Fundoplication for Gastroesophageal Reflux*
A Comparison of Preoperative and Early Postoperative Manometric Findings

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Preoperative and early postoperative studies of esophageal manometry were performed in 16 patients who underwent a Nissen fundoplication for gastroesophageal reflux. All had immediate relief of reflux and the amplitude and length of the inferior esophageal sphincter increased from a mean of 5.2 cm of water $\pm$ 1.3 to 15.2 cm of water and 3.0 cm $\pm$ 0.4 to 5.0 cm $\pm$ 0.4 respectively.

PROLOGUE

Dr. Olsen's many contributions to the advancement of our understanding of esophageal disease and its treatment are widely known and respected. It was my privilege to work closely with him for many years as a collaborator and friend in this challenging field of study. His enthusiasm and interest in stimulating a scientific approach to the evaluation of the effectiveness of surgical procedures on the esophagus reflects a critical and open mind which has benefited not only his surgical colleagues, but more importantly the patients whom he and others are called upon to treat. Though our joint efforts to clarify the confusing aspects of the surgical correction of gastroesophageal reflux were inconclusive, the preliminary studies reported here may point the way to a solution based on objective data. They were initiated at the Mayo Clinic and are being continued at the Lahey Clinic Foundation where two of his students and former colleagues, James A. Gregg, M.D., and myself (FHE), are endeavoring to maintain his high standards of excellence.

Dissatisfaction with classic techniques for the repair of sliding esophageal hiatal hernia has led to the introduction of a variety of surgical maneuvers designed to enhance sphincteric function. Fundoplication, as described by Nissen in 1956,1 was among the first of such procedures to be proposed. It has been widely employed, particularly on the Continent, and the clinical results following its use have been uniformly favorable.2 Unfortunately, little data are available concerning the objective evaluation of the operation. Because of the importance of objective assessment of results of surgery for gastroesophageal reflux, we are reporting the early manometric findings in a group of patients following fundoplication.

MATERIAL AND METHODS

Sixteen patients with gastroesophageal reflux were treated by fundoplication. Ten had sliding esophageal hiatal hernia; in three of these, the hernia had recurred following previous repair. Four patients had gastroesophageal reflux without a demonstrable hernia, in two of whom hiatal hernia had been repaired previously elsewhere. One had severe reflux after limited esophagogastrectomy for an esophageal ulcer, the cause of which could not be determined since the operation was done elsewhere, and one patient had an incompetent sphincter following forceful dilation of the cardia elsewhere for esophageal achalasia.

The technique of the operation has been previously described in detail3 and is pictured in Figure 1. Briefly, it consists of surgical reduction of the hernia and narrowing of the diaphragmatic crura posteriorly with interrupted silk sutures followed by mobilization of the fundus so as to permit it to envelop the distal several inches of esophagus by the use of interrupted silk sutures. In all of the cases reported but one, an abdominal approach was employed. The exception was a patient undergoing surgery for a recurrent hernia in whom shortening of the esophagus was suspected. A trans-thoracic approach was employed with exposure of the upper

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abdomen through a semilunar incision of the diaphragm bordering its costal attachments.4

Gastroesophageal manometry was performed before and after fundoplication. A total of 28 such studies was carried out. Three of the patients had no preoperative study and the postoperative study of one other patient was unsuitable for analysis. All of the postoperative studies to be reported were carried out soon after operation either just before or soon after dismissal from the hospital. The average interval between operation and postoperative manometry was 14 days. The manometric techniques employed have been reported elsewhere.5 Briefly, three polyethylene catheters were used to transmit intraluminal pressures to three Sanborn external pressure transducers. Side openings, 1.5 mm at 5 cm intervals, permitted simultaneous recording of pressures at three separate points. Pressure changes were recorded graphically on a Sanborn direct-writing multichannel recorder. In all but three patients,** catheters filled with water were infused at a constant rate through the side arm of a three-way stopcock with the use of a Harvard infusion pump† at a flow rate of 0.416 ml per minute. A pneumograph was placed around the patient’s waist to monitor respirations. The catheter assembly was swallowed and withdrawn at 0.5 cm intervals to record resting pressures. The deglutitory response was studied after the assembly had been reintroduced and again withdrawn at 0.5 cm intervals. Lower esophageal sphincteric pressure was determined in reference to gastric pressure recorded in the fundus, which was arbitrarily considered as zero.

In ten patients the assembly was positioned so that the middle recording unit was located in the high pressure zone, the distal unit being in the stomach and the proximal end in the esophagus. The adaptive response of the lower esophageal sphincter was determined in these patients after increasing intragastric pressure by manual compression of the anterior abdominal wall in all patients and by straight leg raising maneuvers in some of them.

