ORIGINAL ARTICLE

Esophageal Sphincter Device for Gastroesophageal Reflux Disease

Robert A. Ganz, M.D., Jeffrey H. Peters, M.D., Santiago Horgan, M.D.,
Willem A. Bemelman, M.D., Ph.D., Christy M. Dunst, M.D.,
Steven A. Edmundowicz, M.D., John C. Lipham, M.D., James D. Luketich, M.D.,
W. Scott Melvin, M.D., Brant K. Oelschlager, M.D., Steven C. Schlack-Haerer, M.D.,
C. Daniel Smith, M.D., Christopher C. Smith, M.D., Dan Dunn, M.D.,
and Paul A. Taiganides, M.D.

ABSTRACT

BACKGROUND

Patients with gastroesophageal reflux disease who have a partial response to proton-pump inhibitors often seek alternative therapy. We evaluated the safety and effectiveness of a new magnetic device to augment the lower esophageal sphincter.

METHODS

We prospectively assessed 100 patients with gastroesophageal reflux disease before and after sphincter augmentation. The study did not include a concurrent control group. The primary outcome measure was normalization of esophageal acid exposure or a 50% or greater reduction in exposure at 1 year. Secondary outcomes were 50% or greater improvement in quality of life related to gastroesophageal reflux disease and a 50% or greater reduction in the use of proton-pump inhibitors at 1 year. For each outcome, the prespecified definition of successful treatment was achievement of the outcome in at least 60% of the patients. The 3-year results of a 5-year study are reported.

RESULTS

The primary outcome was achieved in 64% of patients (95% confidence interval [CI], 54 to 73). For the secondary outcomes, a reduction of 50% or more in the use of proton-pump inhibitors occurred in 93% of patients, and there was improvement of 50% or more in quality-of-life scores in 92%, as compared with scores for patients assessed at baseline while they were not taking proton-pump inhibitors. The most frequent adverse event was dysphagia (in 68% of patients postoperatively, in 11% at 1 year, and in 4% at 3 years). Serious adverse events occurred in six patients, and in six patients the device was removed.

CONCLUSIONS

In this single-group evaluation of 100 patients before and after sphincter augmentation with a magnetic device, exposure to esophageal acid decreased, reflux symptoms improved, and use of proton-pump inhibitors decreased. Follow-up studies are needed to assess long-term safety. (Funded by Torax Medical; ClinicalTrials.gov number, NCT00776997.)

From Minnesota Gastroenterology, Plymouth (R.A.G.), and Abbott–Northwestern Hospital, Minneapolis (D.D.) — both in Minnesota; the Department of Surgery, University of Rochester School of Medicine and Dentistry, Rochester, NY (J.H.P.); the Department of Surgery, University of California, San Diego, La Jolla (S.H.), and the Department of Surgery, Keck School of Medicine, University of Southern California, Los Angeles (J.C.L.) — both in California; the Department of Surgery, Academic Medical Center, University of Amsterdam, Amsterdam (W.A.B.); the Gastrointestinal and Minimally Invasive Surgery Division, Oregon Clinic, Portland (C.M.D.); the Division of Gastroenterology, Washington University School of Medicine, St. Louis (S.A.E.); the Division of Thoracic Surgery, University of Pittsburgh, Pittsburgh (J.D.L.); the Department of Surgery, Ohio State University, Columbus (W.S.M.), and Knox Regional Heartburn Treatment Center, Mount Vernon (P.A.T.) — both in Ohio; the Department of Surgery, University of Washington, Seattle (B.K.O.); the Department of Gastroenterology, Gundersen Lutheran Medical Center, La Crosse, WI (S.C.S.-H.); the Department of Surgery, Mayo Clinic–Florida, Jacksonville (C.D.S.); and Southern Reflux Center at Albany Surgical Center, Albany, GA (C.C.S.). Address reprint requests to Dr. Ganz at Minnesota Gastroenterology, 15700 37th Ave. N., Suite 300, Plymouth, MN 55446.

THE FUNDAMENTAL PATHOLOGIC ABNOR-
mality in gastroesophageal reflux disease
is an incompetent lower esophageal sphinc-
ter.[1-3] First-line therapy for gastroesophageal
reflux disease is acid suppression, usually with
proton-pump inhibitors. Although effective, pro-
ton-pump inhibitors provide incomplete control
of reflux symptoms in up to 40% of patients.[4-6]
A partial response can occur because these drugs
do not address an incompetent sphincter or pre-
vent reflux; consequently, some patients have only
partial relief from symptoms and seek alternative
treatment if their quality of life is compromised.
At present, the only established option for these
patients is antireflux surgery, typically Nissen
fundoplication. However, the acceptance of sur-
gery is limited, owing to potential side effects,
such as abdominal bloating, increased flatulence,
inability to belch or vomit, and persistent dys-
phagia.[7,8]

Augmentation of the esophageal sphincter
with a magnetic device may provide an alterna-
tive treatment for patients who have incomplete
symptom relief with proton-pump inhibitors or
who are reluctant to undergo surgical fundopli-
cation.[9-11] The aim of magnetic sphincter aug-
mentation is to improve the barrier function of
the sphincter without altering the hiatal and
gastric anatomy or interfering with swallowing,
belching, or vomiting. The feasibility of this
concept was shown in a pilot study.[11] We report
the 3-year outcomes of a 5-year clinical trial as-
sessing the safety and effectiveness of a mag-
netic device for sphincter augmentation.

