planning Study to Optimize the Dose for Low-Risk Prostate Cancer with IMRT Technique

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Purpose: A comparison study of the plan quality between two intensity-modulated radiation therapy (IMRT) techniques was undertaken to optimize the dose for lowrisk prostate cancer. Methods: Ten patients with prostate cancer treated in our institution were randomly selected for this study. To optimize the IMRT technique, Two IMRTs configurations, differing for gantry angles direction, were tested for each patient. The first technique (IMRT-S) was used as reference plan; these plans utilized a 5-beam configuration, standard for prostate cancer treatment, and the second technique (IMRT-OP) combining 5 plans with 5 beams for each, changing beam directions every 7 sessions (70 Gy in 35 fractions). Dose optimization was carried on according to the institution protocol. Dose normalization was set as D(50%)=70Gy. OAR's included bladder, rectum, femoral heads, and healthy tissue. All plans were generated with 6 MV xrays delivered with a Varian Clinac DHX. Optimization and calculations were done in the Varian Eclipse treatment planning system (version 10.0.28). Statistical differences were analyzed using the paired-sample Wilcoxon's test. Results: For the same PTV coverage, the IMRT-OP plans had significantly better plan quality in terms of organs at risk sparing than the IMRT-S plan ($p < 0.05$). Conclusions: Considering the superior quality of the IMRT-OP plan compared to IMRT-S, IMRT-OP may be the modality chosen for centers that do not have VMAT techniques for the treatment of prostate cancer, taking into account only the protection of organs at risk

Keywords: Intensity modulated radiation therapy; prostate cancer

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A032

Modelling of Treatment Couch Top with Prowess Panther Treatment Planning System for External Beam Radiotherapy

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Purpose: The aim of this work is to evaluate the attenuation effects of a treatment couch and to alternatively model the couch top material with a Prowess Panther treatment planning system which does not support couch top modelling. The Hounsfield Unit classification of the couch structure was determined using a PMMA phantom by comparing ion chamber measurements with the dose forecasted by the treatment planning system (TPS). The transmission factor (TF) of the couch top was determined and was used as a TF for a treatment accessory that represented the treatment couch in the TPS. Methods: A treatment plan was done for various angles with and without the interference of the couch top and a simulated treatment was done using the PMMA phantom. Ion chamber measurement were made and compared with dose predicted by the TPS to evaluate the accuracy of the couch top modelling in the treatment planning system TPS. These investigations were done for various field sizes. Results: The ideal set of HU for the couch was established to be -674. The measured TF was 0.956042 and the TPS calculated Transmission factor was 0.951456. The percentage difference between the measured and calculated TFs was 0.48% and this agrees perfectly with the IAEA recommended tolerance of 2%. Relative attenuation measurements were as high as 54.16% and as low as 0.63% for the beams that exited the couch before interacting with the phantom. In comparing couch modelling by couch simulation and couch TF insert, it was observed that the normalized doses were the same for 5×5 square field but deviated approximately 1% for the other field sizes. The highest deviation was observed at 10×10 square field. Conclusions: This study demonstrates that the couch simulation method of couch modelling is the best method that can be used to account for the effect of the treatment couch top on intersecting posterior beam fields. Thus, the attenuation effects of the treatment couch was effectively evaluated and the couch top material accurately modelled in the Prowess Panther TPS. The most important thing is to set the correct optimum HU for the couch in the TPS. Also in case part of the couch is truncated when imaged, the truncated part should be reconstructed in the TPS and assigned the correct HU.

Keywords: Carbon fibre; plywood; Hounsfield units

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A035

Confirmation of Dose Delivery through Transit Signal with Locally Fabricated Thorax Phantom and in Carcinoma of Middle Third Esophagus Patients Undergoing 3DCRT

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Purpose: This study presents a method to estimate mid plane dose (Diso,transit) in vivo from transit signal (St) measured with thimble ionization chamber in cancer of middle third esophagus patients treated with three dimensional radiotherapy. This detector is positioned at the level of electronic portal imaging device in the gantry of a medical linear accelerator. Methods: A locally fabricated thorax phantom was used to measure the in vivo mid plane dose (Diso,mid) which was also estimated through St. Twenty five patients with carcinoma of middle third esophagus treated with 3DCRT were under taken. Transit signals were recorded (three times, with a gap of 5 – 6 fractions during the course of treatment) to estimate Diso,transit, which was compared with the doses calculated by TPS using superposition algorithm. Results: Percentage deviation of Diso,Transit, Diso,mid with Diso,TPS combined all fields was 2.7 and -2.6% respectively with the thorax phantom. The mean percentage deviation with standard deviation of estimated Diso,Transit with Diso,TPS observed in patients is 0.73% ± 2.09 (n=75). Conclusions: Mid plane dose estimates in vivo using this method provides accurate determination of planned delivered dose in middle third esophagus treatments. This method could be useful in similar clinical circumstances for dose confirmation and documentation.

Keywords: In vivo dose; conformal radiotherapy; transit signal; esophagus cancer

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A036

Fabrication of a Female Pelvic Phantom for Dosimetric Verification of Radiotherapy Treatment of Carcinoma Cervix

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Purpose: An accurate way to do radiation dose assessment is with the help of realistic phantoms. Methods: Various anatomical structures were delineated on Computed Tomography (CT) images and the external contours were altered or smoothed in shapes as required for milling. The electron density of the materials chosen for fabrication was based on HU to electron density calibrations. Results: Physical& Dosimetric properties The phantom was simple to assemble and reproducible with no discernable displacement. The CT numbers of the phantom materials and those of the delineated regions on the CT of the patient used to model the phantom were sampled using the Eclipse planning system and indicates agreement. EBRT& ICBT treatment planning and measurements using the fabricated phantom The doses measured with the ionization chamber and TLDs were compared with TPS calculated dose in different locations in the phantom like target volume, bladder, rectum, left and right femoral head. The average measured dose agreed with the TPS calculated dose. Conclusions: The fabricated phantom is a representative female pelvis, realistic in size and anatomy and suitable for the evaluation of cervix cancer treatments. The materials chosen approximate tissue, organ and bone densities and allow for distinguishable structures in treatment planning. It can accommodate TLDs and ion chamber for measurements; however provision can be made to use film, chemical dosimeters and OSLDs. The dosimetric measurements confirm the suitability of the fabricated phantom for the verification of dose delivery in both tele therapy and brachytherapy of carcinoma cervix.

Keywords: Anthropomorphic; phantom; radiotherapy

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A037

Monte Carlo Evaluation of Air Cavity Effects in JO - IMRT Dose Distributions

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Pupose: The use of small beamlets in the jaws-only intensity modulated radiation therapy (JO-IMRT) techniques may result in inaccuracies in dose distributions of treatment target adjacent to air cavities due to electronic disequilibrium around air-tissue interfaces. In this study, we use Monte Carlo (MC) simulation to examine the dosimetric effects of the air cavity on JO-IMRT dose distribution at air-tissues interfaces in head-and-neck (H&N) patients. Method: The EGSnrc Monte Carlo code system was used. The user codes, BEAMnrc and DOSXYZnrc, were used to simulate 6 MV photon beams produced by Siemens medical linear accelerators so as to calculate the dose reductions in air-tissue interface region for single field irradiations with 1×1 cm^2, 2×2 cm^2, 3×3 cm^2, 4×4 cm^2, and 5×5 cm^2 in solid acrylic phantoms (30×30×20 cm^3) and seven fields in a JO-IMRT plan. With phantom, the PDD values in both with and without an air cavity (15×4×4 cm^3) which is 2.5 cm away from the anterior surface of phantom were used to evaluated. With JO-IMRT plan, the JO-IMRT dose distribution was computed using the DOSXYZnrc and then compared with the ones calculated by the Collapsed Cone Convolution (CCC) algorithm on the TPS, using dose-volume histograms (DVH), slice by slice isodose, and the gamma index using global methods implemented in PTW-VeriSoft with 3%/3 mm criteria. Results: The study results indicate that the dose reductions in air-tissue interface region of phantom is strongly dependent on field size. The average percentage dose reductions at 1 mm from the air-water interface for the field sizes 1×1 cm^2, 2×2 cm^2, 3×3 cm^2, 4×4 cm^2, and 5×5 cm^2 are 62.04%, 52.34%, 40.71%, 26.72%, and 19.85%, respectively. However, beyond 1 cm from the air-water interface, the average percentage dose reductions are similar for all the field sizes. Additional, the mean MC dose in the PTV (65.58 Gy) of patients were lower than the TPS predicted dose (71.41 Gy). Conclusion: From this study, we conclude that the dose reduction in near air-tissue interfaces is significant effect on JO-IMRT dose distribution in head-and-neck (H&N) patients.

Keywords: Radiotherapy; dose calculation accuracy; algorithm; Monte Carlo; air cavity

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A040

SABR Pre-Treatment Verification using Nanodot, Alanine and PTW 60019 Detectors

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Purpose: Stereotactic ablative radiotherapy (SABR), otherwise called stereotactic body radiation treatment (SBRT) is one of the most chosen treatment approaches for early-stage cancer treatment. It was aimed to investigate the quality of alanine, nanoDot, and microDiamond detectors and explore the feasibility of using these dosimeters for pre-treatment verification of the dose delivered to patients during SABR. Method: Prior to SABR pre-treatment verification, all detectors were assessed for dose linearity, energy, directional and dose rate dependence. The Bruker EleXsys E500 EPR spectrometer of 9.5MHz, Microstar Reader, Dose 1 electrometer was used to read out the signal of alanine, nanoDot and microDiamond respectively. All the irradiation was done on ClinaxTH 21ix at 6MV x-ray beam. Three Dimensional (3-D) phantoms were designed for each detector and were placed separately inside the in-house Rod phantom made of Perspex to perform SABR pre-treatment patient verification. Results: For all three sites (sternum, spine and scapula), the average measured and planned dose was recorded for alanine (18.29 ± 0.91 % and 18.57 ± 1.12 %) , microDiamond (17.76 ± 0.65 % and 17.68 ± 0.63%), nanoDot(18.29 ± 0.85 % and 18.64 ± 1.31 %). Alanine and microDiamond percentage difference between the measured and the TPS were within 2% and <2% for nanoDot. Conclusion: The alanine, nanoDot, and microDiamond have been verified. The measured and plan dose is consistent with the excellent agreement. This study confirmed that microDiamond, alanine, and nanoDot dosimeters are valuable dosimeters for SABR pre-treatment verification.

Keywords: Alanine; nanoDot; microDiamond; SABR

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A041

An Evaluation of the Effects of Brachytherapy Applicator Attenuation in the High Dose Rate Treatment for Carcinoma Uterine Cervix

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Purpose: In the present study we try to quantify the difference in dose to point A, in high dose rate intra- cavitary brachytherapy due to applicator attenuation. Methods: The applicator (Varian vaginal applicator set central tandem of 6 cm length having an outer diameter of 3.2 mm and a wall thickness of 0.5 mm) was positioned in the wax phantom, and the dose at point A was measured using an ion chamber for Ir-192 HDR brachytherapy and compared with the TPS calculated dose, which does not assume the presence of the applicator. Another experimental setup where the same HDR applicator was positioned at 20 cm from the FC65G Farmer chamber and meter readings were taken for a given treatment time of 100 seconds. The HDR applicator was replaced with a plastic tube and readings were taken for the same treatment time using the same chamber. The measurements were taken with an FC65G chamber with buildup cap for Co60 energy. Results: The average reduction in the measured dose to the calculated dose at point A observed was 2.46%. The average reduction in the measured dose with HDR applicator in place of a plastic tube at 20 cm distance was 3.18%. Conclusions: Since dose calculations by current treatment planning systems (TPS) are based on the radiation around an encapsulated bare source, and do not take applicator attenuation into account, patients receive a lower dose than planned.

Keywords: Brachytherapy; applicator attenuation; treatment planning

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A050

Patient Specific Pre-treatment QA for IMRT and VMAT using PerFRACTION and Portal Dosimetry: A Comparative Study

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Purpose: The aim of this study is to compare the pre-treatment patient specific quality assurance (QA) results obtained with PerFRACTION and Portal Dosimetry by evaluating gamma index for different sites treated by IMRT/VMAT. Methods:Twelve VMAT plans and Twelve IMRT plans from three treatment sites prostate only, Lung, and head and neck (H&N) — were retrospectively analyzed in this work. Plans were generated in Eclipse (v.13.6), using AAA algorithm and were created using 6 MV photon beams. The same were delivered using Varian Edge linear accelerator equipped with High Definition MLC(HD-MLC) and aSi 1200 portal imager. Following the VMAT/IMRT patient-specific pretreatment QA protocol used in our center, the delivery of all plans was assessed using the Portal Dosimetry. The Gamma index obtained from Portal dosimetry were compared with the recently commissioned PerFRACTION software .PerFRACTION is an software module from Sun Nuclear Medical Systems™ which uses linac treatment logs to efficiently calculate and verify the 3D/2D dose delivered. Results: All the results obtained were under tolerances 3%3mm DTA gamma criteria with a 10% minimum dose threshold. The overall gamma passing criteria for Rapid Arc and IMRT with PerFRACTION was 95.8% and 96% as compared to 98.7% and 97.6%for portal dosimetry. Conclusion: Patient-specific VMAT/IMRT QA based on MLC movement log files is a promising method for patient-specific QA. The PerFRACTION method for pretreatment of patient-specific QA is capable of producing results similar to those obtained by traditional methods.

Keywords: VMAT; IMRT; portal dosimetry; MLC logs

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A051

Impact of Dental Splint on Dose Reduction to the Oral Cavity in Head and Neck Patients Undergoing Radiation Therapy

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Purpose: To assess the utility of dental splint in head and neck cancer irradiation during intensity modulated radiation therapy (IMRT) with the intention to reduce dose to normal surrounding healthy tissues in the oral cavity region. Methods: The maximum and mean doses of the oral cavity of 7 head and neck patients planned for IMRT and treated with a dental splint. Each patient had a customized dental splint consisting of a polymethylmethacrylate (PMMA) acrylic plate that was molded from the teeth impression of either the upper or lower jaw. In order to investigate the effect of the dental splint to the doses received by the oral cavity, we simulated a plan that assumed no dental splint in place and compared the doses between the 2 plans. The simulated plans were done by re-contouring the space occupied by the dental splint as the oral cavity, assuming that that the tongue would flop superiorly into the oral cavity space if there was no dental splint placed and the mouth closed. The new oral cavity was assigned an electron density of 1 and the plan recalculated. The paired Wilcoxon signed-ranked test was used for statistical analysis, with $p<0.05$ deemed as statistical significance. Results: The maximum dose to the oral cavity with and without the dental splint was 6354cGy and 7136cGy respectively ($p=0.016$) while the mean dose was 3704cGy and 3822cGy respectively ($p=0.125$). Conclusions: There was a significant reduction to the maximum dose received by the oral cavity with and without the dental splint. The assumptions of this study has its limitations and further studies simulating the patient with and without the dental splint will need to be conducted to improve the validity of the study.

Keywords: Dental splint; IMRT; oral cavity

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A052

Performance Evaluation of Line Scanning Method in Proton Therapy

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Purpose: Proton therapy system (Sumitomo Heavy Industry, Co. Ltd.) in our hospital can irradiate wobbler beam and line scanning beam. Performance of line scanning is evaluated and beam commissioning with line scanning method is held. Methods: Dose linearity was investigated with water phantom (Blue Phantom2, IBA dosimetry) and large parallel plate chamber (StingRay, IBA dosimetry) with several dose rates. In this measurement, dose was measured with several measurement times (0.1 ~ 40 secconds). For evaluation of irradiation time precision, solid water phantom (Solid Water HE, Gammex) and StingRay were used. Beam irradiation time was controlled by accelerator system in this measurement. Dose was measured with varying irradiation times (0.1 ~ 10 seconds). Furthermore, several spot patterns and line patterns were measured by Scintillator/CCD camera system (Lynx, IBA dosimetry) for the estimation of beam position and scan speed precision. Results: Dose linearity is found with less than 1% error with varying conditions. Repeatability of irradiation time is also confirmed with less than about 1.4 % in this measurement. Beam position and scan speed is also precise enough to be used in clinical use. Conclusions: Performance of line scanning method for proton therapy in our hospital was investigated. It is found that results are good enough for treatment. Measured data are consistent to the acceptance test.

Keywords: Proton therapy; clinical commissioning; line scanning method

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A053

Energy Spectrum and Dose Enhancement due to the Depth of the Lipiodol Position using Flattened and Unflattened Beams

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Purpose: The objective of our study was to evaluate the dose enhancement and energy spectrum of photons and electrons due to the Lipiodol depth with flattened (FF) and FFF beams. Methods: FF and FFF for 6X beams from TrueBeam were used in this study. The Lipiodol ($3 \times 3 \times 3$ cm^3) was located at depths of 1, 3, 5, 10, 20, and 30 cm in water. The dose enhancement factor (DEF) and the energy fluence were obtained by Monte Carlo calculations code PHITS. Results: The DEFs at the centre of Lipiodol with the FF beam were 6.8, 7.3, 7.6, 7.2, 6.1, and 5.7% and those with the FFF beam were 20.6, 22.0, 21.9, 20.0, 12.3, and 12.1% at depths of 1, 3, 5, 10, 20, and 30 cm, respectively, where Lipiodol was located in water. Moreover, spectrum results showed that more low-energy photons and electrons were present at shallow depth where Lipiodol was located in water. The variation in the low-energy spectrum due to the depth of the Lipiodol position was more explicit with the FFF beam than that with the FF beam. Conclusions: Although the FF beam could reduce the effect of energy dependence due to the depth of the Lipiodol position, the dose enhancement was overall small. To cause large dose enhancement, the FFF beam with the distance of the patient surface to Lipiodol within 10 cm should be used.

Keywords: Lipiodol; dose enhancement; Monte Carlo

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A054

A Novel Shielding Paper for Patients with Permanent Prostate Brachytherapy Using ^{125}I

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Purpose: Tungsten functional paper (TFP) is a paper-based radiation-shielding material, which is lead-free and easy to cut. We developed a radiation protection undergarment using TFP for prostate cancer patients treated with permanent ^{125}I seed implantation (PSI). The aim of this study was to evaluate the shielding ability of the undergarment with respect to household contacts and members of the public. Methods: Between October 2016 and April 2017, a total of 10 prostate cancer patients treated with PSI were enrolled in this prospective study. The external radiation exposure from each patient 1 day after PSI was measured with and without the undergarment. Measurements were performed using a survey meter at 100 cm from the surface of the patient's body. The exposure rates were measured from five directions: anterior, anteriorly oblique, lateral, posteriorly oblique, and posterior. Results: The measured radiation exposure rates without the undergarment, expressed as mean ± standard deviation, from the anterior, anteriorly oblique, lateral, posteriorly oblique, and posterior directions were 1.28 ± 0.43 μSv/h, 0.70 ± 0.34 μSv/h, 0.21 ± 0.062 μSv/h, 0.65 ± 0.33 μSv/h and 1.24 ± 0.41 μSv/h, respectively. The undergarment was found to have (mean ± standard deviation) shielding abilities of 88.7 ± 5.8%, 44.0 ± 42.1%, 50.6 ± 15.9%, 72.9 ± 27.0% and 90.4 ± 10.7% from the anterior, anteriorly oblique, lateral, posteriorly oblique, and posterior directions, respectively. Conclusions: This shielding undergarment was a useful device that has the potential to reduce radiation exposure for the general public and the patient's family.

Keywords: Prostate brachytherapy; radiation-shielding undergarment; seed

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A057

Automated Estimation Framework for Lung Tumor Location in Kilovolt Conebeam Computed Tomography Images for Target-Based Positioning in Lung Stereotactic Body Radiotherapy

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Purpose: In recent years, the using of image-guided radiotherapy (IGRT) systems by kilovolt cone-beam computed tomography (kV-CBCT) images are being commonly for high accurate patient positioning in lung stereotactic body radiotherapy (SBRT). However, current IGRT procedures are based on bone structure and subjective correction. Therefore, the purpose of this study was to investigate an automated estimation framework for lung tumor location in kV-CBCT images to improve targetbased patient positioning for lung SBRT. Methods: One-hundred-and-sixty kV-CBCT images from 40 clinical cases treated with lung SBRT were used. The proposed framework consists of four steps, i.e., determination of a search region in which to detect the tumor location in a kV-CBCT image, extraction of a tumor template from a planning CT image, preprocessing for enhancement of the tumor region, and estimation of the tumor location by a templatematching technique. Original, edge enhancement, and tumor enhancement images were obtained by enhancement of a tumor region based on each form of preprocessing and were used for template matching. Results: The mean Euclidean distances of location errors for original, edge enhancement, and tumor enhancement images were 1.2 ± 0.7 mm, 5.5 ± 10.1 mm and 2.7 ± 4.4 mm, respectively. The means of the location errors estimated by the proposed framework using the original images were the smallest; the differences were statistically significant ($p<0.05$). Conclusions: These results indicated that the accuracy and precision of the proposed framework were highest when using the original images.

Keywords: Image-guided radiotherapy; kilovolt cone-beam computed tomography (kV-CBCT) image; lung stereotactic body radiotherapy (SBRT)

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A062

Validation of Varian SRS Head Frame Target Localization using Cone Beam CT and Brainlab CT Localizer for Stereotactic Radiosurgery

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Purpose: To compare localization accuracy using both conventional frame-based localizers and cone-beam CT (CBCT) images for stereotactic radiosurgery (SRS). Methods: An Anzai phantom with known target was attached to Varian head frame and was used to verify the localization accuracy based on a SRS localizer (BrainLAB) and CBCT images (Edge , Varian Medical Systems). The phantom with a BrainLAB CT localizer was first simulated on a conventional CT scanner and then scanned on a Edge Linac using CBCT images. The differences between the conventional and CBCT localizations of the target positions were computed .We also validated the SRS localization workspace for iPlan and Eclipse planning system. The localization workspace uses the stereotactic coordinates to define the target volume and all other structures within the stereotactic frame space. Results: The isocenter coordinates for both the systems correlated well within ±0.5mm. The phantom showed that the Brainlab localizer and CBCT images based localizations agreed within ±1 mm in translational and ±0.1 degree in rotational axis.. The magnitudes of shifts between the Brainlab localizer and CBCT images based localizations for SRS with fixed head rings were ±0.06 cm along x (lateral), ±0.02 cm along y (vertical), and ±0.06 cm along z (longitudinal) direction with ±0.1 degrees of yaw, pitch and roll rotational axis. Conclusions: The results from the phantom study with a fixed head ring show that the CBCT based localization is reliable and can be used to guide SRS treatment setup with accuracy comparable to the currently used frame-based stereotactic radiosurgery systems.

Keywords: Head frame; localizer; stereotactic radiosurgery

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A064

Computational Analysis of Cold Spots in Dose Distributions of VMAT Plans for Prostate Cancer

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Purpose: Cold spots could induce recurrences of tumors due to insufficient irradiation to planning target volume (PTV). The aim of this study is to computationally analyze cold spots in dose distributions of volumetric modulated arc therapy (VMAT) plans for prostate cancer. Methods: Thirty prostate cancer patients with low-, intermediate-, and high-risk groups (10 cases for each risk group), who received VMAT plans, were used for this study. Cold spots, which were defined as regions within planning target volumes receiving doses lower than 93% of the prescribed doses, within PTVs for VMAT plans were measured by calculating volume percentages of cold spots per PTV using a three dimensional labeling technique. To visualize and analyze the distributions of cold spots in the PTVs, three-dimensional probabilistic distributions of cold spot existence were visualized by using a centroid matching technique. Results: The mean volume percentages of cold spots per PTV for low-, intermediate-, high-, and all risk groups were 5.33 ± 2.94%, 4.38 ± 3.25%, 3.41 ± 1.41%, and 4.37 ± 2.68%, respectively. The volume percentage of cold spots per PTV for each risk group did not significantly differ among each other ($P > 0.05$). Most of cold spots distributed on posterior PTVs, where near the rectums. Conclusions: This study revealed the volumes and distributions of cold spots in dose distributions of VMAT plans for the treatment of prostate cancer.

Keywords: Prostate cancer; cold spot; VMAT

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A066

Investigation of Specific Absorption Rate (SAR) Values for Normal Patient's Blood and Diabetic Patient's Blood Irradiated with Low Level Laser Therapy

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Purpose: Specific Absorption Rate (SAR) of human photodynamics blood via conductivity aims at fixing values for avoidance of electromagnetic pollution during Low Level Laser Therapy (LLLT) with the prior knowledge of blood dielectric properties. Methods: SAR values of normal and diabetic patients' blood were studied using Agilent 4294A impedance analyser at frequencies (40Hz – 30MHz). Home designed chemical cells by standard cuvettes, with high purity copper sheet as electrodes, were used in the measurements before and after irradiations. Blood samples were exposed to different LLLT duration. A portable laser diode-pumped solid state with wavelength 632nm at power 60mW was used for exposure. Blood sample collection was approved by Human research ethics committee, University Sains Malaysia, under research proposal USM/JEPeM/16060208. Results: Variations in values of SAR and dielectric relaxation behavior depicted enhanced therapy for a deteriorating blood. Within the frequency range, exposure time variations had been observed to conjoin with changes in the blood physiology and its morphology. Also observed that at higher time exposure, some red blood cells within diabetic blood became little crenated due to profused heating. This formed cell membrane shrinkage with an abnormal notching. This resulted to free intracellular Ca^{+2} concentration affecting K^{+} ion efflux. At higher exposure time, values of blood conductivity dropped, contrary result was obtained at durations of 5 and 10mins exposure. Conclusions: Higher values of SAR and conductivity were measured for diabetic blood samples compared to the non-diabetic blood samples at exposure time of 5 to 10mins of LLLT irradiation and proved better blood conditions.

Keywords: Dielectric properties; specific absorption rates; low level laser therapy

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A067

Addressing the Dose Perturbation of Metallic Implant in Spinal Stereotactic Body Radiotherapy (SBRT)

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Purpose: To compare methods addressing the dose perturbation occurrs in planning and delivery stages of spinal adjuvant Stereotactic Body Radiotherapy (SBRT) caused by the presence of titanium implants. Methods: Dose prediction by TPS was conducted while the CT number of titanium was (a) default, calculated by the AAA algorithm ("No Overridden"); (b) relative electron density, mass density matched, calculated by the AAA algorithm ("AAA"); (c) relative electron density, mass density matched, calculated by the AXB algorithm ("AXB"). In phantom study, dose predictions were compared with measurements using Gafchromic EBT3 films conducted with 2 mm, 6 mm and 10 mm thicknesses of titanium alloy Grade 5 (Ti6Al4V) using field sizes of 1×1 cm^2, 2×2 cm^2 and 4×4 cm^2. In planning study, retrospective dose predictions on clinical patient plans were carried out to evaluate the impact on clinical outcome. Results: The mean discrepancies (%) between measurement and "No Overridden", "AAA", "AXB" at tissue – titanium interface (titanium – tissue interface) were -16.86 (10.93), -14.05 (11.24), 0.71 (1.54) for 2 mm and 6 mm thickness of titanium respectively; and -18.42 (11.20), -18.29 (11.04), -10.14 (0.01) for 10 mm thickness of titanium, respectively. The patient planning study, the "AXB" yielded a significant deficit in tumour volume coverage at prescribed dose compared to "AAA" and "No Overridden" by 5.23 % and 9.06 %, respectively. Conclusions: "No Overridden" and "AAA" can potentially generate acceptable prediction in specific scenarios. However, the AXB algorithm is recommended to be used in routine practice involving titanium implants.

Keywords: SBRT; titanium implants; inhomogeneity; spinal metastasis; AAA, AXB

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A071

Deep Learning Based Regression Of Radiation Protection For Radiotherapy Room

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Purpose: Most Monte Carlo simulations are used as the shielding calculation method when a radiation therapy room is constructed. However, this method consumes a lot of manpower, time and computing device. The purpose of this study was to show a performance of radiation protection regression using deep learning technique. Methods: A total of 300 case simulation results according to variable (thickness, material, beam energy) were acquired by Monte Carlo n-particle extended (ver: 2.6.0 Los Alamos National Lab, USA) to learn the data from deep learning system based on linear regression. The regression based deep learning system code has been written by using Tensorflow through Python. And we verified the performance of this system using unknown test data. Results: There are three variables for simulation results (thickness, material, beam energy). After the learning of data, the regression based deep learning system predicted the results regarding unknow data with over 95% accuracy. Conclusions: This study show a high possibility about the use of the deep learning based radiation protection prediction system. By more data, the performance of system can be more accurate.

Keywords: Radiation protection; linear regression; Monte Carlo simulation; deep learning

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A073

Field Output Correction Factors for Radiophotoluminescent Glass Dosimeter in 6 MV Small Photon Beams: Semi-Empirical Method

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Purpose: The purpose of this study was to determine the field output correction factors for Radiophotoluminescent glass dosimeter (RGD) in 6MV small photon beams. Methods: The measurements were performed by using RGD (GD-302M) embedded in solid water phantom at 10 cm depth, 90 cm SSD, with 6MV photon beams and 0.5x0.5 to 10x10 cm^2 field sizes. To determine the field output factors, the readings of RGD in all clinical field sizes were normalized to 10x10 cm^2 field size. To obtain the calculated field output factors, the calculated absorbed doses from EGSnrc Monte Carlo simulation in all clinical field sizes were converted into the ratio of clinical to 10x10 cm^2 field sizes. The differences of field output factors between measurement and calculation were determined. Finally, the field output correction factors of RGD were calculated by using the quotient of the calculated output factor and the measured output factors. Results: The field output factors of RGD were in good agreement with the calculated field output factors until the field size down to 1x1 cm^2. The highest deviation was found in the smallest field size and the measured field output factor was higher than calculated. The percentage of difference between measurement and calculation increases as decreases field size. The field output correction factors for RGD were within 2% for all clinical field sizes except in 0.5x0.5 cm^2. Conclusions: Field output correction factors of RGD can be obtained using Monte Carlo simulation and the values were within 2% except in the smallest field size.

Keywords: Field output correction factor; Monte Carlo simulation; radiophotoluminescent glass dosimeter (RGD)

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A075

Design and Study of Fluorescence-Based Radiation Field Marker for Accurate and Precision Patient Positioning in Radiotherapy

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Purpose: The main purpose of this study was to indigenously develop fluorescence-based Radiation field setup marker for accurate and precision patient positioning and compare with the regular patient marking, patient comfort and radiotherapy technologist satisfaction. Methods: The fluorescence-based patient isocenter setup marker, Field corner marker and radiation border marker was developed indigenously. The size of the patient isocenter setup marker was 2.5mm circular with extra half circular provision for easy pickup. 1.2mm of cross lines was provided with the florescence material and the other areas were in dark colour. The size of the field corner marker was 1.5mm circular with extra half circular provision for easy pickup. 1.2mm of L shape lines was provided with the florescence material and the other areas were in dark colour. The size of the field border marker was 1.2mm width and 50mm length were provided with the florescence material and the other areas were in dark colour. The dark colour should not reflect the field light and the positioning cross line lasers, So the fluorescence helps to position precisely. These markers have a 1.5mm central axis hole to make a mark on the patient or over the mask, which will help to identify the original initial setup position in the case of knowingly or unknowingly removed the marker from the patient or mask. Results: This novel fluorescence-based marker addresses virtually all the shortcomings of traditional markers. These markers are highly visible on field light and the positioning cross line lasers due to the fluorescence material and help to facilitate a quick and accurate patient setup. Conclusions: The precision of these markers is catching up to the repositioning of the radiation delivery with high precision, easily identifiable, save time, improve accuracy, provide a better patient comfort without any difficulty in patient setup and to the satisfaction of radiotherapy technologist.

Keywords: Fluorescence-based patient isocenter setup marker; field corner marker; radiation boarder marker

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A076

Design and Study of Artifact Free Non Lead Based Non Metallic Breast Scar CT Marker for Radiotherapy

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Purpose: The main purpose of this study was to indigenously develop artifact free, non lead based non metallic breast scar CT marker for Radiotherapy. Methods: Non lead based non metallic artifact free CT breast scar marking wire were developed using various combination of low atomic number materials. The materials are in the powder form which can be modifiable to versatile shape and size according to the needs. Lead based CT scar marking wire and newly fabricated non metallic CT marker wire was used to evaluate the visibility of marker wire, CT number and artifact. Both the marker wire was placed in a 30x30x30cm^3 sheets of solid phantom (SMART) and imaged on a Toshiba multi slice CT scanner for quality analysis. The phantom was scanned using the similar imaging parameters such as 2 to 3mm slice thickness, as commonly used in the simulation. For the visibility test the CT scan topographic as well as the cuts in axial section was acquired. The CT artifact of marker was analysed using a J-image software. Results: On analyzing the CT scan of both the marker wire on phantom, it has been found that the newly fabricated marker wire has the equal visibility and almost no CT artifact when compared with the commercially available marker wire. The metallic marker wire produced bright streak artifact in the CT image, but non metallic CT marker wire was not producing any streak artifact. Conclusions: The newly fabricated marker wire density has nearly equal to human bone density, so it appears as bright spot on CT without streak artifact. To conclude that the newly fabricated CT marker wire will be an alternative to the existing commercially available marker wire with almost no artifact and also cost effective, which can be used for the clinical CT simulation for mainly breast scar marking without producing any metal streak artifact and also can be used all the other anatomical sites during CT scan for Radiotherapy purpose.

Keywords: Non metallic marker; lead marker; artifact free marker

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A082

FF and FFF Patient Specific QA using New Varian aS1200 Portal Imager and Compare with PTW Octavius 1500

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Purpose: This study was designed to evaluate the feasibility of the new Varian aS1200 EPID implementation for pre-treatment QA in FF and FFF beams and also evaluated the new gamma criteria proposed by AAPM TG-218 (3%/2mm), by comparing with AAPM TG-119 criteria (3%/3mm). The results were compared with PTW Octavius 1500. Methods: Random selected 60 VMAT plans with 165 arcs treated on Varian TrueBeam, including 6 and 10 MV (FF & FFF) were planned on Eclipse TPS (V.13.6) and also created verification plans. An aS1200 EPID with Portal Dosimetry was utilized to acquire and analyze the verification plans by comparing between predicted and measured PDI. A PTW Octavius 1500 with 4D phantom was also used for the QA and compared with Portal Dosimetry. According to AAPM TG-119 and AAPM TG-218 criteria field-by-field delivery method, 10% dose threshold and global normalization were used for evaluation of the results. Results: In FF and FFF plans, the results showed most of the γ% of aS1200 EPID were slightly lower with higher SD than PTW Octavius 1500, except in stringent criteria for FFF plans. According to the AAPM TG-119, the mean γ%(SD) of the aS1200 EPID and PTW Octavius 1500 were 99.02%(1.60%) and 99.80%(0.52%), respectively. For AAPM TG-218, the results of the aS1200 EPID and PTW Octavius 1500 were 98.36%(2.50%) and 98.66%(1.86%), respectively. Conclusions: The results of the study revealed that both systems showed comparable results for both criteria. Both systems can be used as alternative detectors for patient specific QA.

Keywords: Patient specific QA; aS1200 EPID; PTW Octavius 1500

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A083

Development of 4DCBCT-Based Lung Ventilation for Adaptive Ventilation-Guided Radiotherapy

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Purpose: Lung ventilation images can be created by a novel technique based on 4D-CT for adaptive ventilation-guided radiotherapy. However, it is known that there are interfraction lung function changes during treatment. 4D-CBCT-based lung ventilation for adaptive ventilation-guided radiotherapy might be able to solve this problem. Thus, this study evaluated 4D-CBCT-based lung ventilation images. Methods: An in-house deformable lung phantom was used. 4D-CT scans were performed on the phantom using SOMATOM Definition AS+ (Siemens). 4D-CBCT scans were performed using XVI with Gantry rotation speed of 0.6 deg/sec (Versa HD; Elekta). Piston movement of the phantom was set to 5, 10 and 15 mm. The 4D-CBCT reconstruction algorithm was the Feldkamp-davis-kress algorithm. 4D-CT-based (VENTCT) and 4D-CBCT-based (VENTCBCT) lung ventilation images were obtained using two different calculation algorithms: Jacobian-based and HU change-based algorithms. Voxel-wise Spearman rank correlation between VENTCT and VENTCBCT was used to evaluate the images. Streak artifacts in the phantom were defined as regions in which CT values were higher than the lung field (CT value > -250), and the percentage of streak artifact was calculated. Results: Spearman correlations (means ± standard deviation) between VENTCT and VENTCBCT were 0.562±0.185 (Jacobian) and 0.282±0.04 (HU). The percentage of streak artifacts was 3.99±0.678%, suggesting that Jacobian-based method has higher accuracy for ventilation images than HU change-based method, which included CT value uncertainty due to streak artifacts. Conclusions: Our phantom study showed moderate agreement between 4D-CT-based ventilation and 4D-CBCT-based ventilation, and also showed that Jacobian-based algorithm may be a suitable method in 4D-CBCT.

Keywords: Cone-beam CT; ventilation; 4D-CT

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A084

Homology as a Novel Radiomic Feature for Prediction of the Prognosis of Lung Cancer Based on CT-Based Radiomics

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Purpose: Radiomics is a new technique that enables prediction of prognosis noninvasively by extraction of features from medical images. To improve the accuracy of prognosis prediction in computed tomography (CT)-based radiomics, we have proposed homology-based radiomic features. In this study, we evaluated the homology-based radiomic features for prognosis prediction in lung cancer patients who underwent stereotactic body radiotherapy (SBRT). Methods: Images from 40 lung cancer patients (Stage I or II) who received SBRT were analyzed. Patients received a dose of 6.25-12 Gy in 4-8 fractions. Pre-treatment CT images obtained by a CT scanner (GE) were used. Three 2D images (axial, sagittal, and coronal planes) were created from 3D volume data of the clinical target volume (CTV). Two homology-based features were used: one was the number of holes and the other was the number of isolated components in the tumor. To clarify the prognostic power, the relationship between the values of homology-based radiomic features and overall survival was evaluated by the Kaplan-Meier method. Results: Significant differences in Kaplan-Meier curves were observed between two groups according to the median value of the two homology-based radiomic features ($p = 0.0125$ and $p < 0.01$, respectively, by the log-rank test). This result indicated homology-based radiomic features can be used to predict cancer prognosis. Conclusions: Our results showed two homology-based radiomic features can be used to predict prognosis for early lung cancer patients who have received SBRT. Homology-based radiomic features have a great potential for improving the accuracy of CT-based radiomics.

Keywords: Homology; radiomics; prognosis prediction; lung cancer

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A086

Development of Japanese Primary Standard of Absorbed Dose to Water in a Carbon Beam

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Purpose: To reduce an uncertainty in carbon beam dosimetry, the National Metrology Institute of Japan is developing a water calorimeter as a primary standard of absorbed dose to water in a carbon beam. In the present study, Farmer-type ionization chambers were calibrated at a plateau region of a mono-energy and a Spread-Out Bragg Peak (SOBP) 290 MeV/u carbon beams. Methods: The absorbed dose to water in each carbon beam was determined with the water calorimeter. The reference point of the calorimeter was positioned at 4.5 g cm^{-2} depth in water, namely in the plateau region of each carbon beam. Two Farmer-type ionization chambers (PTW 30013 and Exradin A19) were calibrated for the carbon beams. The beam quality conversion factors (k_Q) of these ionization chambers were determined using the calibration results for Co-gamma rays. Results: The calibration results for the mono-energy and the SOBP carbon beams did not show any apparent difference over the relative standard uncertainty of 1.0 %. Besides, the k_Q of each chamber at the plateau region of each carbon beam agrees not only with the calculation value listed in the IAEA TRS-398 but also with the experimental results reported by J-M. Osinga-Blättermann et. al.[1]. The relative standard uncertainty of the present k_Q is about 1.0 %. Conclusions: In this study, the water calorimeter successfully determined the absorbed dose to water at the plateau region of the carbon beams. The present k_Q values agreed with those reported previously. The present result supports the validity of our calibration method.

Keywords: Carbon beam; calorimeter; absorbed dose

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A087

Feasibility Study of Microdiamond Detectors as a Reference Dosimeter in High-Energy Photon Beams

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Purpose: A microDiamond detector (PTW 60019) is nearly water equivalent as compared with an air-filled ionization chamber. Such water equivalence is expected to enable the determination of the absorbed dose to water with smaller uncertainty than the air-filled ionization chamber. In order to develop an absorbed dose to water dosimetry method using the microDiamond detector, we investigated several characteristics of the microDiamond detector in high-energy photon beams. Methods: Two microDiamond detectors were used in this study. The sensitivity of these detectors were measured by changing the water temperature from 15 °C to 35 °C. The microDiamond detectors were calibrated for high-energy photon beams from a clinical linac (Elekta, Precise) and ^{60}Co-gamma ray. The beam quality conversion factors (k_Q) of the microDiamond detectors were determined at the $TPR_{20,10}$ from 0.57 to 0.76. Results: The sensitivity of two microDiamond detectors does not depend on water temperature. The temperature coefficient of the sensitivity can be ignored with a relative standard uncertainty of 0.05 % within 15 - 35 °C. The k_Q of the microDiamond was 0.9838 ± 0.0054 (k=1) at the range from 0.68 to 0.76 at $TPR_{20,10}$. The present k_Q were in good agreement with the k_Q = 0.987 ± 0.0075 (k=1) calculated by V. D. Coste et. al. (2017). Conclusions: We investigated the characteristics of microDiamond detector in high-energy photon beams. The temperature and energy dependence of two microDiamond detectors were superior to those of an air-filled ionization chamber. In the present study, the detector is well suited as a reference dosimeter in high-energy photon beams.

Keywords: MicroDiamond detector; high-energy photon beam; radiometry

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A089

Treatment Planning Techniques for Stereotactic Radiosurgery of Cerebellopontine Angle Tumors Utilizing Helical Tomotherapy

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Purpose: To generate an ideal Tomotherapy treatment planning protocol for the stereotactic radiosurgery of tumors located in the cerebellopontine angle. Methods: Treatment plans of patients who underwent stereotactic radiosurgery of cerebellopontine angle tumors were selected for this study. Multiple treatment plans with varying machine modulation factor and pitch combinations were created for each patient. Treatment plans were prescribed at 80% of gross tumor volume with a single fraction dose of 12Gy. Each treatment plan was evaluated through several metrics: Paddick's conformality index, homogeneity index, dose gradient score, treatment time, brainstem dose at 0.5cc, and max dose to the brainstem. Trend lines were projected and analysis of variance was performed to see the statistical significance of the measurements relative to changing the modulation and pitch. Results: Several key points were observed in the study: (1) pitch did not play a role in treatment time, (2) Using a modulation factor above 2.4 did not yield any benefit for sparing the brainstem, instead it produced unnecessary increase in treatment time by 1 minute for every 0.1 increase in modulation, (3) highest conformality, homogeneity, and dose gradient score were achievable for treatment plans at modulation factors ≤ 1.8 with pitches close to 0.2. Conclusions: It is recommended to use a modulation factor ≤ 1.8 and a pitch between 0.18 and 0.2 to produce good conformality, dose gradient, and homogeinety. At this combination there is adequate sparing of the brainstem while not overextending the treatment time.

Keywords: Tomotherapy; stereotactic radiosurgery; cerebellopontine angle

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A094

Dosimetric Differences between Rapidplan and Clinical Manual Optimization Plans in Volumetric Modulated Arc Therapy for Oropharyngeal Cancer

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Purpose: The aim of study was evaluated a dosimetric comparison between knowledge-based plan (KBP) and clinical manually optimized plan (CMO) in volumetric modulated arc therapy (VMAT) for oropharyngeal cancer patients. Methods: The KBP with RapidplanTM were trained 63 nasopharyngeal cancer (NPC) and oropharyngeal cancer (OPC) patients who underwent VMAT with two-step method. For each patient, a total dose of 70.0 Gy in 35 fractions was prescribed to the initial planning target volume (PTV). We generated the number of possible outliers that were identified in the regression of the principal components according to the Cook's distance. Twenty continuous OPC patients were created by a single optimization KBP without planner intervention. The differences between KBP and CMO created by an experienced planner for the same patients were compared (Wilcoxon tests) as follows, PTV (D 98%, D 2%), brainstem (max dose) , spinal cord (max dose) , parotids (median dose, mean dose) and monitor unit (MU). Results: KBP and CMO values of PTV at D 98%, were 80.47% ± 5.75 and 78.92% ± 3.75, D 2% were 111.67% ± 2.38, 113.28% ± 2.28, respectively. There were no significant differences in all organs at risk (OAR) and both plans meet Japan Clinical Oncology Group 1015 ver 1.3. The MU values were KBP: 526 ± 210 MU and CMO: 596 ± 126 MU ($p < 0.01$). Conclusions: RP plans were comparable in VMAT for OPC patients. Our simple model could improve optimization time and highly subjective, independently of planner's skill and knowledge.

Keywords: Volumetric-modulatedarc therapy; knowledge-based plan; oropharyngeal cancer

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A095

A Scintillation Fiber-Based Real-Time Dose Monitoring System (SRDMS) Verification for HDR Brachytherapy

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Purpose: The aim of this study was to develop and validate the scintillation fiber-based real-time dose monitoring system (SRDMS) for brachytherapy. Methods: SRDMS classified of two major parts: the applicator for dose measurement during brachytherapy consisting of 62 channels for patient dose measurement and 2 channels of dummy for confirming Cherenkov radiation effects, and data read-out system that receiving and verifying signal data in real-time. SRDMS performance test was estimated by measuring dwell position and time for various patterns of source motion. The signal output response with distances from the source to scintillation fibers array and linearity with the source dwell time variation was also evaluated. Results: It was verified that there is a difference in signal output intensity depending on the distance between the source and the scintillation fibers; furthermore, the change due to the movement of the source could be confirmed in real-time monitoring. Both source position accuracy and source dwell time accuracy was shown within 5%, and the signal output linearity was maintained within 3%. Conclusions: In this study, we confirmed the possibility of real-time dose monitoring through SRDMS during brachytherapy. We will perform verification for the accuracy of the SRDMS by phantom study with a variety of patient treatment cases.

Keywords: Scintillation fibers; brachytherapy; real-time monitoring; SRDMS

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A096

Determination of Dosimetric Parameters for Vacuum-sealed Miniature X-ray Tube based on Carbon-nanotube Field Emitters

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Purpose: A vacuum-sealed miniature X-ray tube (mXT) based on a novel carbon nanotube was developed to alternate the conventional radiation source for brachytherapy. This study aimed to determine dosimetric parameters of mXT for brachytherapy. Methods: Dosimetric parameters such as dose-rate constant, radial-dose, and anisotropic functions for the mXT were measured by using EBT3 film and a manufactured acrylonitrile butadiene styrene (ABS) phantom at 1 cm below of the mXT. According to the AAPM TG-43 protocol, dose-rate constant and radial-dose functions were measured at standard polar angle and radial-distances. Anisotropic functions were measured restrictively due to the specific condition of film dosimetry. These parameters were also calculated in virtual ABS and water phantoms by using MCNP6.1 code. To correct the measured parameters of the ABS phantom to the values of water, the correlation coefficients for both materials (ABS vs. water) were obtained by comparison with the each calculated depth-dose curves. After all the measured parameters were corrected to those by water, the parameters were determined by comparison with the measured and calculated parameters. Results: The dose-rate constant was 1344.14 $cGy \cdot cm^{-1} \cdot \mu A^{-1}$. The radial-dose functions were 0.49, 0.33, 0.22, and 0.15 at radial-distance of 2.0, 3.0, 4.0, and 5.0 cm, respectively. The difference between the measured and calculated radial-dose function in water was within 0.10, and the average difference was 0.05. The anisotropic functions increased as the radial-distance increased and the angle approached 0^{o}. The azimuthal angular dependence was acceptable. Conclusions: The dosimeteric parameters for new developed mXT were determined in this study.

Keywords: Dosimetric parameters; brachytherapy; vacuum-sealed miniature X-ray tube

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A097

Cell Responses of Lung Cancer after Exposure to X-rays under In-field and Out-of-Field Configurations

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Purpose: Biological effects on non-irradiated cells are induced due to intercellular signaling from irradiated cells, so called non-targeted effects (NTEs). In actual radiotherapy, non-irradiated cells under out-of-field and irradiated cells under in-field exist together. Thus, NTEs have attracted a lot of attention in the precise treatment planning. In this study, we investigated cell responses of lung cancer after exposure to X-rays with co-culture configurations. Methods: Human lung adenocarcinoma epithelial cells (A549) were irradiated with 8 Gy of 6MV linac X-rays. A co-culture system containing irradiated and non-irradiated cells was sustained by placing 50% area of dish onto in-field region, and the cells uniformly exposed were regarded as a control group. We measured the change of cell-cycle distribution after irradiation, and obtained the cell surviving fraction and growth curve. Results: From the results of flow-cytometric analysis with propidium iodide, the accumulation of in-field and out-of-field cells in S or G2 phase was observed at 6-24 h after the irradiation. According to the doubling time 20.5 [h] and cell-cycle study, the in-field and out-of-field cells progressing in cell cycle might stop at S or G2/M checkpoint until 6-24 h after irradiation. By means of clonogenic assay, the cell viability of in-field cells is higher than that of the cells uniformly exposed even at the same dose while the survival in out-of-field cells was the lowest among them. Conclusion: These results indicate that the intercellular signaling from in-field cells to out-of-field cells leads to enhancement of cell-killing and co-culture system makes modulated responses of irradiated cells.

Keywords: Intercellular communication; cell survival; cell-cycle distribution

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A099

Performance Evaluation among Different Optimization Algorithms for Prostate IMRT and VMAT Planning

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Purpose: This study aimed to evaluate the performance among different optimization algorithms on treatment plans for prostate intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT). Methods: Twenty prostate cancer patients were planned to receive 78 Gy in 39 fractions to the planning target volume (PTV). All study plans optimized with dose volume optimizer (DVO) and progressive resolution optimizer (PRO) algorithm for prostate IMRT and VMAT were compared against photon optimizer (PO) algorithm. No interactive action was performed during optimizing for each plan. Dosimetric and radiobiological indices for the PTV and the organs at risk were analyzed. The monitor units (MU) per plan were recorded. Results: On the basis of plan quality for target coverage, prostate IMRT and VMAT plans showed a macroscopic improvement with PO than DVO and PRO. In addition, the PO was generally improved in tumor control probability for the PTV and normal tissue control probability for the rectum. For technical aspect, the PO generated IMRT treatment plans with less number of MU than DVO, whereas it produced slightly higher MU in VMAT plan, compared with PRO. Conclusions: The PO showed over potentiality of DVO and PRO whenever available, although it was increased MU in VMAT than PRO. Therefore, the PO has been the preferred choice for planning prostate IMRT and VMAT in our institution.

Keywords: Optimization algorithm; intensity modulated radiation therapy; volumetric modulated arc therapy; prostate cancer

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A101

Preliminary Study for Improving Dose Grid Size using a Deep Learning

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Purpose: The accuracy of dose calculation based on small dose grid size (DGS) is higher than using large DGS. However, the dose calculation time using the small DGS takes a long time compared to large DGS. The purpose of this study is to propose a deep-learning based method that improves the DGS with less time, and to evaluate its feasibility. Methods: Super-Resolution Convolution Neural Network algorithm with a few modifications was used to improve the DGS from 3.0 to 1.0 mm. This deep-learning model was trained based on 2D dose distributions. Two-hundred 2D dose distributions for two prostate cancer patients, which were calculated by VMAT plan and anisotropic analytical algorithm according to the DGSs, and 2D slices of planning-target-volume (PTV) contours were used as training data. To evaluate the feasibility, fifteen 2D dose distributions for one prostate cancer patient not used for training were used as test data. Results: The mean square error for training and test data were 0.515 and 1.284 at 100 epoch, respectively. The time to convert a 2D dose distribution from 3.0 to 1.0 mm DGS was average 0.592 ± 0.009 s. In penumbra region, dose profiles for the converted dose distribution to 1.0 mm DGS were similar to dose distribution of 1.0 mm DGS than 3.0 mm. In PTV region, the converted dose distributions were underestimated than 1.0 mm DGS case. Conclusions: The proposed deep-learning method in this study improved the DGS with less time in the penumbra region.

Keywords: Dose grid size; deep learning; convolutional neural network

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A103

Quantitative Metrics for Assessing IMRT Plan Quality: Comparing Planning Conformity and Complexity

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Purpose: In Intensity Modulated Radiation Therapy (IMRT) treatment planning, the search for simple and universal quantitative metrics to assess plan quality has been identified as important but as yet not entirely successful. This study was aimed to assess the IMRT plan quality by establishing quantitative metrics for planning conformity and complexity. The metrics proposed were simple, reproducible and universally applicable to all IMRT techniques, which included step-and-shoot IMRT, volumetric modulated arc therapy and helical tomotherapy. Methods: Two metrics, conformity index (CI) and conformation number (CN) were adopted to quantify the plan conformity. By reporting both of these metrics, comprehensive information on target coverage and irradiation of normal tissues could be provided. For the quantification of planning complexity, a new and novel spatial complexity matrix (SCM) was introduced to measure the average dose gradient of a dose profile. In addition, the spatial frequency ratio (SFR) was established to explore the proportion of rapidly varying dose with distance in a treatment plan by using one-dimensional power spectral density (1D PSD). Virtual phantoms were developed for the initial quantitative assessment, in order to form a basis for treatment plan inter-comparisons amongst the different IMRT techniques. Results: Quantitative assessments were undertaken on all the IMRT plans generated using the virtual phantoms. Conclusions: This study has demonstrated the successful development of robust and universal quantitative metrics for objectively and systematically assessing the IMRT treatment plan quality.

Keywords: : IMRT plan quality; quantitative assessment; planning conformity; planning complexity

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A104

Commissioning Electron Monte Carlo and Clinical Implementation in Radiotherapy

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Purpose: Varian Eclipse eMC was commissioned for the Varian Clinac iX. Parameters and tests performed will be described and results presented. The energies commissioned were 6,9,12 and 16MeV for the range of square applicators 6x6, 10x10, 15x15, 20x20 and 25x25. Methods: Data collection measurements were conducted on a the Clinac iX and imported into Eclipse V13.6.23. Data verification was performed by comparing scanned versus planning system (TPS) profiles and PDDs. MU accuracy was determined for a range of standard applicators and selected clinical cut outs and compared to TPS calculations using a range of user defined parameters at 100SSD and 110SSD, based on manufacturer recommendations. Small field cutout corrections were made for the higher energies to include the stopping power ratios. Results: Profile comparison results show an agreement of 2 mm and 2% at the 90% field width position for most of the energies and applicators except 6E for larger applicators (15x15, 20x20 and 25x25cm). TPS parameters using 3-D_Gaussian medium smoothing with a 0.15cm calculation grid size was determined to be the best fit for the data measured when compared with the TPS. PDD comparisons show good agreement at R90, R50, R10 with DTA less than 1mm, 1mm and 2.5mm respectively. Percentage differences at 4 mm depth is between -1% and 8%. Conclusions: Based on the analysis performed, the Eclipse eMC 13.6.23 model was determined to be clinically suitable. For 6E, care should be taken using field sizes greater than 10x10 cm. Further investigation in the buildup region for low energies is recommended.

