

## *Transesophageal Echocardiography and its Potential for Esophageal Damage*

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The purpose of this study was to determine whether the pressure produced by contact between a transesophageal echocardiography (TEE) probe and the esophagus was sufficient to cause esophageal damage. The authors studied the effects of sustained contact and associated surface pressure on the esophagus by a TEE probe in anesthetized dogs and humans. Contact pressure between the tip of the probe and the esophageal wall in dogs was measured using a previously described flat balloon of Silastic® fitted to the end of a TEE probe and the recording system calibrated with a mercury manometer. In the dog studies, the probe was inserted, maximally flexed, and its position fixed for 4, 6, 8, and 12 h. The maximum surface pressure generated by contact between a probe and the esophageal wall was 10 mmHg. Subsequent pathologic studies failed to reveal either gross or microscopic evidence of tissue damage.

The same system was used in short-term patient studies with the surface contact pressure transducer connected to a Camino® Catheter 420 Digital Pressure Monitor. In five of six patients contact pressure was <17 mmHg despite maximal rotation of the TEE controls. However, one of the six patients developed very high contact pressure, up to 60 mmHg, between the probe and the esophagus. This patient had no history of esophageal disease but did have intrathoracic pathology.

The authors conclude that the maximum surface contact pressure between the esophagus and a fully flexed TEE probe is low in dogs and in most humans, and is unassociated with histologic esophageal damage even with long exposure. However, potentially dangerous pressure may be generated in some cases in humans. It is suggested that the TEE probe not be fixed in a flexed position for prolonged periods since a subset of patients may exist who are at risk for development of high contact pressure and potential esophageal damage. (Key words: Complications: esophageal damage. Esophagus. Monitoring: transesophageal echocardiography.)

ALTHOUGH TRANSESOPHAGEAL ECHOCARDIOGRAPHY (TEE) has been used for over 12 yr there are no studies that have specifically addressed its safety. TEE is presumed to present little risk in part because gastroscopic and TEE studies have been performed in thousands of patients and

complications are rarely encountered.<sup>1-7</sup> In fact, the only reported complications associated with TEE have been transient A-V block, nonsustained ventricular tachycardia, supraventricular tachycardia, atrial fibrillation, bronchospasm, and transient vocal cord paralysis.<sup>1-4</sup> Nevertheless, the potential for development of other complications such as pressure-induced ischemic necrosis or esophageal rupture does exist. The risk of esophageal damage from TEE should be related to the magnitude of the pressure that can be generated against the esophageal wall by a TEE probe. The present study was designed to measure the pressure generated by contact between the tip of a TEE probe and the esophagus, and to determine whether long periods of contact between a TEE probe and the esophageal wall can damage the esophagus.

### Materials and Methods

#### ANIMAL STUDIES

Two experiments were conducted. The purpose of the first study was to measure the maximum contact pressure generated between a TEE probe and the esophageal wall and to determine whether sustained pressure by a probe against the esophagus resulted in either gross or microscopic esophageal damage. To measure contact pressure between a TEE probe and the esophagus, but to not register intrathoracic pressure variations, a previously described water-filled flat balloon was modified for this experiment.<sup>8</sup> The balloon was designed to fit over and be firmly attached to the tip of a TEE probe (Hewlett-Packard Model 21362A) in such a way as to be essentially transparent to the transmission of acoustic energy (fig. 1). Construction of the flat balloon used Dow Corning's medical grade Silastic® R sheet, tubing and adhesive. After leak testing, the assemblies were boiled in water for 4 h to ensure that the adhesive was completely polymerized and that all residual acetic acid had been drawn out of the Silastic® sheet and tubing. This was done to minimize the possibility of encountering tissue damage due to chemical irritation. Two pieces of Silastic® tubing, which extended from the flat balloon, were attached to polyethylene 240 tubing. One tube from the balloon was attached to a stopcock used to fill the system with saline and provide a room air pressure reference. A low fluid volume displacement manometer was connected to a Gould electro-

