A Physiologic Approach to Laparoscopic Fundoplication for Gastroesophageal Reflux Disease

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Objective

The authors examined indications, evaluations, and outcomes after laparoscopic fundoplication in patients with gastroesophageal reflux through this single-institution study.

Summary of Background Data

Laparoscopic fundoplication has been performed for less than 5 years, yet the early and intermediate results suggest that this operation is safe and equivalent in efficacy to open techniques of antireflux surgery.

Methods

Over a 4-year period, 300 patients underwent laparoscopic Nissen fundoplication (252) or laparoscopic Toupet fundoplication (48) for gastroesophageal reflux refractory to medical therapy or requiring daily therapy with omeprazole or high-dose H_2 antagonists. Preoperative evaluation included symptom assessment, esophagogastroduodenoscopy, 24-hour pH evaluation, and esophageal motility study. Physiologic follow-up included 24-hour pH study and esophageal motility study performed 6 weeks and 1 to 3 years after operation.

Results

The most frequent indication for surgery was the presence of residual typical and atypical gastroesophageal reflux symptoms (64%) despite standard doses of proton pump inhibitors. At preoperative evaluation, 51% of patients had erosive esophagitis, stricture, or Barrett's metaplasia. Ninety-eight percent of patients had an abnormal 24-hour pH study. Seventeen percent had impaired esophageal motility and 2% had aperistalsis. There were four conversions to open fundoplication (adhesions, three; large liver, one). Intraoperative technical difficulties occurred in 19 (6%) patients and were dealt with intraoperatively in all but 1 patient (bleeding from enlarged left liver lobe). Minor complications occurred in 6% and major complications in 2%. There was no mortality. Median follow-up was 17 months. One year after operation, heartburn was absent in 93%. Four percent took occasional H_2 antagonists, and 3% were back on daily therapy. Atypical reflux symptoms (e.g., asthma, hoarseness, chest pain, or cough) were eliminated or improved in 87% and no better in 13%. Overall patient satisfaction was 97%. Four patients have subsequently undergone laparotomy for repair of gastric perforation (1 year after operation), severe dumping, "slipped" Nissen, and repair of acute paraesophageal herniation. Two patients had laparoscopic revision of herniated fundoplications. Results of follow-up 24-hour pH studies were normal in 91% of patients more than 1 year after operation. In patients with poor esophageal motility, esophageal body pressure improved 1 year after operation in 75% and worsened in 10%.

Conclusions

Although long-term efficacy data are lacking, intermediate follow-up shows laparoscopic fundoplication to be safe and effective. A physiologic approach to evaluation and follow-up of patients with gastroesophageal disease allows the surgeon to tailor antireflux surgery to esophageal body function and follow the function of the fundoplication and esophagus after operation.

Gastroesophageal reflux (GER) is the most common gastrointestinal condition in the United States. At least $10 billion is spent annually on prescription drugs for heartburn and dyspepsia, approximately twice the annual expenditure for gallstone treatment. Although GER is a common problem, surgical therapy was on the wane at the end of the last decade. Reports of improved results with two new medications (omeprazole and cisapride) decreased the interest in surgical therapy even further. A fear existed among patients and practitioners that fundoplication, although curing heartburn, created side effects that were worse than the disease itself.

In the last 5 years, a greater appreciation of the benefits of surgical therapy has emerged. A controlled randomized trial showed superiority of surgical therapy to medical therapy for the treatment of severe GER, without inducing a greater frequency of side effects.[1] Early reports of laparoscopic Nissen fundoplication[2,3] and Toupet fundoplication[4] established that antireflux procedures were amenable to laparoscopic techniques. A new appreciation that effective medical therapy required a lifelong commitment to powerful acid inhibitory agents coupled with good early results of laparoscopic surgery has done much to increase the frequency with which patients and gastroenterologists have selected laparoscopic fundoplication as definitive therapy for reflux disease.

Over the last 4 years, we have found that physiologic evaluation of esophagogastric function before and after fundoplication has provided acceptable clinical, economic, and quality-of-life outcomes. Physiologic evaluation of esophagogastric function also has provided us the necessary information to improve patient selection and operative technique.

METHODS

Between October 1991 and June 1995, 300 patients underwent laparoscopic fundoplication at the Emory University Hospital (287 patients) or at the University of

Utah Hospital (13 patients) for GER. There were 177 men and 123 women. The mean age was 46 ± 13 years. Laparoscopic fundoplication was performed in 13 patients between October 1, 1991, and September 30, 1992 (year 1). Fifty-two operations were performed between October 1, 1992, and September 30, 1993 (year 2), 130 operations were performed between October 1, 1993, and September 30, 1994 (year 3), 105 operations were performed between October 1, 1994, and June 20, 1995 (year 4) (Fig. 1). Two hundred sixty-one operations were performed by one author (J.H.) and 39 by another author (G.B.).

The indications for surgery were as follows: 1) gastroesophageal reflux refractory or incompletely controlled with standard doses of proton pump inhibitors and prokinetic agents; and 2) gastroesophageal reflux controlled with these agents in patients who desired to be free of medical therapy because of young age, medication expense, quality of life, medication dependence, or medication side effects. Although complications of GER (e.g., stricture, Barrett's metaplasia) were not absolute indications for surgery, surgical referral was common in these patients.

During the first 3 years of this series, all patients underwent esophagogastroduodenoscopy, esophageal mo-
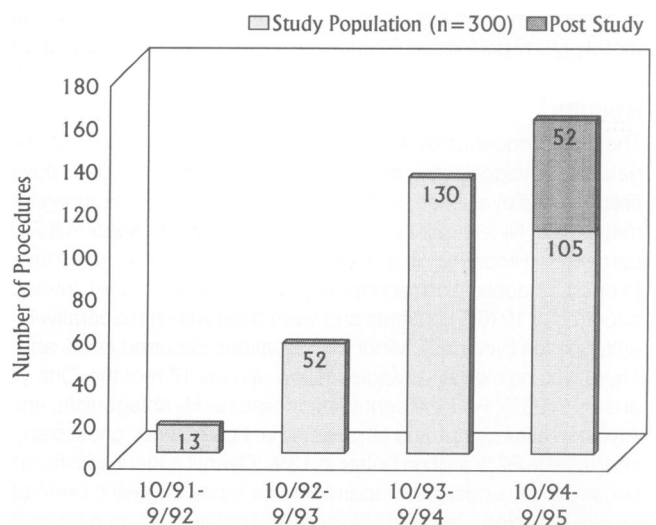

Figure 1. Three hundred fifty-two laparoscopic fundoplications were performed between October 1, 1991, and October 1, 1995. The first 300 of these patients form the study population.

tility study (EMS), barium swallow, and a 24-hour ambulatory esophageal pH study (24-hour pH). In the last year of this study, the 24-hour pH was omitted in patients with typical symptoms and erosive esophagitis. Gastric emptying studies were used liberally in patients with a history of peptic ulcer, diabetes, vomiting, or significant gastroesophageal reflux despite a manometrically normal lower esophageal sphincter.