Keywords: : eMC; clinical implementation; radiotherapy

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A106

The Determination of Suitable Collimator Angle in Volumetric Modulated Arc Therapy for Prostate Cancer

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Purpose: The aim of this study was to determine suitable collimator angle (CoA) in the volumetric modulated arc therapy (VMAT) for prostate-only (PO) and prostate with whole pelvis (WP) irradiation. Methods: The PO plans were created with 1 full arc VMAT with CoA 0° to 90° at every 15°in each of five patients, while the optimization process was performed with the same dose constraints and priority values. The WP plans were created with 2 full arcs with combined CoAs 15 & 345°, 30 & 90°, 30 & 330°, 45 & 90°, 45 & 315°, and 60 & 300° in each of five patients. All plans were verified using the COMPASS system. The differences between measured and calculated dose distributions were evaluated using 3D gamma analysis with criteria 2%/1 mm and dose metrics. Results: In PO plans with CoA 0° to 90° at every 15°, 3D gamma passing rates were 92.6±1.5%, 95.4±1.3%, 95.9±1.7%, 95.7±0.8%, 95.2±0.8%, 94.3±3.7%, and 89.6±5.9%, respectively. The good agreement of mean dose to the target was observed in 30° and 45° plans. In WP plans with combined CoAs 15 & 345°, 30 & 90°, 30 & 330°, 45 & 90°, 45 & 315°, and 60 & 300°, 3D gamma passing rates were 96.3±4.0%, 96.9±2.0%, 99.0±1.3%, 93.1±4.7%, 98.1±0.7%, and 89.3±14.1%, respectively. The good agreement of homogeneity index was observed in 30 & 330° and 45 & 315° plans. Conclusions: The suitable CoA might be 45° for PO plans and 30 & 330° and 45 & 315° for WP plans.

Keywords: Collimator angle; VMAT; 3D gamma pass rate; dose metric; COMPASS

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Feasibility of Novel Thin Bolus using Tungsten Functional Paper for Electron Beam Radiotherapy

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Purpose: Tungsten functional paper (TFP), which contains 80% tungsten by weight, has radiation-shielding properties and has excellent features, such as, it is lightweight, flexible, disposable, and easy to cut. In this study, we investigated the feasibility of using TFP for the skin bolus in electron beam radiotherapy. Methods: The ready-made 5 mm and 10 mm thick tissue-equivalent boluses or TFPs were positioned on the surface of the water equivalent phantoms. Percentage depth dose curves and lateral dose profiles were measured using 9 MeV electron-beam from a clinical linear accelerator. The number of piled-up TFPs was varied from one to six. Results: The measured thickness of the TFP was 0.37 mm. The relative doses at the phantom surface, which were normalized by the value at the depth of maximum dose with no bolus present, for absent bolus, 5 mm bolus, 10 mm bolus, 1 TFP, 3 TFPs, and 6 TFPs were 81%, 91%, 95%, 87%, 95%, and 108%, respectively. The therapeutic depth that corresponds to a 90% dose level for absent bolus, 5 mm bolus, 10 mm bolus, 1 TFP, 3 TFPs, and 6 TFPs were 27.8 mm, 22.8 mm, 18.5 mm, 26.0 mm, 23.0 mm, and 19.0 mm, respectively. Conclusion: TFP contributed to increasing the skin dose, without degrading the depth dose distribution. The findings of this study suggest the feasibility of using TFP as a novel thin and flexible skin bolus for electron beam therapy.

Keywords: Bolus; tungsten functional paper; electron beam radiotherapy

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A110

The Dosimetric Impact of Inhomogeneity Correction Factors on Beam Quality Variations Performed with the Anisotropic Analytical Algorithm

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Purpose: The purpose of the study was to investigate the dependence of tissue inhomogeneity correction factors (ICFs) for a range of photon beam quality. Methods: Heterogeneous lung (0.26g/cm^3), adipose tissue (0.92g/cm^3) and bone (1.85g/cm^3) phantoms were constructed in Eclipse treatment planning system (TPS). The calculations were performed with Anisotropic Analytical Algorithm (AAA) for a range of beam quality for 6MV (TPR20,10 = 0.670±k*0.01) and 15MV ($TPR_{20,10}$ = 0.670±k*0.01), k = -3, -2, -1, 0, 1, 2, 3. This range of energy spectrum was obtained based on the data collected for the 42 accelerators installed in Poland. The ICFs were calculated for several beam sizes and for points lying at several depths inside and below of different thicknesses of heterogeneous tissues. Results: Calculations with AAA predicted that the 6% variations in energy lead to the maximum changes of ICFs 9.2% (6MV) and 13.8% (15MV for points just below the water-lung interface for 5 x 5 cm^2 field size. For fat, less than 1% differences were obtained for both energies. 2% (6 MV) & 2.4% (15 MV) differences were found for points lying just below the bone slab. These differences of ICFs decreased when calculated inside and below heterogeneous slabs where charged particle equilibrium (CPE) exists. ICFs also decreased with increased radiation fields. Conclusion: Variations of beam quality lead to a considerable changes in ICFs for points inside and below the inhomogeneity. Much smaller differences were obtained for larger fields and for points lying below inhomogeneous tissues where CPE exists.

Keywords: Inhomogeneity correction factors; quality index; AAA

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A112

A Deep Convolutional Neural Network Approach for IMRT Dose Distribution Prediction in Prostate Cancer Patients

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Purpose: The focus of this work was to propose a machine learning strategy for performing prediction of IMRT dose distribution using only contours in planning CT. Methods: Our approach employed deep convolutional neural network (DCNN) that learns the dose distributions generated from 80 prostate cancer patients treated with IMRT. A supervised learning approach was used, where the dose for a set of voxels in the dataset was taken as the label for the learning process. The dataset comes from existing patients with dose distributions and contours of planning-target-volume and organ-at-risks. A batch-wise Adaptive Moment Estimation method was employed for leaning and optimizing a 3D U-net similar network. To validate the model architecture, the patient population was randomly subdivided into a training set consisting of 64 patients and a 16 patients validation set for five-fold cross-validation. For the model performance evaluation, additional 15 patients were used for testing dataset. We compared the predicted dose distributions against the true dose distributions, where all dose distributions were normalized with D95 of the target be equal to prescription dose. As evaluation indexes, DVH-endpoints were calculated for each structure. Results: The average differences between true and predicted dose distributions were -0.53%, -0.86% and -1.52% in maximum dose of PTV, rectum and bladder, respectively, whereas they were -0.66%, 0.56% and -0.09% in mean dose of PTV, rectum and bladder, respectively. Conclusions: A novel DCNN method was proposed to accurately and efficiently predict dose distribution only from patient's contours. Our results showed the potential of DCNN to predict dose distribution.

Keywords: Deep learning; radiotherapy; dose prediction

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A117

Comparison of Bladder and Rectum Dose in 2D and 3D Intracavitary Brachytherapy Planning

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Purpose: The main purpose of this study was to compare the bladder and rectum reference points doses of 2D and 3D treatment planning in intracavitary brachytherapy (ICBT) using Manchester-style applicator for cervical cancer. Methods: We have selected 10 numbers of cervical cancer patients treated with brachytherapy planned by conventional 2D treatment planning and 3D treatment planning using computed tomography (CT). Radiation dose to point A, bladder and rectum were first calculated in conventional 2D treatment planning using standard ICRU 38 recommendation, then 3D treatment planning was applied in CT data set. Bladder D_{2cc} and rectum D_{2cc} were calculated in 3D treatment planning system. Bladder and rectal point doses in 2D were compared to bladder D_{2cc} and rectal D_{2cc} in 3D treatment planning. Results: The mean bladder dose in 2D planning was 4.0 Gy while that in 3D planning was 7.49 Gy. The mean rectal dose in 2D planning and 3D planning were 4.89 Gy and 5.42 Gy, respectively. Conclusions: Bladder and rectal doses calculated in 2D brachytherapy treatment planning were significantly underestimate than bladder and rectum D_{2cc} in 3D planning for manchester-style applicator.

Keywords: Manchester-style applicator; bladder dose; rectal dose; cervical cancer

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A120

Dosimetric Comparison between using Daily Cone Beam CT and Planning CT in Volumetric Modulated Arc Therapy Technique for Prostate Cancer Therapy

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Purpose: To investigate the dosimetric change of target and critical organs that impact from patient setup error and volumetric change of those organs in prostate cancer patient based on daily CBCT. Methods: Five patients who were treated with VMAT technique for 79.2 Gy prescribed dose in 44 fractions were selected. The clinical target volume (CTV), the planning target volume (PTV), bladder and rectum volumes were contoured on daily CBCT images after registered with planning CT. The original plan from planning CT was copied and recalculated on daily CBCT images with the fixed monitor unit in each field. The dose volume histograms were selected to analyze the dosimetric results. Results: A total of 220 daily CBCT from 5 patients. The average $V_{100\%}$ of CTV was almost 100% as original plan dose. The average $V_{95\%}$ of PTV of Planning CT was 99.50% ± 1.02%, while the average CBCT image was 96.50% ± 5.36%. The deviation resulted from one patient receiving only 88.85% of $V_{95\%}$ of PTV. This different was due to the organ motion during the course of treatment. The average V_{70Gy} of bladder and rectum of planning CT was 11.36% ± 1.72% and 8.93% ± 1.60%, while average from CBCT showed 13.35 ± 3.72%, 10.35 ± 2.08% respectively. Conclusions: The CTV shows good agreement, while the PTV, bladder and rectum volume present some variation that may cause dose changes. Thus, the patient should be kept consistent in bladder volume as much as possible and the rectum should be clear before treatment. Moreover, the worker should be give priority to the setup position and image registration.

Keywords: CBCT; dose volume histograms; treatment planning

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A123

Comprehensive External Audit for HDR Brachytherapy Systems – The National Experience

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Purpose: Brachytherapy is an important modality for cancer treatment with radiation. Dose distribution around radioactive sources is not as easily measurable as in case of external beams due to the large dose gradients and a shortage of convenient detectors, therefore QA is challenging. This contribution describes design of the audit in the Czech Republic for brachytherapy systems and shows the results obtained in 1996 – 2018 for 30 audited brachytherapy sources. Methods: Following parameters are evaluated within the audit; 1) accuracy of TPS calculation. Monte Carlo data from TG-43 have been used for analytical model used as an independent tool to verify accuracy of TPS calculation, 2) accuracy of source calibration. Air-kerma strength is measured by in-air method, 3) accuracy and precision of source positioning and 4) accuracy and precision of reconstruction process. Results: Systematic differences in calibration techniques (well-type chamber versus in-air method with Farmer chamber) will be discussed. The most important findings will be reported to point out the weakest points in source positioning as a lessons learned. The progress in imaging methods used for brachytherapy planning is well demonstrated. Conclusions: Analysis of results for 30 brachytherapy audits have been performed. Based on the results, the weakest points in QA of HDR sources for brachytherapy observed in last 22 years will be reported.

Keywords: Brachytherapy; QA; Audit

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A124

Intercomparison of Phantoms for CT Numbers to Relative Electron Density (RED)/Physical Density Calibration and Influence to Dose Calculation in TPS

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Purpose: Calibration curves from CT numbers to electron/physical densities in treatment planning systems (TPS) is an important part of commissioning. The aim of this work was to compare phantoms manufactured by different vendors. 6 phantoms were included in the study (2x CIRS, 1x Agmeco, 1x QUASAR, 1x Gammex, 1x CatPhan) to evaluate the sensitivity of dose calculated by TPS to calibration curve. Methods: All phantoms were scanned at two centres with 2 CT scanners under different protocols with various kV. The influence of different calibration curves on dose calculation in the TPS has been estimated. The presence of titanium and the scattering material has been evaluated. Results: The sensitivity of RED to dose is higher for CT numbers higher than 100 HU (10% change in RED caused 3% and 1,5% in dose for 6MV and 18 MV respectively for material of 10 cm thickness). The largest sensitivity was observed for dense bone (up to 3,5% in dose for 6MV). The CT spectra can influence doses up to 4,5% and 2,5% for 6MV and 18 MV respectively. Two phantoms by the same vendor differed for dense bone up to 2% and 1% in dose for 6MV and 18 MV respectively. Conclusions: Phantoms used for CT-RED calibration were compared and various conditions and their influence to dose calculated by TPS was evaluated.

Keywords: CT numbers; RED; TPS; Commissioning

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A126

Phantom Evaluation of Customized 3D-Printed Acrylonitrile Butadiene Styrene (ABS) Boluses for Whole Breast and Post-Mastectomy Radiation Therapy

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Purpose: In breast cancer radiation therapy, tissue-equivalent materials called boluses are placed on a patient's surface to provide adequate dose to the superficial tissues. However, dose discrepancies between planned and actual treatments occur due to the lack of conformity of commercially available sheet boluses to irregular contours of the breast and chest wall. Thus, ABS boluses were fabricated via 3D-printing technique for whole breast (WBRT) and post-mastectomy radiation therapy (PMRT). Methods: 3D-boluses were designed in a treatment planning system and Slicer software using CT-images of Rando phantom with and without breast attachments. These were 3D-printed in 0.5 and 1.0-cm thicknesses via fused deposition modelling technique using ABS as base material. 3D-boluses were compared with commercially available CIVCO boluses (CIVCO Radiotherapy, IA). Treatment plans were generated for each case and surface doses under the boluses were measured using EBT3 films on the phantom breast and chest wall at central, lateral and medial positions. Results: ABS was found suitable to simulate adipose tissue with relative electron density of 0.91. EBT3 film dosimetry revealed significant differences between 3D-bolus and CIVCO bolus in lateral surface doses for WBRT ($p=0.0379$ and 0.0276 for 1.0 cm and 0.5 cm thicknesses, respectively), and central surface doses for PMRT ($p=0.007$ for 0.5 cm thickness). Conclusions: 3D-printed boluses exhibited better surface conformity and trial-to-trial set-up reproducibility than CIVCO boluses and could thus aid in efficient patient set-up during the course of a treatment regimen. Optimization of material use and design, printing cost and time are recommended for practical application.

Keywords: 3D-boluses; acrylonitrile butadiene styrene; breast cancer radiation therapy

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Uncertainty of the Collimater Scatter Factor Measured by the Extended Distance Method

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Purpose: The collimator scatter factor (S_C) for small radiation fields is often measured using a mini-phantom at an extended distance (so-called "extended distance method") In this method, the dominant part of the uncertainty is expected to result from the positioning of the mini-phantom. This study clarifies an uncertainty of the SC by the extended distance method. Methods: Measurements were performed using a 10 MV high-energy photon beam from a linac. The S_C was measured with a Farmer-type ionization chamber in the mini-phantom. The Source to Chamber Distance (SCD) of the ionization chamber was 100 cm, 210 cm and 410 cm. The S_C was measured for the various field sizes from 1 x 1 cm^2~10 x 10 cm^2 defined at the Source to Axis Distance of 100 cm. The positioning uncertainty of the S_C was evaluated with displacing the ionization chamber by 2 mm to the direction perpendicular to the beam axis. Results: The S_C did not depend on the extended distance for the field sizes larger than 4 x 4 cm^2, while not for the field sizes smaller than 4 x 4 cm^2. For the same SCD with the field sizes smaller than 4 x 4 cm^2, the S_C decreased sharply as the field sizes became smaller. The positioning uncertainty of the ionization chamber at the extended distance was 0.05 %, which is much smaller than the sharp decrease of the S_C for the field sizes. Conclusions: The relative standard uncertainty of the S_C for small fields by the extended distance method was within 0.2 %. The S_C for small fields was able to be measured accurately by the extended distance method.

Keywords: Radiation therapy; collimator scatter factor; extended distance method

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A135

A Phantom Study: The Impact of Irradiation Time by Offset Distance with Tomotherapy

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Purpose: Tomotherapy was used a flattening-filter-free device, it is desirable to bring the planning target volume (PTV) close to the gantry isocenter (GIC). Therefore, we investigated the influence in the offset distance from GIC by using a novel indexing bar (HM-Bar) for radiation therapy with Tomotherapy. Methods: The IMRT phantom, HM-Bar and HIP-FIX were employed. The following conditions of intensity modulated radiation therapy plan were generated to a spheroidal PTV of 4 cm in diameter, 50 Gy/25 fr; D95: ≥ 50 Gy; maximum dose: ≤55 Gy by use of images which were obtained Computed Tomography-simulation for treatment planning. The irradiation times were compared with two experiments. 1. The PTV structure was moved from 0 to 12.5 cm in each right-left (RL) direction in the phantom 2.The PTV structure was set the GIC , the phantom was moved in each RL position at -2.5, -5, and -7.5 cm. Results: 1. The irradiation times were increased 1.7%, 9.2%, 16.9%, 42.7%, and 54.4% in 2.5, 5, 7.5, 10, and 12.5 cm PTV offset positions, respectively. 2. Results of the offsetting the phantom position was 2.3%, - 1.3%, and 2.1% at -2.5, -5, and -7.5 cm. Conclusions: In the PTV location movement, the irradiation time was increased at the 5 cm or more distance from the GIC in the RL direction. The PTV for the radiotherapy might be arranged to the GIC position as much as possible by using the HM-Bar etc. for reducing the irradiation time and high precision radiotherapy with Tomotherapy.

Keywords: Offset; tomotherapy; index-bar

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Radiosensitization Characteristic of Superparamagnetic Iron Oxide Nanoparticles in Electron Beam Radiotherapy and Brachytherapy

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Purpose: Superparamagnetic Iron Oxide Nanoparticles (SPIONs) has been the focus in medical imaging as MRI contrast agents. SPIONs demonstrate intriguing properties that not only advantageous in diagnostic imaging but also for therapeutic application. In this study, the radiosensitization characteristic of SPIONs in electron beam radiotherapy and brachytherapy were investigated. Methods: This study was conducted in-vitro using HeLa cells with SPIONs (15 nm) concentration of 1, 2 and 3 mMol/L. Irradiation were done at doses ranging from 0 to 10 Gy using electron beams of energy 6 and 12 MeV as well as 0.38 MeV ^{192}Ir brachytherapy source. Cell survivals were determined from clonogenic assay. Radiosensitization characterization was performed by analyzing the sensitization enhancement ratio (SER) expolated from the survival curves. Results: The results show SPIONs induce radiosensitization effects in electron beams especially at lower energy with SER value obtained up to 1.5. The radiosensitization is more prominent for brachytherapy with SER value around 2 fold. Concentrations of SPIONs also play important roles in which higher concentration of SPIONs resulting in higher radiosensitization effects. Conclusions: In conclusion, radiosensitization are essentially dependent on radiation energy and concentration of the SPIONs. Further characterization of the radiosensitization induced by SPIONs may enable clinical translation of SPIONs as radiosensitizer in radiotherapy.

Keywords: Superparamagnetic iron oxide nanoparticles; radiosensitization; electron beam radiotherapy; brachytherapy

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Development of a Novel Lok-Bar Low-Radiation-Absent in Dose Delivery and Dose Monitoring using Cone Beam Computed Tomography

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Purpose: We developed a novel low-radiation-absorbent lok-bar (HM-bar) that is used to secure the immobilizers to the couch. The aim of this study was to investigate the absorption of the HM-bar in cone beam computed tomography (CBCT) simulation by comparing the Varian Exact lok-bar(VL-bar) as a benchmark. Methods: CT and CBCT images were obtained with or without lok-bar. The absorptions for each lok-bar were measured using a farmer-type ionization chamber (PTW30013) and the IMRT homogeneous phantom (ICRS Model 002H5). The measurement point of phantom center was irradiated at gantry angles between 100 and 180° with 10 MV x-rays with field size of 10×10 cm and 100 monitor unit. The treatment apparatus was TrueBeam (Varian medical systems). The absorbed doses were calculated with anisotropic analytical algorithm. And then, the absorbed dose differences between measurement and calculation for each lok-bar were evaluated. Results: The highest dose difference of CT and CBCT images in the HM-bar was observed at the gantry angle of 112°; the dose difference between the measurement and calculation were 1.7 % in CT simulation and 6.6 % in CBCT simulation, respectively. While, the highest dose difference for the VL-bar was also observed at a gantry angle of 112°; the dose difference between the measurement and calculation with VL-bar were 3.3 % in CT simulation and 14.0 % in CBCT simulation, respectively. Conclusions: The HM-bar could minimize the dose differences in CBCT simulation, which was expected to provide accurate dose delivery and dose monitoring.

Keywords: Novel lok-bar; CBCT; dose monitoring

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A141

Characterisation of Delaminated GAFCHROMIC™ EBT3 Films in Clinical Photon, Proton and ^{192}Ir Brachytherapy Source

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Purpose: This paper aims to assess dose-response of delaminated GAFCHROMIC™ EBT3 films in clinical photon, proton and ^{192}Ir brachytherapy source. Methods: Delaminated EBT3 films were produced by peeling off the top polyester substrate of original EBT3 using surgical precision forceps. The films were irradiated with photon beams of 6 MV and 10 MV, while proton and 192Ir exposures were conducted at nominal energies of 150 MeV and 0.38 MeV respectively. Dose-response curves were plotted across doses up to 500 cGy in Red-channel. Analysis of data fitting, film performance, film uniformity and energy dependence were then implemented as characterisation tests for comparative investigation. Results: The thickness reduction in delaminated EBT3 was found to not affect the digitisation process. Results of R2 in each curve suggested that the selected non-linear function appropriately fits the data with low reduced chi-square. However, the modified films experience mean performance degradation of 5.4% due to active layer damage, affecting the film's uniformity with values extending to ±1.0% of the mean I. Plus, the mean relative difference of energy dependency for delaminated EBT3 in photon irradiations was observed at 4.2%, which is inferior to their original counterpart. Conclusions: In summary, the delaminated EBT3 yields comparable dose-response behaviour despite the deterioration in performance. It is important to factor film delamination uncertainty into existing uncertainty budget as it is instrumental in reading netOD deviations. Accurate response evaluation together with reliable fabrication technique could make delaminated EBT3 attractive in specific applications including alpha particles dosimetry and ultraviolet radiation monitoring.

Keywords: Dosimetry; EBT3 radiochromic films; radiotherapy

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A142

Introducing Stereotactic Therapy Safely: Credentialing Centres and Staff

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Purpose: Stereotactic radiotherapy treatments use high doses of radiation delivered in relatively few fractions compared with conventional radiotherapy. Specialist planning, immobilization and image guidance techniques are needed to achieve accurate treatment. Because doses are high and fractions few, the consequences of treatment errors are more severe than for conventional therapy. Yet the risk of errors is higher when introducing new treatment techniques, particularly when the number of patients treated is low. A credentialing program for staff and equipment is one strategy that can be used to reduce risk. The Icon Group runs a network of 26 radiotherapy centres in Australia and is expanding into Asia. There has been a rapid growth of stereotactic treatments at Icon due to clinical demand. In order to reduce the risks of introducing stereotactic therapy, an in-house credentialing program was developed. Methods: A multi-disciplinary working group comprising medical physicists, radiation oncologists and radiation therapists was established to develop credentialing policies and procedures. Elements considered during credentialing included the purchase, commissioning and quality assurance of equipment, the establishment and documentation of safe work practices and staff competency assessment. Results: The credentialing program has been developed and tested at Icon Cancer Centres introducing cranial and extra-cranial stereotactic therapies. Conclusions: The credentialing program has led to an increased focus on safety and risk reduction for stereotactic therapies at Icon. Credentialing enables systematic assessment of a centre's capability to safely deliver stereotactic treatments. A credentialing program may be applicable to other organizations wishing to introduce new treatment techniques safely.

Keywords: Stereotactic; credentialing; risk management

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Comparative Analysis of HDR Intracavitary Brachytherapy Fractionation: *In-Vitro* Study

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Purpose: Cervical cancer is commonly treated with high dose rate (HDR) brachytherapy. However, the optimal fractionation and dependency on time interval between fractions in HDR intracavitary brachytherapy (ICBT) technique remain controversial. In this study, three types of fractionated irradiation technique were investigated using human cervical cancer (HeLa) cells to determine the most effective fractionation regime that would be implemented in ICBT treatment. Methods: HeLa cells were irradiated using HDR remote-afterloading brachytherapy machine with 3 types of fractionation technique; single fraction, hyperfraction and hypofraction. Fractionated dose used was 9 Gy/fraction with 18 Gy of total dose. Cell survival curves were obtained from standard clonogenic assay fitted with Pade Linear Quadratic (PLQ) model using OriginPro 9.2 software. Radiobiological analysis of irradiated HeLa cells was performed based on the cell survival curves. Results: The cell survival curves irradiated with single fraction, hyperfraction and hypofraction technique indicate the time interval between fractions impacting the cells survival. The survival curve shoulder of single irradiation tends to be constant as the doses increase more than 12 Gy. For hyperfractionation, the shoulder region was wider which indicates the cells have higher survival. Hypofractionated irradiation had steeper shoulder as the dose increase. In this case, the cancer cells do not have chances to recover and have lower survival fraction. Conclusion: Radiobiological analysis presented by PLQ model shows that hypofractionated irradiation with 9 Gy/fraction delivered in two fractions might be the most effective fractionation to be implemented in cervical cancer treatment using HDR-ICBT irradiation.

Keywords: Brachytherapy; PLQ model; HeLa cell; hyperfractionation; hypofractionation

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Effect of Cleaned-Up Rapidplan Model to Plan Quality for Volumetric Modulated Arc Therapy in Prostate Cancer

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Purpose: This study investigated the effect of cleaned-up RapidPlan (RP) model to plan quality for volumetric modulated arc therapy (VMAT) in prostate cancer. Methods: Thirty consecutive prostate cancer patients who underwent VMAT using clinical plans (CPs) were evaluated. The RP modeling methods were as follows: 1. Not clean the outliers (RPREF) trained by the other 50 CPs; 2. Clean the outliers with not meeting the clinical goal of dose-volume histogram (DVH) (RPC-DVH); 3. Clean the outliers of outside the range of ±1SD for principal component analysis (PCA) regression plots (RPC-REG); and 4. Clean the outliers both 2. and 3. (RPC-ALL). The numbers of rectum and bladder structures training the model were 34 and 48 in RPC-DVH, 37 and 33 in RPC-REG, and 26 and 33 in RPC-ALL, respectively. The plan quality for each model were compared. Results: All RP models could generate better or comparable target dose coverage and conformity, and comparable organs-at-risks (rectal and bladder walls) sparing to the CPs. There were no significant differences of plan quality in each RP model. However, the only RPC-ALL model could generate no plans for V100% of rectal wall with more than 1%, while RPREF, RPC-DVH, and RPC-REG include 3, 5, and 8 plans, which was difficult to overcome with RP due to including the overlap region between PTV and rectum. Conclusions: The cleaned-up RP model considering both DVH plots and PCA regression plots could improve the plan quality even though the number of structures training the model was decreased.

Keywords: RapidPlan; cleaned-up model; prostate cancer; plan quality

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A149

Clinical Experience with a Knowledge-Based Planning Solution to Reduce the Patient Plan Variation

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Purpose: The knowledge-based-planning solution, RapidPlanTM, aims to reduce planning time and variations in plan quality. The plan-libraries used consist of different patient plans to make a model that can predict achievable organ-at-risk and dose-volume histograms for new patients. The model is also used for setting optimization objectives. We performed a comprehensive comparative study of the plan quality of manual plans and RapidPlan - generated plans (RGP). Methods: The RapidPlan Modelprostate comprised fifty-five volumetric modulated arc therapy plans. Twenty prostate cancer patients' plans were selected for this study. For each manual plan, we created a new plan with RapidPlan. The manual plans were used as reference plan to evaluate the RGP. All RGPs were optimized to achieve the same level of planning target volume coverage as the reference plans. Plan quality was evaluated by measuring Conformity IndexRTOG (CI), Homogeneity IndexRTOG (HI) for target and mean dose to the organs-at-risk. Results: The mean CI and HI of manual plans versus RGP are respectively 0.937, 0.936 and 1.0869, 1.0872. The manual plans versus RGP mean dose of the bladder and Penial bulb are not significantly different. But the mean dose of rectum and femoral-head are respectively reduced by 7.2% and 18.2% using RGP. Conclusions: Considering the plan consistency as well as plan design efficiency of manual planning compared with RGP, RGP may be the preferred option for prostate treatment planning.

Keywords: RapidPlan; knowledge-based planning; volumetric modulated arc therapy

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A150

Application of a Novel Lok-Bar for High-Precision Radiotherapy with Tomotherapy

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Purpose: A lok-bar needs to establish a reproducible patient position on the couch. In tomotherapy, dose attenuation and difference between calculated and delivered doses may be caused by the lok-bar due to the helical beams. The purpose of this study was to apply a novel lok-bar in tomotherapy. Methods: The effect of conventional lok-bars for CT-simulation (CIVCO-bar) and treatment (iBEAM-bar) were compared with a novel lok-bar (HM-bar), based on: 1. artifacts in CT-simulation images; 2. dose attenuation rate of lok-bar, compared to without lok-bar (non-bar) in 9 delivery quality assurance (DQA) plans for lung, head, head-and-neck, abdominal and pelvic cancers; and 3. dose differences between the calculated and measured absorbed doses at the center of the target in 9 DQA plans. Results: The CIVCO-bar caused metal artifacts from the two pins and fixations, while there were nearly no such artifacts with the HM-bar. The CT values of each profile for the CIVCO-bar and HM-bar were 47.34 ± 45.38 (mean ± SD) and 11.59 ± 16.34, respectively. The mean dose attenuation rates with the HM-bar and iBEAM-bar, compared to the non-bar, were 1.31% and 2.28%, respectfully. The mean dose differences between the calculated and measured absorbed doses were 1.55% and 1.66% for HM-bar and iBEAM-bar, respectively. Conclusions: The HM-bar was useful tool to reduce artifacts on the CT image and improve the dose attenuation.

Keywords: Novel lok-bar; tomotherapy; high-precision radiotherapy

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Evaluation of Organ Doses Following High Dose Rate (HDR) Brachytherapy of Breast Cancer: A GEANT4 Monte Carlo Simulation Study

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Purpose: This study aimed to evaluate the absorbed doses received by the organs at risk (OARs) following ^{192}Ir HDR brachytherapy of the left breast. Methods: The MIRD5 adult female anthropomorphic phantom, readily available in the GEANT4 Monte Carlo package was used. However, the left breast volume was modified from 195 to 145 cm^3, to represent a breast following lumpectomy. Left breast was chosen due to its higher cancer occurrence than the right breast. The HDR sources were constructed with an outer cylindrical dimension of 4.5 mm (length) × 0.9 mm (diameter). Various influencing parameters were studied, i.e. catheter arrangement (single versus dual plane), source inter-dwell distances (0.5 versus 1 cm), and different radionuclides (^{60}Co and ^{192}Ir), by delivering a total treatment dose of 32 Gy to the left breast. Absorbed doses to the OARs (e.g. lungs, heart, right breast, spleen, stomach etc.) were then evaluated. Results: A maximum left lung dose of 1.5 Gy was recorded, while doses to the other OARs were all below 1 Gy. The treatment using dual plane catheter arrangement contributed to a slightly higher dose to the OARs, despite equal dose to the breast. There was no dose difference between different inter-dwell distances used in this study. ^{60}Co resulted in a slightly higher left lung dose than that of ^{192}Ir, while the results were the opposite for the other OARs. Conclusions: HDR brachytherapy allows high dose to be delivered to the breast within a short period of time, with minimal doses to the OARs.

Keywords: GEANT4; brachytherapy; iridium-192

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A157

Detection of MLC Errors with Portal Dosimetry in Patient-Specific VMAT Quality Assurance

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Purpose: In volumetric modulated arc therapy (VMAT), multileaf collimator (MLC) errors lead to significant dose deviation in clinically. This study examined the effects of MLC errors of VMAT plan and the sensitivity of gamma-index evaluation with portal dosimetry for detecting these errors. Methods: Five plans were created with VMAT for prostate cancer. Those plans were modified by means of three error types: (1) both MLC banks are opened; (2) both MLC banks are closed; and (3) both MLC banks are shifted. The errors included to the MLC are 0.5 mm and 1.0 mm. Results of portal dosimetry for modified plans were evaluated with respect to a gamma-index of 2%/2mm, 1%/2mm and 2%/1mm. Dose in the modified plans was recalculated and dose volume histograms for target and critical structures were compared to those of the original plans. Results: The minimum leaf position deviations which failed the >95% criteria for a gamma-index of 2%/2mm were: (1) 1.0 mm, (2) 1.0 mm; 1%/2mm were: (1) 1.0 mm, (2) 0.5 mm; and 2%/1mm were: (1) 0.5 mm, (2) 0.5 mm and (3) 0.5 mm corresponding to the error types respectively. Though these errors might lead to significant changes in mean planning target volume dose, but would fail to detect with 2%/2mm and 1%/2mm gamma-index criteria. Conclusions: In gamma-index evaluation with portal dosimetry, a gamma-index of 2%/1mm was necessary in order to detect positional errors of the MLC. However, even the 2%/1mm gamma-index criteria might be insufficient for MLC errors smaller than 0.5 mm.

Keywords: Quality assurance; portal dosimetry; gamma-index

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Evaluation of Organ Doses Following Prostate Treatment With Permanent Brachytherapy Seeds: A GEANT4 Monte Carlo Simulation Study

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Purpose: This study aimed to evaluate the absorbed doses received by the organs at risk (OARs) following prostate treatment with permanent 125I brachytherapy seeds. Methods: In order to simulate an enlarged abnormal prostate due to malignancy, the MIRD5 adult male anthropomorphic phantom (readily available in the GEANT4 Monte Carlo package) was modified by increasing the prostate volume to 35 cm3. The permanent seeds were constructed with an outer cylindrical dimension of 4.5 mm (length) × 0.8 mm (diameter). The effect of various activity per seed (0.5, 0.6 and 0.8 mCi), number of seeds (62, 78, 94 and 110 seeds) and radionuclides (^{103}Pd, ^{125}I and ^{131}Cs) towards the absorbed doses to the OARs (i.e. rectum, urinary bladder and both testicles) were investigated. Results: Prostate dose of up to 237 Gy was simulated, which resulted in 11 Gy dose to rectum, 7 Gy to urinary bladder and 4 Gy to each testicle. The doses were considered as reasonable, given the low dose rate nature of the treatment, allowing tissue repair for the OARs. Optimal seeds arrangement was found to consist of 78 or fewer seeds, as it resulted in the lowest doses to the OARs. For similar prostate dose, ^{103}Pd resulted in the lowest doses to the OARs, followed by ^{125}I and ^{131}Cs. Conclusions: Permanent seed brachytherapy allows high dose to be delivered to the prostate, while reserving the dose to the OARs to as low as possible.

Keywords: GEANT4; brachytherapy; iodine-125

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Commissioning of SRS-Mapcheck Diode Array for SRS Pretreatment Delivery QA

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Purpose: SRS-MapCHECK was commissioned as a QA equipment for dose distribution verification of stereotactic radiosurgery (SRS) plans, using 6 MV photon beam with flattening filter, and the SNC Patient software (version 8.0). Methods: Commissioning works were performed to verify factory array calibration and verification of stated PMMA water-equivalent depth. Additionally, SRS-MapCHECK was evaluated for its response dependency on linac dose rate, response linearity up to 28 Gy, and comparison of output factors against those of TPS. Angular dependency test is work in progress. Clinical SRS patient plans with target volumes from 0.5 to 4 cm^3 were also investigated. Results: Linac dose rate dependency was within 5% of the standard dose rate reference (600 MU/min). The uniformity of major profiles regarding factory calibrated array were less than 1%. The stated PMMA water-equivalent depth was considered valid with difference up to 1.6% compared to solid water slabs. Linearity of array's response was excellent up to 28 Gy. Output factors measured by SRS-MapCHECK were in very good agreement compared to those from TPS. Results of relative gamma analysis of clinical patient plans on 2%/2mm level and 10% threshold demonstrated a very good agreement between SRS-MapCHECK-measured and TPS-calculated reference doses. Results on angular dependency test will be reported in final presentation. Conclusions: The SRS-MapCHECK was tested and considered acceptable as QA device for verification of SRS plan's dose distribution. The high-resolution diode array makes it a preferred device for SRS QA measurements. Due to current version's software limitation, only relative gamma analysis can be performed.

Keywords: Stereotactic radiosurgery; SRS-MapCHECK diode array; SRS-MapCHECK commissioning

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Commissioning Study of SBRT with the Respiratory Gating Technique Using Varian RPM System in our Institute

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Purpose: Assurance of beam control is indispensable for radiation therapy with respiratory gating technique. Our institute newly installed TrueBeam with real-time position management (RPM) system which monitors the RPM marker block. Commissioning test of stereotactic body radiation therapy with respiratory gating technique using the RPM system has performed. Methods: Beam-on delay time was measured using a newly motion platform we developed. A ball bearing phantom was placed on the platform, together with the RPM system marker block, and moved periodically along the longitudinal axis. Dose difference with and without the respiratory gating technique was measured in some gating windows. We verified 4DCT scan parameter using the platform and PMMA cylinder phantom. We compared the maximum intensity projection (MIP) images of the 4DCT scan and that of the static scan which acquired at longitudinal position corresponding to 0%, 10%, 20%, 30%, 40% and 50% phases of the motion. Results: Beam-on delay time with kV and MV beams was 94 ms and 59 ms, respectively. The maximum dose difference with the gating technique was 0.31% in comparison to the non-gating irradiation. A slight underestimation of size was found in the 4DCT MIP images. Conclusions: We confirmed the result of commissioning test. Next, we want to develop an easy-to-handle QA tool for assessment of respiratory gating technique using RPM system.

Keywords: Commissioning test; RPM system; respiratory gating technique

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Dosimetric Characterization of Homemade Bolus for Radiotherapy

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Purpose: The main purpose of the present work was to perform the dosimetric characterization of the homemade bolus(SENflab) and compare with that of the commercially available superflab and RW3 slab using RW3 slab phantom with high energy photon and electron beams. Methods: The homemade bolus was used to measure the transmission factor, Electron Density and compare with superflab and RW3 slab using RW3 slab phantom. For two megavoltage X-rays, 6 and 15 MV & all electron enegies, the transmission factor of the homemade bolus was measured by means of a 0.6cc Farmer ionization chamber. The SENflab was placed on top of the slab phantom and irradiated by 6 and 15 MV photons and repeated for other boluses. Afterward, the boluses were removed and the irradiation repeated for both photons as well as electron energies. Computed tomography data from the boluses were acquired to assess electron densities with various techniques (mA and kVp). Circular ROIs were delineated on CT DICOM images and densities were calculated using CT numbers. Results: Evaluation of our results is evident that showed that mass electron densities are similar to those of water and soft tissue. Furthermore, transmission factors are close to those of water. Conclusions: The homemade bolus is a reasonable alternative to tissue-equivalent bolus. Bolus is equivalent to tissue in photon attenuation, conforms well to the irregular contours. It should be considered a viable alternative to common bolus materials such as Bee's wax and Paraffin wax. Its need further study to use clinically.

Keywords: Homemade Bolus (SENflap); superflab; transmission factor

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Assessment of the 3D Central Beam Axis using a Plastic Scintillator Imaging System in Proton Therapy

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Purpose: We have developed a prototype system for assessment of the 3D-isocentricity and have measured the 3D central beam axis and the sagging angle in photon therapy. In this study, we measured the size of 3D radiation isocenter and the sagging angle using the prototype system in proton therapy. Methods: The prototype system was composed of a column-shaped plastic scintillator (CoPS), a truncated cone-shaped mirror (TCsM) and a cooled CCD camera. We performed the experiment in National Cancer Center Hospital East. This prototype system was irradiated with 235 MeV proton beams and the scintillation light was measured using the CCD camera. The relationship between the irradiated and the measured angles with respect to the gantry rotation axis was measured. In addition, the size of 3D radiation isocenter and the sagging angle at each gantry angle were measured. Results: The relationship between the irradiated and measured angles had good linearity. The mean and standard deviation of the difference between the irradiated and measured angles were 0.03 and 0.21 degrees, respectively. The size of 3D radiation isocenter was 0.83 mm. The maximum sagging angle was 0.64 degree at the gantry angle of 150 degree. Conclusions: The prototype system enabled to measure the size of 3D radiation isocenter and the sagging angle in proton therapy. As the next step in this study, we want to improve our prototype system using an intensifying screen to increase the measurement accuracy.

Keywords: Plastic scintillator imaging system; proton therapy; sagging angle; mechanical QA

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The Study of Risk Analysis in the Treatment Workflow of the Radiation Therapy

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Purpose: The purpose of this study is to investigate the quality and the risk level of the department workflow in the radiation therapy services. Methods: This study analyzed 900 cases of radiotherapy treatment within an institutional record system collected two years' time. Two different kinds of ways, retrospective and prospective, were used to examine the cases. The cases were recorded at the day of the first treatment and checked for the severe or near-miss events. This study emphasized on first day treatment positioning and other workflow errors occurred at that time. All the cases were separated into two groups, detectable and non-detectable. The categories of the potential failure modes were also assigned. Results: The load of data were analyzed based on the guidance of departmental protocol. The result showed nearly 40% of cases were identified as detectable events at the first day of treatment. However, the cases of nearly 70% expressed in the way of non-detectable events. The most detectable failure modes were design/organization and human failure. Conclusions: The analysis of the risk is the best way to show the errors, failure modes and severity of the radiation incidents, and give a way to create the root cause analysis of those steps of failure modes. The department workflow system of the institution can be improved by using this method.

Keywords: Risk analysis; detectable; failure mode

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A174

Investigate the Characteristics of the Intergrated Depth Dose of Proton Beam in Medium

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Purpose: This study investigated some basic depth dose characteristics of ideal proton pencil beams using the particle therapy simulation framework LAP-CERR in order to validate the dose engine in LAP-CERR for research purpose. Methods: Two main parameters of the intergrated depth dose including the Bragg peak and the lateral spread square of proton pencil beam in water were studied to see their changes according to energy. Moreover, the influence of different bulk heterogeneity intersecting the beam on the dose distribution was also evaluated. Results: With the intensity of proton pencil beam of 108 particles, the depth of the Bragg peak is from 2.2 cm to 43.7 cm and the lateral spread square changes from 0.0325 cm^2 to 0.0027 cm^2 when energy ranges from 50 to 270 MeV. Among three various materials including air, soft bone and hard bone slab intersecting the beam, the hard bone slab causes the most shifted of the peak toward the skin and makes the Bragg peak the most rounded. Conclusion: The results showed that main characteristics of the intergrated depth dose of proton beam calculated by LAP-CERR reflect the theories of proton beam at acceptable level. Thus, LAP-CERRR can be used to make further research in proton therapy.

Keywords: Proton pencil beam; characteristics; proton therapy

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Fast Proton Dose Approximation Based on Water Equivalent Depth of Each Voxel

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Purpose: For evaluation purpose, it is necessary to have a fast and appropriately accurate dose algorithm to calculate the dose distribution under various uncertainties. In this work, we introduce an approximation method for rapid calculation of dose when setup errors occur during the treament. Methods: This approximation derives the new dose distributions undergoing different scenarios based on the original dose distribution from a reference setting. In the reference setting, each voxel has a certain water equivalent depth. Basing on the prior dose distribution and the change of water equivalent depth dose of each voxel, the new dose is calculated. The setup error is simulated by shifting the patient as a rigid body. To validate the method, we calculated dose distribution from our approximation method and the one from recalculation method, and then evaluated the agreement between them using a 3D gamma index. Results: The passing rate of 3D gamma analysis under 2% dose and 2% mm distance to agreement criteria was above 95% for setup errors for 8 considered cases. The computional time from our dose approximation is about 40 seconds for a two beams plan compared with 5 minutes from recalculation method. Conclusions: The result show that our dose approximation is suitable to take account of setup errors while strongly reducing the computational time.

Keywords: Dose approximation; water equivalent depth; proton treatment planning

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Analysis of Physical Properties of Bolus Based on Propylene Glycol for Photon Megavoltage and Electron Radiation Therapy

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Purpose: Bolus is widely used to protect and reduce irradiation in organ at risk in the process of radiotherapy. Generally, the bolus is made of polymer material due to the polymer character is similar or equivalent to tissue. This study aimed to determine the density, transmission factor, effective mass attenuation coefficient on bolus with radiation of photons and electrons. Methods: There are four bolus types, namely B – PG 24%, B – PG 24%; SR 8%, B – PG 24%; SR 8%; Al 0,5%, and B – PG 24%; SR 8%; Al 1,5%, respectively. Bolus is made with dimensions of 11×11 cm and thickness of 1 and 1.5 cm. The bolus density is evaluated through the mass of each volume. For dosimetry testing, the bolus is irradiated using Linear Accelerator with 6 MV and 10 MV photon energy and 6 MeV and 12 MeV electrons. Results: The all of the boluses have density values similar to tissue or water and air density with the range of 0,864 -1,273 g/cm^3. The results showed that B – PG 24%: SR 8%: Al 1.5% for dosimetry testing both 6 and 10 MV photons obtained properties that resemble soft tissue. Meanwhile, for both dosimetry testing of 6 and 12 MeV electrons, the B – PG 24 %: SR 8% has the nature closest to soft tissue. Conclusions: The all of the boluses that have been fabricated have properties similar to soft tissue for photon therapy whereas the addition of more aluminium making a bolus has features as a shield on the process of radiotherapy.

Keywords: Bolus; dosimetry; radiotherapy

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Dose Assessment of 4- and 16-slices Multi-Detector Computed Tomography (MDCT) Scans

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Purpose: To assess the performance of x-ray generator and CT dosimetry in 4- and 16-slices Multi-Detector Computed Tomography (MDCT) scanners in axial mode scanning. Methods: 2 types of CT scanner were evaluated; 16-slices Siemen Somatom Emotion 16 and 4-slices Toshiba Asteion 4 Edition. The x-ray generator dose estimation of MDCT scanners performed under details technique parameters (kVp, mAs and exposure time) had been assessed using multi-function detector (Raysafe Unfors), TLD-100™ and nanoDot™ OSLDs. The assessment of weighted CT Dose Index (CTDIw) is measured using 100 mm standard pencil beam ion chamber, TLD-100™ and nanoDot™ OSLDs, in a 160 mm diameter head and 320 mm diameter body cylindrical acrylic Polymethyl-Methacrylate (PMMA) phantom (160 mm length). CTDIw values were specified either in central axis or 10 mm from the 4 outer edge of the phantom. Results: Comparison between two sizes of phantoms made from measurements of the CTDIw in two types of CT scanners. The weighted CTDIs (CTDIw) were calculated and CT x-ray generator performance were observed. The results using three different type of detectors were examined and compared. The deviation accuracy of the tube voltage lied in between ± 5 kV or ± 5% whichever is greater, whereas the accuracy of exposure time and coefficient of linearity (mAs) lied in between ± 10%. The radiation dose (CTDIw) to dose under exceptional CT scanning condition during axial modes were observed to meet the manufacturer guideline (< ± 20%). Conclusions: The implement CT dosimetry steps ensured the patient safety and can reduce future risk if an estimated dose value is inappropriately above the relevant threshold for any routine CT examination.

Keywords: MDCT; CTDI; PMMA phantom

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Prototype Development of Big Data Based Proton Therapy Planning System

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Purpose: In generally, conventional radiation treatment planning (RTP) system established the treatment plan by using the specific calculation and optimization algorithms. It was caused to treatment delay because dose calculation was taken a long time. Thus, we developed a newly dose calculation algorithm based on big data for reducing the time of establishing a treatment plan. Methods: For the design of an algorithm, we have established the RTP method using the form of the neural network model by some modifications. When a new input (patient data) data has been uploaded, it assigns a proper treatment plan through a supervised learning technique from a database. This database was constructed by using many results from Monte Carlo simulation operation. Our developed algorithm is composed of two sections which are made up of four layers. Results: The algorithm is faster than the conventional dose planning based on either algorithm or Monte Carlo. Also, it can be possible to acquire dose volume histogram (DVH). The dose of planning target volume (PTV) was sufficiently deposited, and the dose of organ at risk (OAR) was less deposited. In addition, the acquisition time of each treatment plan was averagely 3 – 8 second. Conclusions: In this study, we developed the algorithms for treatment planning by accessing the dose distribution database. Although we reduced the time for establishing the treatment planning, the accuracy evaluation for treatment plan was not performed in this study. Thus, we should be progressed by the further studies.

Keywords: Proton therapy; big data; treatment Planning System

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Transformation Program for DOSXYZnrc Simulation of Head First Prone Orientation of CT Image Phantom

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Purpose: To develop a computer program to rotate and reposition the computed tomography (CT) image phantom so that the resulted CT-based phantom could be used in DOSXYZnrc (a part of Monte Carlo EGSnrc software package) simulation. Methods: The CT images of Alderson Rando Phantom head in prone position were used to create CT-based phantom (in the form of egsphant file) using ctcreate code program (a program that installed along with EGSnrc software package). Instead of modified ctcreate code program, a python-based program was developed to rotate and reposition the CT image phantom which respect to DOSXYZnrc coordinate system by using the egsphant file as an input, since the ctcreate program operates by assuming images are head first supine orientation. These transformed coordinates were validated by comparing the resulted dose distribution from DOSXYZnrc simulation with one resulted from treatment planning system (TPS). Results: The dose differences between DOSXYZnrc simulation and TPS-generated dose are within the accepted statistical uncertainty limit which confirms the validity of the derived coordinate transforms. Conclusions: It shown that the developed Python-based program could prevent from bug which could be produced when modifying ctcreate code program since the program links to other program which is ReadCT_DICOM.c.

Keywords: Monte Carlo; DOSXYZnrc; transformations

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A Software Program for Quantitative Image Quality Evaluation of Cone-Beam CT System in Radiotherapy

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Purpose: The study presents application of an in-house software program to calculate image quality (IQ) parameters of kV cone beam CT (CBCT) system in radiotherapy. The IQ metrices include uniformity, contrast-to-noise ratio, CT number stability, low contrast visibility, spatial resolution and geometric distortion as recommended in AAPM TG142 and TG179 quality assurance (QA) programme for image quality performance of kV CBCT. Methods: The computer algorithm packaged in the software program is developed using MATLAB version R2013a (MathWorks, MA, USA). The algorithm was optimised for two CT image quality phantoms, Catphan 600 (The Phantom Laboratory, Salem, NY) and CIRS 062QA (CIRS, Norfolk, VA). The phantoms were scanned with XVI CBCT system (Elekta Oncology System, Stockholm, Sweden) using an optimised CT imaging protocol. Projection images acquired were reconstructed using the XVI system. The algorithm read the DICOM CT images of the corresponding image quality test pattern and analysed the image quality metric in a quantitative manner. Results: The algorithm provided image quality metrices recommended by AAPM QA programme from both phantoms quantitatively. The software program allows the results to be exported and recorded in MS Excel for monitoring the performance trend of the image quality metrices. Conclusions: The software program provided fast quantitative evaluation of the image quality metrices from CBCT image guidance system. The software reduces measurement uncertainties from qualitative human observation of the test pattern.

Keywords: Quality assurance; image quality; kV CBCT

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Real-Time Performance of Agility MLCs during Picket Fence Test

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Purpose: The multileaf collimator (MLC) performance is critical during intensity modulated radiotherapy (IMRT) delivery. Picket fence test is typically performed by acquiring images of MLC gaps using film or electronic portal imaging device (EPID) to assess the MLC positional accuracy as part of a comprehensive weekly quality assurance (QA) programme. This study aims to investigate the real-time performance of Agility MLC (Elekta, Stockholm, Sweden) during picket fence test that is not feasible using film or EPID. Methods: The position of Agility MLCs were tracked in real-time using propriety optical tracking system from the manufacturer. The data were recorded during picket fence test at four cardinal static gantry angles over six weeks. The fluence from the picket fence was constructed using the tracked MLC positions and compared with the fluence obtained from EPID. Results: The fluence of the picket fence pattern constructed from the real-time MLC position showed that the measured range of gap size error were between -0.3 mm to 0.8 mm. The average MLC positional error tracked was 0.07 mm ± 0.14 mm (mean ± 1 SD). Gap size measured from EPID has larger errors of over 1 mm. Conclusions: MLC positions that were tracked in real-time provides a more accurate test method for routine QA of the MLC performance as well as troubleshooting the MLC problem during IMRT treatment. Over the period of investigation, it was found that the MLC performance was within the tolerance of ± 1 mm recommended by AAPM TG142.

Keywords: Quality assurance; MLC performance; EPID

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In-Vitro Study of Biostimulation Effect on Red Blood Cells Irradiated by 589nm and 532nm Low-Power Laser

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Purpose: This study was conducted to investigate the biostimulation effect of low-power laser on human red blood cells (RBCs). The experimental works were using normal and anaemic human blood to study RBCs' deformability and viability after irradiated by 589 and 532 nm laser. Methods: The normal and anaemic blood samples were prepared in two aliquots, one as control while another one was irradiated by laser power of 20, 40 and 60 mW with exposure time of 15, 30 and 45 minutes. After the irradiation process, the samples were smeared to observe morphology of RBCs. Then, the blood samples were centrifuged to separate RBCs from other blood components and by using Cell-Titer Glo® Luminescent Cell Viability kit, the viable cell percentage was determined based on quantitation of ATP. Results: The results showed that normal RBCs sample irradiated by 589nm laser experienced crenation when induced with 60mW power for 45 minutes while the 532nm laser, the cells crenated at power 40mW, exposure time of 45 minutes. For anaemic sample of both lasers, the cells maintain their shapes and the cell viability percentage increases after irradiation for all power and exposure time. Conclusions: The anaemic samples show stimulation effect after induced by low-power laser as the percentage of viable cell increase and the shape maintained. The shape change is due to the deformability nature of RBCs and this related to the cell viability. The percentage of cell viability between the two lasers has significant value ($p = 0.000$) as the cell viability is affected by the energy induced by lasers.

Keywords: Low-power laser; biostimulation; red blood cells; deformability; viability

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Case Report: Dose Estimation Delivered to a Patient Treated with IMRT Prostate Using Deformable Image Registration (DIR)

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Purpose: To estimate total dose received by an IMRT prostate patient by applying DIR on daily CBCT. Methods: A patient whom completed his IMRT prostate treatment is selected from the database. Total of one planning CT study set and 37 CBCT study sets were contoured by one radiation oncologist. All study sets were imported into The Velocity™ platform. Planning CT was deformed according to each daily CBCT set using an elastic B-spline algorithm to generated 37 deformed planning CT study sets. All deformed planning CT were imported into Eclipse planning system and dose was re-calculated on each data set using the approved IMRT prostate plan. Results: Dose to 95% volume (D95) of PTV75 is 75.5Gy for planning and 68.4Gy for estimated delivered dose. D95 for prostate is 76.9Gy for planning and 74.8Gy for estimated delivered dose. Estimated D2cc received by bladder is 78.5Gy which is very close to the planned dose of 79.6Gy. Estimated D2cc delivered dose to rectum is 77.7Gy and the planned dose for rectum is 77.2Gy. Conclusions: Overall, the estimated delivered dose to targets is less than the planned dose. This is due to the daily variation of bladder and rectal volume which alter the positioning of prostate during radiation treatment. Although the PTV75 was 9.4% less than the planned dose, the estimated delivered dose to prostate was within acceptable range with 2.7% less than planned dose.

Keywords: Dose estimation; IMRT; prostate; DIR

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Integrating Gimbal Motion using Target Position Segmentation in Arc Treatment: Conceptual 4D Dose Calculation Approach

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Purpose: This work includes gimbal motion in 4D dose calculation of arc treatment planning. Methods: Machine geometry, target position and patient breathing pattern are required to integrate Vero gimbal motion in the dose calculation. In this study, the target and breathing patterns were simulated using in-house moving phantom prior treatment. The machine geometry and treatment timing from the control points (CPs) of each arc were extracted from the Pinnacle3 treatment planning system (TPS) using scripts. After synchronizing the TPS irradiation timing from the TPS with the target position and breathing phase, segmentation procedures were implemented to select target position, breathing phase, machine geometry, and delivered MU. Based on these data, new plans were created for target positions for which the motion amplitude exceeded 1 mm within a CP. The method was tested using a treatment plan with two-arc sequences using 2-degree gantry spacing resulting in 86 and 82 CPs, respectively. Results: The segmentation procedure created 226 and 247 target positions for the two arcs, respectively. The results showed that the target motions above 1 mm within CP have occurred at 64 and 62 CPs for arc 1 and 2. Moreover, the segmentation procedure manages to provide finer plan sequences as a consequence of including target motion in dose calculation. Conclusions: 4D treatment planning of Vero gimbal motion is possible by synchronizing target and breathing pattern with the treatment planning parameters. The next step would be utilizing the segmentation outputs to reproduce the gimbal geometry inside the TPS.

