ORIGINAL ARTICLE

Pneumatic Dilation versus Laparoscopic Heller's Myotomy for Idiopathic Achalasia

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ABSTRACT

BACKGROUND

Many experts consider laparoscopic Heller's myotomy (LHM) to be superior to pneumatic dilation for the treatment of achalasia, and LHM is increasingly considered to be the treatment of choice for this disorder.

METHODS

We randomly assigned patients with newly diagnosed achalasia to pneumatic dilation or LHM with Dor's fundoplication. Symptoms, including weight loss, dysphagia, retrosternal pain, and regurgitation, were assessed with the use of the Eckardt score (which ranges from 0 to 12, with higher scores indicating more pronounced symptoms). The primary outcome was therapeutic success (a drop in the Eckardt score to ≤3) at the yearly follow-up assessment. The secondary outcomes included the need for retreatment, pressure at the lower esophageal sphincter, esophageal emptying on a timed barium esophagogram, quality of life, and the rate of complications.

RESULTS

A total of 201 patients were randomly assigned to pneumatic dilation (95 patients) or LHM (106). The mean follow-up time was 43 months (95% confidence interval [CI], 40 to 47). In an intention-to-treat analysis, there was no significant difference between the two groups in the primary outcome; the rate of therapeutic success with pneumatic dilation was 90% after 1 year of follow-up and 86% after 2 years, as compared with a rate with LHM of 93% after 1 year and 90% after 2 years (P=0.46). After 2 years of follow-up, there was no significant between-group difference in the pressure at the lower esophageal sphincter (LHM, 10 mm Hg [95% CI, 8.7 to 12]; pneumatic dilation, 12 mm Hg [95% CI, 9.7 to 14]; P=0.27); esophageal emptying, as assessed by the height of barium-contrast column (LHM, 1.9 cm [95% CI, 0 to 6.8]; pneumatic dilation, 3.7 cm [95% CI, 0 to 8.8]; P=0.21); or quality of life. Similar results were obtained in the per-protocol analysis. Perforation of the esophagus occurred in 4% of the patients during pneumatic dilation, whereas mucosal tears occurred in 12% during LHM. Abnormal exposure to esophageal acid was observed in 15% and 23% of the patients in the pneumatic-dilation and LHM groups, respectively (P=0.28).

CONCLUSIONS

After 2 years of follow-up, LHM, as compared with pneumatic dilation, was not associated with superior rates of therapeutic success. (European Achalasia Trial Netherlands Trial Register number, NTR37, and Current Controlled Trials number, ISRCTN56304564.)

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N Engl J Med 2011;364:1807-16.

Achalasia is an esophageal motor disorder that is characterized clinically by dysphagia, chest pain, and regurgitation of undigested food. These symptoms result from the absence of esophageal peristalsis combined with a defective relaxation of the lower esophageal sphincter.[1] Currently, treatment consists mainly of endoscopic pneumatic dilation or laparoscopic Heller's myotomy (LHM). For many years, repeated endoscopic pneumatic dilation has been the treatment of choice, leading to therapeutic success in 70 to 80% of cases.[2] With the introduction of minimally invasive surgery, the surgical approach has gained considerable interest, with LHM combined with an antireflux procedure considered to be the procedure of choice. The results thus far from single-center studies are excellent, with success rates ranging between 89 and 100%,[3] leading to continuously increasing enthusiasm for the surgical approach.

Currently, the choice of treatment is dictated largely by the experience of the physician. Moreover, the outcome measures and treatment protocols in previous studies have varied, making a comparison among various studies of the success rates of the treatment options difficult. Therefore, the major aim of this multicenter study was to compare the two state-of-the-art treatments, pneumatic dilation and LHM with fundoplication according to Dor, in a randomized design.

Methods

Study Design

From February 2003 through February 2008, we enrolled patients at 14 hospitals in five European countries. The institutional review board at each hospital approved the study protocol (which is available with the full text of this article at NEJM.org), and written informed consent was obtained from each patient before enrollment. This investigator-initiated trial was conceived by the first and last authors. All the authors had substantial roles in the design of the study, the interpretation of the data, and the writing of the manuscript. The data were analyzed by one of the authors with the assistance of another author, who is a statistician. The first author wrote the first and final versions of the manuscript and, in consultation with the other authors, made the decision to submit the manuscript for publication. No commercial entity had any role in the study. All the authors vouch for the completeness and accuracy of the data.