Operative technique has been a five-trocar technique that has evolved from our earlier descriptions[5] to a more efficient technique that has decreased operative time and personnel requirements significantly.[6] Three operations were performed: 1) a Toupet procedure (270° posterior fundoplication)[7]; 2) a Rosetti–Nissen fundoplication, 2-cm long around a large (54–60 French) dilator[8]; and 3) a "floppy" Nissen fundoplication, 2-cm long around a large (54–60 French) dilator.[9] The Toupet procedure was used liberally early in this series for patients with no hiatal hernia. Later, it was used only for those patients with poor esophageal motility. The Rosetti–Nissen procedure was abandoned when a complication study showed excessive dysphagia with this operation.[10]

After operation, patients were started immediately on fluids, and a soft, solid diet was instituted the following morning. Discharge occasionally occurred on the first postoperative day but usually occurred on the second postoperative day. Follow-up occurred at 1 month, as needed during the first year, and annually thereafter. In the first 150 patients, 55 patients volunteered for early postoperative pH and motility study. Of the patients followed for more than 1 year after operation, 54 volunteered for 24-hour pH and esophageal motility study. Patients investigated because of the development of reflux symptoms were included with the volunteer group. Symptom scores and quality-of-life survey (Medical Outcomes Short Form-36) were obtained in the clinic 1 month and 1 year after laparoscopic fundoplication. A questionnaire was mailed annually thereafter.

RESULTS

Complete follow-up data are available in 126 of patients 1 to 2 years after operation. Twenty-two percent of patients have returned follow-up questionnaires more than 2 years after operation. The median length of follow-up is 17 months (range, 1–42 months).

Symptoms of Patient Population

Preoperative and postoperative symptoms were graded by the patient using a score of 0 to 4 (0, no symptoms; 1, infrequent symptoms; 2, occasional symptoms, occasionally bothersome; 3, frequent symptoms, fre-

quently bothersome; and 4, incapacitating symptoms) (Fig. 2). The majority of patients (89%) underwent surgery for the treatment of typical reflux symptoms (e.g., heartburn, regurgitation, dysphagia). Most of these patients (64%) also had one or more atypical symptoms (e.g., asthma, hoarseness, chest pain, or cough) graded 3 or 4. Asthma frequently was bothersome or incapacitating in 30(10%), hoarseness in 45(15%), chest pain in 69(23%), and chronic cough in 57(19%) of patients. Atypical symptoms without significant heartburn were present in 32 (11%) (asthma, 5; hoarseness, 8; chest pain, 7; and cough, 12).

Eight percent of patients had a complete response to medical therapy of GER (score, 0–1) and were seeking surgery because of young age, lifestyle, drug dependence, costs of medication, or a combination of these factors. Thirteen percent had occasional (score, 2) heartburn on medical therapy. Seventy percent had frequent or incapacitating heartburn (score, 3–4) on medical therapy, had a side effect to proton pump inhibitors, or were not taking medications.

Anatomic and Physiologic Evaluation

Before operation, precise endoscopic grading of esophagitis was not always possible because of variability in the endoscopic reports from outside our institution. Patients who had recently undergone endoscopic evaluation by their referring doctor (within 6 months) were not re-endoscoped before operation unless they had a history of Barrett's esophagus (Fig 3). Preoperative endoscopic evaluation was performed at Emory University Hospital in 122 patients. In this group, esophageal erosions (Savory Miller grades II–III) were found in 34 patients (28%), an esophageal stricture was found in 12 patients (10%), and Barrett's esophagus was present in 16 patients (13%). The remaining 60 patients (49%) had Savory-Miller grades 0–I on preoperative endoscopy.

The EMS showed impaired peristalsis (peristaltic propagation present in less than 8 of 10 wet swallows or a mean esophageal body contractile amplitude ≤ 30 mmHg) in 17% of patients. Seven patients (2%) had aperistalsis of the esophageal body. During the time of this study, two patients were referred to the swallowing center for antireflux surgery who were found to have achalasia by EMS. Resting lower esophageal sphincter pressure was less than 10 mmHg in 38%, 10 to 19 mmHg in 41%, and normal in 21%.

Ambulatory 24-hour pH testing was performed before operation in all patients in the first 3 years, and 21% of patients in the fourth year of this study. Results of these tests were abnormal in all but seven (2%) and were thought to be inaccurate in these seven patients (probe misplaced or patient noncompliant). The mean percent
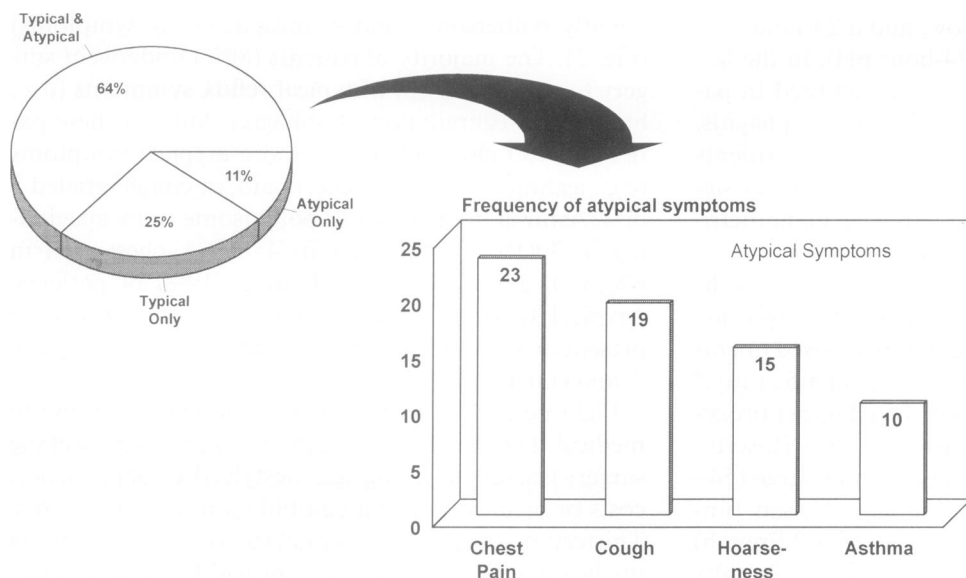
time with a distal esophageal pH less than 4 was 18.9 ± 24% of a 24° period in our study population. Of those studied, 17% had only upright reflux and 4% had only supine reflux. Barium swallows were performed in all patients with dysphagia, history of a stricture, or the endoscopic finding of a large hiatal hernia. In 32 patients, a type II or type III paraesophageal hernia was discovered, and these patients were excluded from this study. Gastric emptying studies were performed in 39 patients. Study results were normal in 33 patients and abnormal in 6 patients. Four patients with the most severe delays in gastric emptying (half emptying time at least twice normal) underwent a pyloroplasty or pyloromyotomy at the time of laparoscopic fundoplication.