METHODS

STUDY DESIGN

The study was designed by the sponsor (Torax
Medical), the investigators, and the Food and Drug
Administration as a 5-year prospective, multicenter,
single-group evaluation of a magnetic sphincter
device. There was no concurrent control group.
The primary objective of the study was to evaluate
the safety, efficacy, and direct effects of the de-
vice on exposure to esophageal acid, quality of
life, and use of proton-pump inhibitors.

PATIENTS

Between January and September 2009, a total of
13 centers in the United States and 1 in the Neth-
erlands enrolled patients in the study. Eligible
patients were 18 to 75 years of age, had at least a

6-month history of reflux disease, and had a par-
tial response to daily proton-pump inhibitors,
with increased exposure to esophageal acid as
confirmed by pH monitoring. Exclusion criteria
were evidence of a large hiatal hernia, esophagi-
tis of grade C or D according to the Los Angeles
classification (in which grade A indicates one or
more mucosal breaks of ≤5 mm in length, grade
B one or more mucosal breaks of >5 mm, grade
C mucosal breaks that extend between two or
more mucosal folds but involve <75% of the cir-
cumference of the esophagus, and grade D mu-
cosal breaks involving ≥75% of the circumfer-
ence of the esophagus), a body-mass index (BMI;
the weight in kilograms divided by the square of
the height in meters) of more than 35, Barrett's
esophagus, a motility disorder, dysphagia more
than three times a week, and allergy to titanium,
stainless steel, nickel, or ferrous materials. A com-
plete list of inclusion and exclusion criteria is
provided in the study protocol, which is available
with the full text of this article at NEJM.org.

STUDY PROCEDURES

Baseline screening included endoscopy, pH mon-
itoring while the patient was not taking proton-
pump inhibitors, barium esophagography, and
manometry. These tests, in addition to chest ra-
diography, were repeated 1 year after implanta-
tion. Endoscopy and chest radiography were also
performed at 2 years and are planned for 5 years.
The dose and frequency of proton-pump inhibi-
tors, along with quality of life and foregut symp-
toms, were evaluated at baseline and postopera-
tively at 1 week, 3 months, and 6 months and
annually starting at 1 year, with plans to contin-
ue annual screening for a total of 5 years.

Quality of life was measured with the use of
the Gastroesophageal Reflux Disease–Health-
Related Quality of Life questionnaire, which is
provided in the Supplementary Appendix, avail-
able at NEJM.org.[12] Total scores range from 0 to
50, with higher scores indicating worse symp-
toms, and no minimally important difference in
scores is defined. Quality of life was assessed
both while the patient was taking proton-pump
inhibitors and while the patient was not taking
proton-pump inhibitors at baseline and then
while the patient was not taking proton-pump
inhibitors at follow-up. Patients were asked about
foregut symptoms, such as regurgitation, belch-
ing, and vomiting, before and after treatment.[13]

The esophageal sphincter device was implant-

ed with the use of standard laparoscopic techniques by surgeons who had experience with fundoplication. The device involves the use of magnetic attraction through adjacent magnetic beads, which augments the resistance of the esophageal sphincter to abnormal opening associated with reflux.[9-11] Each bead contains a sealed core of magnetic neodymium iron boride that produces a precise and permanent force of attraction. The beads are connected to adjacent beads by small wires that allow the device to expand. The device is sized to fit around the external diameter of the esophagus, without compressing the underlying muscle (Fig. 1A). The beads separate with the transport of food or increased intragastric pressure associated with belching or vomiting (Fig. 1B; and see Video 1, available at NEJM.org). There were no dietary restrictions after implantation.

END POINTS

The primary end point was the number of patients who had normalized acid exposure (total proportion of time with a pH of <4 in a 24-hour period, ≤4.5%) or who had a reduction of 50% or more in the proportion of time with a pH of less than 4, as compared with the baseline measurement while the patient was not taking proton-pump inhibitors. The secondary end points, measured separately, were the number of patients with a reduction of 50% or more in the total score for quality of life, as compared with the score at baseline without proton-pump inhibitors, and a reduction of 50% or more in the dose of proton-pump inhibitors, as compared with the baseline dose. All efficacy end points were measured at 1 year, and the treatment was considered to be successful if the efficacy end points were reached in at least 60% of the patients. Safety was monitored throughout the study period, with assessment of the rate and type of serious adverse events related to the device or the implantation procedure.