Patients

Patients were eligible for enrollment in the study if they were between 18 and 75 years of age and had achalasia with an Eckardt symptom score of greater than 3. The Eckardt score is the sum of the symptom scores for dysphagia, regurgitation, and chest pain (with a score of 0 indicating the absence of symptoms, 1 indicating occasional symptoms, 2 indicating daily symptoms, and 3 indicating symptoms at each meal) and weight loss (with 0 indicating no weight loss, 1 indicating a loss of <5 kg, 2 indicating a loss of 5 to 10 kg, and 3 indicating a loss of >10 kg)[4]; thus, the maximum score on the Eckardt scale, indicating the most pronounced symptoms, is 12. The diagnosis of achalasia was made on the basis of the absence of peristalsis and on impaired relaxation of the lower esophageal sphincter (nadir pressure of ≥10 mm Hg during swallow-induced relaxation) on esophageal manometry. Exclusion criteria were severe cardiopulmonary disease or other serious disease leading to unacceptable surgical risk, previous treatment for achalasia, pseudoachalasia, megaesophagus (diameter of >7 cm), previous esophageal or gastric surgery (except for gastric perforation), and esophageal diverticula in the distal esophagus.

Randomization was performed with stratification according to hospital and age (<40 or ≥40 years), with the use of computerized randomization numbers. A numeric code was used in the patient's file at the trial center.

Interventions

Pneumatic Dilation

A Rigiflex balloon (Boston Scientific) was positioned at the esophagogastric junction and dilated at a pressure of 5 PSI for 1 minute, followed by 8 PSI for 1 minute. In the initial study protocol, the first dilation was performed with the use of a 35-mm balloon. However, a perforation of the esophagus occurred in 4 of the first 13 patients treated in this way. The protocol was amended, and subsequently the first pneumatic dilation was performed with the use of a smaller balloon (30 mm), followed 1 to 3 weeks later by dilation with the use of a 35-mm balloon. All patients thus underwent at least two dilations. If the Eckardt score 4 weeks

later was greater than 3, a third dilation was performed, with the use of a 40-mm balloon. If the Eckardt score remained greater than 3, the patient was considered to have had treatment failure. Patients with a recurrence of symptoms during the follow-up period underwent dilation again with the use of a 35-mm balloon and, if necessary (i.e., if the Eckardt score remained higher than 3), with the use of a 40-mm balloon. A third and final series of dilations was allowed only if symptoms recurred more than 2 years after this second series. If symptoms recurred within 2 years after the second series of dilations, the patient was considered to have had treatment failure.

LHM with Dor's Antireflux Procedure

After division of the phrenoesophageal ligament, the distal esophagus was mobilized on the lateral and anterior side, and a myotomy was performed extending at least 6 cm above the gastroesophageal junction and at least 1 to 1.5 cm over the stomach. Thereafter, anterior 180-degree fundoplication according to the method of Dor was performed. If symptoms recurred after surgery, with an Eckardt score of higher than 3, the patient was considered to have had treatment failure.

STUDY OUTCOMES

The primary outcome of the study was therapeutic success (a reduction in the Eckardt score to ≤3) at the yearly follow-up assessment. The secondary outcomes included the need for retreatment, pressure at the lower esophageal sphincter, quality of life, and the rate of complications. The time to treatment failure was calculated from the date of surgery or the first dilation session until the closing visit or the patient's last follow-up visit.

CLINICAL ASSESSMENT AND FOLLOW-UP

The pretreatment evaluation consisted of taking a medical history, performing a physical examination, and performing routine hematologic and blood chemical laboratory tests. In addition, patients completed quality-of-life questionnaires (the Medical Outcomes Study 36-Item Short-Form Health Survey [SF-36], and the European Organisation for Research and Treatment of Cancer disease-specific questionnaire module for assessing quality of life in patients with esophageal cancer [QLQ-OES24]). The SF-36 mental and physical summary scores (which range from 0 to 100, with higher scores indicating better well-being) measure general aspects of health quality of life.[5] The QLQ-OES24 (which ranges from 0 to 100, with lower scores indicating better function) assesses several items of esophageal function.[6] Esophageal manometry and upper endoscopy were performed, and a timed barium esophagogram was obtained to quantify esophageal stasis.[7]

One month after treatment and yearly thereafter, symptoms and quality of life were assessed, and esophageal manometry and timed barium esophagography were performed. Twenty-four-hour pH-metry (a test in which intraesophageal pH is monitored over the course of 24 hours) and endoscopy were performed 1 year after treatment and every 3 years thereafter. Esophagitis was graded according to the Los Angeles classification, in which grade A indicates one or more mucosal breaks of 5 mm in length or less, grade B indicates one or more mucosal breaks of longer than 5 mm, grade C indicates mucosal breaks that extend between two or more mucosal folds (but involve <75% of the circumference of the esophagus), and grade D indicates mucosal breaks of 75% or more of the circumference of the esophagus.[8]

STATISTICAL ANALYSIS

The modified intention-to-treat analysis included all patients except those in whom a perforation occurred during pneumatic dilation (whose data were censored at that time) or those who were lost to follow up. Patients with protocol violations were considered in the modified intention-to-treat analysis to have had treatment failure. For the per-protocol analysis, only patients who received treatment according to the protocol were included.