Operative Results

Toupet fundoplication was performed in 48 patients, Rosetti–Nissen fundoplication in 19 patients, and floppy Nissen fundoplication in 233 patients (Fig. 4). The mean operative time for this series was 185 ± 51 minutes but decreased to 154 ± 30 minutes in the last 20 cases. The primary surgeon was one of the two senior authors (J.H.,

Figure 3. Routine preoperative evaluation included esophagogastroduodenoscopy, esophageal motility study, and 24° pH study.

G.B.) in 181 cases (60%), a junior faculty member in 81 cases (27%), and a surgical resident in 38 cases (13%). In procedures where a resident was not the primary surgeon, a substantial portion of the case (e.g., closing the crura or suturing the fundoplication) was often performed by a surgical resident.

There were four conversions to laparotomy (1.5%). Conversion occurred in cases 47, 79, 89, and 215. The reason for conversion was adhesions from previous subphrenic surgery in the first three patients (splenectomy, aortobifemoral graft, gunshot wound) and left lobe hepatomegaly in the last patient. Intraoperative surgical complications included gastric perforation (three instances) and esophageal perforation (one instance). Gastric perforations were a result of traction. They were immediately apparent and were closed with laparoscopic suturing in two patients and endoscopic stapling in one patient. The esophageal perforation was a scissors laceration and was closed in two layers with laparoscopic suturing and then buttressed with the fundoplication. Bleeding of more than 200 mL was present in eight patients but required neither transfusion nor splenectomy. The most frequent sites of bleeding were the undersurface of the left lobe of the liver (retractor injury) and a branch of the left phrenic artery. Respiratory acidosis not controllable with hyperventilation occurred in three patients and was treated by deinsufflation and a change to nitrous oxide pneumoperitoneum. Small pneumothoraces were identified in three other patients but required neither a chest tube nor a hospital stay beyond 2 days. Mean length of stay was 2.2 days with a range from 1 to 32 days.
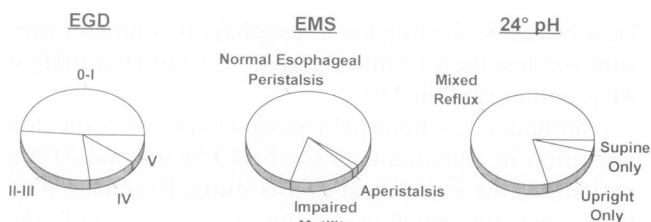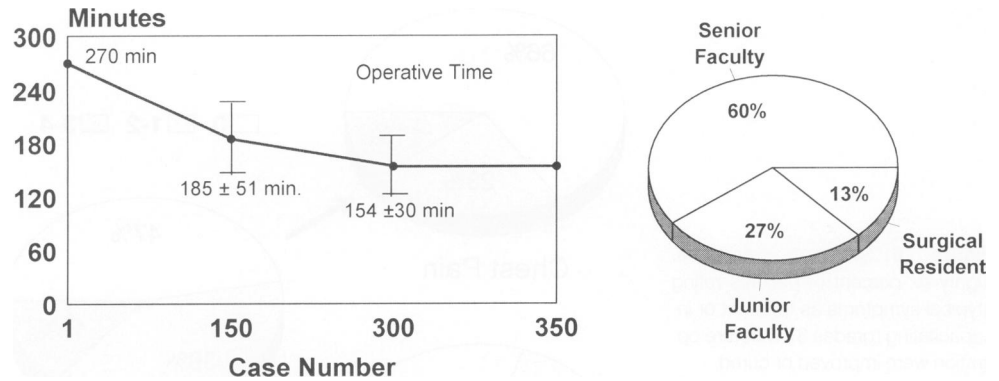
Clinical Outcomes

Clinical outcomes were divided into three areas: 1) clinical efficacy, 2) early complications, and 3) side effects.

Figure 4. Operating time has fallen slowly because of thoroughness of dissection and participation of junior faculty and residents.

Clinical Efficacy

The effectiveness of surgery was gauged by patient responses to the preoperative symptom questionnaire and to additional questions addressing the patient's overall satisfaction with the surgical result. As well, physiologic assessment of the esophagus (EMS, 24° pH study) allowed quantifiable information for comparison with preoperative data.

The mean heartburn score of patients undergoing surgery was 2.73 ± 1.29 before operation, 0.21 ± 0.69 1 month after operation, and 0.35 ± 0.81 1 year after operation (p < 0.01). One year after operation, 93% of patients were symptom free, 4% had occasional symptoms, and 3% were back on medical therapy for controlling daily symptoms (Fig. 5). Three of the four patients with frequent or incapacitating heartburn were investigated with 24-hour pH studies and two had abnormal study results. Regurgitation was scored as 2 or greater in 49% of patients before operation. One year after operation, only four patients (3%) reported more than rare regurgitation (score, ≥ 2). Three of these patients had an abnormal pH study. In all three patients, fundoplication slippage was detected with barium swallow. The response of dysphagia to reflux surgery is discussed below.
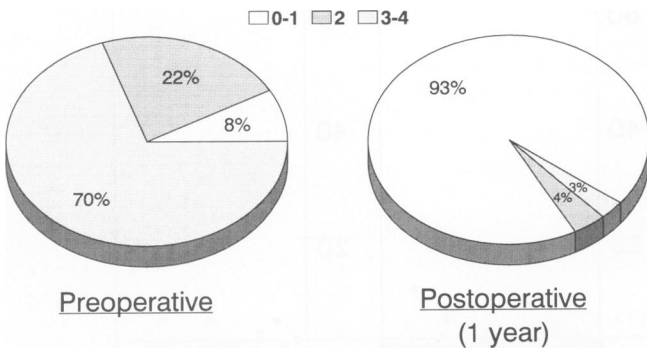

Figure 5. Symptom response to heartburn. Preoperative heartburn was graded as severe in 70% of patients before operation and as absent or rare in 93% of patients after operation.

Frequent or incapacitating atypical symptoms (e.g., asthma, hoarseness, chest pain, or cough) present in 64% of patients with heartburn before operation were improved or eradicated by operation in 86% of patients (Fig. 6). When atypical symptoms were present without typical symptoms, the response was identical. Overall, 97% of patients were satisfied with their surgical results and 3% were dissatisfied.

Fifty-five 24-hour pH studies were performed between 6 and 12 weeks after operation (Fig. 7). Mean total time with pH <4 fell from $18.9 \pm 24\%$ to $3.6 \pm 6\%$ (p < 0.01). Results of seven of these studies (13%) were abnormal; however, none of these patients reported heartburn and only one has required subsequent reoperation. Fifty-four 24-hour pH studies were performed 1 year after surgery, 7 for evaluation of symptoms and 47 on a voluntary basis. Results of 49 pH studies were normal (91%), 45 in the volunteer group (96%) and four in the group studied for symptom evaluation (63%).