STUDY OVERSIGHT

The institutional review board of each site approved the study protocol, and written informed consent was obtained from all patients. The data were analyzed by the investigators and the sponsor. A clinical events committee reviewed all adverse events. All the authors vouch for the integrity of the trial and the completeness and accuracy of the reported data and for the fidelity of this report to the study protocol. The first author wrote the initial draft of the manuscript, incorporating revisions from the investigators. The final manuscript was written by a committee consisting of the first author, an investigator, and a physician involved in study oversight, none of whom were employees of the sponsor. All the authors made the decision to submit the manuscript for publication.

STATISTICAL ANALYSIS

All end-point analyses were performed according to the intention-to-treat principle, 1 year after implantation. Patients who did not undergo the end-point evaluation at 1 year or who had missing data were counted as having treatment failure. Additional clinical findings were assessed after 1 year in post hoc analyses of available data. For esophageal acid monitoring, the median pH components at baseline and 1 year after implantation were compared. For quality of life, scores at baseline with and without proton-pump–inhibitor therapy were compared with scores after implantation without proton-pump inhibitors, along with the percentage of patients who said that they were satisfied with their current condition at 1, 2, and 3 years. In addition, the percentage of patients with complete discontinuation of proton-pump inhibitors was assessed at 1, 2, and 3 years.

Continuous demographic characteristics and baseline variables were summarized with the use of standard descriptive statistics (i.e., means with standard deviations and medians with ranges). Categorical demographic characteristics and baseline variables were summarized by means of frequency distributions. A two-tailed, paired Student's t-test or the Wilcoxon signed-rank test was used to compare values before and after implantation. Differences were considered to be significant at the 0.05 level.

Videos showing the placement and function of the magnetic sphincter are available at NEJM.org

RESULTS

CHARACTERISTICS OF THE PATIENTS

The study population consisted of 100 patients, 52% of whom were men, with a median age of 53 years (range, 18 to 75) and a median BMI of 28 (range, 20 to 35). The median duration of reflux symptoms was 10 years (range, 1 to 40). The median duration of treatment with proton-pump inhibitors was 5 years (range, <1 to 20). Each patient had confirmed increased exposure to esophageal acid while not taking proton-pump

Figure 1. Magnetic Device for Augmentation of the Lower Esophageal Sphincter.

Panel A shows the magnetic device in the closed position, which helps prevent opening of the lower esophageal sphincter and subsequent reflux. Each magnetic bead rests on adjacent beads to prevent esophageal compression. Panel B shows the device in the open position, which allows transport of food, belching, and vomiting.

inhibitors (median percentage of time with pH <4 during a median pH-monitoring period of 45 hours, 10.9%; range, 4.8 to 25.4); the median De-Meester score was 36.6 (range, 16.3 to 83.8). The DeMeester score is a composite score of factors quantified during a 24-to-48-hour pH study, with a score of 14.7 or more indicating abnormal re-flux. Factors include the percentage of time that the pH was less than 4 during the assessment period, during the time in an upright position, and during the time in a supine position; the to-tal number of reflux episodes; the number of episodes lasting more than 5 minutes; and the duration of the longest episode (in minutes). The

median quality-of-life score was 27 points without proton-pump inhibitors and 11 points with them, indicating a partial response to proton-pump inhibitors. A total of 98 patients completed follow-up at 1 year, 90 at 2 years, and 85 at 3 years. A Consolidated Standards for the Reporting of Trials (CONSORT) diagram is provided in the Supplementary Appendix.
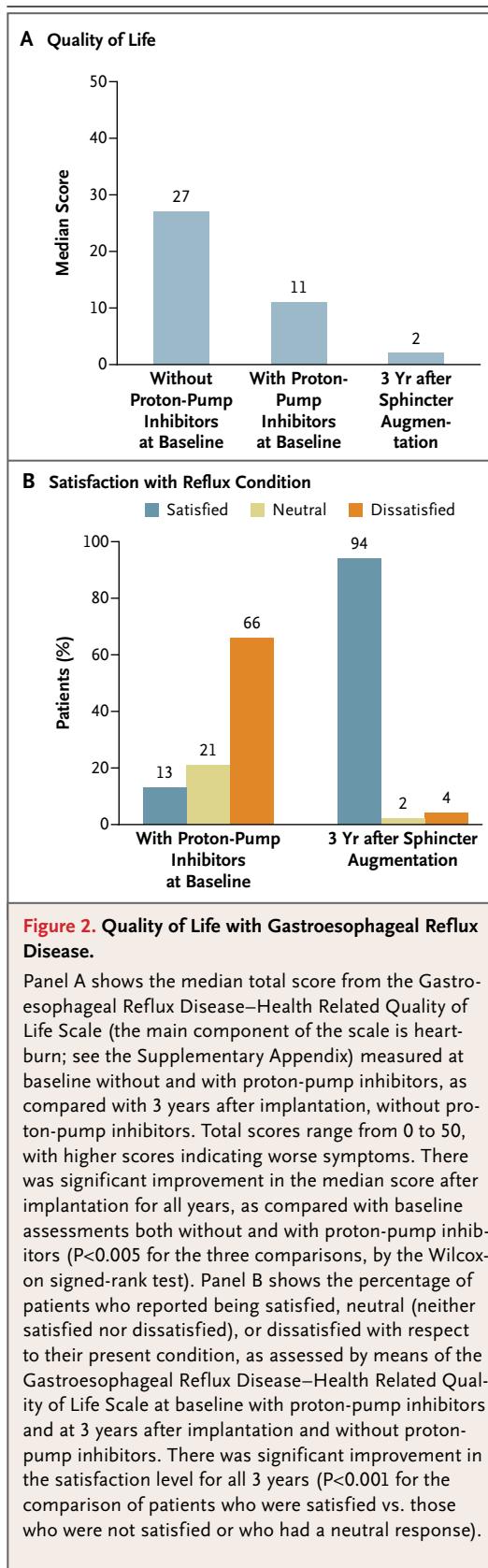
SURGICAL IMPLANTATION