Keywords: Gimbal motion; 4D plan; segmentation; motion synchronization

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Clinical Application Radiosurgery by Linac-Based at Oncology Center of Hue Central Hospital

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Purpose: SBRT, SRS is one of radiotherapy techniques which entails precise delivery of high-dose in one fraction and several fractions, with tumor ablation and maximal normal-tissue sparing. This technique has been approved globally and performed based on Cyber knife, Gamma knife, Proton. SBRT/SRS technique is still not common in Vietnam because that requires high accuracy and synchronous facilities. Hue Central Hospital is the pioneer in Vietnam applying successfully Linac-based SBRT, SRS with imaging guide radiotherapy (IGRT). The aim of this study is to survey and assess treatment planning quality of SBRT for Liver, Lung and brain tumors. Methods: There were 70 patients (20 HCC,15 lung, 35 brain) underwent SBRT, SRS techniques at Hue Central Hospital. We applied volumetric arc therapy technique (VMAT) from 1 to 5 fractions. Radiation treatment was given on LINAC of Elekta AXESSE, planned by Monaco 5.11 version, IGRT by daily cone beam CT/XVI device and assured quality by Verisoft software, OCTAVIUS 4D/PTW system. CT Simulation 4D of PHILIPS with breathing compressor. Results: Mean age was 50. Average tumor size was 3cm. Prescribed doses ranged from 15Gy to 60Gy. Conclusions: SBRT, SRS technique requires high accuracy and synchronous facilities. This techniques entails precise delivery of high-dose, with tumor ablation and maximal normal-tissue sparing. SBRT,SRS is a non-invasive, well-tolerated and effective treatment for patients not suitable to others local ablation treatment. SBRT,SRS is as an alternative ablation treatment of HCC,Lung and brain tumor with promising results. It may concern using for oligometastatic patients. Prospective randomized clinical trials are required to confirm clinical evidence and long term results.

Keywords: Stereotactic body radiation therapy; stereotactic radiotherapy surgery; VMAT

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The Impact of Pitch and Modulation Factor to Tomotherapy Treatment Plan Optimization for Motion Target

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Purpose: The influence on target motion resulted from the respiratory process, the pitch and modulation factor presented in Tomotherapy. This study was aimed to investigate the effect of motion management using CT-images obtained from the fusion process between static and dynamic scanning mode on the CIRS Thorax Phantom. Methods: The images were created using axial and helical modes which amplitudes were varied from 10 mm, 15 mm, and 20 mm. Then, the organ structures were planned using TomoPlan TPS with variation of pitch ranging from 0.25 to 0.5, and the modulation factor (MF) in the range 2 to 3. Furthermore, evaluation of radiotherapy planning was performed using dose parameters on target, organ at risk, homogeneity index (HI), and mean leaf open time (LOT). Results: Target volume for static mode was 3.53 cc, where as target volume has changed to 10.9 cc, 10.3 cc, 16.1 cc for axial and 6.6 cc, 8.5 cc, 14.9 cc for helical scanning. HI value obtained was less than 0.07 and lower HI was resulted for a larger MF. It means that the higher modulation factor values will provide a uniform dose distribution to the target and lower dose to the OAR. The greater value of pitch gave the greater mean LOT. Conclusions: The optimum parameters were at pitch of 0.5 and MF of 3 based on evaluation of mean LOT and HI. Axial scanning mode provides a larger target volume compared to a helical scanning mode. Therefore, the increment of target volume in delineating organ should be considered.

Keywords: Tomotherapy; motion management; treatment planning; lung cancer

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The Characteristics of Small Field Beam Quality and Output Factor of 6 MV FFF

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Purpose: Linear accelerator with the modality of flattening filter free (LINAC FFF) has been installed Indonesia. To ensure the accuracy of FFF irradiation, we evaluate the characteristic of FFF in standard and small fields. Methods: We employed the Monte Carlo (MC) simulation of LINAC FFF 6 MV as a standard reference in this study. Then, we compared the calculation of PDD and beam profile to measurement and TPS in which analytical anisotropic algorithm (AAA) was implemented. In this experiment, we used 10×10, 1×1, 2×2, 3×3, 4×4 cm^2 field sizes by using a water tank phantom. Output factor (OF) and beam quality such that TPR20,10 and penumbra of LINAC FFF were evaluated. Results: Kinetic energy and full-width half maximum (FWHM) of the electron source of LINAC FFF 6 MV were 6.2 MeV and 0.20 cm, respectively. TPR20,10 for 10×10 cm^2 was 0.01 differ between MC and measurement whereas it varied from 0.588 to 0.703 for small fields. Dose difference of lateral axis was agreed within 3% except for the penumbra region. Besides, the PDD ratio of MC and TPS is up to one-sixteenth. Output factor of small fields measurement indicated that field size of 1×1 cm^2 had a large discrepancy to MC according to this works. Conclusions: The TPR20,10 of MC, TPS, and measurement was not a significant difference, while the OF was tending to a large deviation in 1×1 cm^2. The results showed that our LINAC FFF could be used for small field until 2×2 cm^2.

Keywords: Flattening filter free; Monte Carlo; small field

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Evaluation of MLC Errors of LINAC Based on Log File

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Purpose: This study aimed to investigate the MLC QA and fluence map reconstruction based on log files of Varian Linear Accelerator. Methods: The graphical user interface (GUI) was developed using MATLAB to analyze Log files. Log file samples were obtained from seven cases. The MLC QA was analyzed using the error RMS leaf parameter. Meanwhile, the fluence maps were reconstructed based on the information of leaf position, jaw position, and fractional MU every 50 ms. The consistency check of expected fluence map from fraction to fraction was performed using Gamma index evaluation. The gamma index evaluation between actual and expected fluence map was calculated to analyze the segment potential error caused by MLC position. Results: The average of mean error RMS leaves for Bank A and Bank B are 0.213 ± 0.098 mm and 0.207 ± 0.073 mm. The average of max error RMS leaves for Bank A and Bank B are 0.491 ± 0.056 mm and 0.48 ± 0.061 mm. Gamma index results of 3%, 3mm criteria for consistency check of expected fluence map from fraction to fraction are 98.7 ± 0.7%, whereas gamma index results of 2%, 2mm and 3%, 3mm criteria between actual and expected fluence map for each log file are 97.6 ± 1.3% and 99.0 ± 0.6%, respectively. Conclusions: The error of MLC based on the log file analysis is within tolerance level according to AAPM TG-142. The discrepancy between the actual and expected fluence maps was in the range 3%, 3 mm.

Keywords: Multileaf collimator (MLC); error RMS; gamma index evaluation

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Evaluation of Truebeam's Machine Performance Check (MPC) for Daily Output Checks

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Purpose: Varian's Truebeam Linear Accelerator (Linac) offers a new approach in performing Daily Quality Assurance using Machine Performance Check (MPC) which is inbuilt into the Linac. MPC will automatically set up the equipment and the results are automatically updated into the MPC application. In the MPC application, Physicist can set the benchmark and tolerances of the Output Check within MPC, when Daily QA is performed by the Radiation Therapist the results will be updated into the MPC application. Users will be prompted if the daily Output Check is out of tolerance. The aim of this study is to find out when output was adjusted, would the MPC application be able to detect the deviation in output. Methods: Firstly, measurement readings were collected for MPC before any machine output was adjusted using the modalities of 6MV FFF and 10MV FFF. The first readings collected were used as a bench mark value. After machine output was adjusted, measurements were repeated for the MPC application. Measurements of machine output variation of up to 2% with 0.5% intervals were collected. The measurement results were used to plot the graph of MPC's measurements vs the machine output change. Results: After every iteration of adjustment of Machine output, the MPC was performed. While output was being changed from 0% to 2%, MPC's result was able to detect the 0% to 2% changes with an error of 0.143%±0.071% for 6MV FFF and 0.0300%±0.0750% for 10MV FFF. Results showed that for 10MV FFF, the error was lesser as compared to 6MV FFF. Conclusions: MPC is capable of detecting deviations in Machine output, this builds our confidence in using the MPC for our daily output checks instead of the PTW's LinaCheck which require physical set up and recording.

Keywords: Truebeam; MPC; machine performance check; daily QA

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Systematic Investigation on the Validity of Partition Model Dosimetry for ^{90}Y Radioembolization using Monte Carlo Simulation

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Purpose: This study aimed to investigate the validity of the partition model (PM) in estimating the absorbed doses to liver tumour (DT), normal liver tissue (DNL) and lungs (DL), when cross-fire irradiations between these compartments are being considered. Methods: MIRD-5 phantom incorporated with various treatment parameters, i.e. tumour involvement (TI), tumour-to-normal liver uptake ratio (T/N) and lung shunting (LS), were simulated using the GEANT4 Monte Carlo (MC) toolkit. 108 track histories were generated for each combination of the three parameters to obtain the absorbed dose per activity uptake in each compartment ($D_T^{A_T}$, $D_{NL}^{A_{NL}}$ and $D_L^{A_L}$). The administered activities, A were estimated using PM, so as to achieve either limiting doses to normal liver, D_{NL}^{lim} or lungs, D_L^{lim} (70 or 30 Gy, respectively). Using these administered activities, the activity uptake in each compartment (A_T, A_{NL}, and A_L) was estimated and multiplied with the absorbed dose per activity uptake attained using the MC simulations, to obtain the actual dose received by each compartment. Results: PM overestimated D_L by 11.7% in all cases. D_T and D_{NL} by MC were largely affected by T/N, which were not considered by PM. These have resulted in the overestimation of D_T by up to 8% and underestimation of D_{NL} by as high as −78%, by PM. Conclusions: PM leads to inaccurate dose estimations due to the exclusion of cross-fire irradiation. Caution should be taken for cases with higher TI and T/N, and lower LS, as they contribute to major underestimation of D_{NL}.

Keywords: GEANT4; partition model; Yttrium-90

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Determination of Composite Field Correction Factor $k_{pcsr,msr}$ for Tomotherapy

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Purpose: The purpose of this study is to determine the correction factor of the composite field ($k_{pcsr,msr}$) of Tomotherapy for head and neck cases and to investigate the influence of *pcsr* field parameters. Methods: This study employed Exradin A1SL and A16 as the investigated chambers, and EBT3 as the reference dosimeter. The *pcsr* fields were created based on cylindrical water solid phantom (*cheese* phantom) with several variations: three complexity levels (simple, intermediate, complex), and two measurement locations (central and peripheral of the target). *TomoPlan*™ – Planning Station was used to generate the plans by varying jaw width (1.05 cm, 2.5 cm, 5.02 cm) and pitch value (0.43, 0.25). Results: The results of this study show that the $k_{pcsr,msr}$ values for both detectors increased with increasing field width (jaw), decreasing complexity level, and increasing pitch value. The yielded results indicate several factors affecting the $k_{pcsr,msr}$ values: target homogeneity, volume averaging effect, thread effect, and the difference of general recombination at the different field width. These results represent that $k_{pcsr,msr}$ is specific and depends on the parameters of the composite field. Conclusions: The $k_{pcsr,msr}$ values for head and neck cases vary from 0.994–1.028. This variation implies that the determination of *pcsr* field should be according to the parameters used in clinical conditions. Due to the different position of the chamber and the film, the target should have a good homogeneity index to avoid the different response of the detectors.

Keywords: Nonstandard field correction factor; composite fields; tomotherapy

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The Shielding Ability of Novel Tungsten Rubber Against the Electron Beam for Clinical Use in Radiation Therapy

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Purpose: A newly introduced tungsten containing rubber (TCR) is a potentially useful shielding material in electron radiotherapy because it is lead-free, containing as much as 90% fine tungsten powder by weight. This study aimed to investigate the shielding ability of TCR against electron beams. Methods: Transmission of TCR (thickness 0–12 mm) was measured against electron beams for energies of 4, 6, 9 and 12 MeV. Dose profiles, at corresponding equivalent shield thicknesses, were measured with a 2D array detector to compare the TCR and lead. The electron backscatter factor (EBF) was also compared for TCR and lead. Results: The transmission of equivalent thickness for 4, 6, 9 and 12 MeV with TCR (0.78%, 1.34%, 2.16% and 3.08%, respectively) were lower than that with lead (0.81%, 1.44%, 2.19% and 3.16%, respectively) ($p<0.05$). The dose profiles were not significantly different for TCR and lead. The EBF with TCR was up to 17% lower than with lead. Conclusions: TCR is a novel and flexible shielding material containing a metal with a high atomic number in rubber and it has a shielding ability that is equivalent to or higher than that of lead. TCR has adequate radiation shielding ability for electrons within the energy range used in radiotherapy and could, therefore, be employed instead of lead at clinical sites.

Keywords: Radiation shielding; tungsten containing rubber; electron radiation therapy

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The Effect of Polarizer on EBT3 Film Dosimetry with Intensity Modulated Radiation Therapy (IMRT) Cases

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Purpose: This study aimed to analyze the effect of polarized light on flatbed scanner response of EBT3 Gafchromic film and to know the effect of adding polarizers for radiation dosimetry. Methods: EBT3 Gafchromic film, Epson V700 scanner and polarizer were employed in this work. The films were irradiated with 6 MV photons beams which is generated by Varian accelerator. It was inserted in slab phantom and scanned using the polarizer for some configurations. Results: The results of this study indicated that the polarizer has an effect on the dmax value. The highest descrepancy in the polarizer down is at about of ± 14%, while the smallest error in the polarizer up configuration is ± 1.2%. Moreover, the impact of polarizer angle gives the maximum value at 90°. In addition, lateral response obtained in this study indicated that the EBT3 without polarizer has a negative parabolic form and increased with increasing radiation doses. The implementation of gamma index calculation for IMRT plan for brain cases described that the P0U configuration had biggest value compared with other configuration, which was equal to 86,52% for 3mm/3% criteria. Conclusions: The polarizer gave impact in the dmax measurement with the maximum condition at 90°. Moreover, the implementation of planar dose measurement described the impact of predicting of gamma index.

Keywords: EBT3 Gafchromic film; polarizer; dosimetry

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Dose Contribution to Pelvic Lymph Nodes in Intracavitary Brachytherapy for Cervical Cancer

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Purpose: In advanced cervical cancer, high-dose-rate (HDR) brachytherapy is used after external beam radiation therapy (EBRT) with concurrent chemotherapy. However, boost dose to involved lymph nodes needs to take into account the contribution of HDR brachytherapy. Therefore, this study aims to quantify brachytherapy dose contribution to individual pelvic nodal groups, using computed tomography (CT) planning with the Manchester system. Methods: This is a single institution retrospective dosimetric study. CT planning data from 10 patients who received EBRT followed by intracavitary HDR brachytherapy (7 Gy fractions) were retrieved. The common iliac (CI), external iliac (EI), internal iliac (II), and obturator (OB) lymph node groups were contoured on each CT studyset. Applying the initial brachytherapy plan, mean doses to each nodal group were calculated for every patient, and averaged across the study populations. Results: With a brachytherapy dose of 7 Gy to Manchester point A, the mean absolute doses received by the CI, EI, II, and OB groups were 0.46, 0,94,1,37 and 1,70 Gy respectively, corresponding to EQD2s ($\alpha/\beta = 10$) of 0.41, 0.86, 1,32, and 1.68 Gy respectively and a total brachytherapy dose (4 fractions) corresponding to EQD2s of 1.64, 3,44, 5,28 and 6,72 Gy respectively. Conclusions: Our study demonstrates that pelvic lymph nodes receive substantial dose contributions from HDR brachytherapy in cervical cancer. This should be taken into account by the radiation oncologist during EBRT planning, and adequate external beam boost doses calculated to achieve cumulative tumoricidal doses to pelvic nodal disease.

Keywords: Brachytherapy; cervical cancer; lymphnodes

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Determination of Volume Averaging Correction Factor for Small Field Dosimetry

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Purpose: The study aimed to determine the Volume Averaging Correction Factor (VACF) of small field dosimetry. Methods: VACF was calculated small field radiotherapy based on Gafchromic EBT3 Film, ionization chamber CC01 and CC13 (IBA) measurement. The Gafchromic EBT3 Films were irradiated with 6 MV photon beam at field size 0.8 × 0.8 cm^2, 1.6 × 1.6 cm^2, 2.4 × 2.4 cm^2, 3.2 × 3.2 cm^2, 4 × 4 cm^2 and 10.0 × 10.0 cm^2. It was scanned with a Flat-bed scanner Epson Perfection V700 to convert analog data into digital data. Then, the dose distribution was calculated using MATLAB based algorithm to get the VACF value based on Gafchromic EBT3 Film images. The detectors were took placed inside the water phantom and then irradiated with SSD 100 cm. The calculation of VACF of ionization chamber of CC01 and CC13 were calculated using Kawachi formula. Results: The VACF indicated that it increased with decreasing field size. The smallest VACF Gafchromic EBT3 Film was 1.29 at field size of 1.6 × 1.6 cm^2, whereas it was 1.63 and 1.17 for ionization chamber CC01 and CC13 at field size of 0.8 × 0.8 cm^2, respectively. Conclusions: The result of this study was inline and supported the previous work which is the smaller dimension of detector has the highest correction factor.

Keywords: MATLAB; small field; volume averaging

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Optimization of Couch Angles and Number of Arcs in Non-coplanar VMAT for Pituitary Adenomas

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Purpose: Pituitary adenoma is located close to critical organs in the base of skull. Non-coplanar VMAT spares critical organs with short delivery time while it maintains PTV coverage. Due to various patterns of tumor growth, the beam angle selection step was simplified by finding the optimal couch angles and number of arcs. Methods: The 2 clinical cases with difference PTV sizes were selected to study the results of dose distribution between coplanar and non-coplanar techniques. Later, couch angles were varied from 30° to 90° and 270° to 330° with 15° interval. The numbers of arcs were varied from 3 arcs to 4 arcs. All parameters were evaluated and scored. Then, the selected protocol was applied to 5 pituitary adenoma patients. Results: It was found that 90° and 270° of couch angle showed highest score. However, these beams passed directly through the body, the second couch angles, 75° and 285°, were selected instead. For number of arcs optimization, 3 arcs plan and 4 arcs plan demonstrated a similar score. But 3-arcs plan illustrated obviously a shorter treatment time. After the selected was proved to the real clinical patients, there were 4 patients passing the planning criteria and 1 patients did not pass the hippocampal planning criteria. Conclusions: For couch angles, the suggested couch angles were 75 and 285 degrees. The optimal number of arcs for pituitary adenoma was 3 arcs which were consisted of 1 coplanar arc and 2 non-coplanar arcs.

Keywords: Couch angle for pituitary adenomas; number of arcs for pituitary adenomas; non-coplanar VMAT

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Evaluation of Delta 4 System in Patient Specific QA for VMAT Technique: Retrospective Lung VMAT Cases

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Purpose: The objective of this study is to evaluate the Delta 4 system for lung VMAT technique before clinical use. Methods: The 10 x 10 cm field, four fields and VMAT were generated into the homogeneous and heterogeneous phantom. All plans were evaluated by using 2%/2 mm gamma criteria to validate the Delta 4 system. For retrospective study, five lung VMAT QA plans were evaluated using 2%/2 mm gamma criteria. The point dose was measured to ensure the accuracy of beam delivery by treatment machine. In addition, the known 1.0 mm MLC position error was manually introduced into VMAT plan of homogeneous phantom and was evaluated by using 2%/2 mm and 1%/1 mm criteria to evaluate the ability to detect small error. Results: The range of percentage gamma passing rates for 10 x 10 cm field, four fields and VMAT in homogeneous and heterogeneous phantom was 90.0% to 99.1%. For five retrospective lung VMAT plans, the range of percentage gamma passing rate was 96.60% to 99.5%. The point dose differences for all plans were within 3%. For known 1.0 mm MLC position error plan, the percentage gamma passing rate for 2%/2 mm and 1%/1 mm were 90.5% and 63.6%. Conclusions: The Delta 4 system can be used in patient specific QA for lung VMAT case by using 2%/2 mm gamma criteria. The error magnitude 1.0 mm can be detected by 1%/1 mm gamma criteria. The DVH based method will be explored and exploited in further work.

Keywords: Delta 4; patient specific QA; lung VMAT

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Dosimetric Evaluation of Xio Dose Calculation Algorithms for Plans with Metal Artifacts

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Purpose: To evaluate the ability of the XiO treatment planning system (TPS) to produce an accurate treatment plan in the presence of high density materials. Methods: Rods of bone cement and different metal prosthetic implants were fabricated and inserted into an anthropomorphic phantom. CT images of the phantom with the different prosthetic implants were acquired and imported to XiO TPS. A conventional plan with an antero-posterior 6MV photon beam with field size 10 x 4 cm^2 at SSD 100 incident upon the anthropomorphic phantom and the metal implants was simulated in the XiO TPS. Convolution, superposition, and fast superposition algorithms for dose calculations were utilized for each metal implant. Plans were calculated for CT data sets with artifacts, CT data sets with artifact density override, and CT data sets using an extended image value density table (IVDT). Dose measurements were done and were compared to the values generated by the TPS. Results: Uncorrected data set for all three algorithms yielded an average % deviation of 4.15%. CT data sets with artifact density override and extended IVDT yielded an average % deviation of 15. 19%. The highest average % deviation is given by the CT data set with artifact density override using the convolution algorithm. Superposition algorithm of the uncorrected data sets yielded the lowest average % deviation of 3.98%. Conclusions: The XiO TPS is capable of producing an accurate treatment plan with an average % deviation of less than 4% using the superposition algorithm without needing any corrections.

Keywords: Prosthetic implant; radiotherapy; anthropomorphic phantom; XiO TPS; dose distribution

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A Basic Platform for Radiation Treatment Planning in kV X-Ray

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Purpose: In this study, we focused on the development and analysis of radiation treatment plans to determine the possibility of Animal Treatment by using kV x-ray. The aim was to establish and validate the dose calculation algorithm based on Monte Carlo Simulation. Methods: The beam data generated by the x-ray (low-energy) using Monte Carlo (Gate_v7.2) is collected. We wanted to verify accuracy using the dose calculation algorithm, E-TAR, in the experimental RTP, called "CorePlan". To do this, data generated using Monte Carlo were entered into the experimental treatment planning system to generate dose distributions calculated from the low energy x-ray. Based on the energy spectrum of low energy from the Monte Carlo Simulation (Gate v7.2), we used "CorePlan" to do Beam Commissioning; then, the result of its PDD values were compared with PDD, which was obtained from the existing MC simulation. Results: Beam was commissioned with the following set up: SSD 40 cm, Field Size 10 x 10 cm, and Water Phantom. Mean Absolute Difference was within 0.2861%, and Standard Deviation was within 0.1644%. Conclusions: Using Monte Carlo simulation based on the kV x-ray medical device, Virtual beam data were collected and dose - calculation algorithm was developed through this. Although this study was compared using imaginary beam data, further study with directly measured beam data is planned to increase the accuracy of dose calculation algorithms.

Keywords: Low-energy; x-ray; Monte Carlo; gate; RTP; beam data; dose-calculated algorithm

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Factors Influencing the Electron Dose Calculation in Eclipse eMC

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Purpose: To evaluate the factors influencing electron dose calculation in Eclipse electron Monte Carlo (eMC). Methods: The dosimetric accuracy was assessed by MapCHECK2 for 10 x 10 cm^2 applicator. The factors influencing electron dose calculation in Eclipse eMC were evaluated by virtual phantoms (homogeneity, heterogeneity) and various condition (irregular surface and extended SSD). Each parameter of accuracy, calculation grid size, random number generator seed, number of particle histories, smoothing method and smoothing level in Eclipse eMC was varied while other parameters were fixed in default value. Gamma analysis software was used to compare the dose distribution between default parameter plan and vary parameter plans with 2%/2mm criteria. The 6 and 18 MeV energy, the sizes of 6 x 6 cm^2 and 10 x 10 cm^2 applicator were used. Results: The measurement results agreed with eMC calculation with higher than 90% gamma passing rate. The accuracy, calculation grid size, smoothing method, smoothing level and number of particle histories parameters were significantly impact to the dose calculation. The 6 x 6 cm^2 applicator size showed lesser impact in dose distribution than larger size and the lower energy presented the lesser impact except the effect of calculation grid. The average gamma passing rate of all parameter variations in homogeneity phantom, heterogeneity phantom, irregular surface phantom and extended SSD were 75.2±25.8%, 74.4±28.0%, 77.0±22.0%, and 83.3±17.9%, respectively. Conclusions: Electron dose calculation in Eclipse eMC has many factors impacted to dose calculation. Therefore, the selection of parameters is very important. It should understand and know the impact of each parameter in treatment planning system.

Keywords: Electron; Monte Carlo; treatment planning; dose calculation

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The Impact of Flattening Filter Free (FFF) Photon Beams to Ion Recombination Correction Factor

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Purpose: This study aimed to evaluate ion recombination correction for ionization chamber in flattening filter free (FFF) photon beams and compare to conventional photon beams. Methods: The evaluation of ion recombination correction factor was performed for FC65-G, SNC600c, and CC13 ionization chambers. Measurements of three ionization chambers were performed using the water phantom and the Varian Trilogy linac with FFF capability. The ion recombination correction factor value for the three ionization chambers were obtained from the calculation using the simple two-voltage method and Jaffe plot curve fitting. Measurements were also performed for several depth and field size variations. Results: The ion recombination correction factor value obtained from all three ionization chambers were higher for FFF photon beams than the conventional photon beams with discrepancy less than 0.5%. While using several variations of depth and size, the results showed that the ion recombination correction value decreased with increasing depth (with variation less than 0.3%) and increased with increasing field size (with variation less than 0.1%). The ion recombination correction value obtained from the Jaffe plot curve fitting had a discrepancy less than 2% when compared to the two-voltage method. Conclusions: The value of ion recombination correction for the three ionization chambers in FFF photon beams was higher but had no significant difference compared to conventional photon beams. For those ionization chambers, ion recombination correction value obtained from two-voltage method agreed well with Jaffe plot curve fitting method.

Keywords: Flattening filter free (FFF) photon; ion recombination correction; ionization chamber; Jaffe plot; two-voltage method

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Radiophotoluminescent Glass Dosimeters for *in vivo* Total Body Irradiation

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Purpose: To verify the implementation of Eclipse treatment planning system (TPS) version 11.3.10 (AAA algorithm) at extended distance of 500 cm for total body irradiation (TBI) dose calculation using radiophotoluminescent glass dosimeter (RGD). Methods: The RGD (GD-302M) measurements were compared to the Eclipse dose calculation for 6 MV beam at 40 x 40 cm^2 field size. The depth dose at depths of 1.5, 5, 10, 20 and 30 cm and beam profile at 10 cm depth of 500 cm source-to-surface (SSD) were performed in solid water phantom. For ease of treatment delivery in Rando phantom, the two lateral fields, 200 x 200 cm^2 field size at 500 cm source-to-axis (SAD) were used. The RGDs were used to measure in Head, Neck, Chest, abdomen and pelvis regions. Results: For absolute depth dose, the RGDs dose revealed lower value than TPS about -3% at 1.5 cm depth and about -5% at 5 and 10 cm depth. The better agreement, the deviation less than 2%, was found at deeper depth. For absolute beam profile, the RGDs shown the different range about ±4% compared to Eclipse (-3.7% at isocenter). For Rando phantom, the deviation range was about ±10% for whole phantom. The maximum deviation of -11.2% was found at isocenter region. For heterogeneity in lung region, RGDs demonstrated higher dose about 5%. Conclusions: Dose accuracy of Eclipse for extended SSD TBI was verified using RGD. Most of the measurement shown higher result compared to TPS. The special beam data commissioning for 500 cm distance may improve the result.

Keywords: Glass dosimeter; TBI; extended SSD

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A238

In vivo Dosimetry using Moskin Detector during High-Dose Rate Brachytherapy of Skin Cancer

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Purpose: The MOSkin, a MOSFET based detector, is suitable for evaluating skin dose due to its water equivalent depth of 0.07 mm. This study evaluates doses received by target area and unavoidable normal skin during a skin brachytherapy treatment. The MOSkin was evaluated for its feasibility as detector of choice for in vivo dosimetry in the treatment of skin brachytherapy. Methods: High-dose rate Cobalt-60 brachytherapy source was administered to the tumor which was located at the medial aspect of the right arm, complicated with huge lymphedema thus limiting the arm motion. The source was positioned in the middle of patients' right arm with supine, hands down position. A 3 mm lead and 5 mm bolus were sandwiched between the medial aspect of the arm and lateral chest to reduce skin dose to the chest. Two calibrated MOSkin detectors were placed on each target and lateral chest during treatment session for in vivo dose monitoring. Results: The mean dose to the target area ranging between 13.2 – 16.5 Gy and found to be higher in comparison with calculated dose due to contribution of backscattered dose from lead. The mean measured dose at normal skin chest area was 1.3 Gy (0.7-2.1Gy), approximately 8.7% higher of target area mean measured dose. Total dose in EQD2 received by chest skin was much lower than published skin tolerance. Conclusions: The MOSkin detector presents a reliable real-time dose measurement. Due to its small sensitive volume and thickness, this study has verified the MOSkin applicability in monitoring skin dose during brachytherapy treatment.

Keywords: MOSkin; high-dose rate; skin brachytherapy

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A241

The Sensitivity of Patient-Specific IMRT QA in Detecting Systematic Errors: Field-By-Field Versus Single Gantry Angle Composite

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Purpose: This study evaluated the effect of small systematic errors, such as multi-leaf collimator (MLC) and jaw misalignments, on the quality of intensity modulated radiotherapy (IMRT) treatment plan delivery. Methods: Two IMRT quality assurance verification techniques, the field-by-field (FBF) and single gantry angle composite (SGAC), were performed to evaluate the original and modified plans using a 2-D ion chamber array detector. The dose distributions that were measured by the array detector for both the FBF and the SGAC were compared with the dose distribution that was calculated by the treatment planning system (TPS). Results: The FBF method was more sensitive than the SGAC at detecting small systematic errors, such as the opening and closing of the MLC's segments, which were evaluated with respect to a gamma-index of 3%/3 mm and 2%/2 mm. The systematic errors involved in closing the segments of the anterior field by 2 mm and 3 mm showed a significant difference compared with the original field (unmodified): 80.97 ± 1.7% and 41.52 ± 1.9% gamma-index passing rates, respectively, per the FBF. For the SGAC, the magnitude of closing the MLC by 2 mm remained unnoticed and resulted in a 96.95 ± 2.61% gamma-index passing rate. Opening the MLC by 2 mm gave a false negative, but more than 5% of the rectum received 75 Gy, which exceeded the tolerance radiation dose recommended by the Quantitative Analyses of Normal Tissue Effects in the Clinic. Conclusions: Although the sensitivity of a particular method in detecting errors varies, depending on the types of errors that have been introduced, FBF analysis proved more sensitive in detecting modified plans than SGAC for both gamma index criteria (3%/3mm and 2%/2mm).

Keywords: Intensity modulated radiotherapy treatment verification; 2-D ion chamber array detector; field-by-field; single gantry angle composite

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A246

HDR Brachytherapy Target Dose Difference of CT Volume-Based Brachytherapy and Conventional Brachytherapy using Henschke Applicator

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Purpose: To quantify the difference of the dose received by D90 of the GTV from a computed tomography (CT) volume-based brachytherapy (HDR_{VOL}) plan and a conventional brachytherapy (HDR_{PointA}) plan. Methods: Patient plans with an existing HDR_{VOL} plan using a Henschke applicator were chosen for data comparison. 90 and 180 degree digitally reconstructed radiographs (DRRs) were reproduced from the CT images of the patients. Point A and arbitrary ICRU 38 rectal and bladder points were defined on the reconstructed DRRs. An HDR_{PointA} plan for each patient was then created with a prescription dose to point A identical to the prescription dose to D90 of the contoured GTV in the HDR_{VOL}. The dwell times from the produced HDR_{PointA} were then applied to a HDR_{VOL} plan. The dose received at D90 of the GTV for the existing HDR_{VOL} and the dose it received from newly applied dwell times from the simulated HDR_{PointA} plan were then analyzed. Results: Comparison of the doses received by D90 of the GTV for HDR_{VOL} and HDR_{PointA} resulted to an average of 26±14.54% difference. Conclusions: The large target dose difference for HDR_{VOL} and HDR_{PointA} highlights that different imaging and planning techniques can affect the target coverage of the treatment. Choice between the two techniques will therefore require careful consideration by the radiation oncologist, physicists, and cancer care team.

Keywords: Brachytherapy; HDR brachytherapy; conventional brachytherapy; CT-based brachytherapy

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A247

Dosimetric Evaluation of Tomotherapy Treatment Planning System Accuracy in the Presence of Titanium Implant

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Purpose: To evaluate the ability of TomoTherapy treatment planning software (TTTPS) in calculating an accurate treatment plan for images with metal artifacts generated by a titanium implant. Methods: Three components of a titanium intramedullary nail (IM nail) were submerged in halfway depth of a water phantom to simulate different geometries of metal artifacts. A three field 6MV plan with the antero-posterior beam incident to the IM nail was simulated in the TTTPS. The plan delivers a dose of 2 Gy to a target of 8 cm diameter by 10 cm length cylindrical target right below the IM nail component. Treatment plans without correction, with an extended image value to density table (IVDT), and with density overrides were created for each IM nail component. An A1SL ionization chamber was used to measure the delivered dose to the target. The measured doses were then compared to the doses calculated by the TTPS. Results: Uncorrected treatment plans yielded an average % deviation of -4.47% ±1.47%. The highest average % deviation with a value of -5.01% ±1.47% was produced by the treatment plans with an extended IVDT. Treatment plans with density overrides yielded an average % deviation of -3.11% ±0.72%. Conclusions: For cases with titanium implants, the TTTPS can produce a treatment plan without the need to avoid the implant itself. However, making density overrides of the metal artifacts produced by the titanium in the CT images is recommended during treatment planning to achieve a more accurate plan with an average % deviation of -3%.

Keywords: Treatment planning; prosthetic implant; titanium implant; tomotherapy

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A253

Patient-Reported Urinary Outcome of Extreme Hypofractionated Prostate Radiotherapy (≥5Gy/fraction): A Systematic Review

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Purpose: Experimental and clinical studies have suggested that the α/β ratio for prostate cancer may be low (~1.5) which have prompted the utilisation of hypofractionated radiotherapy (HRT) including extreme dose/fraction (ExHRT) given using stereotactic RT. A systematic review was conducted to evaluate the pattern of genitourinary outcome for studies utilising EHRT with dose per fraction ≥5Gy/fraction focusing on patient-reported measures. Methods: A systematic review of Medline database was performed following the PRISMA guidelines. Included studies were retrospective or prospective cohorts that 1) have population of ≥40 patients, 2) delivered RT exclusively using external-beam photon ExHRT (≥5Gy/fraction), 3) reported on genitourinary outcomes at different timepoints relative to baseline using patient-reported measures. Descriptive statistics were generated for included studies. Results: Of 196 initial studies, 15 met eligibility criteria for inclusion, reporting on patient-reported urinary outcome relative to baseline of 1637 patients. No phase III randomised controlled trials found. Dose ranges between 33.5 to 40Gy and dose per fraction between 6.7 to 9.5Gy. Main measures were International Prostate Symptom Score (IPSS) and Expanded Prostate Cancer Index Composite – Urinary Domain (EPIC) or specific components from IPSS and EPIC. The change of urinary function was significant for 9/10 evaluable study at 1-month follow-up, 4/10 (12-month), 2/9 (24-month) and 1/4 (36-month). Conclusions: Change of patient-reported genitourinary symptoms were significant following extreme hypofractionated prostate RT (≥5Gy/fraction) which appeared to be ameliorated and returned to baseline by 2 years in most studies. Confirmation from randomised controlled trials is required.

Keywords: Urinary; prostate radiotherapy; systematic review

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A254

Failure Mode and Effects Analysis in Radiation Therapists-Led Treatment Planning and Delivery Steps

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Purpose: We applied failure modes and effects analysis (FMEA) to treatment planning and delivery steps for external beam radiotherapy (EBRT) performed by radiation therapists (RTTs) to identify potential failure modes. Methods: A working group of 11 RTTs was set up to perform FMEA for EBRT planning and delivery in the framework of a quality assurance program. FMEA was performed in 4 consecutive tasks: (1) formation of a map of the process; (2) identification of failure modes; (3) selection of a risk probability number (RPN) to each failure mode based on tabulated scores of severity, frequency of occurrence and detectability obtaining values from 0 to 1000.; (4) categorisation of failure modes into high-risk and low-risk with a threshold value of 100. Results: The radiotherapy steps involving RTTs was subdivided into 5 process steps; CT simulation, pretreatment, patient setup, treatment delivery and post-treatment. 70 total possible failure modes were identified, and a score of severity, occurrence, and detectability was assigned to each with enough detail provided in text for other RTT teams to repeat our procedures. 58/70 (82.9%) RPN values were below 60, 6 (8.6%) between 60 and 100 , and 6 (8.6%) above 100 threshold value. The 6 highest RPN scores were from CT simulation (incorrect imaging of interested anatomical site; preparation for patients who require contrast), pretreatment preparation (rectum protocol is not followed) and patient setup subprocess (wrong breast board angulation in breast setup; foot parter and knee rest is not placed for pelvis setup). Conclusions: The FMEA provides a systematic method for identifying and evaluating potential errors in radiotherapy treatment. Our results may be adapted for use in other centres and may be used as a guide for local FMEA for RTTs-led treatment planning and delivery.

Keywords: Failure mode effect analysis; radiation therapists; radiotherapy

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A266

Study of Efficiency in Five-field and field-By-field Intensity Modulated Radiation Therapy (IMRT) Plan using Dosxyznrc Monte Carlo Code

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Purpose: Implementation of modern treatment technique such as IMRT has been improved. In line with that, Monte Carlo (MC) simulations of this technique require ability of complex beam configurations modeling with respect to the patient. The source 2 and 20 DOSXYZnrc can be used to simulate the modalities. But, they have different process to obtain the dose distribution in a certain phantom. The aim of this study was to compare the simulation efficiency and dose distribution in water phantom from various beam angles and MLC positions in IMRT plan using source 2 and 20. Methods: The 30×30×30 cm^3 phantom was irradiated with various field sizes from 2×2 to 6×6 cm^2 using some beam angles 5°, 30°, 90°, 180°, and 300° and maintaining the source-to-surface distance 100 cm. The 3-dimensions dose distribution from sources was compared using gamma index. The statistical uncertainty and simulation time affect the simulation efficiency. A higher efficiency is better because it implies that it takes less time to reach a given uncertainty. Results: The implementation of the source 20 has been validated, with the similar results, with source 2 DOSXYZnrc. The identical 3D-dimensions dose distributions using source 20 for five-field and a field-by-field simulation IMRT plan with source 2 was observed. Two simulations used same number of histories with the statistical uncertainty less than 1%. But the efficiency of source 20 was bigger than source 2. Conclusions: The source 20 in DOSXYZnrc can simulate the high-resolution dose distribution with good efficiency with complex beam delivery techniques.

Keywords: DOSXYZnrc; IMRT; dose distribution

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The Bolus Effect with the Tungsten Function Paper in Build-Up Region for Electron Radiotherapy

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Purpose: Tungsten functional paper (TFP) is a novel paper-based radiation-shielding material. The bremsstrahlung caused by interactions between the electron beam and TFP, its can lead to the bolus effects. The purpose of this study was to investigate the bolus effect caused by the TFP shielding in build-up region for electron beams. Methods: The percentage depth doses (PDDs) were obtained with GafChromic EBT3 films. The film was set-up parallel plane to the beam's axis in the water-equivalent phantom. A 100 MU was irradiated with Clinac-iX for 4 and 9 MeV electron beams into field sizes of 10×10 cm^2 and 6×6 cm^2. The TFP was put on the phantom, thicknesses were 0.0, 0.3, 0.6, 0.9, 1.2, 1.8, 2.4, and 3.0 mm. The bolus effect was evaluated as the increasing rate of the dose in build-up region with/without the TFP in each PDD. Results: The maximum bolus effect were observed in 1.2 and 3.0 mm for 4 and 9 MeV with field size of 10×10 cm^2, and the increasing rates of surface doses were 39.3% and 49.2%, respectively. With field size of 6×6 cm^2, the thicknesses of the TFP were 1.2 and 2.4 mm for 4 and 9 MeV, and the increasing rates of surface doses were 69.9% and 50.8%, respectively. Conclusions: We found that the TFP has a bolus effect in build-up region for 4 and 9 MeV electron beams. The bolus effect was much larger in small field size.

Keywords: Tungsten paper; electron beam; bolus effect

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A280

A Separated Calibration System for Therapy Level Dosimeter by ANTM

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Purpose: In the separated calibration, the ionization chamber and electrometer constituting the dosimeter are calibrated individually, and calibration coefficient is given for each. This method has some advantages for both the calibration laboratory and users. In 2018, the Association for Nuclear Technology in Medicine (ANTM) has started a separated calibration organization. Methods: The main equipment used in calibration system are standard electrometer and standard electric charge source. The standard electrometer self-calibrates its sensitivity with a standard capacitor and a DC voltage source inserted in the negative feedback circuit of the electrometer. Both the standard capacitor and the DC voltage source are calibrated by the National Metrological Institute of Japan. The standard charge source was assembled from a DC current generator and a current shutter controlled by a timer. This charge source can be calibrated by reading the charge generated with the standard electrometer. Results: The calibration coefficient of user's electrometer, k_{elec} is determined using charges supplied from standard charge source and readings of electrometer. The uncertainty of k_{elec} is 0.078% in the range of 2 - 200nC. In the calibration of user's ionization chamber, the chamber is installed in the gamma-ray standard field and connected to the standard electrometer. The water absorbed dose calibration coefficient, $N_{D,w}$ is decided by comparing the standard field output with the standard electrometer reading. Conclusions: In Japan, it has been possible to calibrate the ionization chamber and electrometer separately. The improvement of uncertainty and redundancy are expected in therapeutic level dosimetry.

Keywords: Calibration; dosimeter; radiotherapy

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A285

Implementation of the Catalyst™ Optical Surface Imaging System for Left-Sided Breast Cancer Patients with Deep Inspiration Breath Hold Technique

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Purpose: To study the performance and reliability of the optical surface imaging (OSI) system for image guidance in deep inspiration breath hold (DIBH) technique for left-sided breast cancer patient. Methods: Acceptance and commissioning of the Catalyst OSI (C-RAD AB, Sweden) at Division of Radiation Oncology, Siriraj Hospital was performed according to the AAPM TG-147 guideline. The system communication as well as the accuracy and reproducibility of the detection system was conducted. For DIBH implementation, the overall Catalyst system accuracy was carried out with the end-to-end test using dynamic thorax phantom. Accuracy and reliability of the OSI system in patient set-up for left-sided breast cancer was also retrospectively investigated. Displacements in translation directions from OSI and routine CBCT and kV planar image-guided radiotherapy (IGRT) were analyzed. Results: The Catalyst system is able to transfer the correct patient data to the peripheral equipment. The detection accuracy showed mean deviation ± SD at 0.03±0.05mm in translation, 0.01±0.03 degree in rotation for static movement and 0.05±0.41mm deviation in amplitude for the dynamic localization. For the end-to-end test, the whole DIBH process with OSI showed excellent integration and agreement within 2 mm. The median deviation in patient setup between the OSI and 54 CBCT images in vertical, longitudinal, and lateral axis were within 1.2mm, 2.1mm, 2.4mm, and 1.7mm, 3.3mm, 2.1mm when compared with 132 kV-image pairs. Conclusions: The Catalyst OSI system is an efficient image guidance for patient setup and accurate for implementing in DIBH technique for left-sided breast cancer patient.

Keywords: Optical surface imaging; left-sided breast cancer; deep inspiration breath hold; patient setup

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Application of The RapidPlan Knowledge-Based Treatment Planning System for Radiation Therapy of Prostate Cancer Patients

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Purpose: To study the potential of the RapidPlan knowledge-based treatment planning system for the definitive radiotherapy of prostate cancer. Methods: 3 prostate-specific RapidPlan models based on a number of 20, 40, and 60 previous-ly prostate VMAT plans were trained and validated on 10 new prostate cancer patients. Iso-dose distribution between model and manually optimized method were compared. Dosimetric parameters in terms of D98%, D2%, conformation number (CN) and homogeneity index (HI) to PTV, dose to bladder and rectum were collected and analyzed. The one-way repeated measures ANOVA ($p < 0.05$) was used. Results: Model and manually plans passed the clinical goal. The D98% showed similar results between RapidPlan models (99%) with experienced planners (98%). However, significant higher CN, D2%, and HI were observed in the models (0.87 for CN, 105%-106% for D2%, and 0.07 for HI) than the manual plans (0.81 for CN, 104% for D2%, and 0.06 for HI), $p < 0.05$. For the organs at risk, dose-volume parameters of models (10%-11% for rectum and 7% for bladder) were significantly lower than the manual plans (13% for rectum and 8% for blad-der), $p < 0.05$. Model training on a number of 20, 40, and 60 plans showed no significant dif-ference in dosimetric analysis. Conclusions: RapidPlan knowledge-based treatment planning system was found to be an effective tool to create satisfactorily plan quality and improved dose to organs at risk for VMAT prostate cancer. Minimum 20 historic plans in this study was found to be acceptable for the model training.

Keywords: Knowledge-based planning; RapidPlan; prostate planning; VMAT

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Dose Tracking Accuracy of the Dose on the Treatment Day using Cone-beam Computed Tomography for Radiation Therapy of Prostate Cancer: Pilot Study

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Purpose: Dose tracking on the treatment day for prostate cancer patients using cone-beam computed tomography(CBCT) image was investigated and reported. Methods: Dosimetric errors tracking from anatomic changes in 5 VMAT prostate cancer patients were assessed using isodose distribution computed based on planning CT(PCT) and CBCT on the treatment day. The CBCT HU to electron density calibration was generated and CBCT-based dose calculation(DCBCT) accuracy was verified by comparing with dose measurement on CIRS pelvic phantom using IC (0.13cc) and Gafchromic EBT3 film. Velocity 3.2.0 deformable image registration (DIR) was applied to map organ contours from PCT to the daily CBCT and modified by radiation oncologist. The isodose distribution was recalculated on CBCT and dosimetric parameters from dose volume histogram(DVH) following the QUANTEC guidelines for PTV and OARs were collected and analyzed. Results: Point dose and dose distribution between measurement and DCBCT were 2.28%, and 87.7% with 3%/3mm gamma analysis. Mean±SD of CBCT/PCT volume ratio for PTV, bladder and rectum were 0.80±0.21, 1.01±0.53 and 0.72±0.11. Dose difference in D95% and D2% of PTV from CBCT compared to PCT were -6.71±8.43% and 0.95±0.53%. D2%, Dmean and V40Gy, V65Gy, V70Gy for bladder and rectum were deviated from PCT about 1.87±3.38%, 15.74±31.41%, -3.31±23.21%, 3.45±30.79%, 9.14±38.39% as well as -2.29±5.76%, 24.01±20.00%, -2.77±20.56%, 15.19±68.23% and 26.62±92.91%, respectively. Conclusion: Dose tracking on the treatment day using CBCT-based dose calculation and DIR to guide organ contouring is found to be feasible. The dosimetric information from CBCT showed a potential for supporting the adaptive work procedure for prostate cancer patients.

Keywords: CBCT; dose tracking; prostate cancer

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A288

Commissioning and Quality Assurance of Cyberknife Tumor-Tracking Intensity Modulated Radiation Therapy (IMRT) Using Dynamic Thorax Phantom

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Purpose: The multileaf collimator (MLC) based CyberKnife (CK) treatment plans in the previous treatment planning system (TPS) could be carried out only through the finite-size pencil beam algorithm. Recently, new TPS for CK was released and implemented the Monte Carlo algorithm for MLC plans. This update may contribute to performing the more accurate tumor-tracking IMRT (TT-IMRT) for inhomogeneous region tumors. In this study, we evaluated the dosimetric accuracy of TT-IMRT using two different tumor-tracking systems, Synchrony and XSight Lung, which were available in the CK system. Methods: CK M6 with InCise-2 MLC and Precision TPS (Ver. 1.1.1.1; Accuray Inc.) were employed. The treatment plans were calculated with Monte Carlo algorithm including 1% uncertainty. We used the inhomogeneity dynamic thorax phantom with a spherical mock tumor. The basic motion patterns were set as the ideal cosine breathing pattern with cycles of 2, 4, and 8 seconds and amplitudes of 13, 25, and 40 mm along the superior-inferior direction. The complex motion pattern with hysteresis trajectory was also evaluated. The gamma passing rates were calculated through radiochromic film dosimetry with criteria 2% and 1 mm. Results: The gamma passing rate for the static phantom condition was 98.3%. The passing rates exceeded 93% for all basic tumor motion patterns. The passing rates of Synchrony showed slightly higher than XSight Lung. In the hysteresis pattern, the passing rates for Synchrony and XSight Lung were 92.7% and 91.5%, respectively. Conclusions: The results indicated the feasibility of the high-accuracy dose delivery through TT-IMRT under various tumor motion conditions.

Keywords: Tumor-tracking IMRT; synchrony; XSight Lung

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A290

Detectors Response Analysis at the Scatter Radiation of 6 MV Flattening Filter Free Beams

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Purpose: Small fields dosimetry which related to the use of FFF beams is a great challenge because of perturbation effects caused by the size of detector's active volume or detector's materials. This phenomenon encourages researchers to do further study about detectors response. In this work, scatter and primary radiation from 6 MV FFF beams were studied to evaluate the detectors response in small fields for a better understanding in the contribution of every phenomenon. Methods: Ion chamber and Gafchromic films were used in the measurement set-up as follows: (i) detectors positioned under steel block, exposing the detectors only to scatter part of radiation field, (ii) detectors positioned inside mini phantom, approximating the detectors response to primary radiation with minimum scatter, (iii) detectors positioned in the standard open field, which was the superposition of the primary and scatter radiation. Results: Detector responses were heavily depended on its design (i.e. active volume) especially in small beams. Response in the open field could be reproduced from the blocked and primary beam set-up with discrepancy in range from 7,4% - 59%. Moreover, the volume averaging and other phenomenon affecting the detector response could be observed in blocked beam. Conclusions: Observing the scatter and primary radiation separately allow us to study phenomenon influencing the detectors response more clearly. The result of this work showed a similar trend compared to the previous study. We will consider to evaluate the comparison between FFF and WFF (with flattening filter) in the further study.

Keywords: FFF; detectors response; scatter; small field

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Monte Carlo Determination of Dosimetric of Iodine-125 Model ADVANTAGE and Cesium-137 Model 67-6500 Brachytherapy Sources

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Purpose: The American Association of Physicist in Medicine Task Group 43 updated in 2004 (AAPM TG43U1) recommends to determine the dosimetric parameters, i.e. the radial dose function, anisotropy function and dose rate constant of commercially available brachytherapy sources in water phantom to provide theoretical datasets for future research studies and for treatment planning systems. Methods: This study determines the dosimetric parameters of Iodine-125 model ADVANTAGE and Cesium-137 model 67-6500 with and without capsule in liquid water and polymethyl metacrylate (PMMA) phantoms through Monte Carlo simulation in Geant4 Application in Tomographic Emission (GATE) version 8.0 following the calculation formalism outlined by the AAPM TG-43U1. Results: The results of the calculated dosimetric parameters of Iodine-125 and Cesium-137 with capsule in liquid water and PMMA phantoms were in agreement with the published Monte Carlo data and published experimental data. Moreover, for Iodine-125 and Cesium-137 without capsule, the calculated radial dose functions were found to be lower compared to having its capsule. Furthermore, the calculated anisotropy functions of Iodine-125 and Cesium-137 without capsule shows that distribution is less dependent on the angle. Conclusions: In this study, the calculated dosimetric parameters of Iodine-125 model ADVANTAGE and Cesium-137 model 67-6500 in liquid water and PMMA phantoms, where promising results are observed, opens a possibility to be used in future clinical use of brachytherapy provided that the entire necessary formalism are implemented for future studies.

Keywords: Radial dose function; anisotropy function; dose rate constant

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A302

Translation and Rotational Target Motion Effect in NSCLC Case with 3D-CRT, IMRT and VMAT Techniques using In-House Dynamic Thorax Phantom

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Purpose: This study aimed to make in-house dynamic thorax phantom that simulate translational and rotational direction mimicking NSCLC target movement. Furthermore this study also to investigate dosimetric effect of target movement for several translational amplitude. Methods: This work used in-house dynamic thorax phantom made based on CIRS Dynamic Thorax Phantom model 008A. This phantom simulated translation in superior-inferior direction, rotational in the anterior-posterior and left-right lateral plane to mimic human respiratory motion. It was designed and controlled by linear actuator motor, servo motor, Adafruit motor shield L293D and Arduino UNO R3. It was implemented to evaluate point dose of 3D-CRT, IMRT, VMAT technique and for 5 mm; 10 mm; 15 mm translational motion amplitude 90° rotational target motion amplitude. The point dose measurement used film dosimeter GafChromic EBT 3. Results: This in-house dynamic thorax phantom can mimicking NSCLC target movement for translational amplitude 5±1 mm; 10±1 mm; 15±1 mm and rotational amplitude 90°±3°. Average dose deviation of target dose (center and peripheral) of TPS dose planning and tumor motion measurement on 3D-CRT with 5 mm, 10 mm and 15 mm were 1,4%, 4,1%, and 5,5% respectively, and does deviation on IMRT were 1,6%, 2,6%, and 4,8%, while dose deviation on VMAT treatment were 1,6%, 2,2%, and 4,2% respectively. Conclusions: The preliminary result supported the previous work by Mukhlisin. Furthermore, rotational movement of phantom contributed in average of 2% compare to translational movement only.

Keywords: Dose blurring; in-house dynamic thorax phantom; NSCLC

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A303

Out of Field Dose Measurement and Second Cancer Risk Estimation in Carcinoma Cervix Radiotherapy - A Phantom Study

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Purpose: To measure the scatter and leakage dose received by out of field organs while delivering the carcinoma cervix external beam and brachytherapy treatment in a humanoid phantom and to estimate the risk of second cancer (SC). Background: The increasing survival rate of cervix cancer patients steadily warrants the SC risk estimation based on out of field dosimetry, since the Treatment Planning System (TPS) is not commissioned for this purpose. Material and methods: The dose to out of field organs was measured using the LiF-100 dosimeter while delivering 3D Conformal Field in Field technique by 6 MV (Varian –Clinac 2300CD) photon beam and also during intra cavitary brachytherapy treatment by Co-60 beam. Following that the Excess Absolute Risk (EAR) of SC was estimated for stomach, colon, liver, lung, breast, kidney and Excess Relative Risk (ERR) for thyroid based on BEIR VII report. Results: The out of field organ dose varies with respect to distance between organs. The organ received highest dose with external beam and brachytherapy per fraction was colon =11.23cGy and kidney = 23.55cGy respectively. The equivalent dose (per fraction) to nearby organs was higher for brachytherapy than external beam therapy. For the cumulative dose the highest EAR estimated was for kidney (21.3) and stomach (12.9) and the lowest for liver (0.2) per 10000 populations. Conclusion: Out of field phantom dosimetry should be encouraged to provide a solid database on the estimation of radiotherapy induced cancer incidence for various treatment sites.

Keywords: Out of field dosimetry; second cancer; cervix radiotherapy

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A304

Dose Volume Population Histogram- A New Tool to Evaluate Intensity Modulated Proton Therapy (IMPT) Plans with Geometrical Uncertainties in Cases of Prostate Cancer

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Purpose: The goal of this study is to access the validity of the CTV-PTV margin concept under geometrical error in cases of prostate cancer based on the statistical approach via the Dose Volume Population Histogram (DVPH) tool. Methods: The proton plans first is optimized based on the PTV concept. Then, the plans were evaluated using two approaches: using the traditional PTV DVH as recommended by ICRU 50, 62 and 78 and using the DVPH and CL-DVPH (Constant Level- Dose Population Histogram) proposed by T B Nguyen et al., 2009. The DVPH approach is based on the collection of CTV DVHs from 2197 different CTV positions simulated by shifting the CT image of patient and 2197 corresponding occuring probabilities. Results: From 90% CL-DVPH, the minimum doses to CTV are 92% and 89% of prescribed dose compared to the minimum dose of 95% and 98% of prescribed dose from the PTV for case 1 and case 2 respectively. For dose coverage, 99% of CTV received the dose greater than 95% of prescribed dose, while 100% of PTV received the dose greater than 95% of prescribed dose for both cases. The static DVHs of rectum and bladder underesimate the dose a little bit compared with the dose from 90% CL-DVPHs. Conclusions: When the patient is shifted as a rigid body, at the confidence level of 90%, the minimum dose to the PTV does not ensure the minimum dose to the CTV for both investigated cases with IMPT technique. But the dose coverage of CTV is still rather good, 99% of CTV received the dose greater than 95% of prescribed dose from 90% CL-DVPH. For OARs, the conventional DVH evaluation underestimate dose in comparision with the dose from 90% CL-DVPH.