Esophageal motility study was performed in all patients. Abnormalities that changed the operative plan were hypomotility, aperistalsis, or a hypertensive, nonrelaxing lower esophageal sphincter (suggestive of achalasia). Preoperative motility tests detected 58 (19%) patients with aperistalsis or impaired esophageal peristalsis (defined above). Toupet fundoplication was performed in all patients with impaired peristalsis in more than 50% of ten wet swallows. In patients with impaired peristalsis in 30% to 50% of ten wet swallows, 60% had Toupet fundoplication and 40% had Nissen fundoplication. Nissen fundoplication was performed in the remainder of patients. One year after operation, 47% of patients with impaired peristalsis had an improvement in peristalsis, and esophageal body pressure was improved in 75% of those with low preoperative contraction amplitude (< 60 mmHg). Worsening peristalsis was seen in 13% and worsening esophageal body pressure was seen in 10% (Fig. 8). Patients having normal motility before operation had normal motility after operation, with the exception of 9% of patients whose motility diminished into the low range. Early postoperative dysphagia (score, 3–4) was reported by 7(12%) of patients with
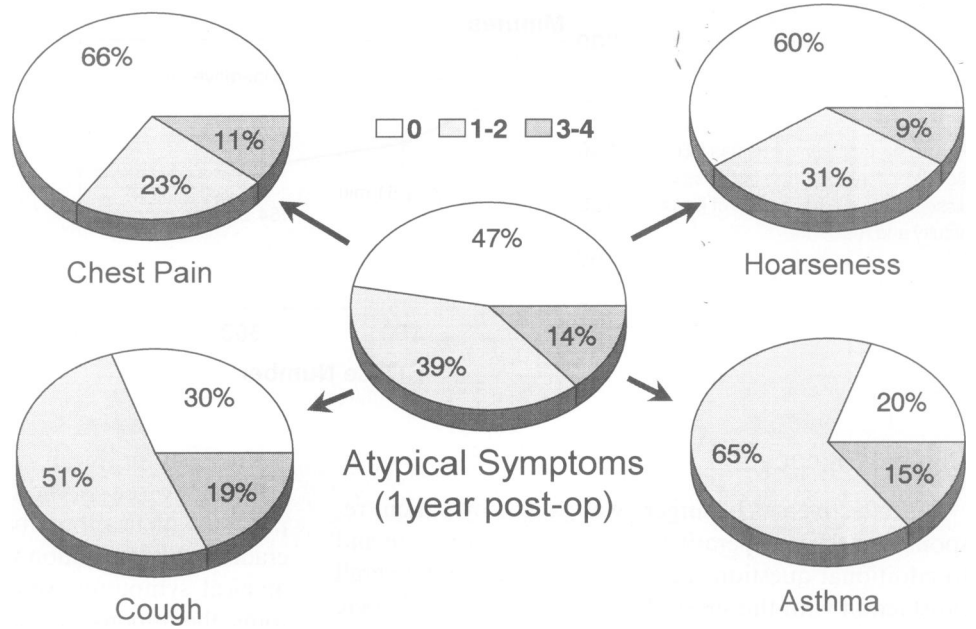
Figure 6. Symptom response. Eighty-six percent of patients rating atypical symptoms as frequent or incapacitating (grades 3–4) before operation were improved or cured.

poor preoperative motility, and persistent dysphagia was reported in one patient (2%). Postoperative dysphagia was no more frequent in this population than in the larger study group (see below), and patients undergoing Nissen fundoplication in this population were no more likely to have postoperative dysphagia than were patients undergoing Toupet fundoplication.

Early Complications (30 days)

Complications have been divided into four categories (Table 1) as follows. Type I complications (delaying patient discharge) occurred in 19 patients (6.3%). Readmission within 30 days occurred in eight patients (2.7%). Type II complications (requiring intervention but not surgery) occurred in six patients (2%) and included pneumothorax in one patient who required a chest tube. Two patients were reintubated in the recovery room. Gastric dilatation requiring nasogastric tube placement occurred on the evening of operation in three patients. Type III complications (requiring operative intervention) occurred in two patients (0.7%). One patient disrupted his fundoplication with postoperative vomiting in the recovery room, and one patient with cerebral palsy and an indwelling Foley catheter had necrotizing orchitis, requiring orchiectomy. There were no deaths in this series.
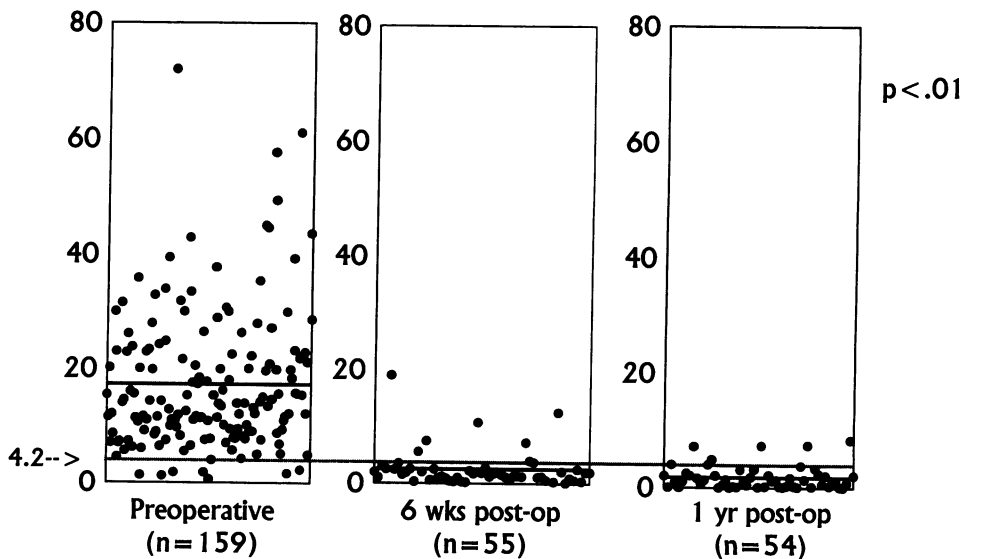