The median time required to implant the device (defined as the interval between the placement of the last port and the removal of the first port) was 36 minutes (range, 7 to 125). All the implantations were completed without the need to revert to fundoplication. No intraoperative complications occurred. A total of 51 devices were placed by investigators at academic centers, and 49 by personnel at community-based medical centers. All patients were discharged within 1 day after surgery, with an unrestricted diet.

EFFICACY END POINTS

The primary efficacy end point, normalization of or at least a 50% reduction in esophageal acid exposure, was achieved in 64% of patients (64 of 100; 95% confidence interval [CI], 54 to 73). Of the patients who completed pH monitoring, 67% (64 of 96 patients) reached the primary efficacy end point (≥50% reduction in esophageal acid exposure in 64% [61 of 96], and normalization of exposure in 58% [56 of 96]). The secondary efficacy end point, a 50% reduction in the quality-of-life score, as compared with the score without proton-pump inhibitors at baseline, was achieved in 92% of patients (92 of 100; 95% CI, 85 to 97). In a post hoc analysis, 73% of patients had a reduction of 50% or more in the quality-of-life score at 1 year, as compared with the score with proton-pump–inhibitor therapy at baseline. A reduction of 50% or more in the average daily dose of proton-pump inhibitors occurred in 93% of patients (93 of 100 patients; 95% CI, 86 to 97).

ADDITIONAL ANALYSES

Post hoc analyses of quality-of-life scores compared changes in the total score and satisfaction level with and without proton-pump–inhibitor therapy. The median total score was 27 points without proton-pump inhibitors and 11 points with proton-pump inhibitors at baseline; the score decreased to 2 at 1 year after implantation (without proton-pump inhibitors) and remained

Figure 2. Quality of Life with Gastroesophageal Reflux Disease.

Panel A shows the median total score from the Gastroesophageal Reflux Disease–Health Related Quality of Life Scale (the main component of the scale is heartburn; see the Supplementary Appendix) measured at baseline without and with proton-pump inhibitors, as compared with 3 years after implantation, without proton-pump inhibitors. Total scores range from 0 to 50, with higher scores indicating worse symptoms. There was significant improvement in the median score after implantation for all years, as compared with baseline assessments both without and with proton-pump inhibitors (P<0.005 for the three comparisons, by the Wilcoxon signed-rank test). Panel B shows the percentage of patients who reported being satisfied, neutral (neither satisfied nor dissatisfied), or dissatisfied with respect to their present condition, as assessed by means of the Gastroesophageal Reflux Disease–Health Related Quality of Life Scale at baseline with proton-pump inhibitors and at 3 years after implantation and without proton-pump inhibitors. There was significant improvement in the satisfaction level for all 3 years (P<0.001 for the comparison of patients who were satisfied vs. those who were not satisfied or who had a neutral response).

at 2 when assessed at years 2 and 3 (P<0.005 for all three comparisons with baseline) (Fig. 2A). Satisfaction with the reflux condition improved after implantation; 95% of patients reported satisfaction at 1 year, 90% at 2 years, and 94% at 3 years of follow-up, as compared with 13% at baseline (with therapy) (P<0.001 for all three comparisons) (Fig. 2B). There was significant improvement in all the individual pH components after implantation (Table 1). The median percentage of time that the pH was less than 4 while the patient was not receiving proton-pump inhibitors fell from 10.9% before implantation to 3.3% after implantation (P<0.001). Complete cessation of proton-pump inhibitors occurred in 86% of patients (86 of 100 patients) at 1 year, in 87% (78 of 90) at 2 years, and in 87% (72 of 83) at 3 years (P<0.001 for each comparison with patients reporting daily use) (Fig. 3A). Three years after sphincter augmentation, 13% of patients continued to take proton-pump inhibitors; all these patients took the medication at a reduced frequency. The proportion of patients reporting moderate-to-severe regurgitation decreased, from 57% before implantation to 2% at 1 year and to 1% at years 2 and 3 (P<0.001 for all three comparisons with baseline) (Fig. 3B).