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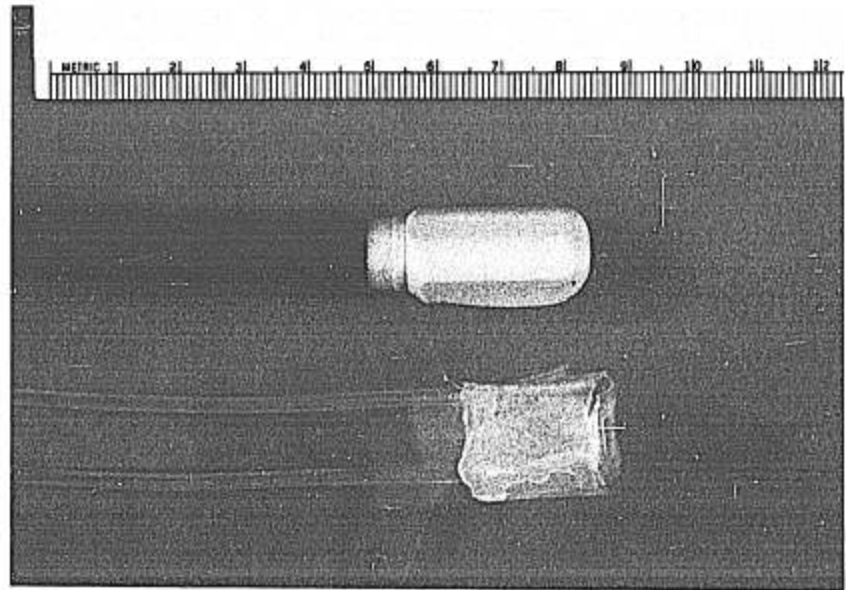
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FIG. 1. Water-filled Silastic® balloon fixed to the tip of the transesophageal echocardiography probe used in this study.



static recorder and calibrated with a mercury manometer *via* a Y connector attached to the other tube leading from the balloon. The manometer was fastened to the animal support throughout the experiment.

With approval from the Stanford University Committee for the Use of Animals in Medical Research, four mongrel dogs, weighing 26–39 kg, were anesthetized with pentobarbital for the duration of the experiment. Three of the four animals were studied with the Silastic® balloon in place over the tip of a TEE probe. A fourth was studied without the device to determine if direct probe-esophageal contact without a layer of Silastic® between would reveal pathologic changes not seen in the other animals. In all of the supine dogs the probe was introduced into the esophagus, set at maximum power output, and advanced to a depth that allowed visualization of the heart at the level of the aortic or mitral valve. Under fluoroscopic observation the transducer was maximally flexed and the flexion control locked in place. The fluoroscope allowed visualization of the esophagus and confirmation of maximum flexion of the probe. The echocardiographic image was monitored for stability of the image throughout the experiment.

In the dogs in which the probe was fitted with the Silastic® balloon, the pressure generated by contact between the probe and the esophagus was measured at 10-min intervals. In these animals the probe remained in place for either 4, 6, or 12 h. The probe without the balloon remained in place in the fourth dog for 8 h. Animals remained fully anesthetized during each experiment and, without regaining consciousness, were killed with an overdose of pentobarbital. With the TEE probe in place

the chest was opened and the thorax inspected. The contact of the esophagus with the heart was verified and the position of the probe within the esophagus was verified. Two sutures were placed within the superficial tissue of the esophagus: one suture was placed at the maximum bend of the probe and the second suture was placed superficially marking the point of contact with the probe tip. A finger was then placed against the esophagus near the probe tip and pressure applied. The ability to measure pressures above those measured during the experiment was verified by this method. The probe was then straightened and withdrawn from the animal. The esophagus was excised so as to include all of the area of the esophagus contacted by the probe and a small area below this. This specimen was placed in 10% formalin overnight for fixation. The Cardiac Pathology Laboratory at Stanford University Hospital then prepared multiple sections with special stains of the esophagus at the level of the maximum bend of the probe, the tip of the probe and below the probe (as a control). An experienced pathologist reviewed the sections for evidence of tissue damage without knowledge of the source of the specimen.

#### HUMAN STUDIES

The purpose of the second study was to measure the maximum pressure produced by contact between a TEE probe and the esophagus in humans. With approval of the Stanford University Panel on Human Subjects in Medical Research and after giving informed consent, six patients undergoing a variety of surgical procedures under general anesthesia were studied. Patients with known

TABLE 1. Patient Characteristics and Measured Esophageal-TEE Contact Pressure

Procedure	Age (yr)	Sex	Esophageal-TEE Contact Pressure (mmHg)							
			Position							
			1	2	3	4	5	6	7	8
Abdominal aortic aneurysm	59	M	3	3	17	0	3	2	0	5
Fiberoptic bronchoscopy, bone marrow biopsy	62	F	0	5	11	0	10	0	0	0
Wound debridement	42	M	0	0	0	0	3	0	0	0
Coronary artery bypass	49	M	0	0	0	0	0	0	0	0
Vesico-vaginal fistula	56	F	17	12	5	4	6	0	0	0
Descending thoracic aneurysm	43	M	60	25	10	15	35	28	17	20

esophageal disease were excluded from the study. Patient data are given in table 1.

The same modification of the water-filled Silastic® balloon used in the animal study was fitted to a TEE probe (Hewlett-Packard Model 21362A) for the human experiments (fig. 1). A hemostatic Y connector was attached to one of the P.E. tubes. Inserted into the Y connector was a transducer-tipped pressure monitoring catheter (Model 110-4 Camino Laboratories®) connected to a Camino® Catheter 420 Digital Pressure Monitor. The second P.E. tube was attached to a stopcock. The entire system could be filled with saline and opened to room air to establish a zero reference. After the system was flushed with saline and the system closed, any changes in pressure in the probe/cuff interface were measured by the digital output of the monitor.