Figure 7. Twenty-four hour ambulatory pH study. Laparoscopic fundoplication-controlled pH in 87% of patients studied 6 weeks after operation and 91% of patients studied 1 year after operation.
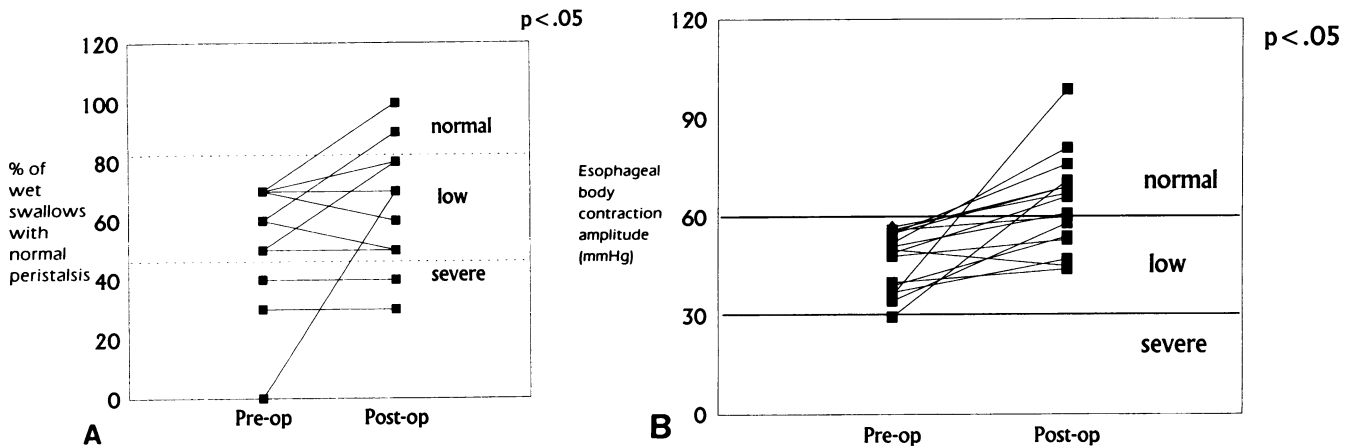
Figure 8. (A) Response of poor esophageal peristalsis to laparoscopic fundoplication (n = 15). (B) Response of poor esophageal contractile force to laparoscopic fundoplication (n = 22). In patients with poor esophageal peristalsis or low esophageal body pressures, laparoscopic fundoplication caused significant improvement in peristalsis.

Reoperations and Symptom Recurrence

Three patients required laparotomy more than 1 month after surgery. A gastric perforation in the fundus resulted from protracted vomiting in one of three patients with cerebral palsy. Severe medically refractory dumping developed in a second patient, perhaps as a result of vagal injury. The patient was treated with antrectomy and Roux-en-Y gastrojejunostomy. A slipped Nissen fundoplication developed in a third patient after an episode of vomiting, who required laparoscopy converted to laparotomy for revision.

An intact fundoplication has herniated through the diaphragm, causing symptoms of dysphagia or reflux or both in five patients (2%). Two of these have been repaired laparoscopically by pulling the fundoplication back into the abdomen, more tightly approximating the crura, and fixing the stomach to the undersurface of the diaphragm. Partial fundoplication failure without herniation causing recurrent heartburn has been identified in two additional patients (Table 2).

Side Effects of Surgery

Side effects of surgery (Fig. 9 and Table 3) were graded on a four-point scale identical to that used for assessment of symptoms.

Dysphagia

The mean preoperative dysphagia score was 1.3 ± 1.4. Severe preoperative dysphagia was present in 81 (27%) of these patients. Thirty-two patients (11%) had an esophageal stricture. After operation, the mean dysphagia score was 0.65 ± 1.0 at 6 weeks and 0.41 ± 0.72 at 1 year. Although dysphagia was decreased, on the average, 10% of patients reported new onset dysphagia with a score of 2 or greater. Esophageal dilation was performed in 20 patients (6%). Occasional dysphagia persisted in seven patients (2%) 1 year after operation. Only two patients reported severe dysphagia (score, 3–4) 1 year after operation, and both patients had preoperative dysphagia from an esophageal stricture.

Gas and Bloating

One hundred one patients (80%) reported increased amounts of flatus 1 year after operation. The mean score for bloating before operation was 1.5 ± 1.4. The mean score for bloating after operation was 0.95 ± 1.1 at 6 weeks and 1.6 ± 1.4 at 1 year. Nine patients (7%) reported new onset bloating (postoperative score, 3–4), but no patient had sufficient bloating to warrant takedown of the fundoplication.

Belching

Although nearly 100% of patients could belch before operation, 85% of patients reported that they could belch at the 4- to 6-week follow-up period. Seventy-nine percent of patients followed longer than 1 year reported the ability to belch. There was no appreciable difference between the procedure performed and the ability to belch after operation.

Vomiting

Vomiting is an infrequent postoperative problem. Yet, of those needing to vomit in the year after operation, 75% could not. Vomiting induced herniation or slippage of the fundoplication in at least three patients. Fundoplication damage occurred at 2 hours, 3 days, and 4 months after operation.

Table 1. COMPLICATIONS OF LAPAROSCOPIC FUNDOPLICATION

Complication	Number
Type I (delayed discharge)	
Pneumonia	2
Atelectasis	3
Wound infection	1
Fever (not otherwise explained)	5
Psychiatric	1
Bloating	2
Urinary retention	1
Acidosis	1
Observation after intraoperative bleeding	1
Observation after gastric perforation and repair	1
Total	19 (6.3%)
(Readmission)	2,3
Pressure necrosis liver segments 2 and 3	1
Nausea, dehydration	2
Duodenal ulcer	1
Rectal bleeding	1
Pain	2
Fever	1
Total	8 (2.7%)
Type II (required intervention)	
Pneumothorax	1
Recovery room respiratory distress	2
Gastric dilatation	3
Total	6 (2%)
Type III (required reoperation)	
Acute paraesophageal hernia (vomiting)	1
Necrotizing orchitis (indwelling catheter)	1
Total	2 (0.7%)
Type IV (mortality)	0

Table 2. REOPERATIONS AND FAILURES

Reason for Reoperation	Number
Laparotomy	
Acute diaphragm disruption (vomiting)	1
Gastric perforation (vomiting one year postop)	1
Slipped Nissen (vomiting)	1
Refractory dumping (vagal injury)	1
Laparoscopy	
Fundoplication herniation	2
Total	6 (2%)
Additional fundoplication failures	
Fundoplication herniation	3
Fundoplication degradation	2
Total	5 (2%)

Emory University Hospital, Belsey Mark IV, have been published previously.[11] These data showed that the mean charge for fundoplication was $15,393, which was $8903 less than that for open Belsey fundoplication (p < 0.01). Average reimbursement for Nissen fundoplication was $9200 and was evenly distributed between hospital charges and professional fees. Actual costs for performance of this procedure are not currently available.

Quality of Life

Quality-of-life assessment for patients with GER referred for surgery was performed with a well-standardized tool (Medical Outcomes Short Form-36) immediately before surgery, 6 weeks after surgery, and 1 year after surgery. This form measures 12 different fields of life quality and reports these as independent outcomes. In all fields, patients with severe GER had an extremely

Nausea

Severe nausea frequently was reported before operation, occurring in 18% of patients. After operation, nausea was present in 4% at 6 weeks, and at 1 year, nausea was present in 6%.

Diarrhea

Before operation, severe diarrhea (score, 3–4) was present in 13%. Troublesome diarrhea (score, 3–4) was reported after operation in 18 (6%) and was present in 15 (12%) at 1 year. Only three patients without diarrhea before operation reported new onset diarrhea after laparoscopic fundoplication.