Keywords: IMPT; PTV concept; setup error

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A305

Pilot Study for Constructing Regional Collaboration Support on Linac Output Dose in Japan

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Purpose: To construct a regional collaboration support network for equalizing output dose using the online collaboration support system in Japan. We will clarify the problem to support facilities with output dose differences and look at solutions through pilot study. Methods: Japanese Organization of Radiotherapy Quality Management (JORQM) was established to prevent radiotherapy accident in 2000. Thus far, JORQM has certified over 1400 radiation therapy quality managers in Japan. We divide 47 prefectural governments into nine regional blocks. From 2018 to 2020, pilot studies of output dose measurement support using online collaboration support system are carried out sequentially in nine blocks. Firstly, we conducted a two-day pilot study in Fukushima prefecture to support output dose measurement in January 2018. Two local quality managers visited the radiation treatment facility which requires support and conducted output dose measurement and check the procedure of dosimetry in facility. Output dosimetry was performed using offline and online measurement support system. After measurement of output dose by both methods, problems of output measurement and future improvement points of network construction were discussed. Results: Through the first pilot study, the output dose measurement procedure was confirmed. In addition, issues such as preparation of manual for output measurement support, financial resources and management of support data have come to light. It was suggested that the problem could be solved by online support system. Conclusions: In the subsequent pilot study, we solve the problem by using online collaboration support system and aim to complete the regional collaboration support network for output dose measurement in Japan by 2020.

Keywords: Output dose; online collaborative support; quality manager

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Comparison of Dosimetric Parameters and Plan Complexity Between Volumetric Modulated Arc Therapy Plans with Different Collimator Angles for Prostate with Whole Pelvis Irradiation

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Purpose: The aim of this study was to determine suitable collimator angle in volumetric modulated arc therapy (VMAT) using simultaneous integrated boost (SIB) for prostate cancer with whole pelvis irradiation. Methods: SIB-VMAT plans were created with 2 full arcs with combined collimator angles 60 & 300°, 45 & 90°, 45 & 315°, 30 & 90°, 30 & 330°, and 15 & 345° in each of five patients, while the optimization process was performed with the same dose constraints and priority values as the dose-volume histogram of organ-at-risks coincides with all plans. Dose metrics of dose receiving to 95% of the volume (D95%), D98%, D2%, the homogeneity index, conformation number, and normalized dose contrast were compared in the prostate planning target volume (PTV) and nodal PTV. The modulation complexity score (MCS), monitor unit (MU), and small aperture score were also analyzed to evaluate the plan complexity. The Wilcoxon signed-rank test was used. Results: The mean D95% for the prostate and nodal PTV were 50.76±0.07, 50.85±0.07, 50.88±0.07, 50.91±0.09, 50.78±0.06, and 50.64±0.23 Gy and 44.71±0.15, 44.59±0.21, 44.78±0.19, 44.68±0.21, 44.53±0.26, and 43.87±0.12 Gy in the plans with collimator angles 60 & 300°, 45 & 90°, 45 & 315°, 30 & 90°, 30 & 330°, and 15 & 345°, respectively. Mean MU were 594±78, 594±72, 642±80, 604±87, 667±66, and 647±74 MU, respectively. Also, mean MCS were 0.270±0.04, 0.278±0.04, 0.273±0.03, 0.280±0.04, 0.289±0.03, 0.309±0.02, respectively. Conclusions: Collimator angle 30 & 90° was suitable in the SIB-VMAT for whole pelvis irradiation.

Keywords: SIB-VMAT; collimator angle; prostate cancer

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Biodegradable Samarium-153–labelled Microspheres for Hepatic Intratumoral Radiotherapy: Preparation, Characterization and Radiolabeling Evaluation after Neutron Activation

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Purpose: A biocompatible and biodegradable radioactive samarium-153 (Sm-153)- labelled Poly(L-lactic acid) (PLLA) microspheres formulation was developed for intratumoral radiotherapy of hepatocellular carcinoma. Methods: Samarium-152 acetylacetonate (50–200%, w/w) was encapsulated in PLLA microspheres using oil-in-water emulsion–solvent evaporation method. The prepared microspheres were irradiated in a nuclear reactor with a neutron flux of 1.49 × 1012 $n.cm^{-2}.s^{-1}$, converting Sm-152 to Sm-153 (E_{max} = 807.6 keV, half-life= 46.3 hours) through $^{152}Sm(n,\gamma)^{153}Sm$ reaction. Physicochemical characterization of the microspheres, gamma spectrometry and *in vitro* radiolabeling studies were performed to study the performance and stability of the microspheres before and after neutron activation. Results: The Sm-153-labelled PLLA microspheres has achieved a nominal activity of 4.0 $Gbq.g^{-1}$ after 6 hours neutron activation. The microspheres remained spherical and the diameters were within 15–60 μm both before and after neutron activation as indicated by the scanning electron microscopy and particle size distribution results. Gamma spectrometry suggested that no long half-life radioimpurities present after neutron activation. The formulation showed more than 95% radiolabeling efficiency in distilled water and blood plasma over 480 hours. Conclusions: Sm-153-labelled PLLA microspheres are potentially useful for hepatic intratumoral radiotherapy due to their biodegradability, favorable radiation characteristics and excellent radiolabeling efficiency. The preparation of the formulation does not involve ionizing radiation hence it reduces the costs of production.

Keywords: Samarium-153; hepatic intratumoral radiotherapy; microspheres

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Multi-center Audit of Physics QA in Radiotherapy

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Purpose: Radiotherapy technical support working group (WG) in Hiroshima, Japan was established in July of 2016. As a third-party organization to validate the physics QA activities, the WG makes audit to confirm each QA item is appropriately managed at participating facilities and issues the certificate of validation. Method: The WG has been mainly engaged in activities of task group (TG) #1 to 3, and X as follows; TG-1: Output audit of external beam therapy unit based on the original spread sheet, TG-2: Heterogeneity correction mailing audit of radiotherapy planning system based on the original phantom., TG-3: Radioactivity audit of HDR brachytherapy unit, to be started in this year, TG-X: New task development. Results: The very first activity of TG-1 has started in October 2017, 10 facilities participated back then, and it increased to 20 facilities in July 2018. TG-2 has been studying the validation method by visiting survey so far, but we are currently making original phantom for mailing survey and preparing to star mailing audit. In TG-3, we are preparing the radioactivity audit of HDR brachytherapy unit and planning system. TG-X has a task to develop a new survey item and method, for example, IGRT or other devices. Conclusion: Even though it seems to be obvious that multi-center audit can improve the quality of radiotherapy in participating facilities, it is still necessary to quantitatively evaluate the relationship between the technical support outcome of each task and the clinical outcome.

Keywords: Radiotherapy; physics QA; audit

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A320

Comparation of Dosimetric Properties from 10 MV Elekta Agility with Flattening Filter (FF) and Free Flattening Filter (FFF) in Heterogeneous Phantom

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Purpose: The aim of this study was to compare Percentage Depth Dose (PDD) and dose profile from head linac Elekta Agility with FF and FFF in heterogeneous multi-layer phantom for 10 MV photons using Monte Carlo (MC) simulations for field size 10 x 10, 15 x 15 and 20 x 20 cm^2. Method: A 10 MV photons beam of Elekta Agility linear accelerator operates with FF and FFF were modeled by BEAMnrc user code for 10 x 10, 15 x 15 and 20 x 20 cm^2 field. Phase space file output from BEAMnrc were used as a source in DOSXYZnrc to perform dose calculation in heterogeneous phantom. 4 layers phantom consist of 4 cm water, 2 cm bone, 5 cm lung and 29 cm water were designed to perform PDD. To perform dose profile calculation bone-water and lung-water phantom were used. Results: The FFF beam maximum depth dose (d_{max}) was 2,1 cm for all field size. On the other hand d_{max} FF beam was 2,3 cm; 2,1 cm; 2,1 cm for 10 x 10, 15 x 15 and 20 x 20 cm^2 respectively. Dose at greater depth than d_{max} decrease dramatically for FFF comparing to FF beam. There were out of field dose reduction for FFF in contrast with FF beam at d = 10 cm about 14,86%, 18,86% and 25,45% in lung and 15,15%, 17,48% and 25,45% in bone for field size 10 x 10, 15 x 15 and 20 x 20 cm^2 respectively. Conclusion: Beam hardening from FF affect the d_{max} and dose distribution for all field size. However, FFF beam had lower out of field dose in every medium.

Keywords: Monte Carlo simulation; EGSnrc; heterogeneous phantom

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Dosimetric Assessment for Whole Brain Irradiation in Mice using a Gamma Irradiator

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Purpose: A gamma irradiator designed for sterilising blood products is equipped with a custom-built mouse holder for preclinical brain cancer research, in particular whole brain irradiation of live mice. We report on the dosimetric assessment using a custom-designed mouse phantom, thermoluminescent dosimeters (TLDs) and radiochromic film. Methods: A protocol was developed using the Gammacell 3000 Elan irradiator (Best Theratronics), equipped with a 48 TBq Cs-137 source and a custom-built mouse holder with lead shielding designed for whole brain irradiation. A PMMA mouse phantom was designed to allow for placement of radiochromic film and thermoluminescent dosimeters (TLDs) along the central plane and on the surface of the phantom. The dose distribution was assessed, and the absorbed dose delivered to the head and different parts of the body was measured. Calibrations of TLDs were performed using a 6 MV photon beam and a Cs-137 calibration source, respectively. Results: TLD and film results allowed quantitative assessment of the dose distribution on the outside and along the central axis and central plane of the phantom, including scatter inside the shielding, and of absorbed dose delivered to brain and to mouse body within the shielding. Conclusions: Dosimetry for partial body irradiation utilising a gamma irradiator is challenging due to the size and location of the target volume and the fact that the system is designed to produce a near-uniform dose profile. A custom-designed mouse phantom enabled radiochromic film and TLD measurements to confirm the functionality of holder, shielding design and irradiation protocol, and to measure central and peripheral dose distributions.

Keywords: Preclinical radiotherapy research; brain cancer; absorbed dose measurement; TLD; radiochromic film

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Developing the Radiation-Induced Second Cancer Risk Estimation Module in Radiation Therapy: Considering the In-Field and Out-Of-Field Radiation Risk

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Purpose: To develop radiation-induced cancer risk assessment module which can be used in clinical cases of photon and proton treatments. This module considers the radiation doses and relative risk inside and outside the treatment fields. Notably, the consideration of secondary neutron out of the field from proton therapy is included. Methods: This study was approved by the institutional review board (IRB) to include pediatric patients with the brain tumor from the Linkou Chang Gung Memorial Hospital (CGMH). The patient data were exported from the dicom files. The organs at risk (OAR) inside the field or outside the field was distinguished from the CT images and treatment plans. The induced cancer risks were then calculated by using the Schneider's OED method for the in-field OAR and the BEIR VII linear model for out-of-field OAR, respectively. Finally, the life attributable risk (LAR) for each organ was derived. Results: The results show that the LAR of the pediatric brain OAR is between 0 % and 9 %. In the group whose tumor locates in the out-of-center of the head or has a smaller volume, the risk from the wobbling proton therapy was significantly lower than that from the photon therapy. Conclusions: This study developed a clinical radiation-induced cancer risk assessment module. Results show that out-of-field risk must be considered, and LAR's distribution of each OAR is related to field design in treatment planning.

Keywords: Radiation-induced cancer; organ equivalent dose; life attributable risk

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Fine-tuning of Davao Doctors Hospital X-ray Linac using the PRIMO Monte Carlo Package

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Purpose: The Monte Carlo (MC) method of radiation transport is generally considered to provide the most accurate estimate of the dose distribution in external beam radiotherapy. In the application of the MC method in a clinical setting, the first requirement is that the simulated three dimensional beam profiles should match and reproduce the measurements. Methods: Using PRIMO version 0.1.5.1307 running on Pentium-type desktop computer, simulations of the Davao Doctors Hospital's Elekta Linac at x-ray energy of 6 MV are performed. With one field of size 10x10 $cm^{2,}$ the dose is tallied on a homogeneous water phantom with dimensions 16.2 x 16.2 x 30.0 cm^3 at a source-to surface distance of 100.0 cm. The dose-scoring bin size was set to 0.2 x 0.2 x 0.2 cm^3. The default beam configuration given in PRIMO is 5.90 MeV for the initial electron beam energy with 0.0 MeV width, 0.120 cm focal spot size and 0.0 deg beam divergence. These beam parameters are modified until the simulated percent depth and lateral dose distributions compare favorably with measurements. Results: In the absence of a beam configuration algorithm, several simulations up to 6.40 MeV initial electron energy are needed. The gamma-index analysis toolkit provided by PRIMO is also useful. The combined dose-difference and distance-to-agreement criteria of 3%/3mm, 2%/2mm and 1%/1mm are used in the comparison of measured and simulated beam profiles. Conclusions: The self-contained, windows-based MC code PRIMO with the gamma-index analysis is used in fine-tuning the DDH linac photon beam at 6 MV nominal energy.

Keywords: Monte Carlo method; PRIMO; linac photon beam fine-tuning; gamma-index analysis

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The Effects of Thermoplastic Mask on the Depth-Dose Distribution in External Beam Radiotherapy: A Monte Carlo Simulation Study

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Purpose: The inaccuracy in dose calculation due to the thermoplastic mask during treatment planning gives this study an idea to determine the effects of thermoplastic mask on the depth-dose profile for incident photon and electron beams. Methods: The effects of thermoplastic mask on the depth-dose profile are determined in Monte Carlo simulations done in GATE v8.0 (GEANT4 Application for Tomographic Emission). Two simulation experiments were conducted, i.e. with and without mask. The simulations were varied by incident beams and their energies (5.12 MeV and 10 MeV gamma beams; 9 MeV and 18 MeV electron beams), material composition of the phantom, i.e. water and polymethyl methacrylate (PMMA), and the thickness (3.2 mm and 4.8 mm) and chemical composition of the thermoplastic mask, i.e. polycaprolactone ($C_6H_{10}O_2$) and polyvinyl chloride (C_2H_3Cl). The data gathered from the simulations are analyzed using the ROOT v6.10.02 (Rapid Object-Oriented Technology) toolkit. Results: For the incident gamma beams, the depth-dose profile decreases exponentially after reaching the maximum dose. For the incident electron beams, the dose as a function of depth reaches a maximum and rapidly falls to zero. In general, for the with mask setup, the depths of the maximum dose are translated at the shallower depths for both incident gamma and electron beams, with respect to the properties of the mask. Conclusions: In general, the results obtained from the simulations indicated that the use of thermoplastic mask contributes to the surrounding healthy tissues before a particular beam reaches the tumor volume.

Keywords: Monte Carlo; thermoplastic mask; external beam radiotherapy

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A341

Optimisation of Refractive Index Solutions for Imaging PRESAGETM Dosimeter using a CMOS-Based Optical CT

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Purpose: Radiotherapy requires advanced dosimetric system that can verify the dose distribution in 3D as well as being able of recording the integrated dose over time. PRESAGETM radiochromic dosimeters in conjunction with optical CT have shown great potential for solving the 3D dosimetric problem in radiotherapy. A CMOS-based Optical Computed Tomography (CMOS-OCT) has been developed in-house. This work presents optimisation of refractive index matching liquid to immerse PRESAGETM dosimeter for scanning using the CMOS-OCT system. Methods: A mixture of 2-Ethylhexyl Salicylate (n=1.502) and 2-Ethylhexyl 4-Methoxycinnamate (n=1.545) was utilised for scanning the solid dosimeter. The ratio of the liquid mixture was optimised by increasing the percentage of 2-Ethylhexyl 4-Methoxycinnamate from 7.9% to 9.1% in attempts to match the refractive index of the solution with the solid dosimeter. OCT scans were performed, and the images were reconstructed using inverse Radon transform. Results: With 9.1 % 2-Ethylexyl 4-Methoxcinamate and 90.9% 2-Ethylexyl Salicylate, the PRESAGETM dosimeter can be reconstructed accurately but with presence of some artefacts. Reducing the percentage of 9.1 % 2-Ethylexyl 4-Methoxcinamate increases the nonuniformity of the reconstructed image due to cupping artefact resulted from refractive index mismatch. Conclusions: Imaging quality of optical CT scanning of PRESAGETM dosimeter is highly affected by the refractive index solutions. Optimisation of the solution used improves the image quality that affects the accuracy of PRESAGETM readout for radiotherapy dose verification.

Keywords: Optical CT; PRESAGE; 3D dosimetry

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A345

A Feasibility Study of a Novel Tumor-Based Detector for Patient Specific QA

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Purpose: The purpose of this study was to develop a novel dosimetry tool to measure a total absorbed energy to tumor and present a feasibility of tumor-based plastic scintillation detector for patient specific QA. Methods: This study was performed to assess an efficiency of tumor-based plastic scintillation detector for treatment planning verification. This plastic scintillation detector was the shape of a specific tumor and organs at risk (OAR) and represented by 3D printing technology. This was coupled to 1.5 m long PMMA-based optical fiber. In this study, modeling of medical linear accelerator and this dosimetry tool was designed by using GEANT4 simulation toolkit. For a phantom study, the treatment plan based on the tumor-shaped detector was created and exported to LINAC in order to delivery prescription dose. Results: We validated the dosimetric performance of a 3D printed detector based on a specific tumor. As a measurement result, we confirmed the total absorbed energy to tumor-based scintillator. Both the total absorbed dose to the detector and calculation dose with MC simulation were compared. Gamma evaluation was carried out as well. Conclusions: We have developed a novel 3D printing plastic scintillation detector for patient specific QA. This study demonstrated a capability of measurement of a total absorbed dose to 3D volume. Hence, this study was to show the feasibility of 3D tumor-based detector for verification of a high precise IMRT/VMAT patient plan.

Keywords: Patient specific QA; plastic scintillation detector; 3D printing; treatment planning verification

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A346

Effects of Transverse Uniform Magnetic Field on Dose Distribution using Parallel Arrays of Microbeam: A Monte Carlo Simulation Study

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Purpose: In this study, the effect of transverse magnetic field on dose distribution during Microbeam Radiotherapy (MRT) was investigated in comparison to conventional wide-beam irradiation case. Parallel array of microbeams could be a viable method to reduce Electron Return Effect (ERE) as it lowers the total tissue interface area exposed to incident beam in the presence of transverse magnetic field. Methods: Monte Carlo simulations were performed using Geant4 Application for Tomographic Emission (GATE). A water phantom exposed to a 6 MeV parallel arrays of microbeam beam in the presence of 1.5T magnetic field with perpendicular orientation to incident beam have been performed. Parallel arrays of microbeam was generated using a wide photon beam source collimated with a microbeam collimator made of tungsten carbide. Individual microbeam sizes was set to 25 micrometer x 3 cm and the total irradiation field was set to 3 cm x 3 cm. The result was then compared with the wide-beam irradiation case. Results: Results revealed that for conventional wide-beam irradiation with transverse magnetic field the dose deposition increases near the exit surface at the tissue-air interface. On the other hand, it was revealed that using parallel arrays of microbeam reduces the total dose deposition in comparison to wide-beam irradiation case. Furthermore, the dose deposition varies directly with individual microbeam size and inversely with center-to-center beam separation distance. However, an apparent increase in dose near the surface of the exit side of the phantom for microbeam treatment were still observed due to ERE. Conclusions: ERE is observed in the presence of transverse magnetic field both in conventional radiotherapy and MRT. However, it was predicted using Monte Carlo simulation that total dose deposition is reduced for microbeam treatment in the presence of magnetic field.

Keywords: MRI-Linac; microbeam radiotherapy; GATE; Monte-Carlo Simulation

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A350

Comparison of the JO-IMRT Dose Distribution Calculated by the Source Type 2 and 20 in Dosxyznrc for Head-and-Neck Cancer

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Purpose: The program package DOSXYZnrc which has many sources model is capable of simulating dose distributions in radiation therapy. For example, source 2 uses a phase space file as a starting point for the simulation while source 20 has been contributed by Lobo and Popescu to model continuously varying beam configurations. Therefore, the aim of this study is to simulate and compare the JO-IMRT dose distribution calculated by the source type 2 and 20 in DOSXYZnrc/EGSnrc Monte Carlo (MC) code for head-and-neck cancer. Methods: The clinical photon beams of the HPD Siemens Primus linear accelerator were simulated using the BEAMnrc. The phase-space files from BEAMnrc was then used as input for DOSXYZnrc to calculate the JO-IMRT dose distributions in patients (in form of CT images) using by the source 2 and 20. The isodose distributions on slices, DVH, and gamma index (3%/ 3 mm) of the two dose distributions calculated with DOXYZnrc and the dose distribution obtained from the calculated TPS used at Dong Nai general hospital, had been compared together by PTW-Verisoft. Furthermore, the efficient computation of dose distributions such as time running, working load, uncertainty error calculation, are also considered to evaluation. Finally, Dosimetry of the JO-IMRT plans were also experimentally verified using an Octavius 4D 1500 (PTW, Freiburg, Germany). Results: We presented results of simulating JO-IMRT dose distribution using two different sources comparisons with a commercial treatment planning system in equivalent geometric conditions. There is good agreement between measured and calculated dose (TPS and MC). Conclusion: Based on result of time running, working load, uncertainty error calculation, we suggest that all JO-IMRT dose calculation should be used source 20.

Keywords: JO-IMRT; BEAMnrc; DOSXYZnrc; isource = 2, 20

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A351

A Prospective Feasibility Study: Use of Mobile Device Technology for Patient Care in Radiotherapy

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Purpose: In radiotherapy, patient's understanding on their disease and treatment is very important in order to achieve optimum patient's compliance during treatment, thus an accurate assessment based on timing provides a supportive measure from the patient in radiotherapy treatment. The current practice requires weekly or monthly evaluation of the patients, however there is lack of automation in the process. The purpose of this study is to determine the feasibility of analyzing patient reported symptoms via mobile device ('apps'). Methods: We have develope a mobile application prototype for radiotherapy patients name as myCare360. It emphasis on all the domains in radiotherapy using questions and providing a total information about the domains. Clinicians reviewed patient-reported symptoms during weekly symptom management visits and patients completed surveys regarding perceptions of the utility of the mobile application. The primary outcome is the use of mobile technology as tool for patient to report their symptoms for better analyzation. Results: There were 34 screens been designed in providing the additional information plus multiple questionnaire's to validate the current practice into an automation process using myCare360 mobile app. Conclusions: Empirically validated Evaluation Rubric for myCare360 Smartphone App Simulation will provides researchers and healthcare givers with a common system to identify best practices to leverage mobile app technology to support healthcare needs particularly in the field of radiotherapy.

Keywords: Radiotherapy; mobile apps.; patient care

SECTION III

PRESENTERS ABSTRACT (IMAGING)

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A011

Dose Optimization in Computed Tomography of Brain using CARE kV and CARE Dose 4D

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Purpose: Computed Tomography (CT) scan of brain is the most widely used CT examination. We aim to determine the application of CARE kV and CARE Dose4D in CT scan of brain. Both CARE kV and CARE Dose4D are innovative technology of Siemens Medical Solutions. Methods: A prospective hospital-based study was conducted from April to August 2015 Tribhuvan University Teaching Hospital (TUTH). The data were collected on a Siemens Somatom Definition edge 128 slices CT scanner. Non-random purposive sampling technique was employed. Ethical approval and consent were taken for every participant. Non-contrast (NC) CT images were acquired without using CARE kV and CARE Dose4D, whereas during contrast-enhanced (CE) investigation, both were turned on keeping other scanning parameters constant for each individual. Results: A total of 72 patients (42 male and 28 female; mean age 41.11±18.75, maximum 87 and minimum 16) were participated in this study. The Body Mass Index (BMI) was 21.97±1.90, maximum 24.98 and minimum 18.08. The mean value of Computed Tomography Dose Index (CTDI), Dose Length Product (DLP) and Effective Dose (ED) before and after switching on both CARE kV and CARE Dose4D were 58.19±0.35 and39.67±3.59 milli-Gray (mGy), 946.67 and 652.58 mGy-cm, and 1.98 and 1.36 milli-Sievert (mSv) respectively. Conclusions: : CARE kV and CARE Dose4D can reduce radiation dose dramatically in CT scan of brain without loss of image quality. CTDI, DLP and ED were all decreased by approximately 31% when CARE kV and CARE Dose 4D were switched on.

Keywords: CARE kV; CARE Dose4D; CT

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A017

Development of kV X-ray Imaging Dose Calculation System for Image Guided Radiation Therapy

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Purpose: Knowledge of the imaging doses delivered to patients and accurate dosimetry of the radiation to organs from various imaging procedures is becoming increasingly important for clinicians. The purposes of this study were to develop kV X-ray imaging dose calculation system for image guided radiation therapy and to evaluate the impact of kV X-ray imaging doses on treatment doses. Methods: The Vero4DRT was equipped with gantry-mounted orthogonal kV X-ray imaging subsystems, consisting of two sets of X-ray tubes and flat-panel detectors. The EGSnrc/BEAMnrc and EGSnrc/DOSXYZnrc packages were used to simulate kV X-ray imaging dose distributions of Vero4DRT. Then, the kV X-ray imaging dose distributions such as 4D-CBCT, 3D-CBCT, correlation modeling and monitoring doses were calculated for 9 lung cancer patients based on the planning CT images with dose calculation grid size of 2.5×2.5×2.5 mm^3. Finally, the imaging dose distributions derived via 4D-CBCT, 3D-CBCT, correlation modeling and monitoring, of planning target volume (PTV), the skin and the bone, were evaluated by examining dose-volume histograms (DVHs). Results: Based on 4D-CBCT and 3D-CBCT, the doses covering 2-cc volumes (D2cc) were maximally 6.0, 10.5 and 58.1 cGy for the PTV, the skin and the bone. Then, the maximum D2cc of correlation modeling and monitoring imaging were 6.0, 9.3 and 48.4 cGy for the PTV, the skin and the bone. Conclusions: We have developed kV X-ray imaging dose calculation system for image guided radiation therapy using Vero4DRT and evaluated the impact of kV X-ray imaging dose on treatment dose.

Keywords: Imaging Dose; IGRT; Monte Carlo

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A022

Evaluation of the Axillary Radiation Dose to the Cardiologist During the Coronary Angiography (CA) and Percutaneous Transluminal Coronary Angioplasty (PTCA)

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Purpose: The coronary angiography (CA) and Percutaneous Transluminal Coronary Angioplasty (PTCA) are the catheterization imaging procedures involve with higher radiation doses. The aim of this study is to measure the absorbed dose receives in the axillary region among cardiologists who wear a lead apron with inappropriate size. Methods: This was a quantitative cross sectional study includes the date from 40 PTCA and 80 CA. Two electronic pocket dosimeters were placed in the axillary area (inside and outside the lead apron) of the cardiologist and used to measure the scattered and leakage radiation during those imaging procedures. Results: PTCA and CA median axillary dose without and with shielding was 25.84 μSv, 0.64 μSv and 9.37 μSv, 0.64 μSv, a significant different ($p < 0.05$) was observed between with and without shielding. Annum dose is calculated in respective to the without and with shielding to axilla is 13.88 mSv and 0.85 mSv respectively, a 93.9% of reduction was observed. Among PTCA and CA procedures a significant association was found between exposure time and axillary dose, DAP and axillary dose with and without shielding and also between DAP and BMI. No significant association was observed among PTCA and CA procedures between BMI and axillary dose with or without shielding. Conclusions: Shielding of the axillary area will reduce the radiation dose significantly to the radiologist and furthermore several factors will contribute to the radiation dose to the axillary region.

Keywords: Axillary dose; interventional radiology; lead aprons

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A024

Automated MTF Measurements in CT using the Edges of a Non-Homogeneous Module of the TOS-Phantom

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Purpose: We developed an algorithm to automatically determine the modulation transfer function (MTF) of CT images from the edges of non-homogeneous module of TOS-phantom. Methods: The algorithm consists of several steps. First, detecting the upper edge of the phantom from its axial image. Second, taking pixel values and creating an edge spread function (ESF). Third, detecting the left tail of the ESF, taking and flipping it horizontally, and placing it on the right tail. Fourth, performing a differential operation on the ESF to produce a line spread function (LSF). And lastly, transforming the LSF into the MTF using a Fourier transform. To validate the automated MTF calculations, the result for the non-homogeneous module is compared to that for a homogeneous module of the TOS-phantom. Results: In a homogeneous module, the MTF curve generated without tail replacement corresponds to its shape in use. However for non-homogeneous module, the MTF obtained without tail replacement differs considerably from its shape in use. The 50% value of MTF (MTF-50) without tail replacement is 0.44 cycle/mm compared to 0.33 cycle/mm in use. Using the tail replacement, the MTFs in the homogeneous and non-homogeneous modules are comparable, with MTF-50 values of 0.33 cycle/mm for the both. Conclusions: An algorithm to measure MTF automatically at the edge of a phantom has been successfully developed. The MTF cannot be conventionally measured from the edge of the non-homogeneous module, but it can be resolved using the tail replacement technique on the edge spread function (ESF). This technique can be potentially applied for direct MTF measurement of patient images.

Keywords: CT image quality; spatial resolution; modulation transfer function (MTF); edge spread function (ESF); line spread function (LSF)

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A034

Comparison of Different Registration Methods on Patient Setup Error in Cone Beam Computed Tomography during Volumetric Modulated Arc Therapy for Lung Cancer

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Purpose: Aim of this study was to compare three different registrations methods on patient set-up uncertainties in Cone beam computed tomography (CBCT) for lung cancer patients. Methods: 105 on board CBCT images acquired for 7 lung patients during volumetric modulated arc therapy (VMAT) for patient set-up verification as per institutional image guidance protocol. Approved CT images were transferred from treatment planning system (TPS) to X-ray volumetric imaging system for reference image registration. The patient set up errors in mediolateral (ML), craniocaudal (CC) and anterioposterior (AP) direction were determined using grey-scale matching between the reference and onboard CT images. For the present study, patient setup verification was performed based on Clip-box registration (CBR). Considering CBR method as a reference, the other two registration methods of mask registration (MR) and dual registration (DR) (CBR+MR) were performed offline. For comparison, systematic error (Σ), random error (σ), mean displacement, mean setup error and maximum error were analyzed. Results: Systematic and random errors were less in CBR as compared to MR and DR ($p>0.05$). Slightly increased mean setup error was observed in MR as compared to CBR and DR ($p>0.05$). Maximum error, mean displacement error were observed less in CBR as compared to MR and DR ($p>0.05$). Statistically, no significant difference was observed between three different registration methods ($p>0.05$). Conclusions: All three registration methods can be used for patient setup accuracy for lung VMAT delivery. However, the present study suggested using CBR because of less translation error, more efficient as compared to MR and DR.

Keywords: CBCT; Clip-box; mask; VMAT; lung

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A038

Simultaneous Assessment of Homogeneity and Relaxation Rate of Magnetic Resonance Imaging Phantom using Relaxation Rate Measurement

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Purpose: The homogeneity and relaxation rate of phantom are several important issues in the development of Magnetic Resonance Imaging (MRI) phantom. This study is aimed to develop the technique to assess simultaneously the homogeneity and relaxation rates of homogeneous phantom built from agarose hydrogel. Methods: The MRI phantom was developed using agarose hydrogel and scanned using MRI 1.5 Tesla with techniques based on T2-weighted imaging (T2WI) sequences. The scanning was performed in 10 slices and signal intensities from each slice was examined to assess their homogeneity while simultaneously obtain the relaxation rates of phantom. Result: The phantom homogeneity was observed by processing signal intensity of several slices and relaxation rates of phantom was obtained from data processing of MRI images. Data and image processing was performed offline and the total acquisition time was approximately 30 minutes. Conclusion: The simultaneous assessment of homogeneity and measurement of relaxation rates of MRI phantom could be performed with the proposed technique in a relatively short time. The technique could be applied for the evaluation of tissue implant in-vitro and in-vivo.

Keywords: Magnetic resonance imaging; phantom; T2 weighted imaging; homogeneity; hydrogel; relaxation

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A044

Qualitative and Quantitative Assessment of a Hybrid Iterative Reconstruction Algorithm in 256-Slice Computed Tomography Scanner

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Purpose: The study aimed to evaluate quantitatively and qualitatively the effect of the iterative reconstruction algorithm installed in the 256-slice CT scanner of St. Luke's Medical Center, Quezon City (SLMC-QC) on image quality and radiation dose with using a phantom before its application to clinical images. Method: The researchers used the 256-Slice CT Scanner (Brilliance iCT-Philips) installed in the CT Scan Section of St. Luke's Medical Center, Quezon City, Philippines and used system phantom and ACR phantom. For quantitative analysis, each images used in the study was evaluated through the measurements of the image noise, spatial resolution and contrast resolution. For qualitative analysis, images were evaluated if there are presence of artifacts and changes in texture and appearances using a 5-point scale. Results: By analyzing the phantom images and dose reduction using iDose4, the quantitative assessment showed that image noise can be improved even up to 30% mAs reduction with CTDIvol reduction of 30% for the head and 50% mAs reduction with CTDIvol reduction 49% for the body. Qualitative assessment results showed that the quality of the images obtained with 40% mAs reduction for the head and 50% mAs reduction for the body were still acceptable. Conclusion: Through this study, it has been proven that image quality is not degraded even with iDose4 applied to reduce radiation dose to patients. Thus, an iterative reconstruction optimizes scanning technique in CT imaging.

Keywords: Computed tomography; radiation dose; iterative reconstruction algorithm; image quality

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A045

Regional DTI-derived Tensor Metrics from White Matter Tracts in Characterisation of Glioma

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Purpose: To investigate diffusion tensor imaging (DTI)-derived tensor metrics obtained from white matter (WM) tracts of the surrounding and within tumour regions for the grading of glioma. Methods: Twenty-four histologically proven glioma patients underwent a standard magnetic resonance (MR) imaging tumour protocol with DTI. The intratumoural, peritumoural and tumour region masks were delineated using the snake model (ITKSNAP) with structural MR images (T1-weight, T2-weight and fluid-attenuated inversion recovery sequence) as reference. Data derived from DTI processing and diffusion tensor fitting generated the DTI metric maps. Tractography was performed to delineate the WM tracts in both regions. Mean values of DTI metrics, such as fractional anisotropy, mean diffusivity (MD), axial diffusivity (AD), radial diffusivity (RD), pure isotropic diffusion (p), pure anisotropic diffusion, total magnitude of diffusion tensor (L), linear tensor, planar tensor, spherical tensor and relative anisotropy, were obtained from mapping the WM tracts on the DTI metric maps. Results: Significant differences were demonstrated in few DTI metrics in the solid enhancing region (MD, AD, RD & p) and solid non-enhancing region (MD, AD, RD, p & L) between different tumour grades. Conclusions: The WM tracts were not completely destroyed but were still intact inside the tumour, even glioblastoma multiforme, as opposed to the common belief that tracts are completely destroyed. DTI metrics provide insights on regional WM tract impairment in the presence of tumour while preoperative identification of WM tracts can improve neurosurgical planning.

Keywords: DTI; tractography; glioma; white matter tracts; probabilistic fiber tracking

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A048

Phantom and Clinical Evaluation of Combined Image Reconstruction Parameters of Philips Gemini TF 64 PET/CT Imaging System

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Purpose: Positron emission tomography-computed tomograhy imaging provides information on glucose metabolism uptake of the FDG. This may also indicate the functional status of cancer lesions. Erroneous image details may lead to false results. Reconstruction is used to enhance the data by minimizing the noise, adjusting the contrast, and modifying the features of the image mathematically. Methods: The study used the NEMA phantom for quantitative analysis and retrospective data for clinical evaluation. The data were reconstructed using defined Time-of-Flight (ToF) protocols of varying relaxation parameter, iteration subsets and kernel width. For the phantom study, the data were analyzed to determine the percent contrast (PC), background variability (BV), and contrast-to-noise ratio (CNR) for each reconstruction protocol. Two experienced nuclear medicine physicians, who were blinded by the reconstruction methods used, evaluated the retrospective data. The reconstructed images are rated on a scale of 1-4 and scored by rank according to 6 parameters. Results: In the quantitative analysis, the smallest radioactive sphere obtained the highest PC of 18.3% on Protocol 5, while the largest radioactive sphere had the highest value of 55.1% on Protocol 6. The BV was least at 4.37% for the smallest radioactive sphere, and at 5.55% for the largest radioactive sphere, both on Protocol 1. The CNR was highest on Protocol 1 across all sphere sizes. The clinical evaluation of the retrospective data subjectively preferred Protocol 1 and Protocol 5. Conclusion: The findings showed that lower values of image reconstruction parameters produced improved CNR and were more favored by nuclear medicine physicians.

Keywords: PET/CT; imaging; reconstruction

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A055

Correlation between CT Number Shift and Tissue Temperature Change during Radiofrequency Ablation: An Ex-vivo Study using Bovine Liver

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Purpose: Current post radiofrequency ablation (RFA) evaluation of unresectable liver tumours relies on visual inspection of non-enhancing tissues on the contrasted CT (computed tomography) images. This research investigated the correlation between CT number shift (dHU) and tissue temperature change (dT) during real-time CTguided RFA of ex-vivo bovine livers. The study aimed to develop a non-invasive CT thermometry method to guide clinicians in assessing ablation outcome. Methods:10 liver samples were individually ablated for 12 minutes using a RFA electrode, powered by an impedance-controlled RF generator (Cool-tipTM, Metronic, USA) and subsequently cooled for 15 minutes. An optical fiber inscribed with 4 equally spaced Fiber Bragg Gratings (FBG) was inserted sideward through the liver to measure 4 temperature points at the grating positions. CT scans were performed at interval of 3 minutes from 0 to 27 minute. CT numbers at the grating positions were manually extracted, and dHU and dT were computed and plotted to establish a relationship. Results: The CT number decreased as temperature increased during RFA, and vice versa. A negative linear relationship ($y = -1.07+0.75$, $R^2=0.71$) between dHU and dT was observed. Spearmon's rho correlation analysis showed a significant strong negative correlation ($r = -0.84$, $p <0.01$) between dHU and dT. The thermal sensitivity was determined as 1.07±0.03 HU/^{o}C. Conclusions: The strong correlation between dHU and dT during RFA could be used to estimate tissue temperature based on the CT number measured during real time CTguided RFA. This approach would help the interventionalist in determining the ablation outcome hence improving treatment efficacy.

Keywords: CT-guided radiofrequency ablation; CT number; tissue temperature

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A058

Breast Cancer Risk Prediction based on Complex Radiomics Features in Screening Mammograms

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Purpose: Evaluate the value of mammographic features, a set of complex radiomic features seen in screening mammograms, for predicting breast cancer risk. Methods: The BC Cancer Breast Screening Program, the first organized breast screening program in Canada offers screening mammography for women aged 40-74 since 1989. All women who had two or more screening mammograms from 1988-2013 within the program were included in the study. They were followed until a breast cancer diagnosis, last screen date +5 years, end of follow-up on Dec 31, 2013, whichever came first. The relative risk (RR) of breast cancer for women with a false-positive test compared with women with negative tests was estimated with Poisson regression, adjusted for age, and five calendar periods. The relative risks were stratified based on the four mammographic features seen on mammograms: Architectural Distortion, Asymmetry, Calcifications, and Mass. Results: When stratified for mammographic features found on the first false positive mammogram, architectural distortion plus mass had the highest RR 4.68(3.16-6.93) for invasive cancers while calcifications alone and calcifications plus asymmetry had highest RR 5.57(4.88-6.36) and 4.07(2.49-6.66) for in situ cancers. Conclusions: Mammographic features seen in screening mammograms are found to predict risk of subsequent breast cancer as well as the type of future breast cancer. Mammographic features can therefore be used in deciding increased surveillance.

Keywords: Screening mammography; mammographic features; breast cancer risk; radiomics

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A059

Tomohistology: Differential Diagnosis of Lung Cancer Sub-Types with Ultra-High Resolution Tomographic Imaging

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Purpose: Lung cancer remains one of the deadliest forms of cancer worldwide. Early diagnosis and treatment can markedly improve survival. Despite improved detection and survival arising from its advent as a screening modality, low-dose computed tomography (LDCT) suffers from a high false-positive rate, often leading to invasive procedures which may result in unnecessary complications. In this study, ultra-high resolution (<100 μm^3 slices) CT images were obtained to assess the feasibility of differential diagnosis of non-small cell lung cancer (NSCLC) through analysis of tomographic images. Methods: Biopsy specimens from two NSCLC patients with squamous cell carcinoma (SCCa) and adenocarcinoma (ACa) were imaged with a Scanco Medical micro-CT100 scanner and 3D images were reconstructed with an isotropic voxel spacing of 7.4 μm. The raw grey-scale images were processed to emulate the appearance of a hematoxylin- and eosin-stained histology slide through inversion, histogram adjustment, and colorization (Hue, 225; Saturation, 100) These radiological images were then compared with standard light microscopic histopathological images from the same patients. Results: A qualitative characterization of the critical differentiating histological features of SCCa and ACa were visible in the tomographical images, using the histopathological images as reference. Conclusions: Our results demonstrate that the tomographical characterization of the discriminating features of histological subtypes of NSCLC is possible at an ultra-high resolution. This finding has significant potential implications for future research in lung cancer, as it may serve to extend the prognostic utility of radiomics algorithms for image analysis.

Keywords: Non-small cell lung cancer; early detection; CT; ultra-high resolution CT; lung screening

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A061

Evaluation of Dose Sensitivity in Non-Additive and Additive Silver Nanoparticles Nipam Polymer Gel using Computed Tomography Scan

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Purpose: Tissue equivalent dosimeter which is sensitive with different dose rate is important to measure the absorbed dose especially in radiation therapy. This study aimed to evaluate the dose sensitivity in non-additive and additive silver nanoparticles N-isopropylacrylamide (NIPAM) polymer gel using Computed Tomography (CT) scan. Methods: Two groups of NIPAM polymer gel dosimeter phantoms (without silver nanoparticles (n=6) and with silver nanoparticles (n=6), respectively) were developed with the mixture of distilled water, gelatine, N-methylenebis (acrylamide) and tetrakis- hydroxymethyl-phosphonium chloride (THPC). The phantoms were irradiated with Co-60 gamma radiation in six series of dose (0 Gy (control), 3 Gy, 6 Gy, 9 Gy, 12 Gy and 15 Gy) following 24 hours preservation at 4 °C. CT number (Hounsfield Unit) was quantified on each series of dose following CT acquisition after 24 hours of gamma irradiation. Results: CT number increased proportionately with the dose in both groups of polymer gel. Higher CT number was observed in additive silver nanoparticles as compared to non-additive silver nanoparticles groups with average 15% increment of CT number. Conclusions: NIPAM polymer gel with additive silver nanoparticles has good dose sensitivity and could be used as a dosimeter in radiation therapy as it has tissue equivalent properties and less toxicity.

Keywords: NIPAM polymer gel; silver nanoparticles; CT number

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A065

Estimation of Intravoxel Incoherent Motion (IVIM) Parameters using Monte-Carlo Simulation of Diffusion MRI

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Purpose: The aim of the study was to estimate intravoxel incoherent motion (IVIM) parameters using a Monte Carlo (MC) simulation of diffusion weighted magnetic resonance imaging (DW-MRI). Methods: The restricted diffusion simulations in water were performed using a Camino diffusion MRI MC toolkit. An environment of cells within tissue was simulated by constructing regularly packed parallel cylinders with a constant radius in a periodic manner, filled with water (diffusivity: 3.0 μm^2/ms). The MR signal attenuations were measured as a function of the b-value by changing the cylinder radius from 5 μm to 100 μm. The diffusivities for slow and fast components D and D*, and fractional volume f of the IVIM model were estimated by applying a non-linear least squares algorithm to the data obtained from the MC simulations. Results: The average slow diffusivities D were 0.35±0.08 μm^2/ms for radii of 5 μm to 100 μm, 0.40±0.07 μm^2/ms for 10μm to 100μm, and 0.44±0.70 μm^2 /ms for 15μm to 100μm. The average fast diffusivities D* for the same ranges as above were 1.35±0.39 μm^2/ms, 1.58±0.38 μm^2/ms, and 1.85±0.34 μm^2/ms, respectively. The average f values were 0.81±0.04, 0.80±0.05 and 0.80±0.06, respectively. Conclusions: The simulation results in this study may be acceptable, compared with those obtained from clinical MR images in three past studies for the prostate cancer; D, D* and f were from 0.3±0.1 to 0.51±0.17 μm^2/ms, 1.7±0.4 to 2.95±0.71 μm^2/ms, and 0.45±0.54 to 0.50±0.10, respectively.

Keywords: Intravoxel incoherent motion; restricted diffusion; Monte-Carlo simulation

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A068

Comparison of the WEKA and SVM-Light Based on Support Vector Machine in Classifying Alzheimer's Disease using Structural Features from Brain MR Imaging

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Purpose: The aim was to compare WEKA and SVM-light software based on support vector machine (SVM) algorithm using anatomical features extracted from brain T1-weighted MRI for differentiating AD patients and normal elderly subjects. Methods: FreeSurfer software was used to extract the brain structural features of T1-weighted brain MRI (100 AD patients and 100 normal elderly subjects) for estimating the cerebral volumes and thicknesses. Seven structures were selected according to the literature suggestions, consisting of hippocampus and amygdala volume, entorhinal cortex thickness of both hemispheres, and total gray matter volume. Relative volume of hippocampus, amygdala, and total gray matter were normalized by total intracranial volume (TIV) to reduce variation of head sizes. Fifteen combinations of seven structures were applied as input features to WEKA and SVM-light. Receiver operating characteristic (ROC) analysis and area under the curve (AUC) values were evaluated to obtain the classification performance. Results: The high AUC values (greater than 0.9) from both software were obtained from all combination models. The highest AUC values resulted from the combination of hippocampus relative volume and entorhinal cortex thickness were 0.913 and 0.918 for WEKA and SVM-light, respectively. There was no statistically difference of the AUC values (p-value > 0.05) between two software using the same input features. Conclusions: The combination of hippocampus volume and entorhinal cortex thickness features showed the highest classification performance. There was no statistically difference between the use of SVM algorithm in WEKA and SVM-light software for differentiating AD patients and normal elderly subjects.

Keywords: SVM; Alzheimer's disease; MRI; WEKA; SVM-light

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A069

Investigation of Factors Affecting Mean Glandular Dose for Patients Undergoing Digital Breast Tomosynthesis

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Purpose: This study was conducted to investigate the factors affecting mean glandular dose (MGD) in patients undergoing digital breast tomosynthesis (DBT) from major ethnic groups in Malaysia due to the potential increment concern of radiation dose to the breast produced by DBT compared to full-field digital mammography (FFDM). Methods: Assessment of MGD was conducted to study the correlation between MGD with volumetric breast density (VBD), compressed breast thickness (CBT), age, ethnicity and projection views. Comparison of MGD for DBT and FFDM was analysed. MGD calculated using the Volpara software was compared to MGD displayed at the system monitor console. The breast density was assessed quantitatively (using the Volpara software) and qualitatively (using BI-RADS classification) and the results were compared. Results: Findings showed that Chinese women had the highest VBD followed by Malay and Indian women while CBT was greater in Indian women. There was an inverse relationship between MGD and age. Strong positive correlation between MGD and CBT was noted for both DBT mode (r=0.965) and FFDM mode (r=0.839). Projection in mediolateral oblique view yields higher MGD in comparison to craniocaudal view. MGD displayed on monitor console was underestimated compared to MGD calculated by Volpara. For breast density determination, positive agreement ($p<0.05$) were found between Volpara and BI-RADS. Conclusions: MGD was affected by CBT, VBD, age and projection view while no significant difference was found between MGD and ethnicity. Radiation dose in DBT was higher than FFDM by 11.3%, but within FDA limits of 3mGy per acquisition.

Keywords: Mammography; digital breast tomosynthesis; Asian

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A072

Investigating the Aberration Found in 4.438 MeV ^{12}C Photo Peak of the Geant4 Simulated Prompt Gamma Spectrum

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Purpose: To investigate the broad 4.438 MeV 12C photo-peak found in the Geant4 simulated prompt gamma spectrum from proton beam collision on thin carbon target. Methods: Simulated prompt gamma spectrum was obtained for 80 MeV proton beam collision on carbon target by counting the emitted prompt gammas over a 4π solid angle using a Geant4(v10. 01. p3) cross-section code with the suggested physics list for inelastic scattering in the proton therapeutic range (binary cascade model). In addition, other Geant4 available inelastic scattering physics models were also used to obtain prompt gamma spectra. Simulated prompt gamma spectra were compared with experimentally measured spectrum; the experiment was conducted at iThemba Labs using the AFRODITE clover detectors. Results: The simulated 4.438 MeV photo peak was considerably broader than experimentally measured spectrum. The default data set (Geisha) against the Tripathi data set, and the two spectra are basically identical, indicating that the cross-section data set has no bearing on the Binary Cascade inelastic scatter model. The precompound model using an exciton number of 1 and the Geisha cross-section data set provides a 4.438 MeV photo peak that is closer to the experimental result. Conclusions: The precompound model with an exciton number of 1 and the default (Geisha) cross-section data set significantly narrow the 4.438 MeV photo peak.

Keywords: Prompt gamma spectrum; Geant4; Geant4 physics list; AFRODITE clover detectors

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A074

Four Projection Tomosynthesis with Different X-Ray Exposure

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Purpose: Tomosynthesis is a reconstruction technique from restricted projection angle. Conventional tomosynthesis acquiring 60 projections image takes 10 sec, so it is difficult to hold breath for patient and requires about 10 times dose compared to chest radiograph. To acquire the tomosynthesis image within 1 sec and lower dose, we proposed 4-projection tomosynthesis. The image quality of 4-projection tomosynthesis is similarly comparable to the conventional method. Since we are trying to apply this technique for chest screening, further reduction of X-ray dose is required. Therefore, one projection was imaged with the same dose of conventional chest radiograph and the other three projections were imaged with low exposure. We evaluated 4-projection tomosynthesis reconstructed from different projection exposure. Methods: Chest phantom including artificial nodules of various sizes was imaged from a limited angle by digital radiographic system. Tomosynthesis image was reconstructed by back projection method. The tube voltage was 120 kVp and the current-exposure time product was set as 0.5, 1.0, 1.6, 2.0, 2.5 and 3.2 mAs/projection. Using different exposure, image reconstruction was performed to one projection with 3.2 mAs as chest radiograph and the other three projections with low exposure. Contrast noise ratio (CNR) was measured quantitatively. Result: In total dose more than 2.5 times of chest radiograph, the CNR value with different exposure is nearly comparable to that with the same exposure at every 4-projection. Conclusion: Four-projection tomosynthesis obtains not only chest radiograph but also tomographic image with approximately 1/4 dose of conventional tomosynthesis.

Keywords: Tomosynthesis; chest; phantom

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A078

Application of Monoenergetic Extrapolation of Dual-Energy CT for Reduction of Metal Artefacts from Different Implant Materials

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Purpose: The aim of this study was to evaluate the application of monoenergetic (ME) extrapolation technique of dual-energy computed tomography (DECT) for metal artefact reduction using phantom study. Methods: This study involved a phantom study on customized phantom consisting different types of metal implants such as Titanium and Stainless Steel. The phantom was scanned using a single-source DECT scanner (SOMATOM Definition AS+, Siemens Healthcare, Germany) with dual-energy mode of 140/80 kV spectrum. The commercially available post-processing software (syngo DE, Siemens) was applied to generate ME image datasets with extrapolated energies of 55, 64, 70, 82, 105 132, 160 keV, respectively. The reduction of artefacts were measured qualitatively and quantitatively using region of interest (ROI) statistical analysis. Results: The results shows 60% of metal streak regions were reduced significantly at higher extrapolation energy which is 160 keV. Quantitative analysis resulted in lower HU reading within the region of artefact for 160 keV. However, at higher extrapolated energy, the noise is the highest and resulted in lower signal-to-noise (SNR) value. ME images at 160 keV appear more noisier while ME images at 64, 70 and 80 keV appear smoother. Conclusions: Metal artefacts induced by both Titanium and Stainless Steel implants were reduced significantly using DECT ME extrapolation and improved the diagnostic quality of CT images. A significant reduction of metal artefacts can be achieved by use of higher monoenergetic energy levels DECT. However, image noise is higher and SNR is reduced with higher extrapolated energy.

Keywords: Monoenergetic extrapolation; dual-energy CT; metal artefact

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A080

Management of High Doses from Interventional Angiography

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Purpose: The WHO has identified endovascular interventions as a medical technology of increasing complexity. This is reflected by the increasing prevalence of high radiation doses indicative of skin damage. Dose monitoring and audit are recommended tools for management. This case study describes dose audit and equipment review for two interventional units, leading to the upgrade of one unit with subsequent improvement in patient dose outcomes. Methods: The dose indicators, cumulative air kerma (CAK) and kerma area product (KAP) were collected using a dose management software system called Radimetrics. The interventional units studied were a Philips Allura Xper and a Philips Allura Clarity bi-plane unit. Typical phantom dose rates were compared for fluoroscopic and acquisition modes for each unit and again after the upgrade of the Allura Xper unit to Clarity. The median of patient CAK and KAP from one month of cases pre and post the Clarity upgrade were compared for embolisation, DSA and all cases. Results: The Xper unit had twice the phantom dose rate of the Allura unit, correlating with the increased frequency of high patient dose (CAK>3Gy). After a Clarity upgrade of the Xper unit the fluoroscopic phantom dose was reduced by a factor 20% to 40%. Acquisition mode dose reduction was 70% on average. Reductions in the median CAK after upgrade were 52% for embolisation, 60% for DSA procedures and 18% over all procedures. Conclusions: Dose audit and equipment review have proved effective tools to manage increasing dose, particularly associated with complex interventional procedures.

Keywords: Cumulative air kerma; dose management; interventional radiology

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A081

Patient Breast Dose from a Mammographic Biopsy Unit

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Purpose: The asymptomatic nature of breast screening examinations has been a driving force for the optimisation of routine breast imaging. However mammography of patients referred for biopsy assessment, classed as symptomatic, has received little attention. This work reports on a patient dose evaluation from one biopsy unit involved in breast screening. Methods: Radiographic and patient/clinical data was collected from 224 biopsy procedures conducted with a Siemens Mammotest unit with the support of a Sectra L30 AIR mammographic unit for workup and post clip images. Radiographic data including the kV, mAs and number of exposures was coupled with equipment QA data to determine the mean glandular dose after consideration of breast thickness and relative proportion of breast irradiation. Results: On average breast thickness was 5.6 cm and was exposed at 28.9 kV for 170.8 mAs with 8.5 exposures. Typically the breast field was 30% of the area of a single breast giving a biopsy breast organ dose of 3.5 mGy. Workup and post clip images gave an additional average breast dose of 1.6 mGy, resulting in a total dose of 5.1 mGy on average and 20 mGy maximum. The procedure outcomes were positive 34% of the time. Conclusions: The risks from these dose levels are dependent on the age of the woman, however are not considered high for a symptomatic x-ray procedure. It should be noted that the dose is very machine specific and could vary considerably with other equipment and follow up protocols, supporting the need to optimize protocols.

