A short history of movement disorders surgery

Spiegel and Wycis performing one of the first stereotactic operations

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This booklet will provide the reader with a short history of movement disorders surgery. We start with early attempts of surgery on the pyramidal system and we conclude when we reach the “goldrush” times of contemporary deep brain stimulation introduced for tremor, Parkinson’s disease and dystonia.

The posters which are summarized in this booklet were shown for the first time during the 17th Quadrennial Meeting of the World Society for Stereotactic and Functional Neurosurgery in Berlin, Germany, in June 2017. Since we received such a nice echo from the visitors we thought it would be worthwhile to make the history as told in these posters available to a wider audience.

History is never linear. But history is also not circular and repeating itself as some people tend to be believe. Furthermore, obviously history is not a process of dialectical change as has been supposed by some prominent philosophers. Rather, history often is a parallel process of different lines of development. Certainly, the exegesis of the history of movement disorders surgery depends on the eye of the beholder introducing some inevitable subjectivity. The latter we tried to minimize by retrieving as much original documents as possible.

We hope the booklet will be of interest to all colleagues involved in the field. May you enjoy browsing through the decades with us!

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Surgery on the pyramidal system
Surgery on the ‘extrapyramidal’ system
Birth of the stereoactic era
Stereoactic lesioning techniques
Ablative surgery on the pallidum
Ablative surgery on the thalamus/subthalamic area
Renaissance of surgery for movement disorders
Peripheral surgery for dystonia
Neurotransplantation surgery for Parkinson’s disease
Evolution of stereoactic frames and imaging modalities
 Early DBS before 1987
History of DBS hardware
DBS for tremor
DBS for Parkinson’s disease
DBS for dystonia
Surgery on the pyramidal system

Victor Horsley, one of the pioneers of modern neurosurgery, introduced removal of cortical areas for athetosis in 1890. Later, in collaboration with Robert Henry Clarke, he introduced the first stereotactic frame for animal research. Thereafter, Putnam and Walker and others carried out open surgery on the pyramidal system including tractotomies.

“In 1949, Walker described mesencephalic pedunculotomy for the treatment of hemiballismus. This procedure was extended to the treatment of Parkinson’s disease by Walker and others. Incisions were made at various depths in the peduncle. The tremor relief was proportional to the severity of the hemiparesis, whereas rigidity always remained unaffected. According to Walker, a compromise between paralysis and freedom of tremor was what best could be expected from pedunculotomy” (Laitinen and Hariz, 1996).

Horsley published a paper in 1909 on successfully excising the precentral gyrus of the cortex in a young man with involuntary movements of the right arm.

Source: Irving S Cooper: Parkinsonism, its medical and surgical treatment, 1961

Arthur Earl Walker (1907-1995)

Source: Irving S Cooper: Parkinsonism, its medical and surgical treatment, 1961

Horsley V. and Clarke RH. 1908. The structure and functions of the cerebellum examined by a new method. Brain 31, 1-45–124
Surgery on the “extrapyramidal” system

Once the importance of the basal ganglia in motor control was recognized, Russell Meyers was the first to perform direct transventricular surgery to alleviate motor symptoms of Parkinson’s disease by lesioning the caudate nucleus, the anterior limb of the internal capsule and the pallidofugal fibres. Mortality rates were high (15.7%), but his work inspired Fénélon and Guiot to coagulate the ansa lenticularis. They reported a 72% benefit on tremor and rigidity.


Russell Meyers et al., J Neurol Neurosurg Psychiatry, 1949

Source: Irving S Cooper: Parkinsonism, its medical and surgical treatment, 1961

Gérard Guiot (1912–1998) as a young man

Complications of open surgery and the difficulties in accessing the control structures of the brain prompted Spiegel and Wycis to develop the first stereotactic frame used in humans in 1947.

The most important development with that frame was that the targeting was not based, as in the Horsley-Clarke system, on external bony landmarks, but on internal landmarks, as seen on pneumoencephalography, providing a higher degree of accuracy.

This method revolutionized surgery for Parkinson's disease and other disorders. Within a short period of time, new frames, atlases, targets, and lesion techniques were introduced worldwide.
Different lesioning methods were developed: direct current (anodal electrolysis), alcohol injection, oil-procaine-wax injection, balloon, leucotome, cryoprobe, ultrasound, interstitial radiation, focused radiation (Linac, protonbeam, Gammaknife) and thermo-controlled radiofrequency. Radiofrequency lesioning became the dominant method for decades and until now.
Surgical procedures involving the globus pallidus flourished in the early 1950s. Born in Kobe, Japan, Hirotaro Narabayashi (1922-2001) performed his first pallidotomy for athetosis using procaine oil wax in 1951, and performed his first surgery for Parkinson’s disease one year later. He reported 26 cases of pallidotomy in Parkinson’s disease in 1956. He also contributed to the neurophysiological analysis of rigidity and spasticity. Many other neurosurgeons worldwide developed their own pallidal targets for treatment of a variety of movement disorders.
The ventrolateral thalamus was introduced in 1952 as a target for tremor based on the work of Rolf Hassler. The first thalamotomy was performed by Fritz Mundinger in the presence of Traugott Riechert and Rolf Hassler. The methods and results were published in 1954.