Cost Effectiveness

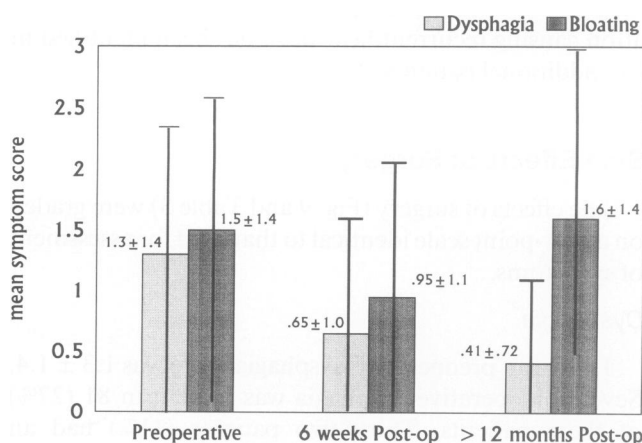Cost effectiveness data of laparoscopic antireflux surgery as compared with the previous operation done at

Figure 9. Dysphagia improves after laparoscopic fundoplication, and bloating becomes no worse after operation.

	Preop (%)	1 Month (%)	> 1 Year (%)
Able to belch	100%	85%	79%
Able to vomit	100%	25%	25%
Nausea	18%	4%	6%
Diarrhea	13%	6%	12%

low quality of life, with scores no different from that of a control population with congestive heart failure.[12] Patients "well controlled" on medical therapy had a slight but insignificantly better life quality than those refractory to medical therapy. Laparoscopic antireflux surgery raised these scores above those of a control population 6 weeks after operation. Scores in all fields were statistically significant and improved at 1 month and 1 year when compared with preoperative scores (p < 0.01). One year later, the scores had returned to the level of the control population, but were still significantly better than preoperative scores in all fields (p < 0.01).

DISCUSSION

The first, and perhaps most dramatic, finding of this and other studies of laparoscopic fundoplication is the large number of antireflux procedures performed in a short period. The number of patients undergoing fundoplication in the last 3 years is equivalent to many esophageal surgeons' lifetime experience. Reasons for this phenomenon are related to the surgeon, the patient, and the gastroenterologist. With laparoscopic cholecystectomy, surgeons who would have been unlikely to perform 50 open cholecystectomies per year began performing more than 250 cholecystectomies annually. In a similar fashion, laparoscopic fundoplication generally has been concentrated to a few surgeons in urban centers who perform two or three of these procedures each week. As interest in laparoscopic fundoplication has spread, these procedures are diffusing out into smaller centers, much as laparoscopic cholecystectomy spread to most general surgeons. Although the desire for laparoscopic cholecystectomy was clearly driven by the patients, the desire for laparoscopic fundoplication has been driven by tandem forces. There is little doubt that many patients with GER harboring strong indications for operation were rejecting open fundoplication because of the incision, the pain, and the rehabilitation time. These patients "came out of the woodwork" at the inception of laparoscopic fundoplication. When these patients re-

turned to their gastroenterologists with a good result, gastroenterologists began referring more patients for laparoscopic antireflux surgery. The concentration of these procedures in a few surgeons' hands has created a dramatic, apparent increase in the number of procedures performed. The real increase is more illusory. It has been estimated that the total number of Nissen fundoplications performed in the last few years has doubled since the late 1980s (R. Kozarek, M.D., SAGES postgraduate course, Orlando, FL, 1995). Hard data currently are lacking.

The indications for surgery have not changed, but perhaps the threshold for referral has changed. Indications as listed in the Methods section are identical to those listed in a 1992 editorial by a prominent gastroenterologist.[13] Nonetheless, many patients with these indications thought open surgery was not in their best interest. These same patients, and their referring physicians, now think that endoscopic surgery is indicated earlier in the course of disease. Superior results should be expected if patients are referred before irreversible esophageal damage has occurred. Although it is thought by some that proton pump inhibitors (e.g., omeprazole, lansoprazole) may lessen the need for surgery, we may find the reverse to be true. These drugs are excellent at curing heartburn, healing esophagitis, and are somewhat less effective at treating atypical symptoms.[14] The value of omeprazole in our patient population has been as follows:

1. To allow patients and physicians to understand which atypical symptoms are likely to be well treated with antireflux surgery. Symptoms that are eliminated or improved with omeprazole are more likely to be well treated with surgery.
2. Proton pump inhibitors allow patients to feel dramatically better, yet symptoms return as soon as the medication is stopped. Many young patients are willing to undergo laparoscopic surgery to achieve equivalent symptom relief rather than agree to a lifetime of omeprazole therapy.
3. Omeprazole may be helpful in reducing the periesophagitis that makes operation more difficult in patients with active inflammatory esophagitis.

Evaluation of patients undergoing laparoscopic fundoplication changed over the course of this study. Initially, an ambulatory 24-hour pH study was required before surgery was considered. When we correlated an abnormal pH study with endoscopic and historical findings, we found that patients who had erosive esophagitis and typical reflux symptoms had an abnormal pH study in 100% of cases.[15] After that study, we have used preoperative 24° pH study selectively. Patients with atyp-

ical symptoms and those without erosive esophagitis require 24° pH study to confirm the presence of reflux. In the absence of typical reflux symptoms, 15% of patients referred for surgery had a normal pH study and did not undergo operation. Postoperative 24° pH testing is a useful research tool to correlate symptomatic response with quantifiable data. However, in our volunteer population, patients with abnormal pH test results had no reflux symptoms, and 50% of the patients evaluated for chest symptoms had no reflux. Six weeks after operation, 7 of 55 patients (13%) had abnormal pH studies, yet only 1 patient was symptomatic, and she had severe gastric dysfunction. The remainder of these patients were asymptomatic, and two of these patients had a normal pH study 1 year after operation. Abnormal studies were found in 5 of 54 patients (9%) 1 year after operation. Two of these patients were asymptomatic. In the three patients with recurrent symptoms and an abnormal pH study, endoscopy showed that a portion of the fundoplication was herniated in two patients, and partial wrap degradation had occurred in the third patient.

Esophageal motility study is a necessary preoperative test. Esophageal dysmotility (defined earlier) was present in 19% of patients. Patients with the worst peristalsis (peristalsis, < 50%) underwent subtotal fundoplication (Toupet) and achieved equivalent postoperative dysphagia and heartburn scores as with patients with normal esophageal motility (Fig. 8). Patients with less peristaltic failure (peristalsis, 50–70%) who underwent Nissen fundoplication (six patients) fared no worse than patients undergoing Toupet fundoplication with equivalent manometric findings. These findings are in agreement with those from two previous studies in the open fundoplication literature describing acceptable results with Nissen fundoplication in patients with poor esophageal motility.[16,17] The finding that esophageal motility improved after laparoscopic fundoplication (but not into the normal range) in the majority of patients with diminished peristaltic function is provocative. Further follow-up of these patients should show the durability of this finding.