Keywords: Mean glandular dose; mammography biopsy

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A085

Assessment of Safety Climate Among the Imaging Department Staff in a Teaching Hospital

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Purpose: Safety climate assessment has been increasingly recognised as a necessary approach to improve patient safety. Safety Attitude Questionnaire (SAQ) is one of the measurement methods of safety culture that has good psychometric properties. The aims of this study were to assess the safety climate in the Department of Biomedical Imaging, University of Malaya Medical Centre and to test the difference in the perceived safety climate between the staff categories. Methods: A cross-sectional survey on patient safety culture using SAQ was conducted from February to May 2018. The healthcare workers participated in the survey were anonymously selected on a voluntary basis. Eight dimensions of the psychometric properties in the SAQ were examined. The internal consistency and reliability were tested using Cronbach's alpha. The score of SAQ was based on percentage agreement with a target of > 60% agreement. Results: A total of 302 valid questionnaires were collected with a response rate of 72%. The Cronbach's alpha for the 8 dimensions ranged from 0.690 – 0.925. The frontline healthcare workers holding positive attitude was 64% for Teamwork Climate, 62% for Safety Climate, 68% for Job Satisfaction, 57% for Stress Recognition, 61% for Perception of Unit Management, 59% for Perception of Hospital Management, 60% for Working Conditions and 58% for Communications and Collaboration. Conclusions: SAQ has good internal consistency and reliability. Patient safety culture in this department has potential for improvement, especially in the areas of Stress Recognition and Communications and Collaboration. This study provides a baseline for long-term continuous assessment for targeted areas through intervention starategies.

Keywords: Patient safety; safety culture; Safety Attitude Questionnaire

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A088

Low-Dose Tripe-Energy X-Ray Computed Tomography using a Cadmium Telluride Detector with High-Spatial and -Energy Resolutions

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Purpose: In our research, major objectives are as follows: to reduce the incident dose for objects, to decrease the scattering photon count form the objects, to perform triple-energy computed tomography (TE-CT) using a cadmium telluride (CdTe) detector, and to improve spatial resolutions. Therefore, we constructed a low-incident-dose TE-CT scanner using line beams to carry out both the iodine (I) and gadolinium (Gd) K-edge CT simultaneously. Methods: X-ray photons are detected using the CdTe detector system, and the event pulses are sent to TE counter to regulate three threshold energies of 15, 33 and 50 keV. Using this counter, the energy ranges are 15-33, 33-50 and 50-100 keV. Results: The energy and spatial resolutions were 1% at 122 keV and 0.3×0.3 mm^2, respectively. K-edge tomograms using I and Gd media were obtained simultaneously. The scattering photon count substantially decreased, and the outlines of tomograms were quite visible. Conclusions: We performed TE-CT using a high-energy-resolution CdTe detector and improved the spatial resolutions. The incident dose for an object was reduced using a lead (Pb) pinhole in front of the object, and the scattering photon count decreased using another Pb pinhole behind the object.

Keywords: CdTe detector; triple-energy CT; high energy resolution; high spatial resolution; low-dose CT

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A090

Comparison of HEMA Gel Evaluation Technique by Using MRI, CT-Scan and Uv-Visible Spectrophotometry

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Purpose: In this study, less toxicity monomer 2-hydroxyethymethacrylic acid (HEMA) was used in polymer gel dosimeter. The measurement of dose was compared with different evaluation techniques such as magnetic resonance imaging (MRI) computed tomography (CT-scan) and Uv visible spectrophotometry. Methods: HEMA gel was fabricated under normoxic condition. Then, HEMA gels were irradiated under linear accelerator using 6 MV photon beam, where the set-up was followed calibration conditions (IAEA, TRS No.398). After irradiated, the degree of polymerization against irradiated dose was evaluated by using MRI, CT-scan and Uv-visible spectrophotometry. Results: The linear correlations coefficient r-squared value for the MRI, CT-scan and Uv-visible spectroscopy were 0.97550, 0.6493, and 0.9753, respectively. Based on result, MRI and Uv-visible spectroscopy have higher accuracy of dose response as an evaluation technique compared to CT-scan. Conclusions: Thus, MRI and Uv-visible spectroscopy are suitable as an evaluation technique for measurement of dose response HEMA-polymer gel dosimeter. Determination of more appropriate evaluation technique were improved expand the dose response parameters of each measurement method.

Keywords: Uv-visible spectroscopy; magnetic resonance imaging (MRI); computed tomography (CT-scan); polymer gel dosimeter

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A091

Establishment of Institutional Diagnostic Reference Level for CT Imaging Associated with Multiple Anatomical Regions

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Purpose: The aim of this study was to establish an institutional diagnostic reference level (DRL) for computed tomography (CT) imaging associated with multiple or combined anatomical regions and compared with other international DRLs. Methods: CT dose data of 705 subjects (15 years old and above) were collected retrospectively from January 2015 until December 2017 at AMDI, USM, Malaysia. The common CT examination of combined anatomical regions such as neck-thorax-abdomen-pelvis (NTAP), thorax-abdomen (TA), thorax-abdomen-pelvis (TAP), and abdomen-pelvis (AP) were reviewed. Distribution of CT dose index (CTDIvol, CTDIw) and dose-length product (DLP) were extracted from the data for contrast, non-contrast, single-phasic and multiphasic examinations. The 50th percentile (median) and 75th percentile of the dose distribution were calculated. The calculated values were compared with other established DRLs. Results: TAP CT was the most frequently performed examination at AMDI (73%). More female patients underwent CT examinations (63%) compare to male patients. Most of local dose values for multiphasic and non-contrast examinations were higher compared to single phasic and contrast study. The results show a weak correlation between different CT sequences (single phasic, multiphasic, non-contrast and contrast) and DRLs for AP examination. The calculated third quartile values were comparable with the dose data from University of California Medical Center (UCMC) but slightly higher for few sequences such as multiphasic and contrast study for TAP CT. Conclusions: The institutional DRL for combined anatomical regions was established using the third quartile values of dose distribution and can be categorized based on sequences.

Keywords: Computed tomography; dose reference level; CT dose index

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A092

Computer Aided Diagnosis for Cervix Abnormalities Detection on CT-Scan Images based on Edge Detection and Region-Based Snake Model Algorithms and Support Vector Machine

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Purpose: Cervical cancer is the second cause leading women death in Indonesia. Nevertheless, most cervical cancer patients came to doctors with end-stage cancer conditions. Various diagnostic imaging modalities have been used to determine the location, the size, and the severity of cervical cancer that affects patients, one of them is CT-Scan. Methods: This study dealed with the CT-Scan image dataset that consisted of two image categories, i.e. abnormal cervical images of cervical cancer patients and normal cervical images from patients with other diseases. The focus of this study was discussing about the ability of segmentation and classification programs to localize areas of cervical cancer and to classify the image data into normal and abnormal categories based on features contained in them. The methods were to segment the cervical area and to get texture features of the area on images. The used segmentation algorithms were edge detection and region-based snake model, while the texture of the cervical image area was arranged in the form of Gray-Level Co-occurrence Matrix (GLCM). The classification process was carried-out based on the texture using Support Vector Machine (SVM) that classified image data into abnormal and normal image categories. Results and Conclusion: The results suggested that these programs could be used to determine whether images belong to normal or abnormal image categories with sensitivity of 95.2%, specificity of 90.5%, accuracy of 92.9%, precision of 90.9% and overall error of 7.1%. Cervical volumes of all cervical images were also calculated to know whether a cervical cancer had an effect on its size.

Keywords: Computer aided diagnosis; cervix abnormalities; CT; snake model algorithm

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A098

Resting-state fMRI: Comparing Default Mode Network Activity in Normal and Low Working Memory Groups

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Purpose: Normal and low working memory (WM) capacity groups have different level of brain activity in default mode network (DMN) at rest. To date, the relationship between resting connectivity among DMN brain regions and cognitive performance is still poorly understood. In the present study, we use resting-state functional magnetic resonance (rsfMRI) data to explore the link between WM capacity and coupling strength between the DMN brain regions, specifically in posterior cingulate cortex (PCC) and medial prefrontal cortex (mPFC). We also correlate the strength of connectivity between these two regions with behavioral performance. Methods: Forty healthy young adult male volunteers were recruited in this study. The participants were divided equally into normal and low WM capacity groups. WM capacity and behavioral performance were assessed outside the MRI scanner. The behavioral task was a word-based backward recall task. The participants performed rsfMRI and the data were analyzed using Dynamic Causal Modelling in Statistical Parametric Mapping. Results: The PCC and mPFC were interconnected in both groups. WM capacity is associated with strength of endogenous coupling between PCC and mPFC at rest. Group analyses showed different coupling strength between these regions for the normal WM capacity group, as compared to the low WM capacity group. In addition, strength of coupling correlates with behavioral scores. Conclusions: The WM capacity is determined by the coupling strength between PCC and mPFC. These findings suggest that strength of endogenous coupling between these two regions at rest play crucial role in cognitive abilities important for this WM task.

Keywords: Resting-state; MRI; default mode network; working memory capacity

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A100

Region-of-Interest Tomography by using Inverse Geometry System: A Simulation Study

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Purpose: By using multi-source characteristics, we intend to present a selective and multiple interior region-of-interest (ROI) imaging method by using a designed source on-off sequence of IGCT. Methods: All of the IGCT sources are operated one by one sequentially, and each projection in the shape of narrow cone-beam covers its own partial volume of full field of view (FOV) determined from system geometry. Thus, through controlling multi source operation, limited irradiation within ROI is possible and selective radon space data for ROI imaging can be acquired without additional X-ray filtration. With this feature, we designed a source on-off sequence for multi ROI-IGCT imaging, and projections of ROI-IGCT were generated by using the on-off sequence. Multi ROI-IGCT images were reconstructed by using filtered back-projection algorithm. All these imaging process of our study has been performed by utilizing digital phantom and patient CT data. ROI-IGCT images of the phantom were compared to CBCT image and the phantom data for the image quality evaluation. Results: Image quality of ROI-IGCT was comparable to that of CBCT. However, the distal axial-plane from the FOV center, large cone-angle region, ROI-IGCT showed uniform image quality without significant cone-beam artifact contrary to CBCT. Conclusions: ROI-IGCT showed comparable image quality and has the capability to provide multi ROI image within a rotation. Projection of ROI-IGCT is performed by selective irradiation, hence unnecessary imaging dose to non-interest region can be reduced. In this regard, it seems to be useful for image guidance purpose in radiotherapy.

Keywords: Region-of-interest; cone-beam computed tomography; inverse geometry

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A105

Conduct of Acceptance/Compliance Test on Hybrid Imaging Equipment (SPECT-CT and PET-CT) in the Philippines

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Purpose: To describe Medical Physics & Health Physics Services, Inc. (MPHPS) activities in the conduct of acceptance/commissioning tests for diagnostic x-ray facilities with emphasis on hybrid imaging. Methods: Service providers for the Acceptance/Commissioning test of diagnostic x-ray facilities, (radiography/fluoroscopy, mammography and CT) in the Philippines are composed of: Service Engineers of X-ray Suppliers (only for radiography/fluoroscopy, confined to private clinics/hospitals), Diagnostic Radiology Medical Physicists (DRMP) in JCI Hospitals (all modalities and these physicists perform Acceptance/Commissioning test at their own facility) and Laboratory Support Division of the Center for Device Regulation, Radiation Health & Radiation Health's (CDRRHR) composed of medical physicist and radiologic technologist, for Commission on Audit requirement to test all government-procured x-ray equipment. Most private medical facilities (hospitals/clinics) without in-house DRMP have their radiography/fluoroscopy, mammography and CT equipment tested by MPHPS and including Hybrid Imaging e.g. SPECT-CT and PET-CT (CT portion). MPHPS Acceptance/Commissioning test protocols followed are from CDRRHR (unpublished), ACR Quality Control Manual, and IAEA Human Health Series No. 19 and Western Australia workbook. Results: While revision of Administrative Order 35, s. 1994 is ongoing; current regulation requires the Medical Physicist and X-ray Service engineers to submit "calibration reports" be made available for diagnostic x-ray facilities. MPHPS started testing Hybrid Imaging SPECT-CT in 2012 (CT component), and PET-CT in 2016 (CT component) and this include the conduct of co-registration test as recommended by ACR Practice Guidelines. Conclusions: MPHPS provides acceptance/commissioning tests for SPECT-CT and PET-CT in accordance with ACR QC Manual and IAEA guidelines.

Keywords: ACR QC Manual; IAEA Human Health Series; SPECT-CT; PET-CT Acceptance/Compliance Testing

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A108

Estimation of Effective Dose in Whole-body ^{18}F-FDG PET/CT Examination

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Purpose: Whole body flourine-18-fluoro-2-deoxy-D-glucose (^{18}F-FDG) Positron Emission Tomography/ Computed Tomography (PET/CT) is a standard care on oncologic diagnosis and staging. However, there is a growing concern over the radiation exposure of patient undergoing PET/CT due to higher radiation dose compared to other imaging modality. The aim of this study is to estimate patient effective dose in 91 patients in University Malaya Medical Centre (UMMC). Methods: Data were collected for 91 patients who underwent ^{18}F-FDG examined with Philips Ingenuity TF (time-off-flight) 64-Slice system. Patient effective dose in PET/CT was calculated using conversion factors applied to the radiotracer activity and to the CT Dose Length Product (DLP) which is base on recommendation from International Commission on Radiological Protection (ICRP) Publication 106 and ICRP Publication 102. To take into account size of the patient, effective dose also was calculated using SSDE method recommended by AAPM Report No. 204. The organ absorbed dose resulting from the radiopharmaceutical injection was estimated by mean of the model proposed by the ICRP Publication 106. CT protocol was selected based on patient body mass index (BMI) and the tube current-time was varying by using the automatic exposure control (AEC) technique. The intravenous injected activity of ^{18}F-FDG given to patient is 3.5MBqkg^{-1}. Results: Total effective dose, ED (mean ± SD) for CT, PET and PET/CT were 10.73 ± 3.29, 4.10 ± 0.98 and 14.83 ± 4.16 mSv respectively. Conclusions: Average whole-body effective dose from PET/CT examination done in UMMC for 91 patient was 14.83 ± 4.16 mSv, where 72% of the dose is due to CT exposure.

Keywords: Dosimetry; PET/CT; effective dose

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A111

Dosimetric Imaging Study of Male Rectum Perspex Phantom using Single-Energy Mode (SECT) and Dual-Energy Mode (DECT) Computed Tomography

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Purpose: This study aimed to estimate and compare absorbed, effective and surface doses between SECT and DECT techniques. Methods: A customized Perspex male rectum phantom mimicked male Asian reference size was used. Thermoluminescence dosimeters, TLD-100 were used to measure the charges as a result of the radiation interactions, while doses were obtained from TLD calibration curve. Three settings were used, i.e. SECT using 80kV and 140kV, and DECT modes. The corresponding absorbed, effective and surface doses were then compared between these settings. Results: DECT resulted in approximately 55.9 % dose reduction compared to SECT with 140kV tube voltage, thus allowing DECT to be utilized with radiation dose sparing. The surface dose recorded from this study also lower, when compared to previous studies, for all settings. For effective dose, the study showed that the values for DECT of abdomen were within acceptable limit, according to AAPM Report No.96. DECT also resulted in lower effective dose compared with SECT with 140kV tube voltage. Conclusions: DECT contributes to lower doses compared to the SECT technique, with a potential as the alternative for the conventional protocol.

Keywords: Computed tomography; dosimetry; absorbed dose

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A115

Optimisation Exercise of CT Thorax Protocol for Obese Paediatric Patients: A Phantom Study

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Purpose: To optimize the Automatic Exposure Control (AEC) settings towards reducing radiation dose to obese paediatric patient for CT thorax examinations. Methods: A paediatric phantom were wrapped using a 2 cm thick fat equivalent material to simulate obese paediatric patient. Optically Stimulated Luminescence Dosimeters (OSLDs) were inserted at selected positions to measure organ doses. Then, phantom was scanned with CT scanner at DoseRight Indices (DRI) of 13, 15 and 17. Images were analysed to find out whether there were any statistically significant differences in images acquired from different protocols. Results: The contrast to noise ratio (CNR) of images with DRI of 13 (211.08 ± 21.35) were significantly lower than CNR of images with DRI of 15 (231.67 ± 20.35) and 17 (245.10 ± 25.44; $P < 0.01$). There were significant differences in signal to noise ratio (SNR) among images with all DRI settings ($P < 0.01$). In terms of visual quality, there were not much different in these images. The dose received by phantom at DRI of 13, 15 and 17 were 1.070 ± 0.050 mSv, 1.165 ± 0.070 mSv and 1.751 ± 0.080 mSv, respectively. When DRI was decreased from 17 to 15, the effective dose remarkably reduced by approximately 33.5%, from 1.751 mSv to 1.165 mSv. However, a further decrease in DRI to 13 reduced only 8% in effective dose compared to that at DRI of 15. Conclusions: There are rooms to reduce radiation dose for obese paediatric patients in CT thorax examinations while maintaining sufficient diagnostic image quality.

Keywords: Obese paediatric patient; CT thorax; automatic exposure control

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A116

Basic Characterisations of Fabricated Germanium-Doped Optical Fibres for Computed Tomography Dosimetry

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Purpose: Preliminary study of basic dosimetric characteristics of fabricated germanium-doped optical fibre irradiated for computed tomography (CT) dosimetry are investigated. Methods: Responses of fibres are compared with Lithium Fluoride thermoluminescence dosimeters (TLD) and optically stimulated luminescence (OSL) dosimeters respectively. The fibres are 2.3 mol% flat fibre (FF) with 633 x 430 μm² size, 6.0 mol% FF (620 x 165 μm²), 2.3 mol% cylindrical fibre (CF) with 475 μm diameter, 6.0 mol% CF (604 μm) and 4 mol% commercial fibre with core diameter of 50 μm. The fibres are screened prior tested for dose linearity, reproducibility, RQT beam quality and fading using a standard tube potentials of 100-, 120-, and 150 kilovoltage peak (kVp) x-ray beam facility at Malaysian Nuclear Agency. Results: Thermoluminescence (TL) yield with dose is highly linear for the fibres ($r^2 > 0.99$) as compared to TLD and OSL and being reproducible to better than more than 3% coefficient of variation (CV) following repeat measurements (n=3). Over a period of 30 days post-irradiation the fading loss for the fibres is less than 10%, while that for TLD-100 is 7% and 2% for nanoDots in comparison. For RQT beam quality, all dosimeters showed approximately similar patterns of variation. It is observed that the lowest TL response per unit mass for optical fibres is obtained at 150 kVp followed by 120 kVp, while the greatest response is obtained at 100 kVp. Conclusions: This work provides support for the viability of preform 6 mol% and 2.3 mol% fibres for use in computer tomography dosimetry.

Keywords: Ge-doped silica; TLD; OSL

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A118

Two-Dimensional Electrical Impedance Tomography (EIT) for Characterization of Body Tissue using a Gauss-Newton Algorithm

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Purpose: The Gauss-Newton algorithm is applied to reconstruct a two-dimensional image of Electrical Impedance Tomography (EIT) using python program. The aim of the study was to determine the characteristics of body tissues either conductive or resistive properties through the tissue structure which is displayed in the form of images. Methods: The EIT technique is performed by injecting a low constant electric current of 1 mA at 50 kHz frequency on a pair of electrodes of 16 copper electrodes (Cu) surrounding a medium filled with ground meat, flat bone, and cord bone of chicken. Voltage measurements from the other electrode pair were achieved by the principle of the neighbouring method. The measurement data is processed with the python program using Gauss-Newton algorithm to obtain a reconstructed image of the tissue structure. Results: The characteristics of body tissues either conductive or resistive properties are identified from the colour scale of the reconstructed image which yellow colour indicates conductive properties and purple colour indicates resistive properties. The results showed that flat bones are resistive properties while cord bones that still attached muscle, fat, and blood are conductive properties. Conclusions: Original analysis of body tissue either conductive or resistive properties could be reconstructed by two-dimensional electrical impedance tomography conjunction with the Gauss-Newton algorithm.

Keywords: Electrical impedance tomography (EIT); Gauss-Newton algorithm; image reconstruction

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Sensitivity Analysis of Thorax Imaging Using Two-dimensional Electrical Impedance Tomography (EIT)

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Purpose: The purpose of the study was to assess the performance of Electrical Impedance Tomography (EIT) system in a thorax imaging by analysis of sensitivity distribution. Methods: Sensitivity distribution was visualized using COMSOL Multiphysics simulation in a human thorax represented as an elliptic cylinder phantom consisting of homogeneous and inhomogeneous medium with varying different dimensions of 16 electrode EIT system. Current density distribution was collected for sensitivity analysis using neighbouring method. Results: The sensitivity distribution at each position in the phantom is different. It caused by the interaction of current density from trasmitter and receiver terminal. The varying different parameter of the system can also influence sensitivity distribution. The sensitivity of inhomogeneous phantom is very non-uniformly distributed. Conclusions: The performance of systems was assessed by analysis of the change of sensitivity with the change of electrode dimensions in the homogeneous and inhomogeneous medium.

Keywords: EIT; sensitivity distribution; thorax

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A125

850-Nm-Peak High-Spatial-Resolution Near-Infrared-Ray Computed Tomography in the Living-Body Window

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Purpose: In our research, major objectives are as follows: to use a near-infrared-ray (NIR) light-emitting-diode (LED) device, to construct a light receiving device using a visible-ray (VR) phototransistor (PT) and an infrared (IR) filter, to perform NIR computed tomography (NIR-CT), and to improve the spatial resolutions. Therefore, we performed a first-generation NIR-CT at a peak wavelength of 850 nm. Methods: In the NIR-CT, the LED-peak wavelength is 850 nm in the living-body (LB) window range, and the NIR photons are exposed to an object through a pinhole. Next, the penetrating NIR photons are lead to another pinhole and detected using the VR PT thorough an IR filter. The photocurrents flowing through the PT are converted into voltages using an emitter-follower circuit, and the output voltages are sent to a personal computer through an analog-digital converter. The NIR projection curves for tomography are obtained by repeated translations and rotations of the object. Results: In the NIR-CT, only penetrating photons are detected using the pinhole. The spatial resolutions of the NIR-CT were 1.0×1.0 mm^2, and the outlines of objects are visible. Conclusions: We developed a first-generation 850-nm NIR-CT scanner to obtain biomedical tomograms at a scanning time of 9.8 min. The NIR photons from the LED penetrated the living bodies, and the penetrating photons could be detected using a high-sensitivity detecting device.

Keywords: NIR-CT; 850-nm LED; line beam; living-body window; high spatial resolution

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A128

Eye Lens Dose Measurement in Patients during Brain Arteriovenous Malformation (AVM) Interventional Neuroradiology (INR) Procedure

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Purpose: Brain AVM interventional neuroradiology is a complex and prolonged procedure which the eye lens may receive the scattered radiation from this procedure. The purpose is to measure the patient eye lens dose and compare with the threshold level of eye lens opacity as recommended by ICRP in 2012. Methods: The equipment used for brain AVM INR therapeutic procedures is a biplane x-ray system. The optically stimulated luminescence (OSL) dosimeters were attached on the thin film eye wear transparent to radiation and close to the patient eyelids. Exposure parameters recorded were kVp, mAs, frame rates, number of images, KAP, air kerma, fluoroscopic time, source-image receptor distance. The size and location of brain lesion and experience of interventional neuroradiologists were recorded. Results: The range of patient left and right eye lens doses were 3.06-110.36 mGy and 2.86 - 48.48 mGy respectively. Fluoroscopic time was 16.41- 83.36 minutes. The left eye located toward to the lateral x-ray tube receive radiation dose 2-3 times greater than the right eye, considerably. The maximum eye lens dose on the left eye during an AVM located at left supratentorial was correlated with the use of exposure mode, number of images, fluoroscopic time, location and volume of lesion. Conclusion: The patient eye lens doses were less than the threshold level of eye lens opacity at 0.5 Gy. The awareness in using exposure parameters such as reduced field size and short distance from flat panel detector to patient have been considered, especially in patients require multiple procedures.

Keywords: Eye lens doses; brain arteriovenous malformation; interventional neuroradiology

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Dual-tracer Parathyroid Imaging using Regularized Joint Methods

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Purpose: To improve image quality in dual-tracer parathyroid imaging based on our previously-developed Joint method and regularization, and to demonstrate improved performance of the new method compared with the Joint method. Methods: We previously developed an iterative method called the Joint method based on Poisson noise modeling and the maximum-likelihood expectation maximization (MLEM) algorithm to obtain the differential image in dual-tracer parathyroid imaging. In this work, we used a regularized joint approach to obtain the differential image based on the maximum a posteriori (MAP) framework and Green's one-step-late (OSL) algorithm, where we explored two regularization options, i.e. total-variation (RJoint-TV) and quadratic (RJoint-Q) functions. We tested our proposed regularized methods and the Joint method using hyperparathyroidism patient datasets with two lesions. We computed the average contrast-to-noise ratio (CNR) value across both lesions in the differential image at 6 iteration numbers (3, 6, …, 18) for all three methods, and at regularization parameter β of 0.001, 0.01, 0.1 and of 0.00001, 0.0001, 0.001 for the RJoint-TV and RJoint-Q methods, respectively. Results: The highest average CNR value at respective optimized parameters was 2.07, 2.32, and 2.89 for the Joint (at 12 iterations), RJoint-Q (at β=0.001, 18 iterations), and RJoint-TV (at β=0.1, 15 iterations) methods, respectively. Conclusions: The proposed regularized approach (both RJoint-TV and RJoint-Q methods) yielded improved image quality for parathyroid imaging as compared to our previously-developed Joint method, and showed great promise to be used for parathyroid localization in clinical practice.

Keywords: Parathyroid; localization; dual-tracer

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The Pharmacokinetic Model of 18F-FDOPA in PET Brain Imaging for Early Parkinson's Disease

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Purpose: Parkinson's disease (PD) symptom usually appear when around 60% - 80% of all dopamine neurons have died. Early detection and treatment approach are; therefore, very important. ^{18}F-FDOPA PET scan is extensively examined to differentiate the normal and pathological dopamine metabolism in the human brain. To develop pharmacokinetic model (PK) of ^{18}F-FDOPA in PET brain imaging for early Parkinson's disease. Methods: The retrospective data from 5 adult patients who underwent ^{18}F-FDOPA PET brain scan at King Chulalongkorn Memorial Hospital (KCMH) were collected. After ^{18}F-FDOPA was administered intravenously, PET images were acquired for 90 min using 3D list-mode and reconstructed into 5-min interval for obtaining each time-point image dataset. PET images were superimposed with brain template on Statistical Parametric Mapping (SPM) software for contouring the boundary and measuring the activity concentration at the striatum. Compartmental model was developed using SAAM II simulation software to estimate transfer rate constants in each side of the striatum. Results: A 3-compartment with 3-transfer rate constant model is sufficient to describe the biokinetic of ^{18}F-FDOPA and its metabolites in the human striatum. The average time-integrated activity curve was steeply increased until reached the maximum at 15-minute time-point, and then slightly decreased accordingly. The FDOPA decarboxylation rate constant (k_3) at the abnormal uptake side of striatum was lower than the normal uptake side of striatum. Conclusions: This study has successfully developed PK model for ^{18}F-FDOPA. The biokinetic data obtained in this study will be additionally used as a reference report for Parkinson's patients.

Keywords: PET/CT; ^{18}F-FDOPA; Parkinson's disease; pharmacokinetic model

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CT Image Contrast of Platinum Nanodendrites: Preliminary Study

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Purpose: Platinum nanodendrites (PtNDs) are high-Z nanomaterials (Z=78) that possess a promising potential to be introduced as a novel contrast agent in diagnostic radiology. Here we investigate the performance of PtNDs as contrast agent in computed tomography in term of CT number and CNR. Methods: PtNDs of different sizes (29, 36, 42, 52 nm) were prepared into final concentration of 0.1 mM in 3 mL syringes. CT scans were performed on PtND samples, distilled water and iodinated contrast agent arranged in phantom. The scans of each samples were conducted at 0.6 mm slice thickness and 80 kVp setting. CT number and contrast to noise ratio (CNR) were measured and calculated. Results: The attenuation property of PtNDs show size dependent characteristics, as the smallest PtNDs tested (29 nm) shows the lowest CT number (3.73±0.37), followed by 36 nm PtNDs (21.23±0.77), 42 nm (62.77±2.08) and 52 nm (89.33±4.60). CNR quantification reveals that there are no significant different of CNR values for PtNDs of size 29 nm, 36 nm, and 42 nm (around 16.52±0.1), while 52 nm PtNDs sees drop of CNR (14.23±0.4). Compared to iodinated contrast agent, 42 and 52 nm PtNDs show higher CT number, with slightly reduced CNR. Conclusions: This preliminary study suggests that PtNDs have the potential to be applied as contrast agents for CT imaging. The study also demonstrate that the performance of nanomaterial based contrast agent and x-ray attenuation properties are dependent on nanoparticles size and further study is required to elucidate multiparameter involved.

Keywords: Platinum nanodendrites; nanoparticle contrast agent; high-Z nanoparticles

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Magnetic Susceptibility Artefact Induced by Personal Care Product with Gold Nanoparticles on Brain Magnetic Resonance Images

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Purpose: This study aimed to investigate the effect of personal care product (PCP) with gold nanoparticles (AuNPs) on brain Magnetic Resonance Imaging (MRI) images. Methods: A brain MRI water phantom was scanned using 1.5T MRI scanner with T1-weighted fast-spin-echo (FSE), T2-weighted FSE and fluid-attenuated inversion recovery (FLAIR) sequences. The images acquired from the initial scan were categorized as control group. Then, the PCP with AuNPs was applied evenly on the micropore tape attached on phantom with oil marker at its left side and scanned using the same MRI sequences. Images acquired from the latter scanning were classified as either moisturizer group or compact powder group. The MRI images analyzed using Visual Grading Analysis (VGA) by two radiologists. Results: Based on the VGA scores, all the brain MRI images in moisturizer group were scored '1' indicated minimal artefact with minimal loss of fine details seen. While, all the brain MRI images in compact powder group were scored '0' for no artefact seen. Wilcoxon-signed rank test indicated that there was statistically significant different between VGA score of control group and moisturizer group of brain MRI images ($p<0.05$). Whereas, the test indicated that there was no statistically significant different between control group and compact powder group ($p>0.05$). Conclusions: It can be concluded that personal care products with AuNPs did not induce susceptibility artefact on brain MRI images. Therefore, patients who wear PCP with AuNPs may not need to clean their face prior brain MRI examination.

Keywords: MRI; susceptibility artefact; cosmetic

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Assessment of the Cumulative Effective Dose for Participants from Lung Cancer Screening Pilot Project in Institut Kanser Negara: A Preliminary Findings

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Purpose: The aim of this study is to evaluate participant's effective dose from Lung Cancer Screening pilot program in National Cancer Institute, Putrajaya. Methods: This retrospective study was performed between Apr 2016 – Dec 2016 where all scanning acquisition protocols and dose information from sixty (60) participants were recorded and investigated. The screening process involves two types of imaging technique, the Dual Energy Subtraction (DES) Chest X-ray and Low-Dose Computed Tomography (LDCT) imaging technique. Participant's effective dose from DES and MSCT were analyzed by using PCXMC (Ver 2.0, Finland) and CT-EXPO (Ver 2.3, Germany) software, respectively. Results: It was observed that the mean (±SD) value for DES (at 60 kV), DES (at 120 kV) and MSCT examinations were 0.006 ± 0.005 mSv, 0.018 ± 0.005 mSv and 1.558 ± 0.129 mSv, respectively. In a whole, the total cumulative effective dose values for participants were ranged from 1.376 mSv to 1.986 mSv. Conclusions: In conclusion, this study found that both optimized techniques are useful for screening needs and the ED value from this study was lower when compared to other established reference.

Keywords: Lung screening; effective dose; dual energy X-ray

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A Comparison of Dose Calculation Algorithms Model in 3-Dimensional Conformal Radiotherapy (3D-CRT) Technique

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Purpose: The aim of this study is to compare the implementations of three dose calculation algorithms model: convolution, superposition, and fast superposition for 3D-CRT technique. Methods: In this study, we adopted protocols described in IAEA-TECDOC-15831, where four typical treatment techniques; single field, multiple field, wedge field, and multi-leaf collimated (MLC) field. The measurement data for calculated dose and measured dose were taken from CIRS anthropomorphic phantom. The assessment of algorithms was done by comparing the point dose calculated with the measured dose. Results: The study shows that the superposition algorithm produced relative error less than ±3% which passed 100% of all reference points, whilst the convolution algorithm and fast superposition presented relative error more than ±3% which passed 82% and 91% of reference points, respectively. Conclusions: In conclusion, the evaluation of radiotherapy treatment plan shall take into account the type of dose calculation algorithm model in order to optimize radiotherapy treatment and ensure the radiation safety to the patient.

Keywords: 3DCRT; algorithms; anthropomorphic phantom

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Impact of Acquisition Time on Image Quality and Visibility of Yttrium-90 Positron Emission Tomography: A Phantom Study

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Purpose: The internal pair production of ^{90}Y was enable the imaging of this isotope with positron emission tomography (PET). Consequently, the acquisition time is a crucial factor that strongly influent the image quality due to very low positron fraction. Hence, the aim of this study was to evaluate the feasibility and impact of acquisition time on image quality and visibility of ^{90}Y image using PET imaging. Methods: A NEMA IEC body phantom with a set of fillable spheres were filled with ^{90}Y to generate a hot lesion to background ratio of 8:1. PET image was acquired by Philips Gemini TF PET/CT scanner with acquisition time per bed varied from 15, 30, 60 and 120 minutes. Image quality was assessed by the hot contrast, signal-to-noise (SNR) ratio, visibility of sphere (VS) using the Rose's criterion for a human observer. Results: The hot contrast and SNR were increased with acquisition time as expected. Additionally, the sphere visibility is not only depended on the SNR but also relied on the object size. Hence, the VS analysis from this study showed that the smallest sphere (diameter of 10 mm) was visible (VS > 5 according to Rose's criterion) when using acquisition time per bed of 60 and 120 minutes. Conclusions: This study demonstrated that the imaging of ^{90}Y with PET was feasible. The smallest object required longer acquisition time to obtain the visible condition.

Keywords: Yttrium-90; image quality; contrast; visibility; SNR

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Simple Reduction Method of Eye Lens Exposure in Routine Head Computed Tomography

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Purpose: Organ-based Tube Current Modulation (Organ-based TCM) technique was developed to reduce the exposure of high radiosensitive organs. The purpose of this study was to compare the radiation shielding ability of Organ-based TCM with tungsten functional paper (TFP) for the eye lens exposure in routine head computed tomography (CT), and analyze the CT imaging quality such as CT values and image noise. Methods: The exposure for our clinical routine head CT examination protocol with Organ-based TCM was measured at center, 12, 3, 6, and 9 o'clock positions in head CT dosimetry phantom by use of a diode detector (CT Dose Profiler, RTI Electronics, Mölndal, Sweden). The 0.3 mm of TFP was wrapped around the head CT dosimetry phantom on the eye level with 4 patterns as follows: 1. 90° covering the crystalline lens, 2. 120°, 3. halfway around, and 4. single around. In CT imaging quality analysis, the CT values and standard deviation (SD) level were measured using a Catphan phantom under three regions (anterior, middle, and posterior). Results: The shielding rate of each shielding methods at 12 o'clock position was 66.0% (90°) 61.6% (120°) 60.7% (180°) and 71.9% (Organ-based TCM), respectively. The exposure was decreased with the area of the TFP increasing. The CT values and SD level were increased with the area of the TFP increasing in all regions. However, with Organ-based TCM, those values weren't changed. Conclusions: Organ-based TCM could reduce exposure simply in routine head CT with maintaining the imaging quality.

Keywords: Radiation protection; computed tomography; eye lens; organ-based; tube current modulation

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Direct and Indirect Entrance Surface Dose Measurement in X-Ray Diagnostics using Nanodots OSL Dosimeter

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Purpose: This study was aimed to assess the prospect of small-type optically stimulated luminescence (OSL) dosimeters for entrance surface dose (ESD) measurements in common X-ray diagnostics. Methods: We used the commercial OSL dosimetry system (Landauer, Inc, Glenwood, IL) including nanoDot dosimeters and microStar reader. The ESDs were measured with OSLDs placed on whole-body anthropomorphic phantom (for direct measurement) and in free air without backscatter material (for indirect measurement) in accordance with the IAEA Technical Report Series No. 457. Measurements were carried out in five projections including AP abdomen, AP and PA chest, AP thoracic spine, and AP skull. Results: The mean ESD for each projection was evaluated from multiple measurements with three different field sizes. The mean ESD values (direct measurements) for abdomen (AP), chest (AP), chest (PA), thoracic spine (AP) and skull (AP) were 4.3 mGy, 0.7 mGy, 0.3 mGy, 6.8 mGy, and 2.8 mGy, respectively. While in the case of indirect measurements, the corresponding mean ESD values were 4.8 mGy, 0.7 mGy, 0.2 mGy, 7.2 mGy, and 3.7 mGy, respectively. The results were found to be within the IAEA and European Commission (EC) diagnostic reference levels range. The percentage difference of the ESDs measured by direct and indirect methods in all projections were between 0 to 40%. Conclusions: It was affirmed that the nanoDots OSLD is a good candidate for ESD measurement in common radiographic examinations, while taking into account the energy correction factors where necessary.

Keywords: NanoDots; entrance surface dose; X-ray diagnostics

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In an Appropriate and Effective Way to CT Imaging for Deformable Image Registration

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Purpose: A Deformable Image Registration (DIR) based evaluation on a respiratory disease such as Chronic Obstructive Pulmonary Disease (COPD), it is important to provide a minute lesion by Breath Hold (BH) CT. The purpose of this study was to evaluate to measure up to Jacobian value between 4D-CT and BH-CT. Methods: Four dimensional-CT was scanned using respiratory waveform, and BH-CT was instructed to breath hold (inhale and exhale) in 55 patients. The breath-hold scans focus on to keep breath on come to rest from first to 18th patients, although, matched up it with the wave pattern amplitude, and breath stopped in a timing of patient oneself after the 19th. DIR was evaluated the ratio to Jacobian values (0.5-1.5; interval 0.1), that was evaluated to wave pattern and the ratio to Jacobian's histograms by medium and standard error to separate 4 groups. Results: The median ratio of Jacobian value less than 1 (contraction) was accorded with 4D-CT group (0.08±0.01), BH-CT group 1 (1st-18th : 0.05±0.02) and BH-CT group 2 (19th-55th: 0.05±0.02). The relationship between the wave and histogram both fine (n=17) and just histogram fine (n=10) had a large correlation for the median of Jacobian values in 4D-CT as a standard. The just wave fine and, wave and histogram both failure had increased to ratio of high Jacobian value distribution. Conclusion: We investigated the according to Jacobian value to both 4D-CT and BH-CT that it is necessary to breath stopped in a timing of patient oneself.

Keywords: Deformable image registration (DIR); breath hold CT; Jacobian value

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Acceptance/Compliance Test for Dental X-ray: 2014-2017

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Purpose: To describe the experience of Medical Physics & Health Physics Services, Inc. (MPHPS) in the conduct of acceptance/commissioning tests for dental X-ray. Methods: MPHPS acceptance/compliance test protocol for dental X-ray is based on IEC Standards and SEDENTEX CT program. IAEA Training Course No. 47, Module 5: Performance testing of imaging equipment, Sub-module 5.12: Dental radiography, acceptance, and QC tests on dental radiographic imaging systems are highlighted. These include direct film imaging, computed and digital radiography, panoramic and cephalometric radiography, and cone-beam CT. Philippine Department of Health Administrative Order 2A, series of 1996: Requirements for the control of radiation hazards from dental x-ray facilities, was issued on 30 January 1996 requires that the Radiation Health Service of the Philippine Department of Health (DOH) conducts Radiation Protection Survey and Evaluation (RPSE) of dental x-ray facilities. Most of the requests for acceptance/compliance test received by MPHPS are from hospital-based dental facility. Results: Under Administrative Order 2A, the following are mandatory to be tested: Leakage Radiation, Filtration, Timer accuracy, Presence of Beam-on indicator at the control panel, kVp and mAs output, Mechanical tests (Mechanically stable. Brakes and locks functioning), and Beam collimation (diaphragm, cones). MPHPS invested in IEC dental X-ray test tools for imaging tests. Conclusions: The tests performed by MPHPS medical physicists for dental X-ray and cone-beam dental CT are based on dental x-ray test tools that comply with IEC standards and the SEDENTEX program.

Keywords: Intraoral, Extraoral, Dental Cone Beam CT, Quality Control Manual

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Evaluation and Measurement of Thyroid Radiation Doses during Mammography Screening Program

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Purpose: Breast cancer is a leading cause of cancer related death in women. Use of mammography for breast cancer screening is a widely accepted practice for early breast cancer diagnosis in whole world. Mammography is a very crucial examination as it involves use of low energy X-rays. Lower the energy of X-rays, higher is probability of its absorption in body. Thyroid gland is one of the most sensitive organ around breast. This study was planned to quantify the scatter radiation dose to right and left lobe of thyroid gland during routine screening mammography examination. Methods: The study included 205 women within the age group of 35-60 years and within BMI range of 22-29. All of them were screened on Hologic M-IVTM Screen-film mammography system single handedly. Measurements were made using optically stimulated luminescent dosimeter (OSLD) detectors taped appropriately to the skin overlying on right and left lobe of thyroid gland. The radiographic parameter ranges used was kV (28-30), mAs (16-22) .The standard technique of two craniocadual views (CC) and two mediolateral oblique view (MLO) was used during screening examination. Results: An average skin thyroid dose of 0.40 +/- 0.33 mGy per mammographic examination was measured with measurements ranging from 0.25 to 0.91 mGy. The MLO view was found to give a 2.1-fold greater skin dose at the thyroid than the CC view. Conclusions: The single examination doses were not found significant but higher frequency of screening examination will increase the risk of radiation doses.

Keywords: Thyroid; radiation dose; mammography; screening

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Development of Automatic Contouring System using PET-CT Fusion Image

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Purpose: To develop an automatic contouring program using both computer tomography (CT) and positron emission tomography (PET) image for achieve the correct radiation treatment planning. Methods: The system was designed to work in the following format. As a first step to contour a tumor region, PET image is overlapped on CT image and primary tumor suspicion regions are roughly extracted. After that, physician select one pixel contained in the tumor region. Through the selected tumor pixel, system calculate and contour a tumor volume. To apply to under development in-house treatment planning system, CT image is divided into air-tissue-bone parts and some factors, e.g., tumor size and standardized uptake value are additionally calculated. Designed program was developed using some machine learning techniques, such as neural network and clustering. The system development and verification were performed using a NEMA body phantom and patient head-and-neck PET/CT image. Results: Developed system operated with relatively high contouring performance in head-and-neck tumor cases. Calculated data was compared to the previously contoured gross target volume data of patients. Conclusions: Developed program demonstrated the constant contouring result from the identical condition except user. The additional accuracy evaluation of output values is required.

Keywords: Automatic contouring; machine learning; fusion image

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Evaluation of Image Quality and Radiation Dose in Kilovoltage Cone Beam Computed Tomography

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Purpose: To evaluate the image quality and radiation dose of kV-CBCT when varying mAs and reconstruction filter. Methods: Radiation dosimetry (CBDIw) and quality control of kV-CBCT image (Varian Edge machine) were done. Routine protocols in the head, thorax, and pelvis protocols were performed as a reference image. Then the images were acquired with the varied mAs by two step-up and two step-down, the other parameters were fixed. Each technique was reconstructed with the different filter. The image quality in terms of low contrast and high contrast resolution including CBDIw were compared. Results: The results found that the variation of mAs with auto reconstruction filter affected low contrast resolution, but no effect in high contrast resolution. When mAs value increased, low contrast resolution detectability increased due to the lower image noise. But it will increase the radiation dose to the patient. Decreasing one step of mAs (16.67%) from a reference protocol kept in acceptable image quality in the head, thorax, and pelvis protocols and reduced about 15% of CBDIw. The smooth filter demonstrated to improve the low contrast resolution, but it decreased the high contrast resolution. While the sharp or ultra-sharp filter improved the high contrast resolution. Conclusions: The study reveals that the changing of mAs affects the low contrast resolution and CBDIW. While the different reconstruction filter changed the both low and high contrast resolution, but no effect to CBDIw. To optimize the image quality and radiation dose of head, chest, and pelvis protocols, mAs can reduce one step-down.

Keywords: kV-CBCT; CBDIw; reconstruction filter

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Optimization of Radiation Dose, Image Quality and Contrast Medium Administration in Retrospectively ECG-Triggered Coronary Computed Tomography Angiography

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Purpose: To develop retrospectively ECG-triggered coronary computed tomography angiography (CCTA) protocol using the combination of low tube voltage and personalized contrast volume calculation algorithm for reduction of radiation and contrast medium doses. Methods: A personalized contrast volume calculation algorithm was developed based on 75 patients' characteristics (age, sex, body surface area (BSA), heart rate) and test bolus parameters (peak contrast enhancement [PCE] and time-to-peak [TTP]). The algorithm was used in combination with low tube voltage (100 kVp) protocol during retrospectively ECG-triggered CCTA and was analysed using multiple linear regression analysis. Radiation dose and image quality of the developed protocol were also assessed in 30 consented patients. Results: A strong linear correlation was found between vessel contrast enhancement (VCE) and contrast volume ($r = 0.97$, $p < 0.05$). Age, sex, BSA and PCE were found to be significant predictors for VCE ($p < 0.05$). When combining both 100 kVp and personalized contrast protocols, optimal VCE (250 to 450 HU) and diagnostic image quality were achieved with significant reduction in radiation dose (33.8 %) and total iodine dose (TID) (43.9 %), compared to the standard 120 kVp protocol ($p<0.05$). Conclusions: The developed retrospectively ECG-triggered CCTA protocol using 100 kVp and personalized contrast calculation protocol significantly reduced radiation dose and TID while maintaining optimal VCE and acceptable image quality when compared to the standard 120 kVp protocol.

Keywords: Coronary computed tomography angiography; contrast medium; image quality; radiation dose; total iodine dose

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Optimization of X-ray CT Images using Iterative Reconstruction by MTF in Radial-edge Method for Early Detection of Ischemic Stroke: Phantom Study

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Purpose: We attempted to visualize ischemic stroke by applying Adaptive Statistical Iterative Reconstruction (IR) images to developed phantom using X-ray CT, and it was newly optimized the image by the radial-edge method. Methods: The developed phantom mimicked the head shape and was composed of three sections: brain, cranium, and imitation disease. Sphere-shaped imitation diseases of with CT values of 34 HU were allocated in the middle cerebral artery region. IR images were created using CT from 10 to 100 % at every 10 % in blending ratio, under conditions of 120 kV, 200, 400, 600 mA, 1.0 s. Calculation of the CNR allowed us to evaluate the visualization of acute-stage cerebral infarction. In addition, a new attempt was evaluate spatial resolution by MTF in radial-edge method, and IR images were evaluate in Figure of Merit (FOM). Results: The CNR were with a slice thickness of 5 mm greater than 1.0, which we defined as the ability to visualize acute-stage cerebral infarction, obtained at 70 % under 200 mA, at 50 % under 400 mA, and at 30 % under 600 mA. MTF exceeded resolution of FBP at 10 to 70% of 200 mA, and FOM was obtained at 16.87 under 70 %. Conclusions: Application of IR images to the developed phantom using X-ray CT, the blending ratio exceeding FBP was 70 % of 200 mA. Therefore, optimal conditions for visualizing acute-stage cerebral infarction were achievable.

Keywords: X-ray CT; iterative reconstruction; ischemic Stroke

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Determination of CT Number and Image Noise of *Rhizophora Spp.* Binderless Particleboard as a Phantom Material in Computed Tomography Applications

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Purpose: In this study the computed tomography (CT) scanner was employed to determine the attenuation properties (CT number) and image noise for the *Rhizophora spp.* binderless particleboard at tube energies 80 and 140 kVp. Methods: In this study, the *Rhizophora spp.* binderless particleboards were scanned by Dual Energy Computed Tomography scanner. The cross sectional CT images with 4 mm slice thickness were created in spiral scan mode used 80 and 140 kVp tube energies. The ImageJ software was used to calculate and analysis the cross sectional scanned images at regions of interest. Results: The CT numbers of the *Rhizophora spp.* binderless particleboard was -45±8.1 and -55±4.9 HU at energies 80 and 140 kVp, respectively. The results demonstrated that the CT numbers of the *Rhizophora spp.* binderless particleboard were in the same range of human's soft tissue. The results also indicated that the CT number of the *Rhizophora spp.* binderless particleboard sample in good agreement compared with those of water. Conclusions: The *Rhizophora spp.* binderless particleboard can be used as a tissue equivalent phantom material in Computed Tomography applications.

Keywords: *Rhizophora spp.* binderless; computed tomography; CT number; image noise

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Clustering Technique to Determine Signal-to-Noise and Contrast-to-Noise of *Rhizophora Spp*. Binderless and Araldite Resin Particleboard as Phantom Material on Computed Tomography Images

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Purpose: To study the image quality Signal-to-Noise (SNR) and Contrast-to-Noise (CNR) of CT scanner using clustering methodology of binderless and Araldite Resin *Rhizophora spp.* Particleboards (ARRP) as a phantom material. Methods: In this study, the binderless and (ARRP) samples and Perspex were scanned by CT scanner at 120 kVp tube energy. Samples with dimension of 20 cm x 20 cm size were prepared. The CT images have been segmented using automatic clustering algorithm. Matlab were used to coding the algorithm. Nine square zones over CT image considered as regions of interest for each sample. The ImageJ software was used to calculate mean and standard deviation the scanned images at regions of interest (ROI). Results: The results showed that the coefficient of variation (COV) of the SNR and CNR results in the 9 ROI of binderless particleboard sample were 8.18 and 0.60 respectively, compared with (ARRP) samples with range (17.08-32.12) and (2.85-2.55) respectively. Therefore, this result indicated that binderless sample has more homogenous density than other samples. In addition, automatic clustering algorithm improved the SNR and CRN results of the sample images, as showed a slight improvement in the Perspex and binderless samples and significantly in the samples that have high variation in CT number of (ARRP) samples. Conclusions: The automatic clustering algorithm improved the image quality. In addition, the binderless particleboard showed the least variation in CT number profile compared with (ARRP) samples, so it has potential to be used as a tissue equivalent phantom material in diagnostic imaging application.

Keywords: Clustering; signal-to-noise; contrast-to-noise; *Rhizophora spp.* binderless araldite resin

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A221

Channelized Hotelling Observer in Assessing Microcalcifications Detectability on 2D Mammography: A First Application to Study the Impact of Tube Voltage

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Purpose: To assess the detectability of microcalcifications in 2D mammography using an in-house developed Channelized Hotelling Observer (CHO) for different tube voltage settings. Methods: The images of the 3D structured L1-phantom, containing acrylic beads of different diameters in water and inserted lesions (microcalcification, spiculated and non-spiculated mass models) were assessed. The images were acquired on a Siemens Mammomat Inspiration system at 5 different tube voltage levels (28–32 kVp) under AEC setting. The detectability of microcalcifications was analyzed in terms of percentage correctly detected lesions (PC) as well as diameter threshold (d_{tr}), using a CHO model and human observers. Two Laguerre-Gauss and 8 Gabor channels were included in the CHO model. The model and human observer results were retrieved from a 4-alternative forced choice (4-AFC) study. Results: At 28 kVp and 32 kVp, the d_{tr} of microcalcification together with its 95% confidence interval (CI95) were 0.114 [0.110-0.118] mm and 0.119 [0.116-0.122] mm for the CHO model; and 0.110 [0.093-0.127] mm and 0.123 [0.111-0.134] mm for the human observer. The Pearson correlation (r) between the PC values of CHO model and human observer was more than 0.934. Conclusions: The in-house developed CHO model and human observer correlated very well for the application on 2D digital mammography acquired with different tube voltages. The overlapping range of CI95 of the dtr for the tested kVp shows that the tube voltage setting does not significantly affect the detectability of microcalcifications neither by the CHO model nor by the human observer.

Keywords: CHO; microcalcifications; mammography

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A224

Characterization of a Small Field of View Hybrid Gamma Camera

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Purpose: A small field of view (SFOV) handheld hybrid gamma camera has been developed for intraoperative and bedside optical and gamma imaging. The purpose of the study was to assess the characteristics of the hybrid camera. Methods: The performance of the camera system was assessed in-house using newly developed test protocols. The tests included uniformity, sensitivity, spatial resolution, spatial linearity, count rate capability, detector head shielding leakage, optical-gamma image alignment, as well as optical image quality assessment. Image analysis was carried out using IDL software v8.5.1, ImageJ 1.50b, MATLAB® R2015b and GraphPad Prism version 6.07 for Windows. The performance of hybrid gamma cameras was compared with a conventional large field of view (LFOV) gamma camera. Results: The results of the characterization work were obtained and served as baseline for performance of the camera system. This provided a better understanding of the characteristics of the camera, and was particularly useful for optimization work. The SFOV camera was superior in term of resolution and linearity in comparison with the LFOV camera. Conclusions: The testing protocols were successfully applied to characterize a hybrid gamma camera for medical use. These tests formed a complete and rigorous testing scheme to assess SFOV hybrid gamma cameras.

Keywords: Hybrid gamma camera; performance test; characterization

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A225

Operator Motion Effects of a Small Field of View Hybrid Gamma Camera: To Hold or Not to Hold, that is the Question?

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Purpose: Recording gamma images using a handheld small field of view (SFOV) hybrid gamma camera requires a few minutes to complete acquisition. Operator motion during image acquisition may deteriorate image quality and hence affect diagnostic accuracy. The purpose of the study was to assess the magnitude of movement caused by the operator when holding a camera weighing approximately 1kg. Methods: Six participants were invited to take part and given full explanation of the study. The SFOV hybrid gamma camera was used to acquire gamma image of a radioactive point source containing approximately 15 MBq of 99mTc-pertechnetate placed at source-to-collimator distance of 7 cm. Each participant was requested to hold the camera for 3 minutes at their convenience during image acquisition in a clinical setting. A control image was acquired with the camera head mounted on a fixed articulated arm. The scintigraphic images obtained were post-processed and saved as DICOM images prior to assessment using bespoke software (MOCO) to determine the magnitude of motion by tracking the centre of mass (COM) of the hot spot. Results: From this study the COM was found to move away from the centre by 4.34 ± 2.43 mm and 7.18 ± 3.34 mm in x and y directions respectively. Subjective assessment of the images acquired with the camera held by an operator showed blurring of details when compared to the control image. The mean COM displacement for the first 30 seconds of the image acquisition was less than 5 mm; however it exceeded 5 mm after one minute of acquisition. Conclusions: This study suggests that the image acquisition time of the SFOV gamma camera should preferably be within a minute when the camera is handheld during use.

Keywords: Hybrid gamma camera; operator motion; handheld

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Anisotropy and Stiffness Effect on Shear Wave Elastography Measurement: A Phantom and *In Vivo* Renal Study

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Purpose: To evaluate the effect of anisotropy and stiffness on shear wave elastography (SWE) measurement using point shear wave elastography (pSWE), two-dimensional shear wave elastography (2D SWE) and dynamic mechanical analysis (DMA) test. Methods: For anisotropy *ex vivo* phantom study, SWE were performed on 4 ruminant kidneys. For anisotropy *in vivo* study, 6 patients were recruited for SWE. Stiffness were measured at renal cortex when shear wave 90° and 0° to loops of Henle. For stiffness phantom study, SWE were performed on 7 phantoms with different gelatin concentration. For stiffness *in vivo* study, pSWE were performed on 9 patients with different interstitial fibrosis severity. DMA test were conducted on all phantoms. Results: In anisotropy *ex vivo* phantom study, Wilcoxon rank sum test showed significant median difference of stiffness values between 90° and 0° ($p<0.05$), with the 90° showing lower stiffness values for SWE and DMA test. In anisotropy *in vivo* study, Spearman's correlation indicated negative correlation between pSWE ($r = -0.495$, $p < 0.001$), 2D SWE ($r = -0.627$, $p < 0.001$) with the degree of angulation. In stiffness phantom study, Spearman's correlation showed positive correlation between pSWE ($r = 0.870$, $p<0.0001$), 2D SWE ($r = 0.969$, $p<0.0001$), DMA ($r = 0.877$, $p<0.0001$) with gelatin concentration. In stiffness *in vivo* study, Kruskal Wallis test reported mean rank SWE score of 2 for 0% fibrosis, 5 for <25% fibrosis, 7.5 for 25%-50% fibrosis and 9.5 for > 50% fibrosis ($p=0.037$). Conclusions: The nature of anisotropy and stiffness affect the SWE measurement. These factor should be recognized prior applying SWE for the interpretation of the measured values.