Thalamotomy became more popular in the late 1950s after Cooper published his work on a misplaced pallidal lesion that had abolished tremor but which was located in the motor thalamus as discovered at autopsy.

In the 1960s, subthalamic targets became popular aiming at the zona incerta, the fields of Forel and the posterior subthalamic area. Many neurosurgeons subsequently used a combination of thalamic and subthalamic targets, avoiding the STN.

Traugott Riechert (1905-1983) and Fritz Mundinger (1924-2010)

Renaissance of surgery for movement disorders

The introduction of L-dopa as a medication for Parkinson’s disease in the 1960s led to a decreased demand for stereotactic functional surgery, which in many centers was abandoned.

In January 1985, Lauri Laitinen in Umeå, Sweden, revived Leksell’s old posteroventral pallidotomy (published in 1960) and demonstrated that not only was it effective on parkinsonian symptoms, but also on the side effects of L-dopa (fluctuations and dyskinesias). Laitinen’s paper, published in 1992, heralded the renaissance of stereotactic functional neurosurgery. Laitinen was among the very first to use stereotactic MRI for targeting and pioneered visualisation of the globus pallidus allowing thus an individual targeting without relying on atlas coordinates. Subsequently, pallidotomy was performed on thousands of patients worldwide and endorsed by the Movement Disorders Society as an evidence-based procedure for Parkinson’s disease.


Lars Leksell (1907–1986) and Lauri Laitinen (1928-2005)
Kenneth G. McKenzie (1892-1964) was instrumental to advance the technique of intradural rhizotomy which had been pioneered also by Walter Dandy (1886-1946). The problem was that denervation could not be performed below the C4 root.

Selective peripheral denervation surgery for cervical dystonia was introduced by Claude Bertrand (1917-2014), and it solved many of the problems associated with intradural rhizotomy.

Nowadays, knowledge about how to perform this surgery is becoming lost. We are sure, it will be rediscovered some day.

In 1950, his interest in pain problems led him to review the spinal and brain pathways of ascending pain fibers, together with Doctor Louis Poirier of the Department of Anatomy of Université de Montréal. This was the beginning of a productive collaboration, when, in 1954, the work on stereotactic surgery of involuntary movements was undertaken. This led to the finding of a safer and more selective method of suppression of involuntary movements. Selective denervation of muscles of the neck evolved from this work, using stimulation under light anaesthesia after recording of muscle activity and nerve blocks, thus enhancing considerably the knowledge of functions of the cervical musculature. A large number of Canadian and foreign patients suffering from spasmodic torticollis have obtained relief from this technique.

Cellular replacement strategies emerged as a potential curative therapy for Parkinson’s disease. In 1985, Erik-Olof Backlund in Stockholm performed the first transplant of adrenal medullary tissue into the striatum for Parkinson’s disease. Unfortunately, the procedure could not be replicated and was abandoned.

In 1988, Stig Rehncrona from Lund performed the first transplant of fetal mesencephalic tissue in the caudate and putamen of two parkinsonian patients.

“The results in these patients resemble those obtained in MPTP-treated primates and suggest that this will be a useful model for the assessment of transplantation therapies in Parkinson’s disease.”

Widner et al., 1992
The history of human stereotactic surgery bears witness to the efforts to unite frame and radiological imaging in a geometrically coherent and practical system. “Stereotactic radiography” became a concept to define “classical” imaging methods such as ventriculography, pneumencephalography or angiography.

For these apparatus “teleradiography” was necessary to avoid parallax and distortion and minimize magnification. The X-ray source needed to be far away from the patient.

After the introduction of CT and then MRI, the adaptation of stereotaxis to the new imaging methods followed somehow the same pattern known from the pre-CT era: the new radiological technique had to be integrated, and the stereotactic frame had to be re-adapted or re-conceived to conform to the requirements of the new imaging tools.

Jean Talairach (1911–2007) and his frame

Beginning in the 1950s, depth electrodes were implanted for days or weeks to ensure satisfactory results prior to lesioning via the chronically implanted electrodes. The first detailed account of this technique was provided by Natalia Petrovna Bechtereva and Carl Wilhelm Sem-Jacobsen. Notably, deep brain stimulation for pain was popular before it became adopted for treatment of movement disorders.