Gastric emptying has been thought to improve after antireflux surgery,[18] yet severe gastric dysmotility frequently has been treated with fundoplication and pyloroplasty.[19] We have used gastric emptying studies frequently (39 patients) to help decide when gastric drainage is adequate. Pyloroplasty or pyloromyotomy was performed in addition to fundoplication when half emptying time was more than twice normal (four patients). The symptoms (e.g., bloating, nausea, vomiting) that prompted gastric evaluation have improved in most of these 39 patients, but follow-up gastric emptying studies have yet to be performed.

The median operative time was 3 hours for the whole series and 2.5 hours for the last 20 cases. Whereas some series have mean operative times substantially shorter than ours, this series contains a slightly longer operative time for three reasons. Many of the cases were performed by surgical trainees and junior surgical faculty. More important, a complete fundic dissection from the short gastric vessels posteriorly to the left crus of the diaphragm requires 25 minutes.[20] This dissection is not performed by some other authors but is important to achieve the concept of a floppy fundoplication. Lastly, it is important to bring a minimum of 2 cm of tension-free lower esophagus into the abdomen. In patients with large hiatal hernias, a thorough dissection of the lower esophagus, often 6 to 8 cm into the mediastinum, is necessary to achieve adequate intra-abdominal length.

Conversions to open laparotomy were few in this series. In other series, early difficulties with instrumentation or inexperience led to more frequent conversion during the "learning curve."[2,21] Infrequent early conversion was made possible by initial training with an experienced esophageal surgeon (Alfred Cuschieri), after which this surgeon assisted on the first two procedures in this series. Subsequently, for the next 11 procedures, another experienced surgeon (Lee Swanstrom) assisted to pass through the learning curve without major difficulties. This seems to be an effective model, which we have used for the introduction of other laparoscopic procedures.

Conversions were related to two factors: large livers and adhesions. Whereas it would be possible to deny all patients with previous upper abdominal surgery the opportunity for a laparoscopic fundoplication, we thought it worth offering these patients a laparoscopic attempt, although the probability of conversion was implicit. Several series from Europe report that the most frequent conversions were performed for a large left lobe of the liver.[22,23] By limiting the acceptable weight of patients undergoing surgery (maximum weight for men, 250 lb; women, 200 lb), we were able to largely eliminate the problems with large livers. When they were encountered, large livers could usually be retracted adequately by the placement of two liver retractors side by side coming in from the right subcostal region.

Intraoperative complications were dealt with during the course of the operation. Holes in the stomach or esophagus occurred in four patients and were technical errors in each case. Careful endoscopic suturing or stapling changed an indication for conversion into a minor nuisance. In all of these patients, methylene blue was used intraoperatively to assess the security of closure, and all patients were subjected to water-soluble contrast swallow on postoperative day 1 before feeding resumed. Esophageal dilator perforation did not occur in this series of patients. In patients with an esophageal stricture, a Maloney dilator approximating the last dilatation size was used initially. In most cases, we were able to increase

this size by 10 French with stepwise dilatation. If resistance was noted, dilatation was halted.

Splenectomy is reported in 2% to 5% of series of open fundoplication.[1] This is generally a result of retractor placement on the spleen or excessive downward traction of the stomach pulling the capsule off the spleen. With laparoscopic surgery, the pneumoperitoneum is the retraction, and inferior retraction on the stomach is hardly needed to accomplish the dissection. It is, therefore, no surprise that in this series and in others, splenectomy has not been reported.[4,21,23] Most bleeding occurring during laparoscopic fundoplication is a result of retractor injury to the fatty liver or inadequate control of epiphrenic vessels, frequently a phrenic arterial branch lying adjacent to the left crus of the diaphragm. Dissection of phrenogastric attachments close to the stomach generally avoids injuring this vessel.

Hypercarbia and metabolic acidosis has been reported a number of times with laparoscopic cholecystectomy and advanced laparoscopic procedures. In this series, the development of hypercarbia correlated with the development of subcutaneous emphysema in the neck, chest, and face. The first response to hypercarbia was to lessen the insufflation pressure to 10 mmHg. This did not seem to adversely affect exposure about the gastroesophageal junction. When hypercarbia was not effectively controlled by lowering the pressure, the insufflating gas was changed to nitrous oxide.[24]

Laparoscopic fundoplication is an effective treatment for gastroesophageal reflux. The most consistent postoperative finding was the elimination of heartburn. Postoperative symptom scores greater than 1 (infrequent heartburn) were only found in 7% of patients early after surgery and 7% of patients 1 year after surgery. In most patients who had recurrent reflux, a defect was found in the valve mechanism. In one patient, after Toupet fundoplication, the gradual dilating of the esophageal orifice clearly was responsible for the development of recurrent reflux.

The response of patients with atypical symptoms to antireflux surgery has been less predictable. Nonetheless, improvement or cure was noticed in 91% of patients with hoarseness, 89% of patients with chest pain, 85% of patients with asthma, and 81% of patients with cough. The response of atypical symptoms to medical therapy (often high-dose omeprazole) predicted the response of these symptoms to laparoscopic fundoplication.

The complications of antireflux surgery have been reported previously.[21,25] Type I complications, which delayed patient discharge or required readmission, occurred in 9% of patients. These minor complications generally were treated with respiratory therapy, antibiotics, and reassurance. If nausea was the reason for readmission, prokinetic agents or antiemetics also were used.

Excessive pressure on the liver retractor, necessary to retract an excessively fatty left lobe, created segmental liver necrosis in one patient. There were no sequelae, but this complication can be avoided by limiting pressure on the liver retractor.

Type II complications were infrequent. Pneumothorax was common early in our experience.[4] It is likely that the pneumothorax occurred during passage of an instrument behind the esophagus from the right to the left above the left crus of the diaphragm. With more experience and the use of a 45° angled telescope, this complication was eliminated. In only one instance was a chest tube necessary, and this was placed because of chest pain and desaturation in a patient with a 20% pneumothorax. When a pneumothorax occurs, carbon dioxide is absorbed rapidly across the pleura, and chest tubes are therefore rarely necessary. The other type II complication seen in three patients was the development of gastric dilatation. In open surgery, the routine placement of a nasogastric tube prevents early postoperative gastric dilatation, yet nasogastric tube placement generally is the primary source of postoperative discomfort in patients undergoing laparoscopic fundoplication. It seems unnecessary to place nasogastric tubes in all patients to avoid gastric distention from developing in the 1% who have it. It is, however, necessary to visit the patient the evening after surgery to ensure the patient is resting comfortably.

The early type III complication most feared and most preventable is early wrap disruption from vomiting. Although postoperative nausea may be difficult to control, newer medications, including ondansetron and standard antiemetics, largely can prevent this complication.