SAFETY

Serious adverse events occurred in six patients and required removal of the device in four of the six. In three of the patients, the device was removed at 21, 31, and 93 days after implantation because of persistent dysphagia, with resolution in all three patients after removal, and in one patient, the device was removed at 357 days owing to intermittent vomiting of unknown cause starting 3 months after implantation, without relief after removal. This patient had been rehospitalized at 236 days after implantation for chest pain, nausea, and indigestion that spontaneously resolved. The other two patients who had serious adverse events required rehospitalization for nausea and vomiting 2 days after surgery; their symptoms resolved with conservative therapy. The device was removed in two additional patients as part of their disease management, at 489 days and 1062 days after implantation. One patient had persistent reflux symptoms, and the other had persistent chest pain. Three of the six patients in whom the device was removed subsequently underwent Nissen fundoplication, with no complications.

The most frequent adverse event was dysphagia, which occurred in 68% of patients (Fig. 3C and Table 2). Ongoing dysphagia was noted in 11% of patients at 1 year, in 5% at 2 years, and in 4% at 3 years. Esophageal dilation for dysphagia was allowed at the discretion of the investigator. A total of 19 patients underwent dilation, with 16 reporting improvement after the procedure. The percentage of patients with esophagitis identified

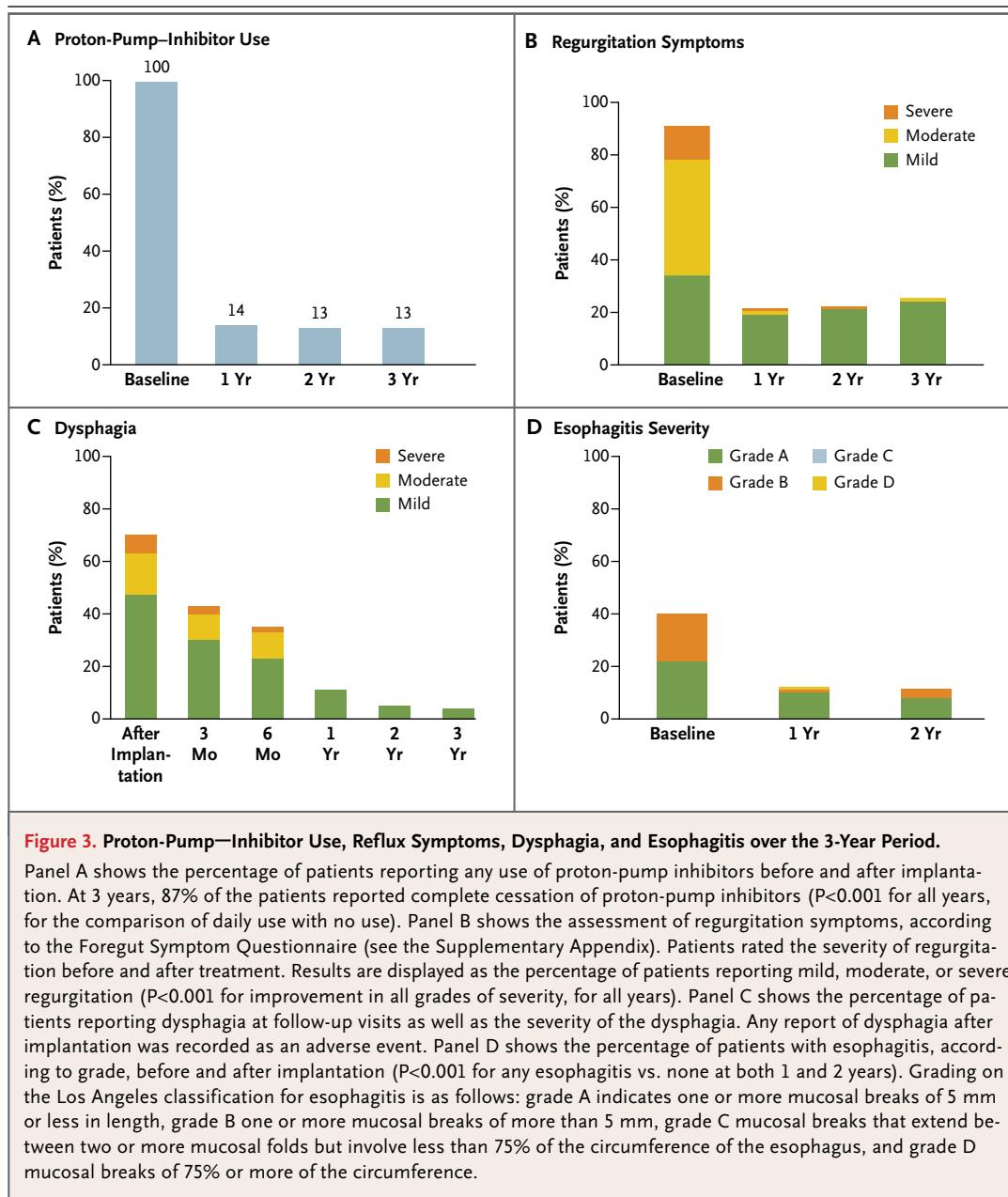**Table 1. Components of Esophageal pH Measurements.***