Keywords: Anisotropy; shear wave elastography; stiffness

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The Eye Lens Dose Measurement and Image Quality Study using Two CT Brain Protocols: Phantom Study

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Purpose: To measure the eye lens dose and calculate the contrast to noise ratio (CNR) using two CT brain protocols in head phantom. According to ICRP 103, the reduction of the eye lens dose limit from 150 to 20 mSv per year was recommended in 2011. The CT brain protocol had been reviewed on new CT scan and special software technique was applied for eye lens dose reduction. Methods: Two CT Brain protocols with and without organ dose modulation, ODM software, GE Revolution CT were applied on anthropomorphic head phantom at emergency unit of Radiology Department, King Chulalongkorn Memorial Hospital. The OSL Nano Dots had been used to measure doses at 7 positions of left and right eyes, ears, and thyroid including one point of occipital area respectively. The image quality has been evaluated in terms of CNR for four regions of different density. Results: The eye lens doses with and without ODM protocols at left and right eyes were 26.08, 26.14, 36.69 and 34.72 mGy respectively. While the CNR at four regions with and without ODM protocols were 19.02, 103.96, 47.74, 145.07 and 23.55, 109.94, 56.94 and 186.63 respectively. Conclusions: The ODM software for brain protocol should be used to reduce the eye lens dose while the image quality in terms of CNR was at little decrease with ODM.

Keywords: Eye lens; image quality; OSL Nanodot; ODM

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A239

Phase-Sensitive Inversion Recovery (PSIR) Segmented IR Turbo FLASH Sequence: A Tool to Assess the Optimal TI to Null Myocardial

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Purpose: To find the precise value of Inversion Time (TI) to null normal Myocardial in Delayed Enhancement (DE) Cardiac Magnetic Resonance Imaging (CMR) by using Signal Intensity of Phase Sensitive Inversion Recovery (PSIR) image. Methods: Stress CMR or Perfusion CMR Studies were studied by 3T scanner (Siemens, Skyra) on March-May 2018 and all studies were no evidence of myocardial scarring. Use of Late Gadolinium enhancement imaging, which were acquired 10-20 min after injection contrast dose(0.1mmol/kg) in single slice Short axis(SAX) view. Place ROIs on 4 locations of Left Ventricle myocardial wall as Anterior, Inferior, Septal and lateral walls, slice by slice from base to apex to measure the mean value of Signal Intensity in PSIR image. Results: The accuracy of setting the null TI depends on operator expertise, contrast agent, and patient tolerance t additional breath-hold acquisitions. When we measure SI in PSIR image the result shows mean values of Signal Intensity (SI) precision to null myocardium in PSIR image around 2000-2100. If SI is lower than 2000 the MAG image shown bright gray, the same as SI higher than 2100 also. Conclusions: Measurement SI Value in PSIR image is usable to assess the Late Gadolinium Enhancement (LGE).

Keywords: CardiacMR; delayed enhancement; phase sensitive inversion recovery

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Performance of X-ray Beam Collimation of Fluoroscopes: National Survey in Taiwan

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Purpose: To evaluate the performance of x-ray beam collimations of fluoroscopes. The beam collimation is to limit the x-ray beam to the image intensifier or the image receptor for safety reasons and to keep the amount of patient tissue being exposed to x-rays equal to the region being imaged. If the collimator blades are set too wide for each FoV, additional patient tissue will be unnecessarily irradiated. Methods: Radiation fields were measured using Gafchromic-film strips placed along the two axes of the fields. On-site measurements for four types of fluoroscopes were conducted in Taiwan. Neither the length nor the width of the x-ray field in the plane of the image receptor shall exceed that of the visible area of the image receptor by more than 3% of the source-to-image distance (SID). The sum of the excess length and the excess width shall be no greater than 4% of the SID. Results: This survey included 669 fluoroscopes over about 1500 fluoroscopes in Taiwan from April 2014 to June 2018. The pass rates are 53% (83/156) for the remote-control fluoroscopy; 95% (170/179) for c-arm fluoroscopy; 66% (148/224) for portable c-arm fluoroscopy; 60% (66/110) for the fluoroscopy used in Extracorporeal shock-wave lithotripsy (ESWL). Conclusions: The collimations of c-arm fluoroscopes for angiography/cardiology fit better with the image receptors. However, almost half of the remote-control fluoroscopes cannot fulfill the criteria. It needs to pay attention to that patients underwent fluoroscopy using remote-control fluoroscopes might obtain more radiation dose and worse image quality.

Keywords: Fluoroscopy; collimation assessment; national survey

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Investigation on Factors Affecting Occupational Eye Lens Doses and Appropriate Dosimeter Position during Cardiac Catheterization: A Phantom Study

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Purpose: Cardiologists who perform cardiac catheterizations may exceed new occupational eye lens dose limits. Our study aimed to investigate factors affecting occupational eye lens doses during cardiac catheterization and determine the appropriate dosimeter position for measuring occupational eye lens doses. Methods: Small optically stimulated luminescence (OSL) dosimeters were placed 3 mm from the surface of a house-made cylindrical acrylic head phantom, corresponding to the positions of left and right eye lenses. The head phantom was secured to a thoracic phantom and OSL dosimeters placed along the left and right sides of the neck, so as to simulate an operator. A body phantom was irradiated using 15-min fluoroscopy mode of two projections, or 10-s cine mode of 15 projections. We compared the air kerma obtained from each dosimeter while changing height of the head phantom, and angle and position of the head phantom. Results: The air kerma at the eye positions decreased as the phantom height increased. The air kerma at the left neck position was higher than those at other positions. As the head phantom was angled away from the X-ray tube, the air kerma decreased at the left and right eye positions. When positioned for a radial approach, the air kerma was higher than that observed during the femoral approach. Conclusions: During cardiac catheterization, occupational eye lens doses are affected by operators' heights, face angles, and standing positions. When a dosimeter is positioned alongside the neck, occupational eye lens dose can be evaluated on the "safe" side during cardiac catheterization.

Keywords: Dose; measurement; eye lens; cardiac catheterization

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Axial Absorbed Dose Distributions with Different Tube Voltages during Abdominal CT: Measurement and the Monte Carlo Simulation Study

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Purpose: Low X-ray tube voltage CT acquisitions are widely used to increase contrast enhancement and decrease the radiation dose; however, tube voltage also influences axial dose distribution that varies according to patient size. The aim of this study was to evaluate the effect of tube voltage on axial absorbed dose distributions during abdominal CT acquisitions, based on measurement and Monte Carlo simulations. Methods: A medium-sized abdominal phantom, which had holes for inserting a pencil ionization chamber, was acquired with a 192-slice dual-source CT scanner at tube voltages of 70, 80, 100, 120, and 140 kVp, and with a displayed volume CT dose index of 5.0 mGy. The pencil ionization chamber and an electrometer were used for measuring absorbed doses, and normalized absorbed doses to center were calculated for all measurement points. The normalized absorbed doses were simulated using the Particle and Heavy Ion Transport code System (PHITS) version 3.02, through large-, medium-, and small-sized abdominal phantoms. Results: During measurement, the maximum normalized doses were 3.07, 2.79, 2.36, 2.15, and 2.09 for 70, 80, 100, 120, and 140 kVp, respectively. In the Monte Carlo simulation, the maximum normalized doses with the medium-sized phantom were 3.14, 2.68, 2.28, 2.04, and 1.92 for 70, 80, 100, 120, and 140 kVp, respectively. When the phantom size was larger, higher normalized doses were observed at peripheral regions under the same tube voltage. Conclusions: During abdominal CT, normalized doses are higher at peripheral regions when larger phantoms are acquired with lower tube voltages.

Keywords: CT; tube voltage; dose; measurement; Monte Carlo simulation

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Quantitative Assessment of Liver Function using 99mTc-Sulfur Colloid SPECT

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Purpose: The assessment of liver function is essential in diagnosis and assessment of therapy of liver diseases. Single-photon emission computed tomography (SPECT) allows the assessment of liver function and measurement of functional liver volume. Several studies reported SPECT imaging of liver using some radiotracers, such as 99mTc-GSA and 99mTc-mebrofenin. In this study, liver function was observed using 99mTc-labelled sulfur colloid SPECT imaging. Methods: 99mTc-labelled sulfur colloid was administered intravenously in the arm area and scanned using SPECT. Images were then processed and liver uptake value (LUV) was calculated to get time activity curve (TAC). Liver function was obtained from calculation of TAC and other parameters. Results: Liver function was obtained from 99mTc-labelled sulfur colloid SPECT imaging and compared with the result from other techniques. Conclusions: The quantitative assessment of liver function can be acquired using 99mTc-labelled sulfur colloid SPECT imaging and the results are comparable to those of other techniques.

Keywords: SPECT; 99mTc; liver; hepar; sulfur colloid; gamma camera; nuclear medicine

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Longitudinal Relaxation Time of Bone Marrow Tissue at 3T

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Purpose: To measure the longitudinal relaxation time (T1) of red marrow and yellow marrow using MRI at 3.0 Tesla (3T). Methods: T1 map for the left femur of eight healthy volunteers (mean and sd,) were acquired using 3T MRI with an 18–channel body matrix coil. Dual flip angle spoiled gradient echo method was applied in this study. B1 mapping was performed to correct for B1 – inhomogeneity effects on T1 values. Three to five regions of interest (ROIs) were drawn for each type of marrow on every subject. T1 values of red and yellow marrow were compared. Results: The distribution pattern of bone marrow on T1 map and physiological distribution of bone marrow conversion agree with each other. The mean T1 value of red marrow is significantly higher than yellow marrow but widely varies due to the ongoing conversion of red–to–yellow bone marrow (903.6 ± 99.1ms vs. 522.2 ± 38.9ms; $p < 0.001$). Conclusions: These results can be applied for optimization of clinical MRI and research investigations of bone marrow.

Keywords: MRI; relaxation times; bone marrow

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Dosimetric Characterization of Optically Stimulated Luminescence Dosimeter to Dual-Source Dual-Energy Computed Tomography

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Purpose: Our study aimed to evaluate the properties of small optically stimulated luminescence dosimeters (OSL) for dual-source dual-energy computed tomography (DECT) dosimetry in terms of energy dependence, angular dependence, and dose dependence. We compared these measures obtained during DECT with those obtained during single-source single-energy CT (SECT). Methods: The properties were investigated from the ratio of air kerma measured by an ionization chamber to those by OSL. The energy dependence was evaluated from 70 to 150 kV, Sn150 kV and 80/Sn150 kV. The angular dependence was evaluated from 90° to -90° at 80, 120, Sn150 and 80/Sn150 kV: 0° means X-ray was irradiated parpendicular to OSL dosimeter, and plus and minus mean clockwise and anti-clockwise positions, respectively. The dose response was evaluated from 1 to 150 mGy at 80, 120, Sn150 and 80/Sn150 kV. Results: SE and DE dose responses differed by 3.8% under equivalent effective energy. The angular dependence observed at 80/Sn150 kV was larger than that at 120 kV. The dose response at 80/Sn150 kV had good linearity from 1 to 150 mGy, but at its maximum, deviated by 8.4% from the dose response at 120 kV. Conclusions: OSL dosimeters have a potential for dose measurement in DECT, but the properties of OSL dosimeters are different are different during DECT and SECT.

Keywords: Dosimetry; optically stimulated luminescence dosimeter; dual energy computed tomography

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Determination of Secondary Particles for Electronic Portal Imaging Device Imaging Using Incident Electron Beam

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Purpose: Electronic Portal Imaging Devices (EPIDs) have been investigated as a potential tool for *in-vivo* dosimetry for radiotherapy. Previous researches suggest that secondary particles such as bremsstrahlung photons can be utilized for electron beam EPID imaging. This study aims to give information on the properties of the secondary particles to help improve the electron beam EPID image quality. Methods: Monte Carlo simulations are conducted using GATE. The virtual set-up is composed of a target enclosed by planar detectors and a radiation source. The composition of the target is varied using water, muscle, skull and rib bone while the incident electron beam energy is varied as 4 MeV, 6 MeV, 9 MeV, 12 MeV, 15 MeV, 16 MeV, 18 MeV, and 20 MeV. Tracking detectors were placed around the target to record the particle type, the kinetic energy, position and direction, and creator process of each particle. Results: The results show that the abundance and the average kinetic energy of the secondary particles detected depend strongly on the incident electron beam energy and target material. The secondary particles detected are dominantly bremsstrahlung photons and their abundance decreases with increasing target material density. The significant amount of highly energetic secondary electrons and secondary photons from Compton scattering and pair production detected suggests that effective filtering of these particles is necessary. Conclusions: The composition of imaging beam for electron beam EPID imaging was investigated. The number of secondary particles detected is much higher for the detector placed downstream the target and hence the most practical placement of EPID.

Keywords: *In-vivo* imaging; electron beam; secondary particles

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Functional Alterations and Plasticity in Patients with Different Location, Types and Sizes of Brain Tumour: A Systematic Review of Resting State-fMRI Study

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Purpose: In the last two decades, there have been increases in studies using resting-state functional Magnetic Resonance Imaging (rs-fMRI) to explore the brain's functional changes and plasticity in patients with brain tumours. However, it remains unclear on the mechanism of brain changes as associated with tumour growth, type and location of how these tumours alter and affects the functional connectivity. Therefore, we conducted a systematic literature search of brain tumours and rs-fMRI studies that investigated brain pathological changes due to the tumour growth. Method: A systematic literature search of brain tumours and rs-fMRI studies was carried out. Fourteen independent studies were identified comprising of adults especially older adults with age ranges between 20 – 75 years old. Six studies reported right handed participants, two studies using both right or left-handed and the rest did not report the handedness. Conclusion: In comparison to healthy controls, rs-fMRI demonstrated that the connectivity of the default mode networks (DMN) were reduced and majority of studies identified distortions of networks in the presence of tumours. However, networks were preserved in the presence of a tumor, although they were often shifted from their normal anatomic position. Abnormalities of low frequency spontaneous brain activity were observed. Studies also demonstrated the alterations in rs-fMRI were related to poorer neuropsychological task performance.

Keywords: Brain tumour; rs-fMRI; DMN; functional changes and alteration

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fMRI Tasks used to Evaluate the Broca's and Wernicke's Area in Frontal Lobe Tumour Patients: A Systematic Review

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Purpose: In the past, the mapping of eloquent areas could be deliberately localized by the Invasive Wada test. Recently, fMRI can be employed to non-invasively localize the eloquent areas for pre-surgical mapping. However, fMRI localization is very dependent on the task paradigm used. Furthermore, it remains unclear what types of fMRI tasks are most suitable to activate the Broca's and Wernicke's areas, as too many areas are related to speech processing. In the present study, a systematic review was used to evaluate the fMRI task that can activate these areas. Methods: A systematic literature search of brain tumours and fMRI studies that activated Broca's and Wernicke's areas was conducted. Fourteen independent studies were identified comprising of 361 adults' participants consisting of 218 brain tumours patients with different types and size in frontal lobe, and 143 healthy controls. Four studies reported right handed participants, three studies using both right or left-handed and the rest did not report the handedness. Results: Of 1932 initial studies, 14 met eligibility criteria for inclusion, reporting the study that evaluate Broca's and Wernicke's areas of brain tumour located in the frontal areas before surgery. Results demonstrated that, word generation and sentence generation were mostly used to evoke Broca's and Wernicke's areas. Conclusions: Word generation and sentence generation can be used to activated Broca's and Wernicke's areas. Therefore, both tasks can be used for pre-surgical planning to localize language areas and may represent an important contribution toward the standardization of presurgical language mapping using fMRI.

Keywords: Brain tumour; fMRI; DMN; Broca's and Wernicke's areas

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The Measurement of Transverse Relaxation Time (T2) Using Histogram From ROI Setting in Muscle Activity Study at 1.5 Tesla MRI

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Purpose: Exercise induces increasing T2 of muscle in comparison to T2 before exercise. Previous studies, exercised physiology used multiple-spin-echo (MSE) sequences for calculating T2 and several ROIs were selected within the target tissue in the images. This method may not reflect all the properties of the target tissue. The purpose of this study is to investigate the possibility of histogram for analysis of muscle activity induced by exercise. Methods: Right quadriceps femoris (QF) were performed by MSE on 1.5T whole-body MR scanner. Subjects performed knee extension exercise of 200 times and MR images were acquired at rest and after exercise. T2-images were calculated by mono-exponential least-squares by T2-weighted images. ROI were placed on rectus femoris (RF) and vastus lateralis (VL). For the setting of ROI, the conventional method was used the average value acquired by the values of several points in target muscle, and our method employed the histogram and mode by selecting whole target muscle. Results: Before exercise, T2 of both muscles were not significantly different by the method, however T2 calculated by the conventional method tends to be slightly higher than our method. RF after exercise confirmed the significant difference of T2 in both methods, however, VL was no significantly different between the resting values of both methods. On the other hand, the tendency of T2 increasing confirmed from the histogram of VL. Conclusions: T2 analysis using histogram suggested comprehending the muscle activity which could not be confirmed by the conventional method.

Keywords: T2; ROI; multiple-spin-echo

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Optimization of Digital Radiography Systems using In-House Phantom: Preliminary Study

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Purpose: The purpose of this study is to obtain information on optimum exposure parameter combination on simulated chest and abdomen examinations using Direct-Digital Radiography (DR) and Computed Radiography (CR) systems. In house phantom dedicated for quick QC is utilized as an image quality quantification tool in term of contrast. Methods: The optimization was performed on Philips Essenta DR, CR Fuji Profect CS, and CR Agfa 10-X. Chest examination was simulated by stacks of cork sandwiched between two 2 cm PMMA (Polymethyl Methacrylate) slabs, while abdomen examination was simulated by various thickness of PMMA. The surface dose was measured using RadCal 10 x 6-6 ion-chamber dosimeter. Exposures were performed using clinical setting with combinations of kVp, mAs, filters, and simulated patient thickness. Three steps of optimization methods were performed, first the value of kVp was varied from 55 kVp to 66 kVp for chest examination and from 81 kVp to 102 kVp for abdomen examination, secondly the obtained optimum kVp was used with mAs variations, thirdly the optimization results from these two steps was used for final optimization with using 4 types of added filtration provided by manufacturer. All steps of optimization were used for each chest measurements (15 cm, 20 cm, 24 cm) and for abdomen measurements (20 cm, 25 cm, 30 cm). The Figure of Merit (FOM) was employed as optimization parameter, calculated as ratio between squared Signal Difference to Noise Ratio (SDNR) and surface dose for every measurements. The image quality was evaluated using Modulation Transfer Function (MTF) and Contrast Consistency (CV). Results: Based on FOM calculations, acquisitions optimization for chest examination using DR was obtained on 55-63 kVp, 5-8 mAs, with additional filter 1 mmAl + 0.1 mmCu and 1 mmAl + 0.2 mmCu. For abdomen examination, the optimized results were 96-102 kVp, 8-12.5 mAs, with the same additional filters. On the other hand, the optimized results using CR on chest examination were on the range of 55-63 kV, 4-8 mAs, also with the same additional filters with DR. The results of optimization of abdomen examination were on the range of 90-102 kV, 8-10 mAs, and again with the same additional filters. Conclusions: This gave information that different image receptors used on the same x-ray unit will require slightly different optimization conditions, particularly on mAs.

Keywords: Digital radiography; figure of merit; optimization

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Comparison of Automated SNR Measurement and Universal Image Quality Index in Homogeneous Phantom CT Image

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Purpose: This study compared an automated SNR (signal to noise ratio) measurement to universal image quality index for homogenous phantom with various kernel sizes and various HU threshold values for different slices. Methods: Automated noise calculation was built as a platform to calculate noise automatically. First step was to create binary density slice using threshold values. Then, masked image was performed by masking original image and binary image. Standard deviation of every pixel for a certain kernel size was calculated by using a sliding window operation. The forth step was to make a noise histogram from the noise map, and determine the final noise in the image as the histogram peak. Then this calculation was normalized by the peak of HU histogram. All these steps were done with various threshold values, various kernel sizes for different slices in homogenous phantom. Besides that, universal image quality index was calculated as the product of three components: correlation coefficients, mean luminance, and contrast luminance. Relationship between universal image quality and automated noise measurement was investigated. Results: Kernel size has to be chosen based on organ size. If kernel size is too small, large noise will not be calculated. But if kernel size too big, boundary will also be calculated. HU threshold range must be selected based on majority HU values in the image. Automated SNR calculations compared to manual quality image index are inversely related. Conclusions: Quality image index is inversely correlated with automated noise calculation.

Keywords: Automated noise calculation; kernel; HU threshold; universal quality image index

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Optimization of Simulated Cranial, Thorax, and Abdominal Examination in Pediatric Digital Radiography

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Purpose: The purpose of this study was to obtain optimum parameter combination in simulated cranial, thorax, and abdominal examinations using computed radiography (CR) and direct digital radiography (DDR) systems. Methods: Optimization using in-house phantom was performed on Siemens Luminos Agile Max DDR and Siemens Axiom Luminos TF CR. Pediatric patients were selected and separated into four age groups; 0-1 year (group A), 1-5 years (group B), 5-10 years (group C), and 10-15 years (group D). Slab phantoms of 12.5, 14, 14.5, and 15 cm thickness were selected to represent groups A, B, C, and D for cranial examination; 14, 17, 20, and 24.4 cm for thorax examinations, and 14, 16.5, 20, and 23 cm for abdominal examinations. Three-steps optimization were performed; initiated with the first step being kVp selection ranging from 41 to 51 kVp for cranial, 41.5 to 51 kVp for thorax, and 44 to 60 kVp for abdominal examinations. The optimum kVp were used while subsequently the mAs values being varied to find optimum tube current. Finally, optimum kVp and mAs were used to select added filtrations. All the steps of optimization were performed based on FOM (figure of merit) values calculated as ratio of squared SDNR (signal difference to noise ratio) and entrance surface dose with the highest FOM representing the optimum condition. Results: The results of this optimization were evaluated based on the highest FOM generated from each exposure. For DDR, in cranial examination, the highest FOM are generated by exposure factors of 44 kV, 3.2 mAs, and 0 mmCu filter (group A), 46 kV, 5.6 mAs, and 0.1 mmCu filter (group B), 49 kV, 7.1 mAs, and 0.1 mmCu filter (group C) and 50 kV, 9 mAs, and 0.3 mmCu filter (group D). For thorax examination, the highest FOM value is generated by exposure factor 45 kV, 2.5 mAs, and 0.2 mmCu (group A), 45 kV, 4 mAs, and 0.2 mmCu (group B), 46 kV, 5.6 mAs, and 0.2 mmCu (group C), and 47 kV, 6.3 mAs, and 0.2 mmCu (group D). For abdominal examination, the highest FOM value is produced by exposure factor 48 kV, 4 mAs, and 0.1 mmCu (group A), 50 kV, 6.3 mAs, and 0.2 mmCu (group B), 53.5 kV, 8 mAs, and 0 mmCu (group C), and 58.5 kV, 8 mAs, and 0 mmCu (group D). Even with different X-Ray units, the CR device had slightly similar optimized parameters. Conclusions: The results of this study can be recommended as a local reference parameter combination in clinical use for pediatric image acquisition using Siemens Luminos Agile Max DDR and Siemens Axiom Luminos TF CR.

Keywords: Optimization; digital radiography; image quality; dose

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Characterization of Computed and Direct Digital Radiography Images using In-house Phantom for Quick QC: Preliminary Study

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Purpose: In this study, two Computed Radiography (CR) receptors and two Direct Digital Radiographic receptors based on two different manufacturers on each units; Fuji and Agfa (CR), GE and Phillips (DR), are characterized in terms of detector sensitivity and image quality. An in-house phantom was employed to study the general characteristics dedicated for quick QC for digital radiography. Methods: Two CR receptors (Agfa CR-85X and Agfa CR-10X) and two DDR receptors (Brivo DR-F and Essenta) were characterized in this study. An in-house phantom was specially designed to accommodate image quality assessment. This phantom includes circular pits with four different sizes and four different depths, as well as 1 mm of copper sheet for MTF measurement with slanted edge method. The image receptor dose measurements were performed using Radcal 10 x 6-6. The quantitative aspect that were used to characterize these unit are the correlation between Pixel Value and image receptor dose. Evaluation of image quality from receptor based on SDNR of each objects images. The results represented by coefficient of variance (CV), ratio of standard deviation and mean of SDNR from pit images with different size, and coefficient of linearity (CL), correlation between difference of logarithmic SDNR and sum of minimum and maximum logarithmic SDNR from pit objects with different depth. On the other hand, modulation transfer function (MTF) were evaluated using the modules that are available dedicated for this in-house phantom. Results: Characterization results on Brivo DR-F GE shown on inverse curve with positive linear correlation between pixel value and image receptor dose. Linear correlation also illustrated on the curve of pixel value against the image receptor dose on Essenta DR. On the other hand, Agfa CR-10X and Agfa CR-85X shown polynomial correlation between pixel value and the imaging plate dose. Brivo DR produced the optimum contrast linearity for simulated abdomen at 6.4 mAs for each kVp that were used. On the other hand, the optimum CV was obtained on 12.5 mAs for each kVp. On the MTF side, the result shown the highest MTF was found at 55kV tube voltage. Essenta DR yield a slightly different result from Brivo DR-F GE for the CL and CV values with an optimum CL found at 4.5 mAs for each kVp, an optimum CV found at 12.5 mAs for each kVp. From the MTF side the result shown that the highest value was obtained at 77 kV tube voltage. On the CR side, the CR-85 X produced the optimum CL at 10 mAs for each kVp that were used, and the optimum CV was obtained at 12.5 mAs. The highest MTF 10% value was found at 70 kV tube voltage.

Keywords: Characterization; digital radiography; image quality; phantom

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Classification of Urinary Stones Based on Edge Detection using Semi-Automatic Threshold

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Purpose: Urinary stones are commonly differentiated into 4 types; calcium, struvite, cystine, and uric acid. While two of them such as, cystine and struvite could not be differentiated easily, in fact, they need different kind of treatments. Significantly, the purpose of this study was to classify of urinary stones based on edge detection using semi-automatic threshold. Methods: Five urinary stones were scanned using eight sources voltage. The source voltage were 65, 75, ..., 115 kV. The parameters, such as of 0.20 step rotation, 13.89 μm resolution, and 1 mm aluminum filter were consistent. Each scanning produced 1200 images which were reconstructed using Nreconstruction software. The parameters of reconstruction were related to beam hardening, ring artefact correction, and smoothing. The reconstructed images were quantified in CT Analyzer 1.16.4.1. The region of interest (ROI) was a circle with a diameter 275 pixels as well as semi-automatic threshold were drawn on the reconstructed image. Results: Based on the HU analysis, there were three groups of urinary stone on source voltage of 85 kV. The first group (struvite) were consisted of stone number 1 (461.42) and 3 (489.05). The second group (cystine) were consisted of stone number 2 (55.08) and 5 (-233.41). The third group was stone number 4 (634.18). Conclusions: The edge detection using semi-automatic threshold can classify five urinary stones into 3 types; struvite, cystine, and the other group.

Keywords: Threshold; urinary stones; hounsfield unit

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Patient-Specific Three-Dimensional Printed Pulmonary Artery Model: A Preliminary Study

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Purpose: To develop a 3D printed pulmonary artery model and test different computed tomography (CT) scanning protocols for determination of an optimal protocol with acceptable image quality but low radiation dose. Methods: A patient-specific 3D printed pulmonary artery model was created based on contrast-enhanced CT images in a patient with suspected pulmonary embolism. Different CT pulmonary angiography protocols consisting of 80, 100, and 120 kVp, pitch 0.7, 0.9, and 1.2 with 1 mm slice thickness, and 0.6 mm reconstruction interval were tested on the phantom. Quantitative assessment of image quality in terms of signal-to-noise ratio (SNR) was measured in the images acquired with different protocols. Measurements in pulmonary artery diameters were conducted and compared between pre-and post-3D printed images and 3D printed model. Results: The 3D printed model was found to replicate normal pulmonary artery with high accuracy. The mean difference in diameter measurements was <0.8 mm (<0.5% deviation in diameter). There was no significant difference in SNR measured between these CT protocols (P = 0.96–0.99). Radiation dose was reduced by 55% and 75% when lowering kVp from 120 to 100 and 80 kVp, without affecting image quality. Conclusions: It is feasible to produce a 3D printed pulmonary artery model with high accuracy in replicating normal anatomy. Different CT scanning protocols are successfully tested on the model with 80 kVp and pitch 0.9 being the optimal one with resultant diagnostic images but at much lower radiation dose.

Keywords: Diagnosis; image quality; model; three-dimensional printing

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Optimisation of CT Pulmonary Angiography Protocols using 3D Printed Model with Simulation of Pulmonary Embolism

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Purpose: To investigate optimal computed tomography pulmonary angiography (CTPA) protocols for detection of pulmonary embolism based on a 3D printed pulmonary model. Methods: A patient-specific 3D printed pulmonary artery model was generated with thrombus placed in the bilateral main pulmonary arteries to represent pulmonary embolism. The model was scanned with 128-slice dual-source CT with slice thickness of 1 mm and 0. 5 mm reconstruction interval. The tube voltage was selected to range from 70, 80, 100 to 120 kVp, and pitch value from 0.9 to 2.2 and 3.2. Quantitative assessment of image quality in terms of signal-to-noise ratio (SNR) was measured in the main pulmonary arteries and within the thrombus regions in both sides. Results: Pulmonary embolism was successfully simulated in the 3D printed pulmonary artery model. There were no significant differences in SNR measured between these CTPA protocols (P = 0.07–0.92), regardless of the kVp or pitch value used. SNR in the main pulmonary arteries was the lowest in the 70 and 80 kVp protocols, highest in the 120 kVp protocol. In contrast, SNR within the thrombus was higher in the 70 kVp protocol than higher kVp protocols. Radiation dose was reduced by 33% and 89% when lowering kVp from 120 to 100, 80 and 70 kVp with use of 3.2 high-pitch protocol, without significantly affecting image quality. Conclusions: Low-dose CT pulmonary angiography can be achieved with use of low kVp and high-pitch protocol with significant reduction of radiation dose with acquisition of diagnostic images of pulmonary embolism.

Keywords: Diagnosis; image quality; model; three-dimensional printing

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Factors Affecting Standardized Uptake Value of ^{99m}Tc-MDP Bone SPECT/CT: A Phantom Study

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Purpose: The aim was to study factors affecting standardized uptake value (SUV) of ^{99m}Tc-MDP bone SPECT/CT using a NEMA body phantom. Methods: A NEMA phantom with 6 spheres (10 mm to 37 mm) was used. The background activity concentration of ^{99m}Tc was 18 kBq/cc and tumor-to-background ratio of 4:1 was studied. The data were acquired three times with clinical bone SPECT/CT protocol. The OS-EM algorithm with corrections for attenuation, scatter, and resolution recovery was used to reconstruct the 3D images using 10 subsets and varying the iteration numbers from 1 to 5. For each iterative update, no post-filter was applied and SUVs (SUV_{mean} and SUV_{max}) were measured for each sphere using Q. Metrix software. Moreover, three cut-off frequencies of Butterworth filter including 0.35, 0.48, and 0.50 cycle/cm with an order of 10 were investigated at optimal iterative update. The percentage difference (%difference) of both SUVs for each sphere was calculated. Results: Both SUVs tended to increase at small iterative update and decreased afterwards for all spheres when no filter was applied. The %difference of SUV_{mean} ranged from -23.85 to -26.43 for 37-mm sphere, and -40.49 to -50.93 for 17-mm sphere. Moreover, the %difference of SUV_{max} ranged from 25.39 to 38.13 for 37-mm sphere and -14.18 to -17.82 for 17-mm sphere. For 20 iterative update, both SUVs were highest when filter cut-off frequency was 0.48 cycle/cm. Conclusions: Measurement of SUVs from SPECT/CT imaging is feasible. However, the iterative update of OS-EM and cut-off frequency of Butterworth filter can affect both SUVs.

Keywords: SUV; ^{99m}Tc-MDP; SPECT/CT

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An Acceptable Image Quality Assessment and Diagnostic Reference Level (DRL) on CT Scan Study in Hospital Sungai Buloh

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Purpose: Computed tomography (CT) is considered one of the most important methods of medical imaging employed nowadays, due to its non-invasiveness and the high quality of the images it is able to generate. Therefore, it is important to know and to control the dose distribution in patient by varying the image acquisition parameters. The overall aim of this study was to find an optimization approach to minimize the exposure dose to patients undergoing examinations, while maintaining the diagnostic image quality and evaluate acceptable image quality assessment in CT scan. Methods: In this study, a retrospective analysis was conducted seven types of examination include head CT adult, head CT Children, head CT Stroke Adult, CT Thorax Adult, CT Abdomen and CT Urethrography (CTU) was chosen to evaluate the image quality and the patient radiation dose. A random sample of 20 patients in each of CT examination was used. Pre data study was collected on August to September 2017 while post data study was collected on November to December 2017. Image quality scoring was done by five in-house radiologists subjectively compared CT image quality, noise, and artifacts from all groups. Results: Mean percentage of DLP reduction between pre and post data were 28.0 % for head CT adult; 6.2 % for head CT Children; 19.0% for head CT Stroke Adult; 74.0 % for CT Thorax adult; 2.8 % for CT Abdomen and 58.0 % for CTU, respectively. The mean image quality score were score 3 in almost all groups. Conclusions: This study demonstrated pre and post protocol review in CT Scan study and to evaluate image quality also to assess patient radiation dose. The effects of altering tube kV, mAs, beam width collimation, SD, reconstructed slice thickness and scan range have a direct influence on CT dose reduction for head CT adult, head CT Children, head CT Stoke Adult, CT Thorax Adult, CT Abdomen and CTU examinations respectively.

Keywords: CT scan; image quality; radiation dose

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Effect of Pitch on CT Image Quality based on SNR Evaluation using in House Phantom

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Purpose: This study is aimed to evaluate symmetrical effect of pitch factor to SNR (Signal to Noise Ratio) in thorax phantom CT images. Methods: Thorax CT phantom was designed to contain cork and cylindrical objects with several sizes located symetrically respect to Y axis. Phantom size is 20 cm diameter, 22 cm length, and the objects simulated vessels filled with contrast medium (diameter A: 2mm, B: 1.7 mm, C: 1 mm, respectively). Distance between two objects: A: 6 cm, B: 8 cm, and C: 12 cm. Image acquisitions were performed:130 kVp, tube rotation 0.6s, 70 mAs, and pitch values were 0.5, 0.8, 1.0, 1.5, 1.8 and 2.0. CT images represented by 9 axial images with slice thickness of 5 mm. Results: The difference of SNRs (Δ) : value of ΔA, in general high at initial slice and fall significantly up to third slice and then followed by nearly constant value. ΔB at initial slice trend decreased with increasing slice images. ΔC at all pitch initially shown zero value and increase to maximum up to second slice (not more than 20 units) and tend to constant after at sixth slice. Conclusions: Effect of all pitch values on symmetrical object images were influenced by distance between two corresponding objects and slice order. Generally at initial slice, the SNR difference between two corresponding objects (Δ) relatively high compared with the following order slice. Therefore, in clinical practice it is recommended to give additional FOV at least 1.5 cm at initial slice interest.

Keywords: SNR; CT thorax phantom; pitch

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Functional Magnetic Resonance Imaging for Language Mapping in Frontal Lobe Brain Tumour: A Systematic Review

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Purpose: Recent advances in functional Magnetic Resonance Imaging (fMRI) have shown that the brain is capable of significant redistribution of function in response to injury like tumour. However, there has yet to be a systematic review which characterizes differences in regional brain activation, anatomical organization and adaptive functions in brain tumour patients. The objective of this systematic review is to summarize and critically appraise the existing literature examining differences between frontal lobe brain tumour patients and healthy samples using fMRI. Methods: A systematic literature search strategy of brain tumours, fMRI and language was implemented to identify the studies comprehensively. We include studies using fMRI in adult to directly compare brain activation and structure in relation to frontal lobe brain tumour and healthy samples. Studies that meet the inclusion criteria for this review were determined by two independent reviewers. Data were extracted from included studies and narrative review is used to explicate the differences in structural and brain activation correlates of frontal lobe brain tumour. Conclusions: This review provides a needed critical analysis of the fMRI studies that have been conducted investigating brain differences in frontal lobe brain tumour patients to healthy samples. Clarity on the elements of neural activation and structure is seen in patients with frontal lobe brain tumour.

Keywords: fMRI; brain tumour; language

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A297

Comparison of Contrast Enhancement and Image Quality using Different Protocols for Routine Thorax Computed Tomography in Two Centres

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Purpose: To evaluate the degree of contrast enhancement and image quality of thorax computed tomography (CT) using different intravenous contrast administration and scan timing technique. Methods: Data was retrospectively collected from 140 patients [70 each from Advanced Medical and Dental Institute (IPPT), Universiti Sains Malaysia, and Hospital Pulau Pinang (HPP)] who underwent thorax CT using different protocols: group A from IPPT (19 male,51 female; mean age±SD 53.6±11.2 years) using automatic bolus tracking (ABT) with weight-based contrast volume (WBV) technique, and group B from HPP (24 male,46 female; mean age±SD 54.5±13.2 years) using fixed time-delay (FTD) with fixed contrast volume (FV) technique. The degree of enhancement was quantified by measuring Hounsfield unit (HU) values in different arteries and veins, and rated on a 5-point scale (1=very poor,5=excellent) for qualitative assessment. $P<0.05$ was considered statistically significant. Results: The mean enhancement values in group B were significantly greater than those in group A ($P<0.001$). The mean HU±SD in group A and B: ascending aorta 174.8±33.9, 229.2±54.1; superior vena cava 161.9±47.3, 327.9±123.4; pulmonary trunk 170.3±37.8, 227.1±58.5; and pulmonary vein 165.1±35.5, 222.3±53.6, respectively. There was no statistically significant difference ($P=0.185$) between mean enhancement on a 5-point scale in group A (4.4±0.6) and group B (4.3±0.7). A weak correlation was seen between HU values with administered contrast volume ($r=0.1152$). Conclusions: Use of FTD with FV protocol provides a higher degree of contrast enhancement for routine thorax CT examinations. ABT with WBV technique did not demonstrate significantly better CT image quality although with higher grading by assessors.

Keywords: Contrast enhancement; image quality; technique; protocols; computed tomography

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A301

Brain Responses to Vibratory Stimulation of Human Fingertips: An fMRI Study

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Purpose: Stimulation from vibratory devices such as piezoelectric, able to stimulate the cortical responses from somatosensory area during functional magnetic resonance imaging measurement. Methods: Seven healthy right-handed subjects (n=7, age 20 ± 10 years) were scanned with 3.0 T magnetic resonance imaging scanner (Achieva, Philips, Netherlands) with a piezoelectric vibratory attached to the tips of index finger with stimulation of 30Hz, 60Hz, 90Hz, 120Hz, 150Hz, 180Hz, 210Hz, and 240Hz. The functional images were analyzed using MATLAB R2015a and Statistical Parametric Mapping 12 (SPM12) software. Random effects analyses of one-way analysis of variance (ANOVA) were performed within-subject factor of frequency where activated regions were identified with WFU PickAtlas software at $p<.001$ (uncorrected) for multiple comparisons. Results: Main effect of frequency revealed significant activations of somatosensory area at left precentral, left and right postcentral, and right inferior parietal. Significant activation at other region was also detected such as left superior motor area, left lingual gyrus, right superior frontal, and right medial frontal. One-way ANOVA revealed a significant difference between 30Hz and 60Hz at right postcentral gyrus, 120Hz and 150Hz at left precentral, 180Hz and 210Hz at right precuneus, 210Hz, and 240Hz at right superior parietal. There is no significant activation found between 60Hz with 120Hz, and 150Hz with 180Hz. Conclusion: Delivery of various frequency evoke responses from the somatosensory area and neighboring regions thus provide insight into areas activated with varying frequencies. Additional of sample size and the number of measurement will help to provide systematic protocols to further improve the study.

Keywords: Somatosensory; functional magnetic resonance imaging; piezoelectric

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Scattered Radiation Dose Measurement from Brain Computed Tomography and Neuro-Interventional Radiology

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Purpose: To study the scattered radiation doses and their profiles from brain CT and neurointerventional procedures using OSL dosimeters at KCMH. Methods: Anthropomorphic head phantom was used to generate the environment of scattered radiation occurred from brain CT using GE Discovery CT750HD and neurointerventional procedures using Siemens Artis Zee bi-plane with clinical protocols. Jungle Gym (JG), 50 cm length of each paper pipes were connected up to 150 cm height by plastic joints, was setup surrounding the CT gantry and bi-plane C-arm unit include their couch. The OSL dosimeters (nanoDot; Nagase Landauer) were taped every 50 cm apart at each JG connected joint. 3 times signal readouts of each nanoDot were done using Microstar (Nagase Landauer) reader. Scattered radiation profiles were colored plotted. Results: The highest amount of scattered radiation measured from total DLP 4,968.5 mGy.cm of a brain CT protocols was 0.78 mGy in front of gantry next to the isocenter at 150 cm height. While, 1.34 mGy of the highest amount of neurointerventional protocols at 150 cm height where was above the lateral x-ray tube from 20.2 minutes of fluoroscopy mode and 45 frames of cine mode by bi-plane protocols simultaneously. Conclusions: The most typical working points of interventional radiologists for caregivers will be produced very high doses which can induce the lens opacities if without protective goggle using. Both interventional radiology and CT procedures tend to be more increasing examinations per capita. Therefore, QA program by taking the scattered radiation measurement into accounts is necessary.

Keywords: Scattered radiation; brain CT; neurointerventional procedures; Jungle Gym

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Preliminary Study of Ring Artifact Detection in SPECT Imaging using Jaszczak Phantom

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Purpose: To study artifact simulation of SPECT images resulted by disturbance of small copper sheet located on surface LEHR collimator. Methods: Artifact and non-artifact SPECT image have been generated from Siemens Intevo Symbia E SPECT/CT using LEHR (Lower Energy High Resolution) collimator. To simulate artifact, 4 x 4 cm^2 copper sheet located close to detector center. The copper sheets were varied by thickness of 1.00, 0.75, 0.50, and 0.25 mm. Part of Jaszczak phantom dedicated for uniformity study filled with 3 mCi ^{99m}Tc was used for acquisition image. To define ROI, each image were process with Shepp-Logan filter. To confirm the ring shaped artifact, we used Edge Detection and Circle Hough Transform that was provided by imageJ. Histogram of ring artifact and non-artifact area were calculated statistically to determine t-value of each image. From these t-value, the present probability of artifact can be detected. Results: The presence of artifact was characterized by using Edge Detection, then the ring shaped artifact was confirmed by using Circle Hough Transform. From calculation t-value of images homogeneity from each images (confidence level 95% with t-value 1.983), it confirmed that the images with copper thickness of 1.00 mm, 0.75 mm, and 0.50 mm were categorized as artifact. Furthermore, the images with copper thickness of 0.25 mm was not significantly different with homogeneous images. Conclusions: The recent result was not very clear to detect ring artifact accurately, further study in various configuration of copper sheet on detector will be a significant point to be considered.

Keywords: Artifact; copper sheet; Jaszczak phantom; SPECT image

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Image Quality and CT Number Accuracy of Virtual Noncontrast Abdominal DECT Imaging

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Purpose: The purpose of this study is to objectively assess the efficacy of iodine subtraction from abdomen DECT images by evaluating and comparing image quality of the virtual non-contrast (VNC) images to the true non-contrast (TNC) images acquired in dual source (DS), dual energy computed tomography of abdomen CT. Methods: Thirty patients underwent abdomen CT examinations with unenhanced single energy CT (SECT) and enhanced DECT using the third-generation DSCT. The VNC images were generated from DECT datasets using commercial software. The measurement and comparison of Hounsfield unit (HU) between TNC and VNC images were performed by placing volume of interest (VOIs) in 11 different anatomical locations. The standard deviation of HU from circular-ROIs at aorta is an indicator for image noise. The sharpness of object edge was assessed by measuring the slope of HU along a line of liver and visceral fat boarder. Results: Mean attenuation differences between TNC and VNC (HUTNC-HUVNC) images were: right lobe liver-0.97HU, left lobe liver 2.79HU, spleen7.59HU, pancreas 9.44HU, right kidney 9.7HU, left kidney 10.55HU, Fat -12.31HU, muscle 2.35HU, portal vein6.39HU, vena cava12.25HU and aorta 13.64HU. The good correlation between TNC and VNC were found in majority of organs. The image noise was higher in TNC images. The image sharpness was equivalent between TNC and VNC images. Conclusions: The VNC images resulted in equivalent of HU in most organs in abdomen and allowing for low image noise compared to the TNC images with acceptable image sharpness.

Keywords: Virtual noncontrast images; dual energy computed tomography; abdomen computed tomography

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Phantom Design for Quality Control of Positron Emission Tomography/ Computed Tomography (PET/CT) Imaging

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Purpose: The purpose of this research was to develop an in-house phantom for quality control (QC) of image quality in PET/CT imaging. Methods: Wax and rice powder were mixed to produce tissue-equivalent materials characterized by Hounsfield Unit (HU). The in-house phantom was two circular cylinders with 20 cm in diameter and 10 cm in length which consists of six symmetric vessel pairs with varied diameters of 4.20, 6.20, 8.30, 9.80, 16.30, and 19.00 mm. Each measurement was performed using radioactivity concentrations of 18F-FDG with variation from 1 to 17 μCi/mL by Philips Gemini PET/CT. Images were displayed with pixel size of 4×4 mm^2. Image quality was evaluated in terms of conversion factor between full-width-half-maximum (FWHM) and actual diameter, and pixel value for local uniformity of each object. Results: Two types of phantoms have been designed which were liver-equivalent material (LEM) and muscle-equivalent material (MEM). HU and electron density were (74.17±1.48) HU and 3.396×1023 electron/m^3 for LEM, while (20.27±0.33) HU and 3.461×1023 electron/m^3 for MEM, respectively. The conversion factor was initially high at 2.240±0.07 for diameter 4.20 mm, falls to 0.99±0.003 for diameter 9.80 mm, slowly decrease up to 0.82±0.01 at diameter 16.30 mm, and then nearly constant at 0.82 with increasing diameter for both phantoms. Local uniformity tended to increase with object diameters. Conclusions: The in-house phantom could be used to analyze the image quality performance of PET imaging with tissue-specific material. The phantom design including the development of tissue-surrogate materials, size, and geometrical considerations of the features will be beneficial for innovating QC tools.

Keywords: Image quality; PET/CT imaging; quality control; tissue-equivalent phantom

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Effect of Pitch Factors on Organ Absorbed Doses at CT Phantom Abdominal Imaging: XRQA2 Gafchromic and TLD Study

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Purpose: This study was aimed to measure doses on liver, kidney, ovary, and bladder at using XRQA2 gafchromic and TLD. Methods: Abdominal phantom was designed in the form of elliptic cylinder with 20 cm minor axis and 32 cm major axis, and 39 cm length. Point measurements in liver, kidney, ovary, and bladder were selected symmetrically at each organ. At each measurement 3 TLD rods and 3 sheets of 1 cm x 2 cm XRQA2 gafchromic were required. Image acquisitions were carried-out using Simatom Siemens CT (64 slices) with exposure parameters 130 kVp, 80 mAs, tube rotation 1.5 s, delay time 3 s, with pitch factor values were 0.8, 1.0, 1.5. Results: TLD measurement results shown that generally point doses at left and right for liver, kidney, ovary, and bladder in good symmetry with 3 pitch factors. The dose differences at left and right side for almost all organs were less than 15%. Differ from TLD measurements, film gafchromic measurements revealed the dose at left and right organs had nearly the same values. This can be understood since film gafchromic sensitivity depend on angle of incident beam. Lower pitch factor would decrease the organ dose. The dose decrease from pitch factor 0.8 to 1.0 for all point organs in the range of 11%-17% whereas from pitch factor 1.0 to 1.5 was the range of 0.2%-4.0%. Conclusions: Pitch factor from 0.8 to 1.5 would reduce the point organ dose with consistently shown good symmetry dose at corresponding point to the left and right organs.

Keywords: Abdominal CT; pitch factor; gafchromic; TLD

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A318

Development of Anatomical Mouse CT Phantoms using Tissue Embedding and Plastination Techniques

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Purpose: We report a series of mouse phantoms for use in pre-clinical imaging with spectral and micro computed tomography (CT) scanners. Embedding and plastination methods traditionally employed in anatomy are utilised to preserve ex-vivo PTP wild black type mice. Methods: Suitable embedding materials were identified via monoenergetic 25 keV and 30 keV CT at the Australian Synchrotron Imaging and Medical Beamline. Five embedding techniques were investigated, based upon epoxy (E12), methyl methacrylate (MMA) and polyethylene glycol (PEG). Techniques applied perfusion based tissue fixation for all three embedding materials; epoxy was also used for two immersion-only plastination techniques. Micro CT scans of head, chest and abdomen regions of all mice and synchrotron CT scans of the immersion-only mice were performed. Results: Based on the synchrotron CT results, E12, MMA and PEG were chosen due to relative tissue equivalent X-ray absorption properties, and silicon based embedding materials were excluded from the study. Outcomes of embedding techniques were assessed in regard to feasibility of method, cutting and handling of hardened mice, tissue shrinkage, anatomical detail and artefacts (e.g. gas bubbles). Conclusions: Perfusion based tissue fixation generally resulted in better resin penetration and less anatomical artefacts. In comparison to E12 and MMA, PEG methodology is relatively simple but the resulting mice are sensitive to temperature and handling. Each method allowed identification of different anatomical detail in the preserved mice, e.g. abdominal structures and muscle in PEG, brain structures in E12, and spleen and liver in MMA.

Keywords: Computed tomography; mouse phantom; plastination; pre-clinical imaging

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Thermoluminescence Characteristic of $CaSO_4$:Dy on β and γ Radiation

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Purpose: Research development of thermoluminescence (TL) material in nano- and microstructure are increasing in recent years. There are many new techniques for preparing TL material to improve and investigate the structure, morphology, and TL characteristics. In this study, the TL characteristics of $CaSO_4$ doped with Dysprosium (Dy) were observed. Methods: $CaSO_4$:Dy was performed by co-precipitation method with 0.1 mol% Dy concentration. The obtained sample was irradiated with Cs-137 for gamma source and Sr-90 for beta source with doses 5, 10, 15, 20 and 25 mGy. After irradiation, the structure, morphology, and TL response was observed using XRD, SEM, and TLD Reader Harshaw 3500. Results: From XRD results, the average crystallite size for $CaSO_4$:Dy are 58 nm. But, the presence of dysprosium cannot clearly observe from XRD results. The characterization results from SEM for $CaSO_4$:Dy has shape resemble needle like crystal. The TL response of $CaSO_4$:Dy was compared from beta and gamma radiation source. TL responses for Cs-137 source are 26.56, 34.09, 51.85, 75.97, and 86.29 nC for 5, 10, 15, 20, and 25 mGy, respectively. Sr-90 source with the same dose obtain TL response as follows: 35.67, 68.60, 100.87, 121.69, and 179.85 nC. The shapes of glow curves are almost identical, but these curves have different intensities. Conclusions: The TL response from β-ray source obtains a higher intensity than from γ-ray source because of the beta source is a particle with certain weight so that it has more interaction than gamma source in TLD material.

Keywords: DOSXYZnrc; IMRT; dose distribution

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Double Low-Dose CT Pulmonary Angiography in the Diagnosis of Pulmonary Embolism

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Purpose: To study the feasibility of double low-dose (low radiation and low contrast medium doses) CT pulmonary angiography (CTPA) in the diagnosis of pulmonary embolism. Methods: This retrospective study involved analysis of 59 patients (38 males and 21 females, mean age 49.6 ± 18.3 years) who underwent 64- and 128-slice CTPA. CTPA with use of 100 kVp and 120 kVp protocols were scanned with pitch 0.9, while flash mode of CTPA with 120 kVp was done with pitch 3.2. Quantitative assessment of image quality in terms of signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) were measured in the main pulmonary arteries, while subjective assessment of image quality was performed by two radiologists independently. Both radiation dose and contrast medium volume were compared between these CTPA protocols. Results: Pulmonary embolism was found in all cases with more than half (54%) of them having both sides emboli. There were no significant differences in SNR and CNR between the low kVp and standard kVp or high-pitch CTPA protocols ($p = 0.09$-0.96). The mean effective dose for 100 kVp protocol was significantly lower than that for 120 kVp and flash mode protocols (2.43 ± 0.41 vs 4.66 ± 1.76 and 3.33 ± 0.60 mSv, $p<0.001$). The contrast medium was between 35 - 45 ml for 100 and 120 kVp protocols, and 20-30 ml for 120 kVp flash mode protocol. Subjective assessment shows good agreement between the two observers ($k = 0.78$). Conclusions: Double low-dose CT pulmonary angiography is feasible for detection of pulmonary embolism with acquisition of diagnostic images.

Keywords: CT pulmonary angiography; diagnosis; image quality; pulmonary embolism

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Determination of Conversion Factors of SPECT Hot Images Respect to Hot Objects in Bone Medium: Preliminary Study Using In House Phantom

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Purpose: The purpose was to determine conversion factors (CF) of SPECT hot images respect to original size of hot objects in bone medium. Methods: In house phantom has been made in the form of a cubical acrylic (37cm x 15cm x 15cm) provided with cylindrical channel filled with bovine bone powder with diameter (1.5; 3.5; 5.4; 7.4 cm). As hot objects, a mixture of bone powder and ^{99}mTc source with various activity and diameter were embedded in filled bone channels. Image acquisitions were carried using Intevo Symbia E Siemens SPECT/CT and LEHR collimator, with surface collimator distance 9.6 cm. There were 6 different in activity and diameter of hot objects in each channel. Conversion factor (CF) was defined as ratio between FWHM of hot object image profile and the original hot object size. Results: CF value for each diameter channel were varied with the activity and size of object diameter. The source activities used were 0.1–0.2 mCi and the observed object diameters were 7–12 mm. For hot object size less than resolution stated in SPECT specifications (4 mm), CF values were in range 1.7–3.4 for 1.5 cm and 3.5 cm channel diameter. For hot objects diameter 7.5–12 mm, CF value was mostly independent from channel diameters, with the value of (1.1±0.2). Conclusions: This preliminary study inform that CF values of SPECT hot images independent with the size of host bone medium. Whereas for object diameter ≤ 7.5 mm very relatively higher and influenced by the size of host bone medium.

Keywords: Nuclear medicine; imaging; conversion factor; ^{99}mTc; bone

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A332

Comparison Quick QC SPECT between using In-House Hot Phantom and Jaszczak Phantom: Preliminary Study

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Purpose: To compare measurement results of contrast and local uniformity on SPECT image using generated with in-house hot phantom and Jaszczak phantom. Methods: In-house hot phantom was designed in the form of acrylic circular cylinder with 19 cm diameter and 9 cm length, provided with several vessels for ^{99}mTc with diameter of 4.2, 5.6, 8.6, 12.2, 18.1, and 23.7 mm. Image acquisitions were carried-out using dual-head Symbia E Siemens SPECT/CT with LEHR collimator, and 4 variation source activities, from 0.64 to 3.94 MBq/mL for hot phantom and from 0.068 to 0.115 MBq/mL for Jaszczak phantom. Contrast and local uniformity of hot and cold image attributed to in-house and Jaszczak phantom were compared. Results: Measurement results from in-house phantom showed that lowest activity (0.64 MBq/mL) generated hardly visualized hot image for small diameter object (4.2 and 5.6 mm), and starting to be visible for 8.6 mm object with contrast value 46.44 Pixel values of hot images tend to decrease with increasing activity concentration, whereas the local uniformity decrease with diameter object. The same trend occurred to cold images generated by Jaszczak phantom, at lowest activity (0.068 MBq/mL) the ROI 8,6 mm on diameter object of 15.9 mm give rise to nearly the same contrast of that in hot image. Local uniformity measurements were also decrease with increasing diameter. Conclusions: In-house hot phantom was more robust and can be used as quick QC tool for SPECT system.