After induction of anesthesia with the patient supine, the probe was inserted into the esophagus and advanced to the level that permitted imaging of the aortic valve.<sup>8</sup> Before moving the control knobs, a zero reference was established. The probe tip was then flexed anteriorly as much as the control knobs would allow. The contact pressure generated against the esophageal wall was recorded. The probe tip was then maximally moved posteriorly and to each side. Pressure was recorded at each position. After advancing the probe to image the left ventricle at the midpapillary muscle level, a zero reference was again established.<sup>9</sup> The tip of the probe was moved anteriorly, posteriorly, and to each side with maximum rotation of the control knobs. The pressure developed by contact between the probe and the esophagus at each position was recorded. Pressure measurements were thus made at eight positions in each patient. This set of measurements required no more than 5 min in any patient.

## Results

### ANIMAL STUDIES

Despite maximum rotation of the controls on the probe, high pressures against the esophageal wall could not be

produced in the dogs. Of 126 measurements made in three dogs, only once was a pressure as high as 10 mmHg recorded. Esophageal-probe contact pressure was less than 7.7 mmHg for all other measurements.

Autopsy findings were consistent with the results of the pressure study. None of the four dogs displayed any evidence of either gross or microscopic damage to the esophageal mucosa or muscular layer on pathologic examination.

### HUMAN STUDIES

In five of the six patients contact pressure between the esophagus and a TEE probe was less than 17 mmHg (table 1). In one patient contact pressure was as high as 60 mmHg. Although that patient did not have a history of esophageal disease, he did have intrathoracic pathology, a descending thoracic aneurysm. None of the patients had any complications associated with the study.

### Discussion

Our results demonstrate that in most instances this TEE probe is unable to exert high and potentially damaging pressure on the esophageal wall. In all animal studies, TEE-esophageal contact pressure was consistently low throughout the prolonged periods of observation. The recorded pressures were less than 10 mmHg in each animal. The surface contact pressure measurement device has been previously described and is used specifically for studies of pericardial surface pressure, as opposed to fluid pressure, which is the more common type of pressure measurement.<sup>9</sup> This is the reason the respiratory variation in intrathoracic pressure was not registered using this system even though it was in the esophagus. Pathological examination of the esophageal wall in dogs after up to 12 h of continuous contact between the probe and the esophagus, with the probe set at maximum power output, did not reveal either gross or microscopic abnormalities of the esophageal wall. This ultrasonic transducer has a thermistor built into its tip and while there is no direct read-out of temperature, the circuitry is designed

to shut off power to the probe if the temperature rises to 42° C. There is no reason to believe there was important tissue heating by the ultrasonic energy as this safety feature was not activated and there was no histologic evidence of thermal injury.

In five of six patients studied, TEE-esophageal contact pressure was <17 mmHg. However, in one patient, contact pressures of up to 60 mmHg developed (table 1). This patient had no history of esophageal disease but he was undergoing repair of an intrathoracic lesion, a descending thoracic aneurysm. Unfortunately, we failed to ask the surgeons to evaluate the esophageal-aortic region under direct vision. One could speculate that in this instance the presence of a descending thoracic aneurysm and potential fixation of the esophagus to surrounding tissue may be related to the high pressures measured. Generation of such pressures is of concern since pressure of this magnitude could damage normal tissue. Whether a sustained pressure of 60 mmHg would lead to esophageal erosion or a more serious complication such as abrupt esophageal rupture is unclear. In clinical experience so far, complications are rarely encountered.<sup>1-7</sup> These have included transient A-V block, nonsustained ventricular tachycardia, supraventricular tachycardia, atrial fibrillation, bronchospasm, and transient vocal cord paralysis.<sup>1-4</sup> Further studies are needed to determine whether a subset of patients who are at risk for development of high contact pressure between a probe and the esophagus can be identified. Unfortunately, over a 9-month period no other suitable patients with descending thoracic aneurysms were available for study.

This small series suggests that contact pressure between a TEE probe and the esophagus is generally low and that prolonged use of the TEE probe in the setting of low-contact pressure does not lead to esophageal damage. But we also note that some patients exist in whom high-contact pressure between the esophageal wall and a TEE probe can develop. We can only speculate that these patients

may be at risk for esophageal injury. Further studies are needed to better define this group of patients. In any case, it is prudent not to fix the TEE probe in a maximally flexed position for prolonged periods of time, and specifically to exert the minimal torque on the TEE controls, which provides adequate visualization in order to avoid high esophageal-probe contact pressure.

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