Variable	Baseline		1 Year		P Value
	No. of Patients	Median Value	No. of Patients	Median Value	
pH <4					
Total percentage of time	100	10.9	96	3.3	<0.001
Percentage of time upright†	100	12.7	96	4.3	<0.001
Percentage of time supine‡	98	6.0	96	0.4	<0.001
Total no. of reflux episodes	100	161.0	96	67.0	<0.001
No. of reflux episodes lasting >5 min	99	12.0	96	4.0	<0.001
Longest reflux episode (min)	99	29.0	96	13.0	<0.001
DeMeester score§	97	36.6	96	13.5	<0.001

* All testing was performed with the use of the Bravo pH monitoring system (Given Imaging) at baseline and at 1 year.
† Time upright was defined as the time during which the patient was not recumbent.
‡ Time supine was defined as the time during which the patient was recumbent.
§ The DeMeester score is a composite score of factors quantified during a 24-to-48-hour pH study, with a score of 14.7 or more indicating abnormal reflux. Factors include the percentage of time that the pH was less than 4 during the total period of assessment, during the time in an upright position, and during the time in a supine position; the total number of reflux episodes; the number of episodes lasting more than 5 minutes; and the duration of the longest episode (in minutes).

Figure 3. Proton-Pump—Inhibitor Use, Reflux Symptoms, Dysphagia, and Esophagitis over the 3-Year Period.

Panel A shows the percentage of patients reporting any use of proton-pump inhibitors before and after implantation. At 3 years, 87% of the patients reported complete cessation of proton-pump inhibitors (P<0.001 for all years, for the comparison of daily use with no use). Panel B shows the assessment of regurgitation symptoms, according to the Foregut Symptom Questionnaire (see the Supplementary Appendix). Patients rated the severity of regurgitation before and after treatment. Results are displayed as the percentage of patients reporting mild, moderate, or severe regurgitation (P<0.001 for improvement in all grades of severity, for all years). Panel C shows the percentage of patients reporting dysphagia at follow-up visits as well as the severity of the dysphagia. Any report of dysphagia after implantation was recorded as an adverse event. Panel D shows the percentage of patients with esophagitis, according to grade, before and after implantation (P<0.001 for any esophagitis vs. none at both 1 and 2 years). Grading on the Los Angeles classification for esophagitis is as follows: grade A indicates one or more mucosal breaks of 5 mm or less in length, grade B one or more mucosal breaks of more than 5 mm, grade C mucosal breaks that extend between two or more mucosal folds but involve less than 75% of the circumference of the esophagus, and grade D mucosal breaks of 75% or more of the circumference.

at endoscopy decreased to 12% at year 1 and to 11% at year 2, as compared with 40% at baseline (P<0.001 for both comparisons) (Fig. 3D). Among the patients without endoscopic esophagitis at baseline, grade A esophagitis developed in 3 at 1 year and in 4 at 2 years. Grade D esophagitis developed in 1 patient at 1 year; this patient was asymptomatic and therefore did not take proton-pump inhibitors, and reevaluation at 2 years showed complete resolution of esophagitis. Chest radiography and endoscopy performed at 1 year

and at 2 years after implantation showed no evidence of device migration or erosion. At 3 years, 2 patients reported an inability to belch or vomit.

DISCUSSION

The barrier function of the lower esophageal sphincter depends, in part, on its ability to resist effacement and opening when challenged by gastric distention.[3,14,15] Failure to do so results in episodes of gastric juice refluxing into the esoph-

Table 2. Adverse Events and Device Removal.