RESULTS

All the patients survived operation and at the time of dismissal from the hospital had experienced complete remission of their preoperative symptoms of gastroesophageal reflux. A number of patients who, prior to operation, were forced to sleep in the erect position because of the severity of their symptoms of reflux were able to sleep normally in the recumbent position without difficulty after surgery. None of the patients was bothered by bloating and all on direct question stated that they were able to belch following surgery. Commonly noted, however, was the presence of mild dysphagia for a few days when solid food was first taken. This symptom was of a transitory nature with one exception. One patient experienced total esophageal obstruction five days after operation, during which time intravenous feedings were required. Complete resolution

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**Three patients were studied at the Mayo Clinic by Mr. Jerry Schlegel in Dr. C. M. Code’s laboratory. The recording catheters in these three patients were not infused, and the distal catheter had a balloon-covered transducer at its tip. We are grateful for permission to report these cases.
Figure 2. Preoperative and postoperative esophageal manometry in a patient who underwent hiatal hernia repair and fundoplication. PD, potential difference; OT, open tip catheter; BT, balloon-covered transducer. Note the increase in amplitude and length of the high pressure zone after operation which persists at the time of late study. (We are grateful to Mr. Jerry Schlegel, who prepared the tracing, for permission to reproduce it.)

ranged from 0 to 11 mm Hg with a mean of 5.2 ± 1.3, postoperatively they ranged from 5 to 36 mm Hg with a mean of 15.2 ± 2.0, a threefold increase. This difference was highly significant (P < 0.001). There was also a significant difference in the length of the high pressure zone after operation (P < 0.001), the mean values increasing from a 3.0 cm ± 4.0 to a mean length of the high pressure zone after operation of 5.0 cm ± 0.4. While in some patients the amplitude of relaxation and contraction increased after operation, this was not a uniform observation. Many patients demonstrated no demonstrable change in these characteristics after fundoplication.

The response of the inferior esophageal sphincter to artificially increased intragastric pressures and the presence or absence of transmission of these increased pressures to the esophagus were studied before and after operation in ten patients. In all but two there was a demonstrable increase in sphincteric pressure without esophageal transmission.

**Comment**

Despite the glowing clinical reports concerning the clinical effectiveness of fundoplication in preventing gastroesophageal reflux, objective data concerning the results of operation are rare. Some, in fact, have emphasized the lack of correlation between symptoms and manometric findings. Moran and associates studied seven patients before and after fundoplication and reported an increase in the amplitude of the high pressure zone from 10 mm Hg before surgery to 15 mm Hg after operation. Stucker noted an approximate 100 percent increase in sphincteric pressure in 37 fundoplication patients which restored the amplitude of the high pressure zone to levels recorded in normal individuals without reflux. Skinner and Booth noticed a 5.8 mm Hg increase in sphincteric pressure in 14 patients after either a Belsey or a Nissen fundoplication. Lind and associates reported their findings in 16 patients undergoing what they called a “Belsey” operation, though their illustrations resemble more closely a modified type of a Nissen fundoplication. After correction of their data to an intragastric pressure of 0, an approximate doubling of sphincteric pressure was recorded after operation (9.8 cm of water to 20.1 cm of water). A normal sphincteric response to increase of intragastric pressure occurred after operation without transmission of the increased intragastric pressure to the esophagus. Lind and associates and Affolter and Rossent both reported an improvement in sphincteric function after fundoplication, as evidenced by increased amplitudes of sphincteric relaxation and contraction. No data concerning the length of the high pressure zone after fundoplication are provided in any of these reports, most of which represent studies carried out after a longer postoperative interval than was true in the case of those reported here.

The manometric findings after fundoplication reported here are quite similar to the isolated reports referred to previously. All patients exhibited an increase in length and amplitude of the high pressure zone. The differences were highly significant and correlated well with the uniform clinical relief of gastroesophageal reflux and the absence of radiographic evidence of reflux. Further objective evidence that sphincteric function was improved by surgery was provided by its normal adaptive response to increased intragastric pressure in eight of the ten patients in whom it was tested. However, in contrast to others, there was no consistent increase in the amplitude of sphincteric relaxation and contraction.

These studies were all performed early after...
operation when postoperative edema and reversible local tissue reaction were obviously present. Late studies will be required to define more clearly the manometric effects of fundoplication. Some question the permanence of the procedure suggesting a possible tendency for sutures to pull through with loosening of the periesophageal fundic noose. Though not included in the data presented in the body of the paper, five patients were restudied by esophageal manometry two to ten months after operation. Sphincteric pressure remained the same in three and decreased slightly in two.

The mechanism by which the operation of fundoplication succeeds in preventing reflux has not been clarified by these studies. The fact that sphincteric relaxation and contraction show no real improvement suggests that it succeeds more by developing a form of mechanical obstruction than by producing a new physiologic sphincter. For its complete elucidation, studies carried out after longer postoperative intervals will be required. Whatever the mechanism may be, the initially favorable results in terms of heightening and lengthening sphincteric pressures and in preventing gastroesophageal reflux warrant continued study of the physiologic effects of fundoplication.

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REFERENCES

Early Attempts at Pulmonary Embolectomy

Ranzi, writing in 1908 about postoperative embolic complications, said that in von Eiselsberg’s Clinic, in Vienna, in six thousand eight hundred and seventy-one operations since 1901, there had been fifty-seven pulmonary emboli. The first attempt to operate in such a case was recorded by him. The patient had a hernia repaired. On the second postoperative day, a diagnosis of pulmonary embolus was made. He was operated upon within a few minutes without anesthesia. Two clots were removed from the pulmonary artery 5 cm long and 10 cm long. The left branch seemed to be free from clots, but it could not be determined whether or not the right one was free. The heart beat stopped forty minutes after the first symptoms. Autopsy showed that the right pulmonary artery was still occluded with clot which extended down into the smallest ramifications.