Keywords: Quality control; SPECT; local uniformity; contrast

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A334

Investigation of Parameters for Metallic Artifact Reduction using 3-D SPACE in MR Lumbar Spine at 1.5 Tesla: A Phantom Study

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Purpose: To determine the appropriate 3D T2-SPACE parameters for reducing the metallic artifact in MR lumbar spine. Methods: Two most common metallic implant materials (stainless steel and titanium) were inserted into the cylindrical phantom filled with 3.3 g/L, $NiCl_2$-$6H_2O$ and 2.4 g/L NaCl. The phantom was imaged at 1.5T using turbo spin echo (TSE) and sampling perfection with application-optimized contrasts by using flip angle evolution (SPACE) in T2-weighted image contrast with 2D and 3D imaging techniques. The appropriate SPACE pulse sequence was determined by varying a receiver bandwidth and flip angle parameters. The metal artifact volume of TSE and SPACE was quantitatively assessed using a histogram distribution for taking into account the range of normal background signal intensity (mean value ±3 SD) of the blank phantom scan. The signal values outside the normal range in each image dataset were calculated as a susceptibility artifact from the metal implants. Results: In both cases of TSE and SPACE pulse sequences, the artifact volume was reduced by increasing the receiver bandwidth. The metal artifacts were reduced by 55.76%, 53.72%, 52.64% for stainless steel, and 95.84%, 93.30%, 82.91 for titanium. The volume of susceptibility artifacts using SPACE in titanium was smaller than stainless steel by 96.46%, 94.54% and 86.39% after applying the bandwidth of 726, 501, and 296 MHz respectively. Conclusions: 3D SPACE technique demonstrated a potential of metal artifact reduction in different metal implants. This technique is likely to improve the evaluation of embedded metal postoperative patients.

Keywords: Magnetic resonance image; metal artifact reduction; SPACE

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A347

Dual-Tracer Subtraction Parathyroid SPECT Using Tc-99m Pertechnetate and Tc-99m MIBI

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Purpose: The aim was to develop software for dual-tracer subtraction parathyroid SPECT using Tc-99m pertechnetate and Tc-99 MIBI in the detection of abnormal parathyroid gland. Methods: The software was developed by MATLAB program and GUIs of software were created by GUIDE tool. The software was divided into 3 major steps including image registration, intensity normalization, and subtraction SPECT. Firstly, SPECT images in transaxial plane obtained from both radiotracers were read and then reformatted into coronal and sagittal planes. Image registration was then performed for all image planes and can be manually adjusted slice-by-slice. To do normalization, an ROI was drawn around thyroid gland for all transaxial slices of Tc-99m pertechnetate SPECT and the thyroid contours were automatically copied to the Tc-99m MIBI SPECT. Scale factor was then calculated and used to normalize Tc-99m pertechnetate SPECT. Finally, Tc-99m MIBI SPECT was subtracted from Tc-99m pertechnetate SPECT to generate subtraction SPECT images. To evaluate this software, retrospective data of 4 patients who underwent dual-tracer parathyroid SPECT imaging at Siriraj hospital were used. The abnormal findings on subtraction SPECT were confirmed with pathological results used as the gold standard. Results: A total of 10 parathyroid glands were surgically removed and 8 areas of abnormal findings were identified on the subtraction SPECT images. These findings corresponded to the pathological results that confirmed 2 adenomas and 6 hyperplastic glands, however, 2 hyperplastic glands were missed. Conclusions: This software is a user-friendly, efficient and can be used for dual-tracer subtraction parathyroid SPECT.

Keywords: Dual-tracer subtraction SPECT; abnormal parathyroid; Tc-99m pertechnetate; Tc-99m MIBI

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A352

Dose Evaluation for Thyroid Cancer Induction under DECT using a 3D Printed Thyroid Phantom

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Purpose: The aim of this study is to characterise the dose received by adult and paediatric thyroid undergoing CT examination in the neck region. Methods: Two sets of TLD and OSL dosimeters were installed into a solid 3D printed thyroid phantom of adult and 10 years old paediatric patients to measure the radiation dose during neck scanning in DECT. The displayed dose quantities on the CT workstation were used for effective dose evaluation in the thyroid. In addition, CT-Expo software was used for verification purposes. The effective dose to the thyroid was calculated from the displayed DLP using the k-factors of neck area published in AAPM report no.204. Results: The CTDIvol was very close to the absorbed dose from dosimeters inside the thyroid phantoms. The effective dose values from the reported DLP were higher than the values from the dosimeters by factor of 2. The effective dose from the CT-Expo shows a good match with the resulting values of the dosimeters. Conclusions: The study reveals that the risk for cancer induction of the thyroid from the standalone CT or SPECT/CT scans is up to 192 per million children. The number is considered as low, but should not be ignored, while CT scans procedures are increasing every day. Although the exposure from CT is considered acceptable, much care needs to be taken when adding the CT to the SPECT imaging.

Keywords: 3D phantom; dosimetry; thyroid cancer; CT; paediatric

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A353

Multi-Center Study on Pediatric Computed Tomography Patient Dose: Preliminary Result

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Purpose: The study was performed to preliminarily assess the need of optimization in pediatric computed tomography (CT) procedures in three CT-scanners from two hospitals in North Sumatera. The results obtained will be considered as a means of optimization to find best applicable practice. Methods: Manual recording of dose metrics and exposure parameters for a total of 399 pediatric patients are performed for selected anatomies of interest, namely head, abdomen, and thorax scans. Record was obtained from three different CT-scanners; GE Bright Speed 16 and GE Optima CT660 operated in Adam Malik General Hospital, and Philips Brilliance Ict SP in operation in Sumatera Utara University Hospital. The results was compared with Indonesian preliminary diagnostic reference level as published by the Indonesian Nuclear Energy Regulatory Agency to firstly identify any need of change in site practice. Results: For GE Bright Speed16, 73.4% (0-1y), 67.6% (1-5y); 29% (5-10y) and 23.9% (10-15y) past IDRL for head and 83% (1-5y) past IDRL for abdomen and GE Optima CT660 50% (0-1y), 50,5% (1-5y) past IDRL for head, and 44.2% (0-1y), 41.4% (1-5y), 45.7%, (5-10y) and 13.2% (10-15y) past IDRL for abdomen. For Philips Brilliance Ict SP 4.6% (0-1y), 5.6% (5-10y) 6.7% (10-15y) past IDRL for head and 59.4% (0-1y), 53 , 1% (5-10y), 28.5% (10-15y) past IDRL for abdomen. On the other hand, CT head and abdomen produce CTDIvol and DLP higher past IDRL at all ages of pediatric patients indicating the need for optimization. The use of tube voltage, tube current and proper protocol selection is proposed as a workable best practice. Conclusions: This preliminary results recording dose metric for three CT scanners on examination head and abdomen of all age group pediatirc higher doses IDRLby the Indonesian Nuclear Energy Regulatory Agency, requiring optimization with changes in exposure parameters and proper protocol selection.

Keywords: Computed radiography; dose; pediatric

SECTION IV

PRESENTERS ABSTRACT (RADIOBIOLOGY, RADIATION PROTECTION AND OTHERS)

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A007

Quantitative Verification of Scanner Movement for a Scanning Water Tank Using an on Board Imaging System

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Purpose: Advances in radiotherapy technology have led to an increase in the amount of commissioning data required for radiotherapy treatment planning systems (RTPSs) due to the improved dosimetric accuracy and the varying data requirements for different manufacturers. However, little is known about the precision of scanning water tank positioning. The purpose of this study was to describe quality assurance measures to account for scanning water tank movement using a kV X-ray imaging system mounted on a linear accelerator. Methods: Movement of the scanning water tank in x, y and z-directions was quantified using an On board imaging (OBI) system mounted on a linear accelerator. The geometric accuracy of the scanning water tank position was evaluated by setting up the water tank 10 times on different days. Furthermore, the orthogonality of the planes was evaluated following image rectification to correct for image distortion by homography. Results: The positional reproducibility in the x, y and z-axis was within 0.13, 0.18 and 0.05 mm, respectively. Using OBI, we have demonstrated the ability to verify the orthogonality of planes with a 0.06° /pixel resolution by measuring the distance between two points with a 0.13-mm/pixel resolution. Conclusions: Our data suggests that the method provides a high degree of reproducibility considering the accuracy of the kV imaging system and the positioning of the scanning water tank.

Keywords: Water scanning systems; beam Commissioning; radiation measurements

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A010

An Inspection of Radiographic Displays using TG18 Test Pattern and TOR CDR Phantom

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Purpose: To compare the age of monitors, the monitor resolutions and the ambient lights that affect the quality of radiographic monitors. Methods: The basic information of 54 displays was recorded. TOR phantom and AAPM TG18 tests were used for qualitative and quantitative evaluating the contrast, resolution, reflection, geometric symmetry, grayscale display function, uniformity and luminance of monitors. Results: The hour of monitor's usage, monitor's resolution and ambient light significantly affect the detectability of low contrast and low-resolution objects. Monitors with a resolution of more than 3 megapixels are consistent in displaying the luminance uniformity and optimum to use as a diagnostic monitor. However, the monitor's age more than 10 years tend to fail the luminance response test. In addition, the amount of ambient light and the direction of the surrounding light are an important factor affecting the ability to distinguishable low contrast object. Conclusions: The high quality of the monitor help to diagnostic radiography accurately. The 3 megapixel or higher resolution monitor is recommended to use for diagnosis because it enhance the ability to detect low contrast and small detailed objects. The backlight of monitors has a limited usage hour and affect the luminance uniformity of the monitor. To extend the lifetime of the monitor, turn if off when not using. The main factors affect image viewing are the amount of ambient light and the direction of surrounding light sources that cause the light reflection on the screen. A proper room design and adjustable light can reduce light interfering.

Keywords: Quality control; medical display; AAPM TG18 test pattern

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A015

Determination of Counting Efficiency and Minimum Detectable Activity of NaI(Tl) Detector Used in Thyroid Monitoring System

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Purpose: To investigate the effects of NaI(Tl) detector positioning on the counting efficiency (CE) and minimum detectable activity (MDA) using four standard radionuclides of Co-57, Ba-133, Cs-137 and Co-60. Methods: The CE is determined at three different setups using the radionuclides in the standard neck phantom; (a) X-axis: The phantom is moved horizontally from 16.8 cm to 23.8 cm from the detector and the CE is measured at 1 cm interval; (b) Y-axis: The neck phantom is rotated horizontally from -40° to 40° from the central axis of the detector and the measurements are taken at 8° interval; and (c) Z-axis: The detector is adjusted vertically from -12° to 12° from the central axis of the neck phantom and the measurements at 2° interval are recorded. The MDA at X-axis setup is determined using a blank neck phantom. Results: The Ba-133 shows the lowest CE in comparison with other radionuclides where 33% and 22% of CE decreased when the detector is positioned at 40° of x-axis and -12° of y-axis, respectively. At z-axis, the CEs for all radionuclides are approximately 42% higher when the neck phantom – detector distance (NDD) decreased from 23.8 cm to 16.8 cm. The MDAs for all radionuclides decrease with increasing of NDD and it is found to be 56% lower when NDD increases from 16.8 cm – 23.8 cm. Conclusions: The detector position during thyroid monitoring is very important to ensure the correct CE and MDA are applied in calculating and reporting the intake of radionuclide in thyroid organ thus may reduce the uncertainty of estimation of internal dose.

Keywords: Thyroid counter; counting efficiency; minimum detectable activity

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A018

Establishment of Internal Dosimetry Laboratory for In-vivo Measurement using Whole Body Counter in Malaysian Nuclear Agency

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Purpose: To study the performance parameters of ORTEC whole body counter (WBC) used in monitoring of potentially exposed workers to internal radiation as well as for the preparedness of response in the case of nuclear and radiological emergencies. Methods: The ORTEC WBC is calibrated in energy and efficiency using five containers of mixed standard sources having gamma energies range between 59.5 keV and 1836.2 keV which are placed in the abdomen body phantom, with scanning time for the measurement is set at 40 minute with 0.03 inch/s of bed movement. These efficiency values then were used in calculating the Minimum Detectable Activity (MDA) for several nuclides of interest. Finally a quality assurance routine includes background monitoring were performed in order to assure the reliability, consistency and accuracy of the measurement. Results: The detector efficiencies vary between 0.017 % and 0.069 % for gamma energies between 59.5 keV and 1836.2 keV. The MDA for each nuclide of interest is within 67 Bq and 3259 Bq. The stability of background radiation in the laboratory is maintained from 0.01 cps to 1.76 cps for each nuclide of interest. Conclusions: The internal dosimetry laboratory for in-vivo measurement using whole body counter has been established in Nuklear Malaysia. Routine monitoring for assessing intake of radionuclides for radiation workers in nuclear medicine departments is currently being prepared.

Keywords: In vivo measurement; whole body counter; detector efficiency; minimum detectable activity

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A033

Fading Extent of Optically Stimulated Luminescence (OSL) Signal as a Result of Measurements, Time, Exposure to Light, Temperature and Humidity

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Purpose: Investigate fading of Optically Stimulated Luminescence (OSL) signal due to measurements, time, light, temperature and humidity. Methods: The OSL dosimeters were irradiated by ^{60}Co. Then the irradiated OSLs were sorted into different groups to study fading of the signal due to different factors. Initially, OSLs were read 35 times, then read within 144 days. Next, OSLs were placed on the desk in a bright room with illuminance of 100 lux and others were fixed in 4500 lux fluorescent lights up to 202 hours. Moreover, OSLs were exposed to sunlight of 10000 lux up to 202 hours. Then, OSLs were kept inside oven at; 30 °C, 40 °C and 50 °C for 62 hours. Finally, OSLs were placed inside humidity growth chamber at 83% humidity level for 288 hours. Results: The fading per readout were between (0.400 ± 0.002) % and (2.800 ± 0.006)%. The extreme fading within 144 days was (17.34 ± 0.04)% while the maximum fading due to ambient, fluorescent and sun light after 202 hours were (15.38 ± 0.05)%, (18.40 ± 0.04)% and (13.9 ± 0.2)% respectively. The reductions of OSL data due to temperature and humidity were minimal. Conclusions: The fading due to measurements is found to be dose dependent. The OSLs should be read within short period to avoid fading due to time. The irradiated OSLs should be stored in a closed box to avoid fading due to light. There was no significant impact on temperature up to 50 °C and 83% humidity level on the OSL data.

Keywords: OSL; fading; ambient light; fluorescent light

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A042

Identification of Activation Products and Radiation Dose Estimates in Havar® Foils For a GE Pettrace800 Medical Cyclotron via High Resolution Gamma Ray Spectroscopy and MCNPX Simulation

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Purpose: The main objective of this study is to identify the associated activation products in a Havar® window foil for a GE PETtrace800 medical cyclotron using high resolution gamma spectroscopy and quantify their respective activities and dose estimates contribution via calculation method. Methods: Two methods were done to acquire the necessary data: simulations using MCNPX to acquire an estimate of the individual dose contribution of each activation products from the window foil and a high-resolution gamma spectroscopy analysis using high purity germanium (HPGe) in Philippine Nuclear Research Institute (PNRI) to identify the presence of these activation products and their count rates as well. Simulations of the window foil were limited to a single activation product homogeneously distributed throughout the foil. Results: The gamma spectroscopy showed that ^{56}Co, ^{57}Co, ^{58}Co, and ^{54}Mn were present. Calculation method and *f8 tally were used to compute the dose estimate contribution of each activation products. After a period of one year, the major contributors, ^{56}Co and ^{58}Co, to the dose received by a personnel would have decayed significantly due to their short half – lives. The guiding activation products would then become ^{57}Co and ^{54}Mn due to their long half – lives. Conclusions: The results of the gamma spectroscopy confirmed the presence of activated products. The dose estimates via calculation method do not exceed the annual dose limit set for the whole body and for the extremities. The contributions of these activation products are insignificant and pose no threat to the radiation worker when general guidelines for controlling exposure are followed.

Keywords: Havar® foils; activation product; gamma spectroscopy

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A047

Trial Study for Development of a Novel-Formed Dosimeter having Lower Angular Dependence

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Purpose: When we perform actual dose measurements using commercially available small-type OSL dosimeters, we have to consider angular dependence; dosimeter's response varies depending on incident angle of X-rays. Currently, we are developing a novel type of OSL dosimeter having lower angular dependence. In this study, we present a prototype dosimeter, and estimate its characteristics. Methods: First, we developed a prototype dosimeter in which there is a 3 mm^2 hole in the center of a disk shaped dosimeter. The dosimeter can be read using a commercial type dosimeter reader. Next, to estimate angular dependence of the dosimeter, we performed experiments using diagnostic X-ray equipment. The dosimeter was irradiated at a tube voltage of 80 kV and at 15 degree steps. Dosimeter's angle was controlled by a rotational actuator. The source to dosimeter distance was 150 cm, and tube current-time product was 50 mAs. Then, the same procedure was also applied to commercial type OSL dosimeters. Finally, we compared angular dependencies of both prototype and commercial type OSL dosimeters. Results: In the diagnostic region, we enabled to derive the angular dependence of the two types of OSL dosimeters. When dosimeter's angle was 90 and 270 degrees, response of dosimeters was reduced. Reduction rates of prototype and commercial type OSL dosimeters were 10% and 25%, respectively. Conclusions: In this study, we measured angular dependence of both prototype and commercial type OSL dosimeters. The prototype OSL dosimeter achieves lower angular dependence compared with the commercial type OSL dosimeter.

Keywords: OSL dosimeter; dosimetry; angular dependence; diagnostic X-ray

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A079

Fundamental Study on a Disposable Condenser Dosimeter Using a Skin-Insulated USB-A-Substrate With a Silicon X-Ray Diode in Radiation Therapy

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Purpose: To measure patient-skin doses in radiation therapy, we developed a disposable condenser dosimeter without a cable using a skin-insulated USB-A-substrate with a silicon X-ray diode (Si-XD). We performed X-ray dose measurements at 4 and 10 MV accelerating voltages using a linear accelerator and carried out fundamental study on this developed integral dosimeter. Methods: The Si-XD is a high-sensitivity photodiode selected for detecting X-rays. The USB-A substrate with dimensions of 24×14 mm^2 is inserted into the microcomputer dock, and the condenser is charged to 3.23 V through a 10 kΩ resistor using a pin 10 in the dock. The charging voltage is reduced by photocurrents flowing through the Si-XD during X-ray exposing. After the exposing, the charging voltage is measured using an analog to digital converter in the dock. Thermoluminescence dosimeter (TLD) was used to convert the discharging voltages into doses in this study. Results: The doses were proportional to decreases in the charging voltage, and the integral doses beyond 1.0 Gy could be measured using 4 and 10 MV X-ray beams from a linear accelerator. Conclusions: We developed a condenser-discharge integral dosimeter with a USB-A mini-substrate and a low-cost mbed dock for charging and measuring the voltage. To measure the dose variations using the TLD reader, the one-point calibration using the maximum dose might be desired.

Keywords: Condenser dosimeter; Si X-ray diode; disposable USB-A-substrate

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A093

Preliminary Study for *in vivo* Dosimetry of the Small Animal Irradiation

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Purpose: The applicability to *in vivo* dosimetry with 3D printer based self-manufactured mouse immobilization device in small field is preliminary irradiated in this study. Methods: The mouse immobilization device made by 3D Printer consists of the support flat, fixing units, sensor areas and build up cap. Radio-photoluminescence glass dosimeters (RPLGD, GD-302M) were inserted at upper left (UL), upper right (UR), lower left (LL) and lower right (LR) in device at center of target. EBT3 film was inserted into the device located at the top of mice head. After the CT simulation of the mice with immobilization device, an irradiation plan was performed using the ECLIPSE system. Using 6 MV x-ray, the mice were irradiated 5 times by 180 cGy. The dose measurements from RPLGDs and films were compared with the calculated doses in Eclipse system. Results: The percentage differences between the RTP System and measurement of RPLGDs were 5.56% ± 3.89, 6.52% ± 5.32, 10.00% ± 8.97, 15.87% ± 17.49 at UL, UR, LL, and LR position. The gamma passing rate of all film measurements exceed 90% in the 2 mm / 2% range. The error values of 3rd measurements were outliers due to set up. With the exception of the 3rd measurements, the percentage difference decreased to 4-7%. Conclusions: In this study, we evaluated the applicability of mouse immobilization device in small field. We performed *in vivo* dosimetry using RPLGD and EBT3 films, it may be helpful in analyzing accurate results in animal clinical trials using radiation.

Keywords: Radiation; mice; *in vivo*, 3D print; immobilization; dosimetry

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A113

Monte Carlo MCNP-based Simulation and Radiation Measurement of Yttrium-90 Bremsstrahlung Produced from Radiation Shielding Apparatus

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Purpose: ^{90}Y has been widely used in therapeutic nuclear medicine. However, undesirable radiation exposure might be generated when ^{90}Y interacts with matter. So, the aim of this study was to evaluate bremsstrahlung produced from radiation shielding apparatus using scintillation detector and Monte Carlo simulation. Methods: ^{90}Y with activity about 800 μCi was prepared in glass vial and kept in the radiation shielding apparatus. The bremsstrahlung measurement of the count rate and spectrum were performed using well calibrated NaI(Tl) scintillation detector. The counting time and the distance between detector and apparatus was varied to obtain the optimal condition. For Monte Carlo simulation, the MCNP5 was used to construct the detector and the radiation protection apparatus with similar geometry, dimensions, and materials as used in the measurement. Results: For experimental measurement, the optimal distance and counting time was set at distance of 10 cm and counting time of 120 s to preserve the dead-time and standard deviation. Although the result of measurements and Monte Carlo simulations exhibited similar trend, the certainly greater count rate was observed in simulations than those of measurements as expected. Conclusions: ^{90}Y bremsstrahlung can be produced from radiation protection apparatus and possible evaluated by either measurement or simulation. Despite simulation results showed higher count rate than those measurement, it is possible as a result of suboptimal efficiency of the scintillation detector to detect bremsstrahlung. Therefore, the result of simulation would be further utilised to estimate occupational exposure dose of the staff rather than measurement.

Keywords: MCNP; Yttrium-90; Bremsstrahlung; scintillation detector; Monte Carlo simulation; radiation protection

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A114

The Basic Characteristics of a Prototype Eye Lens Dosimeter Using Thermoluminescence Detector

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Purpose: An eye lens dosimeter is expected to be used for accurate dose evaluation. We produced the prototype of eye lens dosimeter so we evaluated the basic characteristics of it. Methods: The eye lens dosimeters using TLD are designed to be hooked on protective goggles. The dosimeters were put on 40 × 40 × 15 cm of PMMA phantom and exposed to 0.1-1000 Gy of ^{137}Cs gamma-rays to evaluate the linearity and accuracy. The energy dependences were evaluated by 24 – 1250 keV of photons in Hp(3) = 3.0 mSv; N-series X-rays, and gamma-rays from ^{137}Cs and ^{60}Co were used. In addition, the angular dependences were evaluated by N-30, N-40, and N-60 X-rays; the effective energy range was 24 – 48 keV. The energy and angular dependences were also obtained with a Monte Carlo simulation using EGS5 code. Results: The response of the eye lens dosimeter has good linearity and the statistical fluctuation is less than 8% even in 0.1 mSv exposure. The response of the dosimeter exposed with 24 keV X-rays was 70% higher than that of 662 keV. The dosimeter showed small angular dependences. The experimental results were in good agreement with the simulated ones. Conclusions: We found that the prototype eye lens dosimeter has good characteristics and they were consistent with the results from the Monte Carlo simulation. Based on this, we plan to improve the design of the eye lens dosimeter in the near future.

Keywords: Occupational dose; eye lens; TLD

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A122

Basic Dosimetric Characteristics of Fabricated Germanium (Ge) Doped Optical Fibres for Electron Beams Dosimetry

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Purpose: The aim of this study is to establish the basic characteristics of fabricated 2.3 mol% germanium (Ge) doped cylindrical optical fibres for electron beams irradiation in terms of dose linearity, reproducibility, fading signals, minimum detectable dose (MDD), energy- and field size dependences. Methods: A total of 300 pieces of fabricated fibres were used for all analyses. The fibres were irradiated at doses ranging from 1 Gy to 5 Gy using nominal electron beam energies of 6-, 9-, 12- and 15 MeV, with 100 cm focus to sample distance (FSD), 10 x 10 cm^2 field size, delivered at a rate of 600 cGy/min to the depth of dose maximum using a Elekta® synergy linear accelerator (LINAC) located at IPPT, Bertam. For the field size dependences study, field size ranges from 6 x 6 cm^2 to 25 x 25 cm^2 were employed. The thermoluminescent (TL) fading signals were measured up to 74 days. Results: TL signals exhibited a linear dose response over dose ranges, mean reproducibility with a coefficient of variation (CV) of less than 5% and no dependency with different field sizes at $p > 0.05$. The MDD values were 3.51 to 4.13 mGy. The minimum TL fading of the Ge-doped optical fibres was reported for a 9 MeV electron beam. Conclusions: Present work has sought to establish the characteristics of fabricated Ge-doped cylindrical fibres. The results have shown that new fabricated Ge-doped cylindrical fibres have a potential as a new dosimeter for electron beams measurement.

Keywords: Dosimetric; Ge-doped optical fibres; depth of dose maximum

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A127

An Evaluation to the Morphological Structure, Elemental Composition, and Chemical Composition of Microwave-Assisted Synthesis of Copper Hydroxyapatite with Varying Concentration of Cu Added

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Purpose: Hydroxyapatite (HAp) is a calcium phosphate that is similar to the inorganic compounds that be found in hard tissues such as bone and teeth. It has a stoichiometric Ca/P ratio of 1.667 and it has also an osteoconductive property (ability to be absorbed in the body). Basically, HAp is used as coating materials for metallic implants to stimulate further its bone bonding ability because of its superior cytocompatability, ability to stimulate cellular functions, and osteoconductivity. However, several problems will be encountered in trying to synthesize synthetic HAp. Synthesizing HAp would be time consuming (depending on what methods you are using with) which may affect the production of HAp. Furthermore, the lack of antibacterial properties has an impact for its long term stability which eventually gives rise to implant failures. To solve these problems, microwave heating is introduced to hasten the production of HAp. Also, the incorporation of copper ions to HAp may help to reduce the bacterial adherence and colonization of the metallic implants coated with HAp. Methods: The synthesis was done in an ambient environment and the power of the microwave oven was kept constant at 450 W and was heated for 10 minutes. The wt% concentrations of the copper source added into HAp were varied from 0% (synthesized HAp), 1%, 2%, 3%, 4%, 5%, 10%, 15%, and 30%. All samples were characterized by SEM-EDX to determine its morphological structure and FTIR spectrometry to determine its chemical composition. Results: Results from SEM show that the morphological structures of all samples are the same and showing a smooth, "spherical-like" shape. Further, the SEM images were characterized by an imageJ software and results show that as the concentration of the copper increases, the particle's sizes decreases by an average of 25.89%. There's also a decreased to its stoichiometric Ca/P ratio by an average of 15.85% as observed in EDX result. Presence of phosphates and hydroxyl ions were observed in FTIR results which validates the assumption that the sample is HAp. However, merging of phosphates and hydroxyl peaks which tend to form a single broad peak were also observed in FTIR results as the concentration of the copper increases. Conclusion: It can be concluded that it is possible to synthesize a rapid synthesis copper HAp by the use of a microwave oven. Furthermore, the results taken from the experiment are promising for the biomedical applications.

Keywords: Hydroxyapatite; copper; microwave-assisted

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A145

Release of Radiation Iodine Patients based on Patient-Family Member Specific Effective Dose Calculation at 0.3 Meter

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Purpose: To review the adequacy of RAI patient release criteria based on specific dose calculation at 0.3-meter. Methods: External exposure rate measurements were taken from 20 female patients (10 hyperthyroidism and 10 postoperative thyroid cancer patients), using a calibrated survey meter. For thyroid cancer patients treated with 100 mCi, the exposure rates were measured at 1-meter distance and at 0.3-meter shoulder level after 24 hours of I-131 administration. For hyperthyroidism patients treated with 10-15 mCi, the exposure rate was measured at 1-meter and 0.3-meter immediately after I-131 administration. All the patients were informed with 2 weeks nighttime restriction from children and infant and to repeat their external exposure rates measurements at 0.3-m on the weekly basis. Results: Cancer patients treated with 100 mCi of RAI-131 demonstrated an exposure rate less than 8 μSv/hr at 0.3-meter on Day 14. However, hyperthyroidism patients showed slow rate of clearance of exposure rate, due to larger thyroid gland volume that retain iodine compare to remnant thyroid tissue mass in thyroid cancer patients. The exposure rate ranged from 9 μSv/hr to 40 μSv/hr (mean 24.5 μSv/hr) at 0.3-meter on Day 14. Thus, applying standard 14 days restriction is inadequate as release criteria for their infants and children. Conclusions: Radiation exposure from hyperthyroidism patients to others take longer time to decrease to safety level than a thyroid cancer patient. Our current patient specific release criteria which is based on patient-family member specific effective dose calculation needs to be more restrictive for hyperthyroidism patients with infant or children.

Keywords: RAI patient release criteria; specific dose calculation; hyperthyroidism; thyroid cancer; I-131

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Study on Thermoluminescence Properties of Commercial Glasses Used in Bangladeshi Dwellings for Accidental Dosimetry

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Purpose: Commercial glasses used in Bangladeshi dwellings were analyzed by the thermoluminescent (TL) technique, to verify the prospect of their use as dosimeters for measurements of environmental and accidental radiation exposures, due to their easy handling, low cost and moisture protection. Therefore, the investigated samples were studied in terms of their dosimetric characteristics: energy and dose response, glow curve and reproducibility in typical irradiation procedures. Methods: All the powdered glass samples and TLD-100 were annealed for a period of 1 hour and irradiations were made using X-ray and gamma beams, from an ERESCO 200 MF4 and a conventional Gamma cell-220 ^{60}Co respectively. X-ray mean photon energies from 20 keV to 185 keV and gamma dose of range 10 Gy to 50 Gy were used in this study. The sample TL measurements have been carried out using a Harshaw 3500 TLD reader (USA) supported by WinREMS software. The TLD reader was set up as following the preheat temperature of 50 ^{0}C, heating rate of 10 ^{o}C.s^{-1} and maximum temperature for data acquisition of 400 ^{o}C. Results: The glasses under this study showed linear TL response with gamma dose range 10 Gy to 50 Gy, glow peaks were between 1500 C and 3000 C. In energy range 20 keV to 120keV the TL response of the investigated glasses partially followed the trend of TLD-100. Reproducibility of TL response was estimated to have a maximum variation of 5.0%. The fading rate of the glass response at room temperature is small. Conclusions: These results demonstrate the potential use of commercial glass as TL dosimeters to determine radiation dose (for both the 'emergency' and 'retrospective' case) following catastrophic, large-scale radiological events.

Keywords: TLD; TL; dosimetry

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Evaluating the Energy Dependence of the Small Type Optically Stimulated Luminescence (OSL) "Nanodot" Dosimeters in the Energy Region of Diagnostic X-Rays by using Monte Carlo Simulation

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Purpose: The small type OSL dosimeter called nanoDot exhibit energy dependence, therefore, we need to consider evaluating its influence; however, it's difficult to evaluate by experiments only because different experimental conditions need to be set up in order to get results. Thus we also wanted to evaluate the energy dependence using Monte Carlo simulation. In this study, we discussed the reliability of using Monte Carlo simulation to evaluate the nanoDots energy dependence in diagnostic X-rays energy range. Methods: EGS5 was used for Monte Carlo simulation. In EGS5, nanoDots were irradiated with 40 – 140 kV diagnostic X-rays and the absorbed dose of each dosimeter was evaluated. At the same time, air Kerma was evaluated based on the X-ray spectrum incident on the nanoDots. In the experiments, the nanoDots were irradiated under the same conditions in the simulation. An ion chamber was used to determine the air Kerma. The ratio of the nanoDots response to Air Kerma from experiments and the ratio of the nanoDots absorbed dose to air Kerma from the simulation were compared. Results: When choosing 80 kV as the standard point, the energy dependence at energies below 80 kV is higher up to +10% while at energies above 80 kV becomes lower up to -10% in the simulations; the experiments also showed the same tendency. In addition, the ratio of the simulated and experimental data had a deviation of +/- 2%. Conclusions: The results showed that the EGS5 Monte Carlo simulation can evaluate the energy dependence of the nanoDot.

Keywords: Nanodot; optically stimulated luminescence; Monte Carlo simulation

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A160

Monte Carlo Simulation of the Energy Deposition by Ionizing Radiations in Micro- and Nano-Meter Scales

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Purpose: Photons incident on biological tissues generate secondary electrons which contribute to energy deposition substantially through ionization and excitation processes. The radiation weighting factor (w_R) is unity for both photons and electrons, however investigation for energy dependence remains insufficient. In this study, we calculated the dose-mean lineal energy (v_D) values for electrons and photons, and evaluated the relation between v_D and the relative biological effectiveness (RBE). Methods: First, we calculated the v_D values (for spherical volumes with 2nm-1μm diameter) for electrons starting with mono-energy (0.1-1000 keV) by an in-house Monte Carlo code, WLTrack. We then calculated the v_D values for 6MV linac x-rays and 60-250 kVp x-rays based on the energy spectra of secondary electrons by PHITS and WLTrack codes. In parallel, in vitro experiments to detect the number of DNA double-strand breaks (DNA-DSBs) in mammalian cells were performed for comparing with the v_D values calculated. Results: The v_D values for electrons considering ionization and excitation correspond to the reference data (Famulari et al). The v_D values for photons considering all interactions of electrons are in good agreement with the values by TEPC (Okamoto et al). The v_D value of diagnostic x-rays (with relatively low energies) is higher than that of therapeutic x-rays (with relatively high energies). RBEDSB (RBE based on DSB yield) has a linear tendency proportional to the v_D value. Conclusion: Diagnostic x-rays have larger biological impacts than therapeutic x-rays. Further investigations may be necessary for the v_D calculation reviewing the electron impact cross sections in liquid water.

Keywords: Monte Carlo simulation; dose-mean lineal energy; dosimetry; electron cross section

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Development of Light Scattering Methods for Urinary Stones Diagnosis

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Purpose: Light scattering method is commonly used to measure the size distribution of the liquid particles at nano and micro-particle scale. In this research, light scattering method has been developed to analyze standard solution (polystyrene) as a tools calibration. Methods: The research stages consist of preliminary study, instrument set-up, tools calibration, experiments and data analysis. Tool calibration has used standard (polystyrene) solution with a molecular weight of 4000, 90000, 200000, 400000, 900000 g/mol respectively. Polystyrene was dissolved with 10 ml of tetrahydrofuran and measured by varying the concentration of polystyrene solution. Results: The result of this research shows that the peak was shifted with the addition of polystyrene concentration. Conclusions: The greater molecular weight of polystyrene not only reduces the intensity value but also reduces the distance from central beam axis to first diffraction minimum or full width at half maximum.

Keywords: Light Scattering; urinary stones; polystyrene

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A165

Characterization of an AMPS Polymer Gel Dosimeter using X-ray CT for Radiotherapy Photon Beam Dosimetry

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Purpose: This study highlights the dosimetric characterization of a polymer gel dosimeter (PGD) using 2-Acrylamido-2-methyl-1-propanesulfonic acid (AMPS) as monomer on X-ray CT-based gel dosimetry for radiotherapy. Methods: Radiological properties and water/tissue equivalence were established for a 6%T, 50%C AMPS-Bis PGD through determination of mass and electron densities (ρ and ρ_e), effective atomic number (Z_{eff}), and photon cross section. PGD in vials were irradiated with known absorbed doses (D_{Gy}) (0, 0.5, 1.0, 2.5, 5.0, 10.0, and 20.0 Gy) delivered by opposed lateral photon beams of a Cobalt-60 teletherapy machine and 6-MV LINAC. Dosimeter range and sensitivity were taken from the resulting CT Number (NCT) vs. D_{Gy} curve after readout using a 16-slice X-ray CT, NCT values for PGD irradiated with Co-60 and 6-MV LINAC photons were compared and the effect of dose-rate to NCT were investigated for evaluation of energy and dose-rate dependence respectively. Results: The unirradiated PGD has ρ_e = 3.454E+23 cm^{-1}, ρ = 1.039 g cm^{-3}, and Z_{eff} = 7.432. Results from NIST XCOM show a 0.584% difference in total attenuation cross-section of water for energies >1.0 MeV. Dosimeter response is biexponential with linear dose response from 0 to 5 Gy (0.445 HU Gy^{-1}, R^2 = 0.998) and dose resolution of 0.111 Gy. There was no observed energy dependence in the dosimeter and dose-rate dependence was only available at dose-rates <200 cGy min^{-1}. Conclusions: The AMPS-based PGD has near-water radiological properties (closest to brain tissue, ICRU-44) with dosimetric range, sensitivity, and energy and dose-rate dependence showing feasibility as a radiotherapy dosimeter.

Keywords: AMPS; polymer gel dosimetry; radiological properties; water/tissue equivalence; X-ray CT

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Survey Report on Women in Medical Physics: Education, Professional Issues, Possible Solutions: Indian Perspective

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Purpose: Medical Physics is an established and booming profession in India with this, role of women in Medical Physics is also increasing. A survey was conducted to analyze the difficulties faced by women medical physicist (WMP) in India, possible reasons and probable solutions. Methods: A survey was planned with open-ended questions; responses were used as data for qualitative analysis. A total of 302 WMP were included in survey from which 284 WMP have completed the survey, out of which 259 WMP are the member of association of medical physicists of India (AMPI) and rest 25 are not AMPI member yet. Results: The survey revealed that 96.2% of them agree that they have faced gender biasing in some or other stage of their professional life. Major reasons were rigid opinion of male senior colleagues out of rigid cultural mindset (76%), other main reason found was unwillingness of hospital administration to give maternity leaves to young WMP (56%). Further the most interesting observation of this survey was that some of them (17%) feel that sometimes the attitude of senior WMP's is also responsible for such rigid mindset but it was found that this opinion was debatable. They have suggested possible solutions as governmental rebates or incentives to private institutions, which have higher number of female staff, promoting WMP to leadership positions etc. Conclusions: The present survey attempted to provide the direction for the possible practical solutions. Detail results will be communicated in this paper.

Keywords: Medical physics; women; education, professional issues

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A170

Collimator and Energy Window Optimization for Practical Imaging Protocol and Quantification Of ^{90}Y Bremsstarhlung SPECT/CT: A Phantom Study

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Purpose: To improve ^{90}Y bremsstrahlung imaging protocol and quantitative accuracy of planar scintigraphic imaging and single-photon emission computed tomography/computed tomography (SPECT/CT) for our hospital by optimizing the choice of collimator and energy windows (EWs) settings. Methods: All images were acquired using low-energy high-resolution (LEHR) collimator, medium-energy general-purpose (MEGP) and high-energy general-purpose (HEGP) in one energy window (100-300 keV), two energy windows (60-100 keV & 102-138 keV) and three energy windows (60-90 keV & 100-140 keV & 140-230 keV) respectively. The images were assessed based on image quality, signal-to-background ratio (SBR) and coefficient of variation (CV) in static images of a cylindrical acrylic phantom with a ^{90}Y chloride solution vial inserted in the center of phantom and surrounded with low background activity of ^{90}Y chloride solution. Results: HEGP has the highest SBR followed by MEGP and LEHR whereas LEHR has the lowest CV followed by MEGP and HEGP. EW with two energy windows always has highest SBR followed by three energy windows and one energy windows. In term of image quality, MEGP with 2 or 3 energy windows have the images with best spatial resolution compared to septa effect in HEGP images and grainy images with poor resolution in LEHR images. Conclusions: MEGP collimator with 2 energy windows gave good results in term of good spatial resolution and moderate SBR and CV. The proposed imaging protocol in planar imaging can readily to be used to tailor ^{90}Y SPECT/CT acquisition, attenuation correction (AC), scatter correction (SC) and reconstruction protocols for improved ^{90}Y imaging in our hospital.

Keywords: Quantitative ^{90}Y; bremsstrahlung SPECT/CT; planar scintigraphic imaging; energy windows and collimator

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Spectral Analysis of the Gafchromic EBT 2 Dosimetry Film Irradiated with X-Ray

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Purpose: With the advancement in innovation and complexity of radiation dosimeter, Sensitivity of film dosimeter ought to be benchmarked precisely with measurements data. In film dosimetry, absorption spectrum affects dosimetry characteristics because the delivered dose is related to the optical density. Subsequently, the optical properties of the film are vital elements to comprehend film dosimetry in clinical radiotherapy applications. Along these lines, exact knowledge of the films optical properties is critical for understanding the distinctions in dosimetric sensitivity of the film. The objective of the investigation was to confirm the film sensitivity by utilizing the optical band gap of the film. Method: The films were positioned in a solid water phantom of dimensions 30 × 30 × 30 cm^3. The films were irradiated with diagnostic range (40-110 kVp and 3.2-50 mAs) using 10 × 10 cm^2 diagnostic x-ray machine field at 100 cm source to surface distance at the dmax position which is at the surface. The films were irradiated placed perpendicular to the central axis of the beam. Film pieces 3 × 3 cm^2 were cut for experiments. Spectra data were then analyzed using Shimadzu UV-1800 UV-visible recording spectrophotometer to calculate sensitivity values at various specific wavelengths. Result: Values of film optical band gap measured from the absorbance spectra of the films were found to be reduced as the beam exposure increasing. Maximum difference is observed at the 100 kVp with different mAs where the band gap of the film is reduced from 1.96 eV to 1.92 eV respectively. Conclusion: As the optical band gap reduced, small energy can provide enough energy to electrons of yellow dye and silver halide in film. Thus, makes the electronic transition between the valence band to the conduction band become easier. Therefore, the relationship between the measured optical band gap and the absorbed dose/film sensitivity can be obtained.

Keywords: Physics; medical physics; optical band gap; film dosimetry

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Dose Distribution Verification using Two-Dimensional Al_2O_3 Thermoluminescence Dosimeter in Robotic Radiosurgery

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Purpose: Two-dimensional (2-D) thermoluminescence dosimeters (TLDs) based on aluminum-oxide (Al_2O_3) ceramics can be used repeatedly. Therefore, they can be calibrated, and they may be used to verify absolute dose distributions. A previous study has shown that 2-D Al_2O_3 TLDs have energy dependences in robotic radiosurgery. In this study, we try to verify absolute and relative dose distributions using them. Methods: The 2-D Al_2O_3 TLDs consists of Al_2O_3 doped with 0.05 wt% Cr_2O_3. The effective atomic number and bulk density was 11.14 and 3.7 g/cm^3 respectively. A 63×63×0.7 mm^3 Al_2O_3 TLD was set in 150-milimeter cube of solid water phantom, and it was irradiated with 6 MV X-ray beams from CyberKnife®. DD-system analysis software (R-TECH.INC) was used to verify the dose distribution with a gamma analysis which can evaluate both dose differences and distance-to-agreement (DTA). Results: The maximum dose of the dose distribution calculated by a treatment planning system (TPS) was about 1.15 times of that measured by the 2-D Al_2O_3 TLD owing to the field size dependence and depth dependence. However, when criteria of dose differences and DTA were respectively 2% and 2 mm, with a low dose threshold of 10%, the pass rate of the relative dose distribution verification using the 2-D Al_2O_3 TLD was 91.43%.
Conclusions: To verify absolute dose distributions, corrections of energy dependences of the 2-D Al_2O_3 TLD is necessary. The dose response curve measured with the field size used for the plan is required when using the 2-D Al_2O_3 TLD. However, it is suitable for dose distribution verification.

Keywords: Thermoluminescence; radiotherapy; QA

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Occupational Dose During Fluoroscopy Guided Interventional (FGI) Procedures at Institut Kanser Negara

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Purpose: Fluoroscopy-guided interventional (FGI) tends to involve in long procedures, will increase the fluoroscopy time and dose area product (DAP). Hence, radiation protection for interventional radiology staff is a major concern. This research represents occupational radiation dose for interventional radiology staff, especially non-physician, to clarify the present dose level for radiographer and nurse. Methods: We compared the occupational dose among interventional radiology staff in a Institut Kanser Negara, Putrajaya, Malaysia where 230 FGI procedures are performed in one-year observation. The occupational doses of interventional radiologist (IR), medical officer (MO), radiographer and nurse were recorded using two optically stimulated luminescence (OSL) dosimeter, one worn over and one under their protective aprons. All the OSL dosimeter will be readout using microStar reader system (Landauer, Inc.). Results: The occupational dose (effective dose) shows that the IR, MO, radiographer and nurse using two dosimeters was 9.82, 7.91, 6.42 and 6.02 mSv/year, respectively. By using one dosimeter, the effective dose of IR, MO, radiographer and nurse was 7.63, 7.91, 6.42, 5.66 mSv/year, respectively. It shows statistically significant difference in the effective dose worn two dosimeters and one dosimeter ($p < 0.001$) for interventional radiology staff. Conclusions: According to the order of the highest effective dose among the interventional radiology staff was IR > MO > radiographer > nurse, for both method. But, occupational dose using one dosimeter are lower than two dosimeters. We highly recommend the interventional radiology staffs to wear two dosimeters during the FGI procedures, so that occupational dose can be evaluated correctly.

Keywords: Occupational dose; interventional radiology; OSL

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Adult Radiation Doses for Computed Tomography (CT) from an International Dose Registry

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Purpose: To create international CT radiation dose benchmarks for adults (>=15 years). We report the distribution of radiation dose metrics based on CT scans submitted in 2017 to a large international dose registry comprised of 139 institutions in 7 countries. Methods: We describe median (target) and 75th percentile (benchmark) doses for CT dose index volume (CTDIvol, in mGy) and dose length product (DLP, in mGy-cm) by anatomic area across all institutions. Results: Japan and Europe contributed 27,304 CT and 85,686 adult scans, respectively, including examinations of the head (30%), chest (33%) abdomen (27%), and combined chest-abdomen (CAP) (10%). CTDIvol target and benchmark values in Japan were: head (21 and 41), chest (3 and 7), abdomen (9 and 13), and CAP (9 and 12). Corresponding values in Europe were: head (38 and 47), chest (4 and 7), abdomen (7 and 11), and CAP (9 and 14). DLP target and benchmark values for Japan were: head (821 and 857), chest (141 and 338), abdomen (867 and 1442), and CAP (1362 and 2175). Corresponding values in Europe were 18-48% lower: head (685 and 789), chest (163 and 334), abdomen (425 and 675), and CAP (670 and 1045). The results changed minimally after accounting for patient diameter. Differences in usage of multi-phase scanning in Japan (43%) and Europe (23%) could explain the large differences in DLP. Conclusions: We find similar doses between Japan and Europe, with notable exceptions of abdomen and CAP DLP, possibly due to differences in multi-phase scanning.

Keywords: Computed tomography (CT); benchmarks; diagnostic reference levels (DRL)

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Differences Between Singlephase and Multiphase Scanning in Adult Abdomen Radiation Doses for Computed Tomography (CT)

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Purpose: To examine the usage of multiphase CT scanning and to contribute to the creation of CT radiation dose benchmarks for adults (>=15 years). We report the distribution of radiation dose metrics based on CT scans submitted in 2017 to a large international dose registry comprised of 139 institutions from 7 countries. Methods: We describe median (target) and 75th percentile (benchmark) doses as dose length product (DLP) for abdomen and combined chest-abdomen (CAP) CT scans in one institution in Japan. Results: Japan contributed 27,304 CT adult scans during 2017, including examinations of the head (31%), chest (50%) abdomen (18%) and combined chest-abdomen (CAP) (1%). 72% of abdomen scans and 83% of CAP scans were multiphase. DLP target and benchmark values (in mGy-cm), respectively, in singlephase scans were: abdomen (623 and 837), and CAP (458 and 618). Corresponding multiphase values were 18-48% higher: abdomen (1077 and 1759), and CAP (1362 and 2175). Conclusions: There were mostly minimal patient (age and size) and technical parameter (slice thickness and kVp) differences between singlephase and multiphase. However, there is a bimodal distribution for singlephase scans in pitch at 0.8 and 1.4, and a multimodal distribution for multiphase at 0.8, 1.0, and 1.4. Tube current for singlephase is skewed towards 100 mAs and multiphase is skewed towards 200 mAs.

Keywords: Computed tomography (CT); benchmarks; technical parameters

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Adult Radiation Doses for Computed Tomography (CT) by Age and Patient Diameter in Japan

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Purpose: To create age and size-based CT radiation dose benchmarks for adults (>=15 years). We report the distribution of dose metrics based on CT scans submitted in 2017 to a large international dose registry comprised of 139 institutions from 7 countries. Methods: We describe the mean dose length product (DLP, in mGy-cm) for adult abdomen and head CT scans by 10 year age groups and deciled patient diameter groups in one institution in Japan. Results: We analyzed 27,304 adult CT scans and found the following mean DLP values: youngest age group and smallest patient diameter: abdomen (662) and head (363); youngest age group and largest patient diameter: abdomen (2808) and head (1103); oldest age group and smallest patient diameter: abdomen (531) and head (641); oldest age group and largest patient size: abdomen (1961) and head (1042); Conclusions: We found small changes in mean abdominal doses by age group, compared with a four-fold increase in dose by patient diameter within age categories, and a three-fold increase in mean head dose by patient diameter within age categories. Similar patterns occur for CT dose index volume (CTDIvol) and for DLP in other scan regions.

Keywords: Computed tomography (CT); dose variation; age and size reference levels (DRL)

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Current Pediatric Head Radiation Doses from a Computed Tomography (CT) Dose Registry by Age Category

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Purpose: To create age-based CT radiation dose benchmarks for pediatric head scans (<15 years). Methods: We report the distribution of radiation dose metrics based on CT scans submitted in 2017 to a large international dose registry comprised of 139 institutions from 7 countries. We describe median (target) and 75th percentile (benchmark) doses for CT dose index volume (CTDIvol) and dose length product (DLP) for pediatric head scans by individual age groups. Results: We include 471 pediatric CT scans of the head (84%), chest (6%), abdomen (7%), and chest-abdomen-pelvis (CAP) (4%) performed in children in Japan. Pediatric scans were split into 10 age groups, The youngest age group was 0-1 years and the oldest 12-14 years. 87% of the pediatric head scans were multiphase scans as opposed to single phase scans. CTDIvol target and benchmark values (in mGy), respectively, for head scans were: youngest age group (7.76 and 8.98), and oldest age group (21.49 and 26.10). DLP target and benchmark values (in mGy-cm), respectively, for head scans were: youngest age group (256.40 and 281.60), and oldest age group (819.29 and 821.14). Conclusions: We found a three-fold difference in dose for both CTDIvol and DLP in head scans comparing the oldest age category to the youngest age category.

Keywords: Computed tomography (CT); pediatric benchmarks; pediatric diagnostic reference levels (DRL)

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Thermoluminescence Efficiency of Thermoluminescence Detector Based on Chromium-Doped Alumina Ceramic to Linear Energy Transfer

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Purpose: Heavy charged particle (HCP) therapy is attracting attention because it can deliver high dose to deep-seated tumor and less dose to normal tissues. We developed a measurement system of 2D dose distribution using thermoluminescence detector based on chromium-doped alumina ceramic (Al_2O_3:Cr). The detector is reusable and has high reproducibility. This work aims at investigating thermoluminescence (TL) efficiency of Al_2O_3:Cr for HCPs with different atomic numbers and energies. Methods: Irradiations were performed at the Heavy Ion Medical Accelerator in Chiba (HIMAC), Japan. The species of irradiation source and the initial energies are as follows: 160 MeV/u H, 150 MeV/u He, 290 MeV/u C, 135 MeV/u C, 400 MeV/u Ne, 500 MeV/u Ar and 500 MeV/u Fe. The distance between source and detector was fixed and energy was changed by the binary filter. Linear energy transfer (LET) was calculated by Monte Carlo simulation. The integral TL signal from 295°C to 305°C was used to estimate dose and the dose conversion factor was obtained using 6 MV X-ray. The TL efficiency was defined as the ratio of absorbed dose by Al_2O_3:Cr and dose by ionization chamber. Results: TL efficiency of Al_2O_3:Cr increased from 0.8 to 1.48 when LET is between 0.5 keV/μm and 10 keV/μm. And then it decreased to 0.4 when LET increased to 1350keV/μm. Conclusions: In this work, the tendency of the variation of TL efficiency of Al_2O_3:Cr to LET was clarified. By correcting LET dependency, Al2O_3:Cr may has potential to be a 2D measurement detector for HCPs.

Keywords: Heavy charged particle; thermoluminescence detector; linear energy transfer

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Radiation Dose Intensity and Local Tumor Control of Non-Small Cell Lung Cancer: A Radiobiological Modeling Perspective

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Purpose: Several clinical situations call for the use of radiobiological principles as powerful clinical tools. The aim of this project was to examine the effect of radiotherapy dose intensity on local tumor control for Non-Small Cell Lung Cancer(NSCLC) using the Biological Effective Dose (BED) concept. Methods: BED quantifies treatment expectations based on the following parameters: tissue/tumor radiosensitivity, dose per fraction, and total number of doses. A two-year Tumor Control Probability (TCP) model was developed based on linear-quadratic model combined with Poisson statistics. The two-year TCP outcomes were analyzed regarding radiotherapy doses using BED. The BED calculations and the TCP model were fitted to a series of NSCLC patients drawn from the literature. Based on the clinical data, the two-year local tumor control rate for stage I–II NSCLC for dose fractionation size varied 1.5–20 Gy per fraction, delivered via three radiotherapy treatments: conventional treatment, Continuous Hyperfractionated Accelerated Radiotherapy(CHART), and Stereotactic Ablative Body Radiosurgery (SABR). Results: The BED values of 2,280 patients were analyzed as a function of local tumor control. To quantitatively assess the correlation between BED and local tumor control, residuals analysis and linear regression were employed. Higher radiotherapy doses were associated with improved local-tumor control and survival for NSCLC, as suggested by the coefficient of the correlation R2 statistical test: 0.82 for conventional treatment, 0.86 for CHART, and 0.72 for SABR treatment. Conclusions: This study demonstrated that higher BED values are associated with improved local tumor control and survival for NSCLC, as deduced from the coefficient of the correlation R2 statistical test.

Keywords: Tumor control probability; biological effective dose; non-small cell lung cancer; conventional treatment; continuous hyperfractionated accelerated radiotherapy; stereotactic ablative body radiosurgery

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The Survey of Radiation Dose From Sewer and Admitted Ward of Patient Treated with Radioiodine-131 Therapy

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Purpose: To investigate the radiation dose from admitted ward of patient treated with radioiodine-131 and the radiation dose in the building's sewer. Methods: OSL were placed on the outer surface of the sewer line and on the external wall of the patient room treated with I-131. The accumulated radiation dose was measured for 1 month. Results: The radiation dose from I-131 patient room located on the 5th floor was 7.24 μSv/h.The amount of radiation from both sides of the drainage pipe was not equal. Radiation dose on the 2nd, 3rd, 4th and 5th floors was 1.70, 1.28, 2.97 and 7.24 μSv/h, respectively. Conclusions: The calculation of accumulated dose for one year exceeds the ICRP dose limit. This is not safe for staffs and public to be in the high radiation area. Radiation warning sign should be placed to alert the staffs. To reduce the amount of radiation dose, lead shield should be added to the patient room. The radiation dose measurement should be performed again after reconstruction.