Event	Patients (N = 100)	Maximum Level of Intensity*			Device Removal
		Mild	Moderate	Severe	
		percent			
Dysphagia	68	47	16	5	3
Bloating	14	12	2	0	0
Pain	25	7	13	5	1
Odynophagia	8	4	3	1	0
Hiccups	8	7	1	0	0
Nausea	7	3	2	2	0
Inability to belch or vomit	6	5	1	0	0
Decreased appetite	4	4	0	0	0
Flatulence	2	2	0	0	0
Belching	2	2	0	0	0
Weight loss	2	2	0	0	0
Food impaction	1	0	1	0	0
Globus sensation†	1	1	0	0	0
Irritable bowel syndrome or dyspepsia	1	1	0	0	0
Regurgitation of sticky mucus	1	0	1	0	0
Uncomfortable feeling in chest	1	1	0	0	0
Vomiting	1	0	1	0	1
Persistent GERD symptoms‡	1	0	1	0	1

* Mild intensity was defined as an awareness of signs or symptoms that did not interfere with usual activities, moderate as discomfort intense enough to cause interference with usual activities, and severe as incapacitating discomfort, with inability to perform work or usual activities.
† The globus sensation is the sensation of having a lump in the throat when no visible abnormality is present on examination.
‡ GERD denotes gastroesophageal reflux disease.

agus, which can injure the esophageal mucosa and underlying muscle, causing permanent damage to the sphincter and leading to further loss of barrier function.[14,16,17] Therefore, reducing esophageal exposure to gastric juice is an important goal of antireflux treatment. If reflux is not reduced, symptoms or mucosal injury often persist. Samelson et al. found that a loose ligature placed around the lower esophageal sphincter prevented the sphincter from yielding when challenged by gastric distention.[15] The expandable magnetic device for augmentation of the sphincter builds on this observation by providing greater control of resistance to sphincter effacement and opening than is provided by previous devices, allowing expansion for the passage of food, belching, or vomiting.

Numerous studies have shown that reflux symptoms persist in up to 40% of patients who receive therapy with proton-pump inhibitors and that these symptoms have a negative effect on both quality of life and health care utilization.[4-6,18,19] The results of the current study show that after magnetic sphincter augmentation, quality-of-life scores significantly improved, as compared with preoperative scores without or with proton-pump inhibitors. At 3 years, 87% of patients (72 of 83 patients) had completely eliminated the use of proton-pump inhibitors. These results suggest that sphincter augmentation may be helpful for patients with a partial response to proton-pump inhibitors.

The significant reduction in exposure to esophageal acid provides quantitative evidence that magnetic sphincter augmentation improves the ability of the sphincter to resist the reflux of gastric juice into the esophagus and is associated with sustained control of heartburn and regurgitation. The sustained control of regurgitation implies control of both acid and nonacid reflux. The procedure preserved the ability to belch and vomit in most patients. These outcomes were similar in academic centers and community centers, suggesting that the technique of implanting the device can be standardized. Although these findings are encouraging, we recognize that they are preliminary, given the small study population and the 3-year follow-up.

It has long been recognized that surgical alteration of the lower esophageal sphincter by means of fundoplication may result in dysphagia.[13,20-23] Dysphagia also occurs after magnetic sphincter augmentation. In both situations, the postoperative dysphagia is most commonly mild to moderate and resolves with time. Our findings suggest that the risk of dysphagia and need for esophageal dilation after sphincter augmentation is similar to the risk after fundoplication.[13,21-23] Most of the patients in our study who underwent dilation had improvement. We speculate that dilation disrupts scarring by actuating the beads, resulting in reduced dysphagia. After sphincter augmentation in this study, persistent dysphagia that led to the removal of the device developed in 3% of patients. This rate of persistent dysphagia is similar to that observed in the pilot study and in registries in the United States and Europe.[10,11] Removal of the device was required in six patients within 21 days to 2.9 years

after placement. The possibility of easy removal of the device after a longer interval is unknown.

The placement of a foreign body around a mobile muscular tube such as the esophagus raises concern about erosion and hence the safety of the device. The current study, along with the previously published pilot trial[11] and the commercial registries in the United States and Europe, brings the worldwide clinical experience to 497 magnetic implants, with a median implant duration of 2.9 years. To date, no erosions or migrations have been reported. The risk over a longer period of follow-up is not known. The continued collection of data from the present study, existing registries, and current clinical use will allow assessment of the long-term risk of erosion.

The current study was designed so that the direct effects of the sphincter augmentation device on each patient's exposure to esophageal acid, use of proton-pump inhibitors, and symptom control could be measured before and after the implantation. This design is limited in that it does not allow direct comparisons with other forms of therapy. Prospective, randomized trials with appropriate controls are needed.

In conclusion, this single-group trial showed that a magnetic device designed to augment the lower esophageal sphincter can be implanted with the use of standard laparoscopic techniques. The device decreased exposure to esophageal acid, improved reflux symptoms, and allowed cessation of proton-pump inhibitors in the majority of patients. Studies with larger samples and longer-term follow-up are needed to confirm these early results and assess longer-term safety.