One of the first to use deep brain stimulation via externalized electrodes as a therapy was Natalia Petrovna Bechtereva in Leningrad. A large number of patients were implanted for PD and other disorders and treated with intermittent courses of stimulation for periods of up to 18 months.

Natalia Petrovna Bechtereva (1924-2008)

Fritz Mundinger reported the effects of thalamic/subthalamic chronic stimulation in 7 patients with torticollis in 1977 in an article written in German which almost nobody noted.

Irving Cooper reported in 1980 on the effects of electrical stimulation of the thalamus and internal capsule in man.

Jean Siegfried reported beneficial results of chronic stimulation in the sensory nucleus of the thalamus in 1986.

Orlando Andy, 1983: 9 patients implanted in thalamic targets. “Optimum site for alleviating parkinsonian tremor and other movement disorders are the Vim and other thalamic and subthalamic areas.”

Fritz Mundinger reported the effects of thalamic/subthalamic chronic stimulation in 7 patients with torticollis in 1977 in an article written in German which almost nobody noted.

Gabriel Mazars, 1980 & 1982. Low frequency DBS in the VPL. Good effect in dyskinesias associated with post amputation pain but no effect in tremor or PD.

Neurologist Lindsay McLellan (pictured here) and neurosurgeon Jason Brice, 1980: Two MS patients permanently implanted in the zona incerta. High-frequency stimulation resulted in suppression of severe intention tremor.


Founded in 1957 by Earl Bakken and Palmer Hermundslie in Minnesota, Medtronic started to design hardware for DBS in the early 1970s. Initially, DBS was developed as a treatment for chronic pain. Within a few years, the first pioneers applied the new technology for the treatment of movement disorders.

In the 1980s, Alim-Louis Benabid and Pierre Pollak collaborated with Medtronic and introduced the first modern fully implantable DBS system. Over the next years, the classical quadripolar DBS electrodes and rechargable pacemakers became available.
The modern breakthrough for DBS, in general, and for tremor in particular was heralded by Benabid’s seminal paper from 1987 describing Vim DBS for parkinsonian and essential tremor. Initially, these findings were met with limited interest. Only after the results were convincingly demonstrated using pre- and postoperation videos and confirmations, long-term studies became available, and after multicenter studies were conducted, this method gained wide acceptance.

Only after DBS was applied to the STN did this method reach global popularity. Although most DBS for tremor has targeted the Vim nucleus, the posterior subthalamic area has been revived as a target for PD and essential tremor, either alone or in combination with Vim DBS. Since then, DBS became the main surgical procedure for treatment of tremor and it virtually replaced thalamotomy for some decades.

“Although still experimental, VIM stimulation appears to be a helpful additional therapy to thalamotomy, which could provide a way to manage patients with bilateral dyskinesias without side effects.”

Alim-Louis Benabid 1987
The subthalamic nucleus (STN) had been avoided as a target in functional neurosurgery during the lesional era for fear of hemiballism. In the early 1990s, Hagai Bergman, then Tipu Aziz, and collaborators performed lesions of the STN and demonstrated improvement of parkinsonian signs in the MPTP model of Parkinson’s disease. Benazzouz used high frequency stimulation of the STN in the MPTP-monkey. These findings set the stage for a new era in the surgical treatment of Parkinson’s disease.

Alim-Louis Benabid and Pierre Pollak were the first to use DBS of the STN in Parkinson’s disease in 1993. This procedure has spread worldwide since then and has proven to be the most efficient surgery for Parkinson’s disease.

In 2014, the Lasker-DeBakey Clinical Medical Research Award was bestowed to Benabid and Mahlon Delong to “honor two scientists who developed deep brain stimulation of the subthalamic nucleus”.

Aziz TZ, Peggs D, Sambrook MA, Crossman AR. 1991. Lesion of the subthalamic nucleus for the alleviation of 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP)-induced parkinsonism in the primate. Mov Disord 6(4):288-292
Pallidal DBS was inaugurated by Jean Siegfried in Zürich in the early 1990s as an alternative to pallidotomy for Parkinson’s disease. Pallidal DBS, however, became more important only later in the treatment of dystonia. During the lesional era various other targets had been used.

Pallidal DBS for dystonia was pioneered in the late 1990s by Joachim K. Krauss (cervical dystonia) in Berne, Switzerland, and by Philippe Coubes (generalized dystonia) in Montpellier, France. Initially, these results were met with skepticism. However, subsequent multicenter studies provided evidence-based proof confirming the posteroventral lateral globus pallidus internus as the target of choice for DBS in dystonia. In particular, blinded study designs including a sham-stimulation algorithm were pivotal for the general acceptance of this therapy.