Keywords: OSL, Iodine-131, Radiation dose

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Primary Activity Standardization of ^{177}Lu for Calibrating Commercial Dose Calibrator

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Purpose: The aim of this research is to determine the activity value of ^{177}Lu and obtain the cal. set of the standard reference ionization chamber which further used to calibrate the commercial dose calibrator for ^{177}Lu as a new radioisotope for radionuclide therapy in Indonesia. Methods: The 4πβ (LS)-γ coincidence counting method with digital counting technique was applied to determine the absolute activity of ^{177}Lu. The result was then used as a reference value to calibrate dose calibrator in hospitals using a relative method through the standard reference ionization chamber (IC). A gamma spectrometry measurement was also performed to check the impurities of ^{177}Lu solution used in the experiment. Results: The impurities test using gamma spectrometry method shows that there are no other radionuclide detected as impurities in the ^{177}Lu solution. The activity standardization of ^{177}Lu giving a value of 148 kBq/g ± 1.78 kBq/g at a reference time with uncertainty 1.2% at k=2. Using the result as a reference value, a cal set value of 024 was obtained on the standard reference IC. Two commercial dose calibrators were calibrated by relative method with the standard reference IC giving a result of 1.00 calibration factor (C.F) for both calibrators with slightly difference in the uncertainty value. Conclusions: A final activity results of 148 kBq/g ± 1.78 kBq/g at a reference time was obtained with uncertainty 1.2% at k=2. The value was used as a reference to determine the cal. set of standard reference IC and the cal. set value of 024 was obtained. Two commercial dose calibrators were calibrated by relative method giving a result of 1.00 calibration factor (C.F) for both calibrators.

Keywords: 4πβ (LS)-γ coincidence; activity standardization; lutetium-177; dose calibrator; calibration factor

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Comparison of Air Kerma Measurement Standards for Diagnostic Radiology between Medical Physics Calibration Laboratory (MPCL), Malaysian Nuclear Agency and Dosimetry Laboratory, IAEA

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Purpose: The objective of this paper is to present the result of comparison of air kerma measurement standards for diagnostic radiology between Medical Physics Calibration Laboratory (MPCL), Malaysian Nuclear Agency and Dosimetry Laboratory, International Atomic Energy Agency (IAEA). The aims of this comparison program is to verify that MPCL can carry out calibrations in terms of air kerma within acceptable limits, and to validate the traceability of the MPCL diagnostic radiology standards. Methods: The IAEA's transfer chamber Exradin #A3 was received from Dosimetry Laboratory, IAEA on August 2017. The comparison was conducted between the Exradin #3 and reference standard chambers in MPCL which are PTW ion chambers model TN77337 and TW30009. The comparison was conducted in terms of air kerma. The air kerma rate was between 18 – 52 mGy/min with the beam diameter 11 cm Ø. The comparison parameters was the calibration coefficients, N_{Kair} [mGy/nC] of the transfer chamber and reference standard chambers of MPCL. Results: The result of the comparison were calculated as the average ratio of the IAEA and MPCL calibration coefficients obtained with the transfer chamber and reference standard chambers at MPCL, Nuclear Malaysia. The comparison results, R for the selected beam qualities were in the range of 0.985 – 1.008. Conclusions: The comparison results, R for the selected beam qualities were in the range (0.985 – 1.008) within the uncertainty of comparison. The R is considered to be acceptable if $0.975 < R < 1.025$. It can be concluded that level of agreement of the calibration coefficients of both laboratories is well within the relative standard uncertainty of the comparison of about 1.5 %.

Keywords: Air kerma; calibration coefficient; comparison result

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Fingernail Dosimetry using Electron Spin Resonance for Radiation Disaster Response

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Purpose: This study investigates the use of electron spin resonance (ESR) signals from human fingernails as part of radiation disaster response, focusing on the analyses of individual responses to radiation. Methods: Here we report human fingernails collected from 8 donors (Asian type) and irradiated to 0, 35, and 70 Gy. The samples were exposed to gamma-rays from a Cs-137 source at a dose rate of 0.857 Gy/min. All irradiated fingernails were measured for 39 days with an X-band ESR spectrometer (JEOL JES-FA100) and stored inside a vacuum desiccator unit (30% humidity, 20°C) in between measurements at all times. All samples were harvested using one specific nail cutter and given no other special treatments. Results: It was observed that the measured radiation-induced signals of the fingernails from all the donors faded fast over 24h but reached certain constant levels after 3 days of post-measurement. Though the dose-response curves were significantly different among the donors, a greater linearity was seen from the samples of younger donors. Conclusions: Our results suggest the possibility of fingernails to measure absorbed radiation doses in the range of 0 – 70 Gy and thus could be a useful tool for retrospective dosimetry after an unexpected radiological accident or medical treatment error. In its current state, however, further investigations are still needed to arrest the radiation-induced signal from quick fading; hence, appropriate storage conditions and other physical/physiological factors must be considered for practical applications of nail dosimetry.

Keywords: ESR; fingernails; retrospective dosimetry; radiation disaster response

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Using Google Trends Data to Study Public Interest in Radiation

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Purpose: This study evaluates cycle of public interest in radiation worldwide with radiation-related incidents using web-based search tools from 2008 to 2018. Methods: Google trends was employed to normalise traffic data on a scale of 0 to 100, and were presented as monthly relative search volume (RSV) using radiation, radioactive, nuclear medicine and x-ray as a search term. Results: A remarkable peak was identified in March 2011 during the Fukushima Daiichi nuclear disaster. Conclusions: Public interest towards radiation is correlated with radiation-related incidents or events.

Keywords: Social media; Twitter; radiation

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Challenges and Opportunities for A CAMPEP-Accredited Medical Physics Graduate Program in Galway, Ireland

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Established in 2002, this long running MSc in Medical Physics program was awarded CAMPEP accreditation in 2015, thus being one out of only two CAMPEP approved graduate programs outside North America. The program is a full-time one-year taught master course delivered by a close university – hospital collaboration. This presentation will give an outline of the current program structure and will identify challenges likely affecting the areas of teaching, research and course administration. Strategies to address these challenges will be discussed. Since the accreditation the number of students enrolled in the program increased from 8 in 2015/16 and 16 in 2016/17 to 21 in 2017/18 and 30 in 2018/19. The number of non-EU students in these cohorts was 2, 5, 4, and 7 respectively. Non-EU students predominantly originate from North America and Saudi-Arabia. The total number of applicants averages at approximately 55 per year. A further increase in student intake has been advocated but might impact negatively on the quality of the clinical training which forms a vital part of the program. Students are given access to clinical systems for laboratory exercises as well as for pursuing research projects, thus gaining some clinical experience which will increase their employability. However, local clinical access has to be limited. In order to mitigate the situation, the program cooperates with medical physics departments nationwide and internationally. Curricular challenges arising from clinical implementations of ever-evolving technologies and from a rapidly changing medical physics landscape in general will be expanded on.

Keywords: Education; MSc in Medical Physics; CAMPEP

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Design of Data Acquisition System Based on Wireless Sensor Network for Safety and Protection of Radiation Workers

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Purpose: Utilization of ionizing radiation contributes to radiation exposure to the environment, medical field, public, and radiation workers. Radiation exposure negatively impacts both health and genetic traits. The radiation cannot be directly observed, hence requiring a radiation monitoring tool called detector. Methods: We applied the Design of Data Acquisition System Based on Wireless Sensor Network for Safety and Protection of Radiation Workers to monitor the dosage of radiation accepted by workers and nearby environments. We also pointed out the process of designing a wireless sensor network based radiation detector and established centered real time data acquisition system for several radiation dosage measurements in a data processing unit. Findings: The radiation dosimetry system designed consisted of multi sensors. Each sensor node was equipped with the Pocket Geiger Type 5 sensor radiation. The photodiode radiation sensor had an active area of 100 mm2 and measurement range of 0.05 μSv/hour to 10 mSv/hour. To collect and deliver the data of sensor module measurement results, we used the IEEE 802.15.4 standard digital radio, type of Xbee module. Furthermore, we also used an Arduino microcontroller as the controlling unit. Conclusion: The system should be designed more efficiently in terms of time and radiation exposure data collection process for the environments and workers in diverse units, particularly those utilizing nuclear energy.

Keywords: Detector; radiation protection; WSN

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The Simulation of the Energy Dependence for Al_2O_3:Cr TLD In Various Volumes

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Purpose: The aim of our study is develop to a personal dosimeter of Al_2O_3:Cr thermoluminescence dosimeter (TLD) which can manufacture at low cost. We examined the energy dependence in various volumes, which little has been reported on radiation detectors. Methods: We obtained absorbed doses to Al_2O_3:Cr TLD(DTLD), radiophotoluminescence dosimeter (DRGD) for comparison and air kerma (K_{air}), to photons of 0.01–3 MeV using Particle and Heavy Ion Transport code System (PHITS). We placed each detectors on air, which were spheres with radiuses of 0.75, 2.5 and 5 mm. Then we calculated ratios of DTLD/K_{air} and DRGD/K_{air} from obtained results. We had similar simulations for electrons of 0.1–3 MeV. The statistics errors were 1% or less. Results: Peaks of ratios of D TLD/K_{air} and DRGD/K_{air} were in 30–50 keV. The smaller volumes of detectors were, the higher both ratios of DTLD/K_{air} and DRGD/K_{air} to photons were. Moreover, in the ranges of 0.1–1 MeV, Both ratios of DTLD/K_{air} and DRGD/K_{air} with 2.5 mm–sphere almost agreed with them of 5 mm–sphere. Both ratios of DTLD/D_{air} and DRGD/K_{air} with a radius of 0.75 mm–sphere became maximum in the range of 0.9–1 MeV to electrons. Both ratios of DTLD/K_{air} and DRGD/K_{air} of radiuses 2.5, 5 mm increased as the energy increased. Conclusions: The energy dependence of the 5 mm–sphere was the smallest. In the future we examine the optimization of the size of the TLD in consideration of other points such as sensitivity.

Keywords: Monte Carlo; TLD; energy dependence

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A250

Technical Note: Using Starch in Routine Work for Decontamination of I-131 Isolation Rooms

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Purpose: This notes explain the starch effect on I-131 decontamination compare to usual method (Commericial, Radiacwash).The first purpose is to investigate that the elemental iodine trapped permanently by starch powder. Second is to assess the effectiveness of starch powder in case of Iodine-131contamination practically. Methods: Firstly, The stable iodine was heated by hot air gun. The violate iodine fumes came out by heating. These fumes were exposed to two dishes of sugar and starch. Both powders were colored by iodine fumes. The dishes were followed for a 3 months. Secondly, the I-131 decontamination was compared between two different. Methods; Starch and Commericial,Radiacwash (i.e. most popular general purpose decontamination solution). After each decontamination attempt, wipe test was performed to check the I-131 radioactivity. Results: The starch has affinity of trapping iodine permanently, while the sugar as an example has not. Moreover, for I-131 decontamination by starch proved to be a successful practical solution. Conclusions: Using starch for I-131 decontamination proved to be a successful practical solution for cleaning up the I-131 isolation rooms which involves considerable risk of cross contamination and inhalation of volatile iodine radioisotope.

Keywords: Iodine-131decontamination; starch

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A255

Assessment of a Localized Deterministic Spatial Interpolation Method in Generating an Indoor Radiofrequency Radiation Map

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Purpose: This study assessed the robustness of a localized deterministic spatial interpolation method compared to its global interpolation counterpart used in generating a radiofrequency radiation (RFR) map. This was investigated to speed up the data analysis by taking a smaller number of samples. Methods: An omnidirectional picocell antenna located in an office lobby area was chosen inside a tertiary hospital in the Philippines. A calibrated NARDA Selective Radiation Meter SRM-3000TM with tri-axis antenna was used in all measurements. The spectrum analysis mode was used to check the central frequency emitted by the indoor antenna. The average power density was measured in each assigned point for six minutes per grid point. A global and a local spatial interpolation method was implemented using a grid pattern around the antenna. Then, a radiofrequency map was generated using a smaller size of samples (20 samples). Results: The local Shepard interpolation method with a radius of influence equal to 100cm and a power factor of 1 gives a result with a mean absolute difference of 0.144. This is more accurate compared to the global interpolation method investigated. Conclusions: Both the global and local interpolation methods produced varying errors. This is due to the multiple reflection, diffraction, and scattering of RFR as it propagates. For the Shepard method used, the local-original Shepard method produced a more accurate result compared to its global interpolation counterpart. Thus, error contribution in RFR map generation can be minimized by considering a smaller region of samples in the interpolation.

Keywords: Radiofrequency radiation; spatial interpolation; non-ionizing radiation protection

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Tailor-Made Ge-Doped Cylindrical Optical Fibres: Their Dosimetric Properties for Proton Beam Measurements

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Purpose: In present study, the principal dosimetric characteristics of tailor-made 2.3 mol% and 6.0 mol% germanium (Ge) doped cylindrical optical fibres have been investigated, including radiation dose linearity, linearity index, minimum detectable dose (MDD), reproducibility and post-irradiation signal fading, all subjected to proton irradiations. Methods: The tailor-made Ge-doped cylindrical optical fibres were fabricated using a modified chemical vapour deposition (MCVD) process and pulled using a pulling tower. SEM-EDX analysis was performed to map the relative distribution of Ge concentration inside the fabricated optical fibres. Proton beams (150 MeV) were used for irradiation of the samples over radiation therapy doses, ranging from 1 to 10 Gy. The obtained measurements were compared with the TLD-100, nanoDot™ and commercial optical fibres. Results: The results show that the fabricated optical fibres are linearly sensitive to the investigated radiation dose range with a coefficient of determination (R^2) greater than 99%, with their responses remain close to the linearity index value of one. The MDD of the fabricated optical fibres has been shown to be around 10 mGy. Reproducibility testing of the fabricated optical fibres reveals a better uncertainty to within 4 to 8% (without screening) and no statistically significant difference ($p > 0.05$) between repeated measurements for various irradiation beams and energies. After 96 days post-irradiation, fabricated optical fibres have demonstrated minimal signal fading by 13% to 19% at the most. Conclusions: The results presented herein underline the potential of the fabricated Ge-doped cylindrical optical fibers as next-generation alternative radiation dosimeter, particularly in proton beam dosimetry.

Keywords: Dosimetric characteristics; fabricated Ge-doped optical fibre; proton beam

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A263

Characterization of the Changes in Electroencephalogram Patterns Due to Sound Stimulation

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Purpose: Some activities, such as sports, meditation and therapy are often accompanied by music with different tempo, for example ~60 bpm (adagio) for yoga and taichi, ~180 bpm (presto) for treadmill and 120-156 bpm (allegro) during aerobic exercise (Caplin et al, 2010). Music can affect emotions and brain activity. Brain activity can be measured through brain waves which are recorded by electroencephalograph. The aim of this research is to characterize the electroencephalogram patterns due to sound stimulation. Methods: In this study, EEG data acquisitions are conducted using wireless electroencephalograph. EEG power spectra is measured for healthy subjects in relax conditions when listening music with different tempo and intensity. An investigation also carried when the subject is stimulated with music using left ear only, right ear only, and both ears. Results: Our preliminary results found that the EEG power spectral in right-brain hemisphere higher than the left hemisphere which is associated with the more active right-brain hemisphere when listening to music. The comparison for EEG power spectra in association with the tempo and intensity of the sound will be presented. The electroencephalogram patterns are also presented for which ear is stimulated with the music. Conclusions: From the results, it can be concluded that the right brain hemisphere is more active when listening music in spite of which ear is stimulated.

Keywords: EEG pattern; sound stimulation; EEG power spectra

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A268

A Study on the Reduction of Effective Dose using Hand-Made Radiation Shield in the Pediatric Computed Tomography

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Purpose: We studied how effective dose were reduced by using hand-made pediatric radiation shield with pediatric phantom during the Chest CT and Abdomen CT examinations of pediatric patients. Methods: The study uses a pediatric phantom inserted with OSLD to provide detailed information about the dose to the organs of the patient in the body in children's patients, Chest CT and Abdomen CT. In particular, effective dose values before and after shielding were analysed, particularly when hand-made pediatric radiation shield were used. OSLD employed the Chest CT and Abdomen CT assay protocols for standard pediatric patients for each individual site, including thyroid, breast, T-L spine, ovary and prostate in the pediatric phantom. Results: The quantitative assessment of the effective dose in the pediatric phantom showed a dose reduction of 68 % on the left side of the ovary, 67 % on the right and 86 % in the prostate when the pediatric radiation shielding tool was used. In addition, Abdomen CT performed a 32 % to the left breast and 12 % dose reduction on the right when using hand-made pediatric radiation shield. Conclusions: The use of hand-made pediatric radiation shield during the Chest CT and Abdomen CT examinations of pediatric patients is recommended for more aggressive use, as they may reduce the radiation effective dose in pediatric patients.

Keywords: OSLD; hand-made pediatric radiation shield; effective dose; pediatric phantom

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Synthesis and Characterization of Fluoridated Hydroxyapatite Nano-Powder via Microwave Irradiation Method

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Purpose: Fluoridated hydroxyapatite (FHA) occur in teeth and form the basis for application as biomaterial. This work aims to synthesize and analyze the characteristic of FHA nano-powder with different degrees of fluoridation via microwave irradiation method. Methods: FHA nano-powder with a chemical formula of $Ca_{10}(PO_4)_6(OH_{2-x})F_x$ (where degrees of fluoridation, x values were selected equal to 0.7 and 1.3) were synthesized using a mixture of calcium hydroxide, diammonium hydrogen phosphate, and ammonium fluoride solutions by utilizing microwave with variation of irradiation power. X-ray diffraction (XRD), fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), and energy dispersive x-ray (EDX) spectroscopy analysis techniques were utilized in order to evaluate the characteristic of synthesized FHA nano-powder. Results: The XRD and FTIR results confirmed highly crystalline FHA powder with the carbonate peaks in the IR spectrum. Using modified Scherrer formula, the average crystallite size was found to be 40 nm. The SEM and EDX results indicated various element composition and several morphology with the lattice parameter increased along with irradiation power. Conclusions: FHA nano-powder could be synthesized via microwave irradiation method. The results from different kind of analysis illustrated that synthesized FHA nano-powder could fulfill the requirement of ASTM F1185-88 for used as biomaterial.

Keywords: Fluor; hydroxyapatite; biomaterial; microwave irradiation

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Synthesis of Magnesium-Hydroxyapatite Crystal via Microwave Irradiation

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Purpose: Magnesium-Hydroxyapatite (MgHA) is synthesized by substituting Magnesium (Mg), an essential element found in bones that affects the metabolism of the bones, into Hydroxyapatite (HA), which is one of the main components of bones. The aim of this study was to synthesize MgHA nano-powder via microwave irradiation and determine the effects of microwave irradiation's power and irradiation time variations on the synthesis of the magnesium-hydroxyapatite crystal. Methods: In this study, synthesis of magnesium-hydroxyapatite (MgHA) was done by titrating both solutions of diammonium hydrogen phosphate and magnesium nitrate into a solution of calcium hydroxide. The mixed solution was then irradiated by the microwave, with variations of microwave irradiation power and time. The phase composition, functional groups, morphology, particle size, and the element composition of the MgHA powder was evaluated using the following characterization method; x-ray diffraction (XRD), fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), and energy dispersive x-ray (EDX). Results: The XRD patterns show that the crystal index of the MgHA powder decreases as the irradiation time increases. The crystallite size was calculated using the modified Scherrer formula, determining the average crystallite size of 25 nm and showing that the average crystallite size increases as the irradiation power increases. Various element compositions and several morphologies were shown by the SEM and EDX results. Conclusions: MgHA nano-powder could be synthesized via microwave irradiation. The results show that average crystallite size increases as the irradiation power increases, and the crystallinity index decreases as the irradiation time increases.

Keywords: Biomaterial; magnesium, hydroxyapatite; microwave irradiation

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A273

Microwave – assisted Precipitation of Carbonated Hydroxyapatite

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Purpose: Carbonated hydroxyapatite (CHA) is a bone implant material that has good solubility and resorption. In this study, carbonated hydroxyapatite (CHA) was synthesized and characterized using microwave – assisted precipitation method under different irradiation power and time. Methods: CHA powder was synthesized starting from calcium hydroxide, diammonium hydrogen phosphate, and calcium hydroxide. Chemical analyses, XRD, FTIR, SEM, and EDX, were applied to investigate the composition, crystallinity, crystallite size and morphology of CHA powder. Results: XRD patterns show that CHA powder have similar apatite to the hexagonal hydroxyapatite and the sharp and narrow characteristic peaks mean good crystallinity. The crystallite size of the samples was approximately 44 nm. FTIR and EDX affirmed that the proposed method showed that CHA bond existed. Conclusion: Chemical analyses suggest that CHA powder can be obtained using microwave-assisted precipitation method with good results.

Keywords: Biomaterial; carbonate; hydroxyapatite; microwave; irradiation

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Characterization of Properties in Microwave Irradiated-Hydroxyapatite

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Purpose: Hydroxyapatite (HA) is a calcium phosphate with a chemical bond of $Ca_{10}(PO_4)_6(OH)_2$, which is contained in the human bones. Thus makes HA convenient for further development as biomaterial. The aim of this work is to understand the effect of variation in microwave power and time in synthesizing HA. Methods: HA was synthesized by a mixture of calcium hydroxide and diammonium hydogen phosphate, maintaining the molar ratio between calcium and phosphate of 1.67. The sample was irradiated using microwave irradiation at different powers and time durations. The properties of all samples were investigated by x-ray diffraction (XRD), Fourier transform infrared (FTIR), scanning electron microscopy and energy dispersive x-ray spectroscopy (SEM-EDX). Results: The mass of HA samples showed a quite significant change. The crystallite size of the samples reached approximately 37.65 nm. The FTIR results showed some carbonate peaks. Conclusions: It is proved that the change in irradiation power and time affects the properties of the synthesized HA. The synthesized HA powders showed a similar structure to hydroxyapatite in hexagonal P63/m space group a=b=9.417 and c=6.88.

Keywords: Hydroxyapatite; microwave; irradiation

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Synthesis and Characterization of Hydroxyapatite-Chitosan Composite *in situ* by Microwave Irradiation Method

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Purpose: Chitosan is natural polysaccharide which has bioresorbable, biocompatible, and non-toxic properties. The combination between chitosan and hydroxyapatite will form a nanocomposites which improve its mechanical properties and can be applied as bone implant material. The aim of this work was synthesis and characterization of composite hydroxyapatite-chitosan through in situ way utilized by microwave irradiation with time variation. Methods: A composite which was formed by hydroxyapatite (calcium hydroxyapatite, diammonium hydrogen phosphate) and 2% chitosan solution through in situ way were irradiated by 270-watt power for 20-60 minutes. X-ray diffraction (XRD), fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), and energy dispersive x-ray (EDX) spectroscopy analysis techniques were utilized in order to evaluate phase composition, functional groups, morphology, particle size, and element composition of synthesized composite. Results: The FTIR spectroscopy identified functional group of hydroxyapatite and chitosan (NH). Increase in irradiation time caused reduction of chitosan based on existence of NH composition. Highest mass was present at time 20 minutes which means reduction of mass also occurred with increasing irradiation time. The SEM and EDX results indicated the morphology of composite in the of chunks and various element composition. Conclusions: The presence of NH cluster proved that microwave irradiation method can be used to synthesize nanocomposites hydroxyapatite and chitosan. Increase in irradiation time caused a reduction of chitosan existence and its mass.

Keywords: Chitosan; hydroxyapatite; microwave irradiation; biomaterial

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Dosimetric Response of a Novel Plastic Diode at High Energy X-rays

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Purpose: The plastic diode was developed and constructed in house for the purpose of radiation detection. Methods: During measurement, the plastic diode was connected to a necessary electrical circuitry so that its response against irradiation can be recorded by a standard electrometer. The plastic diode was irradiated using high energy X-rays from medical linear accelerator. Results: The measured sensitivity of this plastic diode was found to be 0.05nC/cGy which is almost similar to some commercial diode dosimeters. The response of the plastic diode is linear in the whole range tested i.e. of 10-1000 cGy, which covers most of the range of radiation dose encountered in radiotherapy treatments. The non-linearity of the diode response is 3.5% at 10cGy and less than 1.5% at higher dose values. Dose repeatability is within 0.5%. Conclusions: These studies indicate that the characteristics of plastic diode are sensitive for high energy x-rays.

Keywords: Plastic diode; plastic dosimeter; radiotherapy; dosimetry

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The Influence of Kv in Reducing Computed Tomography Urography Dose Exposure for Suspected Renal Calculi: Single-Centre Trials

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Purpose: The aim of this study is to evaluate the influence of kV in reducing computed tomography (CT) dose exposure particularly CT urography examination in routine clinical practice for the detection of renal calculi. Methods: In this study, the scan acquisition parameter and the CT dose parametric information were collected retrospectively from 16-slice CT scanner (Toshiba Activion) console display with preset auto-modulation mAs. This experiment involved two sets of study, the pre-intervention (n=28, 50 ± 16 years, 120 kV, June 2017 to December 2017) and post-intervention (n=28, 51 ± 17 years, 100 kV, January 2018 to June 2018), respectively. Results: The mean CTDIvol values recorded for pre- and post-intervention were 8.8 ± 1.3 mGy and 6.6 ± 2.2 mGy, respectively. Generally, the mean dose-length product (DLP) for pre- and post-intervention were 321.41 ± 31.21 mGy.cm and 230.61 ± 58.16 mGy.cm, respectively. Conclusions: The reduction of kV in CT urography examination has significantly reduces the radiation exposure to the patient to almost 30%, while maintaining the same level of diagnostic accuracy.

Keywords: Computed tomography; urography; radiation dose

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EEG Power Spectra in Children with Mental Retardation

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Purpose: According to Diagnostic and Statistical Manual IV-TR (DSM IV-TR), mental retardation is a disorder characterized by deficits in intellectual function accompanied by limited adaptive function. In general, mental retardation sufferers have an IQ lower than 70. Children with mental retardation may have different neurophysiological characteristics compared to normal children. Therefore, this study aimed to examine changes in EEG signal patterns based on the power spectral analysis in children with mental retardation. Methods: The test subjects were consisted of 7 mentally retarded children with an age of 10 to 15 years. Data acquisitions were conducted using 14-electrodes Emotiv EPOC EEG. The EEG recording was performed under closed eyes, opened eyes, audio stimulation and audio-visual stimulation. Total recording time for each subject was about 12 minutes for all measurement conditions combined. The absolute power spectrum of each frequency band (delta, theta, alpha and beta) was calculated using Welch periodogram method. The relative power spectrum of each frequency band was expressed in Relative Delta Power (RDP), Relative Theta Power (RTP), Relative Alpha Power (RAP), and Relative Beta Power (RBP). Results: Based on the analysis results, it was obtained that the power spectral of theta in children with mental retardation was increased, while the power spectral of alpha and beta were decreased. The power spectral ratio RAP/RDP and RAP/RTP were decreased, as well as the ratio between the summation of alpha and beta due to the delta and theta (RAP+RBP)/(RDP+RTP). Conclusions: The changes in the power spectral of the EEG in mental retardation are a hallmark of abnormalities of the brain functionality.

Keywords: EEG signal; power spectral; mental retardation

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A310

Activities of the Japan Society of Medical Physics (JSMP) and Future Tasks

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Background: The Japan Society of Medical Physics (JSMP) was originated from the physics committee of Japan Radiological Society (JRS) established in 1953. In 2000, the Japanese Association of Radiological Physicist (JARP) and the Japanese Association of Medical Physicists (JAMP) were merged into the JSMP. The JSMP was certified as a Public Interest Incorporated Association in May 2018. Activities: The current activities have been to hold the academic meetings, to study on physics and technologies in medicine, to publish the academic English journal "Radiological Physics and Technology" with the Japanese Society of Radiological Technology (JSRT), which is one of the AFOMP official journals, and Japanese journal, to cooperate with domestic and overseas organizations and to perform other necessary activities. We have also been one of the property contributors of general incorporated foundation of Japanese Board for Medical Physicist Qualification (JBMP) and involved in the medical physicist certification in Japan. Future Tasks: The situations around medical physics and medical physicist have been varying due to the progress of medical and information technologies as well as recent social and economic factors. The well-timed implementation for the situations should be required, so we will discuss and perform the activities to contribute the human health by expanding the scope of activities more interdisciplinary and internationally. The Japan Radiology Congress 2019 (JRC2019) of which JSMP is one of host organizations will be held in Yokohama next year. Any AFOMP members can participate in the congress with no fee, and can be candidate for the presentation awards.

Keywords: Medical physics; medical physicist; academic Society

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Effects of Varying the Temperature and Solvent on the Morphological Properties of Zno Nanoparticles using Hydrothermal Method for Antibacterial Application

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Purpose: Zinc Oxide (ZnO) is a semiconductor material that has large surface area, low toxicity, and antibacterial properties which makes it a good candidate in synthetic textiles, medical and environmental care. It exists in diverse morphology which strongly affects the properties and possible application of the material. In this work, the effect of the variation of temperature and solvents on the morphological structures of ZnO nanoparticles are studied for antibacterial applications. Methods: ZnO nanoparticles were synthesized via modified hydrothermal set-up using zinc acetate and sodium hydroxide as precursors. The solutions were prepared using water and ethanol as solvents at 70°C and 200°C. The samples were characterized using scanning electron microscopy-energy dispersive x-ray (SEM-EDX) to determine the morphology and elemental composition. Results: SEM images revealed sea-urchin like structures with average diameter of 10 nm for sample with water as solvent at 70°C. Increasing the growth temperature to 200°C modified the structure into flower-like measured 13 nm in diameter. Meanwhile, sample heated at 70°C and 200°C in ethanol produced sponge-like structures with average pore sizes of 7 nm-15 nm. Accordingly, ZnO was produced with particle size that is 500% smaller in comparison with other conventional synthesis process. Water and ethanol contain hydroxyl groups that interact with ZnO from nucleation and growth giving rise to these different structures. Conclusions: Results showed the control over the size and shape manipulation ZnO nanostructures by adjusting the temperature and type of solvent. The effective control over the ZnO nanostructures shows a promising result for photocatalytic degradation and antibacterial application.

Keywords: Zinc oxide; hydrothermal; antibacterial

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Comparative Study Between Bonenavi Software and Visual Assement to Evaluate Bone Scintigraphy

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Purpose: This study was to compare betwen Bone Navi Software and visual assessment in the evaluation of bone scintigraphy. Methods: Retrospective study was done on 53 subjects, 32 males and 21 females, 15 subjects with breast cancer, 24 subjects with prostate cancer, 5 subjects with nasopharinx, and 9 with other cancers. Patients were injected with 740 MBq of ^{99}mTc-methylene diphosphonate and bone scintigraphy was performed at 3 hrs. after injection. The number of pathologies hot spots were obtained from BONENAVI software as well as visually assessed. The number of hot spot Bone Navi Soft ware were compare to the number of Visual Assessment. Results: There were 66% data was concordance and 34% discordance. Among discordence 26% out of 34% discordence positive on bone navi, 8% on opposite. Bone navi positive with negative visual assessment could due to the generative disease or the position of bone close to detector. Conclusions: BONENAVI reading of hot spot numbers was sensitive but Visual assessment is necessary to rule out this possibility.

Keywords: Bone Navi; visual assessment; bone scintigraphy

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A322

Synthesis and Characterization Properties of Nanocrystals Hydroxyapatite

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Purpose: Nanocrystals calcium Hydroxyapatite (HA) was the main mineral constituent of human bones and assisted the growth of bone tissue. In this study HA nanocrystals can be synthesized by using chemical precipitation and hydrothermal methods. Methods: HA nanocrystals synthesized from the chemical precipitation by variation of reacting precursors with 1 M of CaO, $CaCO_3$ and $(NH_4)_2HPO_4$ aqueous solution with using hydrothermal method at temperatures 150 °C and 300 °C. After drying, the hydroxyapatite samples were sintered at 900 °C with variation times of 1, 3 and 5 hours. All the samples were characterized by XRD, SEM and EDX. Results: The products were evaluated using X-Ray Diffraction (XRD). The result shown that the particle size of the nano HA obtained that sintered at 900 °C for 3 hours was 47.6 nm corresponding to the particle size of nano HA in native bone. Scanning Electron Microscope (SEM) showed that the morphology of nano HA such as rod, and Energy Dispersive Analysis X-Ray (EDX) was found the ratio Ca/P is 1.8. Conclusions: The hydrothermal synthesis of nano HA was hexagonal crystalline and the average particle size of the rods nano HA crystals for the sintered were 47.59 nm and 32.53 nm for the unsintered sample. The result of EDX showed that the elements contained on the samples were C, O, P, and Ca which had similar constituent elements of HA. However, the EDX analysis showed that all samples had a ratio of Ca / P aws 1.8 that were not exactly 1.67, but still closed to that value.

Keywords: Nano hydroxyapatite; hydrothermal; sintering

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A323

Evaluation of Novel Radiation Dosimeter using a Multi-Channel Real-Time Monitor

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Purpose: Radiation-induced injuries after interventional radiology (IR) have been reported in patients. Real-time monitoring of radiation doses administered to patients during IR is important to avoid such injuries. To the best of our knowledge, no feasible real-time dosimeter with a multi-channel monitor is available for IR. Therefore, we developed a novel radiation dosimeter with a multi-channel real-time monitor. The purpose of this study was to evaluate the usefulness of the developed dosimeter. Methods: We evaluated the basic performance (i.e., measured the energy, dose linearity, dose rate, and angular dependence) of the novel real-time dosimeter. We also compared a new sensor of the novel dosimeter with an old sensor. Results: Both the new and old sensors of the novel real-time dosimeter demonstrated the low energy dependence, excellent dose linearity (R^2=1), and good dose rate dependence (i.e., within 5% - statistical difference). In addition, the angular dependence of 0°± 180° in the horizontal and vertical directions demonstrated almost 100% sensitivity for the new sensor. Moreover, the new sensor of the novel dosimeter exerted less influence on X-ray images (fluoroscopy and radiography) than the old sensor. Conclusions: The developed dosimeter system is expected to be useful for measuring exposure of patients to radiation dose during IR procedures. In addition, the novel dosimeter does not interfere with clinical practice.

Keywords: Developed dosimeter system; interventional radiology; radiation-induced injuries; real-time dosimeter

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A324

Development of GPU-based Monte Carlo Dose Calculation for Proton Therapy: Architecture of Electromagnetic Process

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Purpose: Most of the current commercial TPS calculates proton dose uses pencil beam algorithm and this algorithm can be inaccurate in highly heterogeneous geometry. Monte Carlo method for dose calculation presents the highest accuracy but at the expense of an increasing computation time which is impractical in clinical setting. Thus, in this work, we present a GPU-based solution which can significantly increases the speed of Monte Carlo simulation of proton transport and can potentially serve as a QA tool in the new Proton Therapy centre in NCCS. Methods: The GPU-based Monte Carlo is coded using the CUDA toolkit and is run on a GTX 1080 Graphics card. The electromagnetic process of the Monte Carlo simulation was developed using the condensed history algorithm and only the protons are explicitly simulated. The beamspot size and depth-dose curve in homogenous medium such as water are calculated and was compared with GEANT4 simulation code for the validation of the electromagnetic model used in our GPU code. Results: Excellent beamspot and depth-dose agreement was observed between our newly developed GPU Monte Carlo simulation and the GEANT4 simulation for water and other clinically relevant materials. Conclusions: The electromagnetic model in our GPU-based Monte Carlo dose calculation has been developed and validated.

Keywords: Monte Carlo; GPU; proton therapy

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A328

Study of Longitudinal Relaxation Rate Nanopartikel Gadolinium in MRI Based on Monte Carlo Simulation

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Purpose: Enhance of MRI signal depend on the concentration amount of Gadolinium as a contrast agent. On the other hand, the longitudinal relaxation rate (R_1) has a linear relation to the concentration amount of Gadolinium also. This study aims to investigation the relation between R_1 and the diffusion rate of Gadolinium around the synapse based on Monte Carlo Simulation. Methods: Agarose phantoms were constructed for *in vitro* T1 weighted imaging. The phantoms scanned was performed at 1.5 T with a clinical MRI instrument (GE Healthcare) using a spin echo sequence with time echo, TE = 9 ms, time repetition, TR = 60, 100, 200, 300, 500, 700 and a 90° flip angle. An 8 channel head coil was used for RF transmission and reception. The samples have high dispersibility properties in a water based solution. Gadolinium powder was dispersed in 0.3% agarose gel with various gadolinium concentration variations (0 – 6.36 mM). The T1 weighted images were analyzed using MIPAV and ImageJ software to determine the correlation between the phantom intensity and concentration and longitudinal relaxation parameter, R_1, of the powder samples. On other hands, the diffusion rate was obtained by performing Monte Carlo Cell simulation. The simulation was performed around synapse with different amount of Gadolinium on 0.02s. Results: The curve of relaxation phantom to the concentration of GdO1 produce value of R_1 was 7.8 $mM^{-1}s^{-1}$. The rate diffusion of Gadolinium use Monte Carlo simulation was slop linear-line 0.044. Conclusions: The longitudinal relaxation rate and diffusion have a linear relationship.

Keywords: Longitudinal relaxation rate; gadolinium; Monte Carlo; diffusion rate

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A331

Formation and Characterization of Collagen and Hydroxyapatite Composite

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Purpose: Investigating the formation of composites of collagen and hydroxyapatite (HA) with ex situ precipitation method: Preliminary Study. Methods: Synthesis of HA was carried out by precipitation of $Ca(OH)_2$ 1 M and $(NH_4)_2.HPO_4$ 0.6 M with the Ca/P ratio 1.67, the mixture was exposed to microwave irradiation (450 W) for 45 minutes. Subsequently, the result was sintered to produce the powders of HA. Verification of HA powders was performed using X-Ray Diffraction (XRD). Chicken collagen was prepared in our lab (Physics Department, Universitas Indonesia). Composite was synthesized by ex situ precipitation method with a mass fraction of collagen and HA was 2:1. The mixture was stirring continuously for 2 hours and aged for 20 hours at room temperature. The precipitate was dried by freeze drying method. The composite result was examined by Scanning Electron Microscopy (SEM). Results: XRD pattern of sintered powder shown as HA crystal. The unit cell of HA crystals was evaluated by High Score plus program (a = b = 9.425 and c = 6.884) with the accuracy 98.175% for a and b lattice and 98.406% for c lattice. The collagen had been verified by SDS PAGE as type 1 collagen and the micrograph illustrated the presence of macropores. Based on SEM examination, the composite revealed that HA had been deposited onto collagen and filled part of void space of collagen. Conclusions: The preliminary study will be beneficial for leading the formation of composites of collagen-HA as biomaterials.

Keywords: Composite; collagen; hydroxyapatite

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A335

Visualization of Ra-223 Chloride using an Omnidirectional Compton Camera for Radioactive Environmental Monitoring

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Purpose: We investigated the possibility of visualizing low-level radioactive contamination by Ra-223 chloride injection in medical facilities using a highly sensitive gamma-ray omnidirectional imaging Compton camera. Methods: Our Compton camera technique is based on a two-fold coincidence between a number of independent scintillators that act as either scatterers or absorbers. The detector consisted of 16 CsI(Tl) scintillator cubes of 3.5 cm, each of which was read out by super-bialkali photo-multiplier tubes (PMTs). We adopted a flash ADC board operating at 2.5 MHz with SiTCP technology. An online program that was possible to operate on Windows was created using Visual C++ language and ROOT library. The measurements were done using the detector in the nuclear medicine facility, where the Ra-223 sources (used vial, syringe, etc.) with the radioactivities of less than 1 MBq were placed inside the preparation room. Results: We confirmed four groups of gamma-ray full-absorption peaks between 270 keV and 830 keV as expected in the energy spectrum made by the sum of energy deposits in two counter coincidence events. Furthermore, we successfully detected the direction of the Ra-223 source in the reconstructed omnidirectional gamma-ray image. Conclusions: Our proposed technique would be used as a low-level imaging dose monitor to visualize radioactive contamination by Ra-223 in medical facilities.

Keywords: Compton camera; radioactive contamination; radium-223 chloride

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A339

Dose Estimation Model for Weakly Penetrating Radiation in Radionuclide Radiotherapy

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Purpose: In radionuclide therapy, beta and alpha particle emitters have been used as weakly penetrating radiation sources. However, the conventional dose calculation method for photons would not always be suitable for radionuclide therapy due to the short range in the body. The purpose of this study is to make a model of dose estimations for weakly penetrating radiation in radionuclide radiotherapy. Methods: The issues of dose estimations to be considered in radionuclide therapy are the heterogeneously distributed doses and the higher dose levels for the possibility of not only stochastic but also deterministic effects. The former depends on the local concentrations of radionuclide with high radioactivity, and the latter is related to the physical and protection quantities with respect to radiation and tissue weighting factors. The dose distributions are determined based on the diagnostic images, and the exposed volumes are considered in each dose levels. Results: The absorbed fractions from the source to target organs can be calculated considering the volumes as the sources in which the radionuclide concentrated. The wide range dose gradient in one organ requires the reconsideration of the concept of averaged absorbed dose, radiation and tissue weighting factors. The model estimates the internal doses in radionuclide therapy considering both stochastic and deterministic effects. Conclusion: This method can be applied for other radiotherapy and interventional radiology.

Keywords: Radionuclide therapy; dose estimation; radiological protection

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A340

Response of Fabricated Germanium Optical Fibre Subjected to Low Dose Neutron-Gamma Irradiation

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Purpose: The main purpose of this study is to establish the thermoluminescence response (TL) of fabricated 6% mol Ge-doped optical fibre towards a low dose neutron-gamma irradiation which includes dose linearity, fading signal, minimum detectable dose (MDD) and glow curve analysis. Methods: A cylindrical optical fibre with diameter of (604 μm and 483 μm) and flat optical fibres with diameter of 620 μm were employed in this study. All fibres were exposed with mixed neutron and gamma radiation that emitted from a 241Am–Be radiation source, located at Neutron Laboratory, Nuclear Science Building, Universiti Kebangsaan Malaysia for 5-, 7-, 14-, 21-, and 28 days. The source to the sample distance was set at 5 cm. For fading effect, the samples were kept at room temperature and read-out up to 65 days' post-irradiation. The glow curve and the minimum detectable dose were evaluated using the glow curve deconvolution techniques and in correspond with formula of Furetta et al. (2001) respectively. Results: All the fibres show a dose linearity response for a range of dose given 30, 50, 101, 151 and 201 mGy. The minimum detectable dose for 604 μm and 483 μm cylindrical optical fibre are 0.25 mGy and 0.42 mGy meanwhile for 620 μm flat optical fibre is 0.99 mGy. At 65 days' post-irradiation, all the fibres shows less than 10% of signal fading. Single broad peak can be found for cylindrical fibre and double peak for flat fibre. Conclusions: These result shows that fabricated Germanium optical fibre give a good response to a low dose mixed gamma and neutron irradiation.

Keywords: Optical fibre; low dose; mixed neutron-gamma; dosimetry

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A342

The Development of Arduino-based Low-cost Wireless Modular Device for Brainwave Acquisition

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Purpose: Brainwave is widely used as an indicator of brain activity and can be detected by Electroencephalography (EEG). The development of EEG device has become more advanced along with the invention of low-cost tiny electronic modules and wireless technology. This research aimed to develop a low-cost wireless modular device for brainwave acquisition based on Arduino microcontroller. Methods: The system was designed into sensor block for brainwave receiver and conditioning, and mainboard block for data processing. Dry-active electrode was developed as the receiver. Preamplifier module was also installed at the sensor block. Active filter and DRL circuits were developed as the mainboard part. Arduino UNO R3 was used as the main processor of the device. The developed device was then tested using signal generator to examine the capability of the device in detecting brainwave frequencies. The data was then analyzed to examine the signal and noise composition. Results: The developed device was observed to be working on the generated signal based on brainwave frequencies. The signal-to-noise ratio was examined to be in an acceptable result. Conclusions: The device was successfully developed and found to be reliable in detecting brainwave frequency and filtering the noise signal.

Keywords: Electroencephalography; brainwave; arduino; low-cost EEG; wireless device

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A344

Study of Thermoluminescent Response in Germanium Doped Silica Glass Fibers due to Radiation Dose Deposition from Kv Energy X-Ray Source

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Purpose: The study focuses on thermoluminescent (TL) characterisation of germanium doped silica glass fibre due to on-board kV x-ray source of a radiotherapy linear accelerator. Methods: Previous studies show that impurity of the glass fibers may contribute to a good TL response due to photon irradiation. Therefore, study made used of various core diameters (11 μm, 50 μm and 113 μm) of commercial glass telecommunication fibers (CorActive High Tech, Canada). Irradiations were made using an x-ray tube arm attached to a radiotherapy linac providing 70 kVp, 100 kVp and 120 kVp photon energy. The exposure time and current were varied in the range of 20 – 400 mAs to allow different dose integration. Results: Linearity of TL has been observed with a correlation coefficient (r^2) of better than 0.970 (at 95% confidence level). The least square fits show the change in TL yield, in counts per second per unit mass, obtained from 113 μm core diameter fibres irradiated at 100 kVp of photon to be greater than that of 11 μm core diameter fibre. With respect to energy response, the TL yield at 120 kVp decreases by ~7% compared to that at 70 kVp, primarily due to the lower mass energy absorption coefficient at higher energy. Conclusions: Doped silica glass fibers provide good dosimeter characteristics in term of dose linearity and energy dependence for the dose ranges studied. It shows promising application as a dosimeter for kV imaging during image guided radiotherapy (IGRT).

Keywords: Thermoluminescence dosimetry; germanium doped silica glass; x-ray

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A348

Simulation of Two Red Blood Cells (RBC) Collision based on Granular Model

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Purpose: Investigate collision characteristics of two red blood cells (RBC) based on the granular model, whether kinetic energy is transformed into elastic energy. Methods: Simulation is performed using molecular dynamics method implementing Euler algorithm, where an RBC consists of N granular particles, where adjacent particles are connected with a spring with spring constant k and length l. Results: It is observed that during collision both colliding RBC are deformed in order to transform the kinetic energy into potential (elastic) energy and later transform it back to kinetic energy. Conclusions: Energy and momentum are conserved in the simulation even there is viscous force dragged from the fluid to each granular particle forming the RBC.

Keywords: simulation; red blood cell; granular particles; molecular dynamics

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A217

Intra Vendors Clinical SPECT/CT System Activity Validation in Phantom

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Purpose: This study was to establish various conversion factors and its impact on the quantitative accuracy of an absolute activity in phantom between 2 variant clinical SPECT/CT system from the same vendors in different center. Methods: Multiple series of uniform phantom scans were performed for 3 different activities (37 MBq, 18.5 MBq, and 3.7 MBq) and different isotropic voxel sizes (643,1283 and 2563). For activity validation purpose, single anthropomorphic phantom scan with different activities ratios for different organs (0:0:1:10, lung: spine: background: liver), matrix sizes and iterations were performed. Various conversion factor (in cps/MBq) estimated from various matrix sizes (CF64, CF128, and CF256) were applied to generate the activity concentration of distribution in SPECT/CT images. The measured activities for background and liver were then compared to an absolute activity distribution and reported as a percentage difference, while for lung and spine region were reported as activity relative errors percentage. The identical methods were replicated in the other system and the differences between the system were evaluated. Results: Both systems produced an identical trend of CF curves over the different iterations number and voxel sizes. Both systems were capable to estimate the activity distribution within 10% and 15% of error for the liver and background respectively using 2563 voxel sizes. Furthermore, the relative error percentage was within 10 to 15% of error. Conclusion: Different variant of SPECT/CT system from the same vendor could be able to estimate an accurate activity distribution in phantom according to an identical procedure of CF establishment.

Keywords: SPECT/CT; validation; quantification; phantom; calibration

ADDENDUM

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The Leading Role of the International Union of Physical and Engineering Sciences in Medicine (IUPESM) in Promoting Workforce and Technology Dedicated to Human Health

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The International Union of Physical and Engineering Sciences in Medicine (IUPESM) was jointly formed in 1980 by IOMP and International Federation of Medical and Biological Engineering (IFMBE). The IUPESM currently represents the combined efforts of more than 25,000 medical physicists and 120,000 biomedical engineers working on the physical and engineering science of medicine. The key objectives of the organization are to contribute to the advancement of physical and engineering science in medicine for the benefit and well-being of humanity; to organize international cooperation and promote communication among those engaged in health-care science and technology; to coordinate activities of mutual interest to engineering and physical science within the healthcare field, including international and regional scientific conferences, seminars, working groups, regional support programs and scientific and technical publications; to represent the professional interests and views of engineers and physical scientists in the health-care community. In 1983 IUPESM became an Associate and in 1999 a full member of ICSU, currently International Science Council (ISC), representing the global national and international scientific bodies. IUPESM plays an important role in bringing together medical physicists and biomedical engineers from all parts of the world to exchange ideas on issues of common interest and to share their knowledge and research -findings for the purpose of promoting human health through advances in science and technology in healthcare.

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Towards Real-Time Treatment Verification using Radiotherapy Linac Log Data

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Intensity Modulated Radiation Therapy (IMRT) delivers highly conformal dose to the tumour while sparing normal tissues. Any error in the treatment delivery may result in unnecessary radiation side effects or tumour recurrence due to overdose of healthy tissues or underdose of tumour. The conformability of the dose is achieved by varying the size, the shape and the intensity of the beam, to match the tumour volume using dynamic treatment parameters especially multileaf collimators (MLCs). The complexity of the MLC-based radiotherapy delivery requires patient specific pre-treatment verification typically using 2D array detectors. Modern linac uses digital control system to adjust and monitor linac parameters during treatment delivery. The work focused on Elekta Synergy linac (Elekta AB, Crawley, UK) that uses an optical tracking system to digitally control and monitor the position of the MLC at 4 Hz. The MLC positions tracked by the linac control system were recorded and characterised to verify the accuracy of the tracking data. A computer algorithm was developed to extract the MLC positions and other treatment parameters from the control system. The algorithm also uses IMRT treatment parameters to reconstructs the fluence delivered to the patient and measure the accuracy of the treatment delivered for head and neck cancer patients. The results of the real-time tracking data agree with the measurements made with a 2D array system and provides more detailed analysis of accelerator performance such as MLC position errors, but the technique significantly reduce the time required to perform the verification. Further study is required to provide accelerator-specific indicator of the delivery performance so that safety precaution can be taken before any error happens during radiotherapy treatment delivery.

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Application of functional-MRI in Pre-Surgical Planning

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In the last two decades, there have been an increase in studies using functional Magnetic Resonance Imaging (fMRI) for pre-surgical planning. As this technique is a non-invasive pre-surgical tool and can be used to assess and localize the eloquent areas or functional areas in brain tumour and vascular lesion patients to guide neurosurgeons as they devise a surgical approach to treat these lesions. Although there have been improvements in image resolution and artefact correction, there are still limitations of this modality. In the presentation, I will discuss the limitations of fMRI in pre-surgical planning. Among the limitations of fMRI in pre-surgical planning are the foundations of fMRI, physiologic effects of the disease, distinctions between clinical and research fMRI, and the design of the fMRI study.

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An Inhouse Developed Dose Accumulation Methodology to Evaluate Dose During Re-Irradiation in Gamma Knife Radiosurgery

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Purpose: The purpose of this study is to evaluate the dose delivered to Gamma Knife patients during re-irradiation. Methods: Treatment planning was done for six patients in Leksell Gamma Plan TPS (LGP 10.1). MRI imaging parameters: MPRAGE sequence, FOV - 256 x 256 mm^2, Matrix Size - 512 x 512 mm^2, slice thickness–1mm. Patient1(Pituitary Adenoma) underwent re-irradiation after 2 years of Gamma Knife Radiosurgery(GKR). Patient2(AVM) underwent volume fractionation as volume was more than 30cc. Patient3 and Patient4(Acoustic Neuroma & Pituitary Adenoma) underwent dose fractionation, to avoid dose to critical organs. Patient5 (Mutliple Metastasis) underwent three fractions. Patient6 (Single Metastasis) underwent second treatment after tumor reduced in size. The MRI images of first fraction (FF) were co-registered with second set of MRI images acquired for second fraction dose delivery. Dose maps were extracted from TPS, processed with open source and in-house developed software codes which performed translation, rotation and warping steps to combine dose volumes and evaluate accumulated dose after second or third fraction. Results: The line profile measured through dose maps of FF and subsequent fractions showed 50% increase in dose at junction regions. The peak dose at midpoint of tumor regions was between 5% -150% more than actual delivered dose. The Dose Volume Histogram (DVH) comparison showed mean brain volume receiving lower dose, 2.5Gy increased from 27cc to 210cc and 6Gy increased from 5cc to 30cc. LGP TPS fuses/co-registers patient images from different fractionation treatment, however unable to display cumulative dose effect after re-irradiation. Conclusions: Through this study we have shown cost effective and simple technique to evaluate cumulative dose, essential for better understanding of tumor progress during re-irradiation.

Keywords: Gamma knife radiosurgery; reirradiation; open source software

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A325

Study of Lung Tumor Response and its Densitometry Parameter Changes During the Course of Radiation Therapy Assessed with Weekly CBCT

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Purpose: To investigate the possibility of predicting tumor response to treatment image information obtained from weekly CBCT. The responses to treatment is assessed by, quantifying the gross tumor volume (GTV) size reduction, change in GTV CT numbers (CTN) and GTV CT contrast during a course of radiotherapy. Methods: 15 retrospective patients with NSCLC Stage T1–T4, completed a course of radiotherapy (prescription: 60Gy in 30 fractions) with weekly CBCT imaging were selected for this study. GTV was delineated on weekly CBCT and the attenuation histogram data for the delineated GTV were collected and analyzed. Results: Comparison of CBCT-based GTV acquired prior to Fraction 1 (CBCT GTV1) to 30th fraction (CBCT GTV7). Correlation was identified between volume reductions and dose delivered highly statistically significant association. Compared with CBCT GTV1. For all patients in the study, the mean, median and lower inner fence CTN value there was a significant reduction in relation to the radiation dose with $R^2 = 0.3444$. $R^2=0.4034$ and $R^2=0.645$ but the GTV upper inner fence CNT values were slightly increased with dose $R^2=0.005$.While correlating between GTV integral non uniformity with radiation dose and low contrast visibility of CBCT GTV 1 with weekly CBCT GTVs there were significant changes with $R^2=0.1673$ and $R^2=0.3287$. Conclusions: Sensitive changes were observed from the beginning of treatment and during the course of radiotherapy. These changes correlated to delivered dose which could be used potentially to predict tumor response to treatment and therefore could be useful in response assessment and plan adaptation.

Keywords: Lung tumor response; densitometry parameter; tumor volume reduction

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Is Brain Connectivity Reduced According to the Severity of Asymptomatic Carotid Artery Stenosis

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Purpose: Cognitive impairment is widely found in asymptomatic carotid artery stenosis (CAS) patients. Previous neuroimaging research reported the association between reduced functional connectivity (FC) and the decline of cognitive performance. We hypothesized that FC disruption deteriorates along with the stenosis severity, leading to the poor performances in neuropsychological tests. To this aim, we explored the intrinsic FC in different degrees of CAS severity including both unilateral and bilateral asymptomatic CAS cases. Methods: We divided recruited 44 patients into three groups according to different degrees of stenosis: severe (70-99%), occlusion (100%), bilateral stenosis and 20 controls for a total of 64 subjects. MRI images were acquired using a 3-Tesla Tim-Trio Siemens scanner. The seed was located in the bilateral PCC (centered at MNI coordinates: 0, −53, 26). All subjects performed multiple neuropsychological tests including Montreal Cognitive Assessment (MoCA). Results: Aberrant brain connectivity within DMN could be found across three groups. The occlusion group showed decreased FC in the affected side and bilateral group showed decreased FC in the midline DMN. The occlusion group showed higher connectivity than bilateral stenosis group in affected side and midline. However, neuropsychological tests presented significant difference between occlusion/bilateral and control groups, without between-group differences. Conclusions: DMN showed significant connectivity changes in occlusion and bilateral patients compare to control subjects. However, FC patterns between the patient groups (occlusion and bilateral) did not show corresponding differences in neuropsychological tests. Henceforth, it needs further investigations to confirm the association between functional connectivity and cognition tests.

Keywords: Carotid artery stenosis (CAS); functional connectivity (FC); default mode network (DMN)

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