REFERENCES

1. Dodds WJ, Dent J, Hogan WJ, et al. Mechanisms of gastroesophageal reflux in patients with reflux esophagitis. N Engl J Med 1982;307:1547-52.
2. DeMeester TR, Wernly JA, Bryant GH, Little AG, Skinner DB. Clinical and in vitro analysis of determinants of gastroesophageal competence: a study of principles of antireflux surgery. Am J Surg 1979;137:39-46.
3. Pandolfino JE, Zhang QG, Ghosh SK, Han A, Boniquit C, Kahrilas PJ. Transient lower esophageal sphincter relaxations and reflux: mechanistic analysis using concurrent fluoroscopy and high-resolution manometry. Gastroenterology 2006; 131:1725-33.
4. Kahrilas PJ. Gastroesophageal reflux disease. N Engl J Med 2008;359:1700-7.
5. Katz PO, Zavala S. Proton pump inhibitors in the management of GERD. J Gastrointest Surg 2010;14:Suppl 1:S62-S66.
6. Castell DO, Kahrilas PJ, Richer JE, et al. Esomeprazole (40 mg) compared with lansoprazole (30 mg) in the treatment of erosive esophagitis. Am J Gastroenterol 2002;97:575-83.
7. Finks JF, Wei Y, Brinkmeyer JD. The rise and fall of antireflux surgery in the United States. Surg Endosc 2006;20:1698-701.
8. Wang YR, Dempsey DT, Richter JE. Trends and perioperative outcomes of inpatient antireflux surgery in the United States, 1993-2006. Dis Esophagus 2011; 24:215-23.
9. Ganz RA, Gostout CJ, Grudem J, Swanson W, Berg T, DeMeester TR. Use of a magnetic sphincter for the treatment of GERD: a feasibility study. Gastrointest Endosc 2008;67:287-94.
10. Bonavina L, Saino GI, Bona D, et al. Magnetic augmentation of the lower esophageal sphincter: results of a feasibility clinical trial. J Gastrointest Surg 2008;12:2133-40.
11. Bonavina L, DeMeester T, Fockens P, et al. Laparoscopic sphincter augmentation device eliminates reflux symptoms and normalizes esophageal acid exposure: one- and 2-year results of a feasibility trial. Ann Surg 2010;252:857-62.
12. Velanovich V. Comparison of generic (SF-36) vs. disease-specific (GERD-HRQL) quality of life scales for gastroesophageal reflux disease. J Gastrointest Surg 1998;2: 141-5.
13. DeMeester TR, Bonavina L, Albertucci M. Nissen fundoplication for gastroesophageal reflux disease: evaluation of primary repair in 100 consecutive patients. Ann Surg 1986;204:9-20.
14. Ayazi S, Tamhankar A, DeMeester SR, et al. The impact of gastric distention on the lower esophageal sphincter and its exposure to acid gastric juice. Ann Surg 2010;252:57-62.
15. Samelson SL, Wieser HF, Bombeck CT, et al. A new concept in the surgical treatment of gastroesophageal reflux. Ann Surg 1983;197:254-9.
16. DeMeester TR, Ireland AP. Gastric pathology as an initiator and potentiator of gastroesophageal reflux disease. Dis Esophagus 1997;10:1-8.
17. Oberg S, Peters JH, DeMeester TR, et al. Inflammation and specialized intestinal metaplasia of cardiac mucosa is a manifestation of gastroesophageal reflux disease. Ann Surg 1997;226:522-30.
18. Everhart J, Ruhl CE. The burden of digestive diseases in the United States part I: overall and upper gastrointestinal diseases. Gastroenterology 2009;136:376-86.
19. Toghanian S, Johnson DA, Stålhammar NO, Zerbib F. Burden of gastrooesophageal reflux disease in patients with persistent and intense symptoms despite proton pump inhibitor therapy: a post hoc analysis of the 2007 National Health and Wellness Survey. Clin Drug Investig 2011;31:703-15.
20. Kahrilas PJ, Lin S, Manka M, Shi G, Joehl RJ. Esophagogastric junction pressure topography after fundoplication. Surgery 2000;127:200-8.
21. Vakil N, Shaw M, Kirby R. Clinical effectiveness of laparoscopic fundoplication in a U.S. community. Am J Med 2003; 114:1-5.
22. Galmiche JP, Hatlebakk J, Attwood S, et al. Laparoscopic antireflux surgery vs esomeprazole treatment for chronic GERD: the LOTUS randomized clinical trial. JAMA 2011;305:1969-77.
23. Stefanidis D, Hope WW, Kohn GP, Reardon PR, Richardson WS, Fanelli RD. Guidelines for surgical treatment of gastroesophageal reflux disease. Surg Endosc 2010;24:2647-69.
Copyright © 2013 Massachusetts Medical Society.