The most common reason for fundoplication failure in this and other series is transhiatal migration of the fundoplication.[25,26] This is in contradistinction to open surgery in which fundoplication slippage or misplacement of the fundoplication around the stomach is more frequent.[27] The most frequent reason for symptomatic transdiaphragmatic migration of fundoplications in this series was vomiting. This occurred in four of seven patients with symptomatic fundoplication displacement. Obesity was associated with transdiaphragmatic migration and symptoms in two patients. None of these patients had esophageal strictures and none were thought to be at greater risk for herniation because of esophageal shortening. Conversely, follow-up endoscopy in patients with Barrett's esophagus has shown asymptomatic migration to be present in 5 of 10 patients entered into a laser ablation trial. It appears that patients with Barrett's esophagus may be more prone to the development of this complication. The treatment of symptomatic transdiaphragmatic migration has been to laparoscope the patient, get around the esophagus above the fundoplica-

tion, and pull the herniated portion of the fundoplication down. If possible, the crura are closed more tightly and the fundoplication is anchored to the undersurface of the diaphragm. The disruptive forces (vomiting) are assiduously avoided with the use of antiemetics. This has been effective in the two patients who have undergone laparoscopic revision.

The side effects of surgery, although not insignificant, have been minor compared with preoperative symptoms as judged by the 97% overall satisfaction score registered in postoperative surveys. Symptoms of early satiety and increased passage of flatus, the most prevalent side effects, were generally little more than social inconveniences. Conversely, several male construction workers found that the smaller meal size affected their on-the-job performance, and several elderly women found the passage of increased amounts of flatus disruptive to their social lives.

Postoperative dysphagia was a significant problem early in the series, but it was entirely related to the performance of the Rosetti–Nissen fundoplication. Troubles with dysphagia after this operation led many surgeons to abandon it in favor of the Toupet fundoplication. Our response was to start performing full fundus mobilization on all patients, Toupet or Nissen. With this technical adaptation and dietary counseling before hospital discharge, troublesome dysphagia has been reduced significantly. Postoperative food impaction can be eliminated by the institution of a soft diet during the period when postoperative edema is resolving (2–4 weeks).

The "gas bloat" syndrome has been a frequent topic of study. After we started collecting preoperative symptom scores, we found bloating to be no more prevalent in the postoperative period than in the preoperative period. Others have reported similar findings.[28] There is no doubt that many of these patients have subtle generalized gastrointestinal motility disturbances and appear to report bloating more frequently than do the general population. New onset bloating was seen only in a small percentage of patients, and it appeared less frequently after the Rosetti–Nissen fundoplication was abandoned.

One of the most frequent fears of patients considering antireflux surgery is the inability to belch. A long, tight fundoplication will eliminate this option, but the short, loose fundoplication has preserved belching ability in 85% of our recent patient group. Nausea and vomiting are reported frequently by reflux patients before operation, perhaps a reflex response to large volume reflux. After operation, nausea is not infrequent, but it is usually short lived. If persistent, this symptom should be evaluated with a gastric emptying study, because vagal nerve injury may be responsible. Rarely is nausea a result of hyperacidity or withdrawal of antisecretory agents.

Significant diarrhea is an extremely rare problem, but may be terrifically disabling if persistent and in large volumes. We suspect this also is an indication of vagal injury and should be treated with cholestyramine and, occasionally, an antidumping diet. Vagal injury may be an under-recognized complication of laparoscopic fundoplication, perhaps more common than after open fundoplication. Steps to minimize vagal injury include the careful use of monopolar electrocautery around the esophagus. Leaving the posterior vagal trunk adjacent to the esophagus decreases the need for its dissection and may lessen the chance of injury.

The cost effectiveness of laparoscopic fundoplication has been difficult to assess. If one compares retail costs of proton pump inhibitors to "retail costs" of surgery at our institution, the break-even point is 10 years (surgery, $15,000; medical therapy, $1500/year).[11] These retail charges rarely are paid by insurance companies and even more rarely borne by patients. Many patients have chosen laparoscopic fundoplication because insurance will cover the cost of operation but not the cost of chronic proton pump inhibitor therapy. The hidden costs of gastroesophageal reflux are found in physician visits and procedures. It is estimated that the annual average cost for medical treatment of reflux disease is as high as $7000.[29] Whereas this is probably an overestimate, the postoperative costs to the surgical patient are minimal. Outside of routine postoperative checks, only one in five patients visited a physician in the year after operation. A more sophisticated economic analysis, including the costs of managing symptomatic patients after operation and of lost work time related to GER, is part of a larger study currently in progress.

The quality-of-life assessment has been the most dramatically improved outcome variable in our patients.[12] The degree of poor life quality exhibited by our patients before operation was underappreciated. Although the poor quality of life seen in preoperative patients with refractory reflux may not be reflective of the general population with medication-dependent GER, the subgroup of patients rendered symptom free with good medical care should be representative. These patients scored their quality of life nearly as low as those with refractory GER symptoms. The initial response to surgery was to create supranormal quality-of-life scores that reverted back to normal scores 1 year after operation. The ability to bring patients with gastroesophageal reflux from an extremely low quality of life to a normal level after laparoscopic antireflux surgery should be the barometer by which our future results are measured.

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Discussion

DR. J. PATRICK O'LEARY (New Orleans, Louisiana): Vice President Haller, Secretary Copeland, Professor Wood, and Dr. Hunter. I would like to take this opportunity to thank the authors for the chance to review their manuscript.

Gastroesophageal reflux is a mechanical disease. It is a mechanical abnormality, and it is really good to see that a repair of the mechanical problem produces symptom relief. You have heard a number of people talk about hallmark studies that are being presented at this meeting. But this is truly an important presentation. It is the largest U.S. study that has been reported with regard to laparoscopic treatment of esophageal reflux. I view this as a feasibility study. As such, I think it has clearly shown that it can be done laparoscopically. It can be done safely. The results are similar to those done in an open procedure, and, in fact, a 97% good-to-excellent result is a remarkable achievement.

It would suggest that these results are maintained at 1 year, the hospital stay is short, and conversion rate to open is infrequent. I have three questions.

In the manuscript, it is clearly identified that the quality of life of these patients before the operative procedure is horrible. I wonder, Dr. Hunter why is that? What negatively impacts on the lifestyle of these patients? Why would correction of the reflux improve that?

There are 300 patients in this study accrued over 4 years. That is one every 4 days. Where have these patients been? They certainly do not seem to be in my practice. I guess they sort of emanated from the woodwork.

You describe several patients with migration of the fundoplication. In my experience with open cases, the migration is of the stomach up through the wrap. But in your discussion, it seems that the wrap itself is heading north. Will you try to expand that?

This study goes a long way toward establishing a laparoscopic procedure (Nissen) as a standard for the treatment of patients with esophageal reflux. As an individual who has spent a great deal of my academic career treating this disease through a laparotomy incision, the study is a little bit distressing. However, if tomorrow I personally developed reflux symptoms, I would find the possibility of having the procedure done laparo-