We estimated that with 80 patients in each group, the study would have 90% power to detect a significant difference in the success rate between LHM and pneumatic dilation, assuming success rates of 90% and 70% with LHM and pneumatic dilation, respectively, with a two-sided alpha level of 0.05. To allow for dropouts, we aimed to enroll 200 patients.

Categorical variables were compared with the use of the chi-square test. Continuous variables are presented as means (with 95% confidence intervals) and were compared with the use of Student's t-test. To compare the success rate between the two treatment groups, we used log-rank tests on Kaplan–Meier estimates. Cox pro-

portional-hazards models were used to estimate hazard ratios for treatment failure and the need for redilation in the pneumatic-dilation group. We conducted prespecified subgroup analyses for risk factors of treatment failure according to age (≤40 vs. >40 years), sex, basal pressure at the lower esophageal sphincter after treatment (≤10, >10 to ≤20, or >20 mm Hg), chest pain (daily vs. none or less than daily), height of the barium-contrast column 5 minutes after ingestion of barium (≤5, >5 to ≤10, or >10 cm), and maximum esophageal width before treatment (≤4 vs. >4 cm). The analyses were performed on data from the entire group irrespective of treatment, on data from the pneumatic-dilation and LHM groups separately, and on data from patients in the pneumatic-dilation group who required retreatment. All reported P values were two-tailed, and P values of less than 0.05 were considered to indicate statistical significance.

RESULTS

PATIENTS AND ENROLLMENT

Of the 218 patients who were enrolled in the study, 4 were excluded before randomization because they had pseudoachalasia. In the first 13 patients randomly assigned to pneumatic dilation, the initial dilation was performed with a 35-mm balloon. Four of these patients (31%) had an esophageal perforation. Since this complication rate is significantly higher than rates reported in the literature and than the rate observed after revision of the protocol (4%, as noted below; P=0.001 with the use of the chi-square test), this protocol for distention was considered to be too risky to be introduced in clinical practice. Comparing the efficacy of pneumatic dilation according to this protocol with another treatment in a primary outcome analysis was therefore considered to be undesirable. The data from these 13 patients were excluded from the analysis (Fig. 1).

Of the remaining 201 patients, 182 — which included patients who were still being actively followed at the end of 2 years or who had been categorized as having had treatment failure — were included in the 2-year modified intention-to-treat analysis (Fig. 1). The mean follow-up period was 43 months (95% confidence interval [CI], 40 to 47). The baseline characteristics of the groups were well balanced (Table 1).

CLINICAL OUTCOMES

In both the modified intention-to-treat analysis and the per-protocol analysis, there was no significant difference between the two study groups in the primary outcome of therapeutic success, defined as a reduction in the Eckardt score to 3 or less (P=0.46 and P=0.33 in the two analyses, respectively, with the use of a log-rank test) (Fig. 2A and 2B and Table 2). Similar results were obtained when the patients who underwent pneumatic dilation according to the initial protocol were included. In addition, the results were similar in analyses that included, rather than censored, data from the four patients who were enrolled after the protocol was revised to specify the use of a 30-mm balloon for the initial dilation and in whom a perforation occurred nevertheless.

In the pneumatic-dilation group, 4 patients did not have a response to treatment (i.e., the Eckardt score did not fall to ≤3) after the initial pneumatic-dilation series, and 23 patients had a recurrence of symptoms requiring redilation (Fig. 1 in the Supplementary Appendix, available at NEJM.org). Redilation was performed in 17 patients (6 patients declined the procedure) but was not successful in 5 patients, who were then referred for surgery. Of the 106 patients treated with LHM, 15 patients were considered to have had treatment failure and were subsequently treated with pneumatic dilation. Symptoms and pressure at the lower esophageal sphincter were reduced and esophageal emptying and general and disease-specific quality of life were improved to a similar extent in the two study groups (Table 2).

SUBGROUP AND RISK-FACTOR ANALYSIS

We identified the following factors as predictors of treatment failure: preexisting daily chest pain (hazard ratio, 2.8; 95% CI, 1.1 to 7.1; P=0.03), a height of the barium-contrast column of more than 10 cm (as compared with ≤5 cm) as measured 5 minutes after ingestion of barium on a post-treatment barium esophagogram (hazard ratio, 1.3; 95% CI, 1.1 to 1.5; P=0.01), and a width of the esophagus of less than 4 cm before treatment (hazard ratio, 3.5; 95% CI, 1.3 to 9.9; P=0.02). As shown in Table 3, preexisting daily chest pain, age younger than 40 years, and height of the barium-contrast column of more than 10 cm 5 minutes after ingestion of barium, on a timed barium esophagogram obtained 3 months after treat-

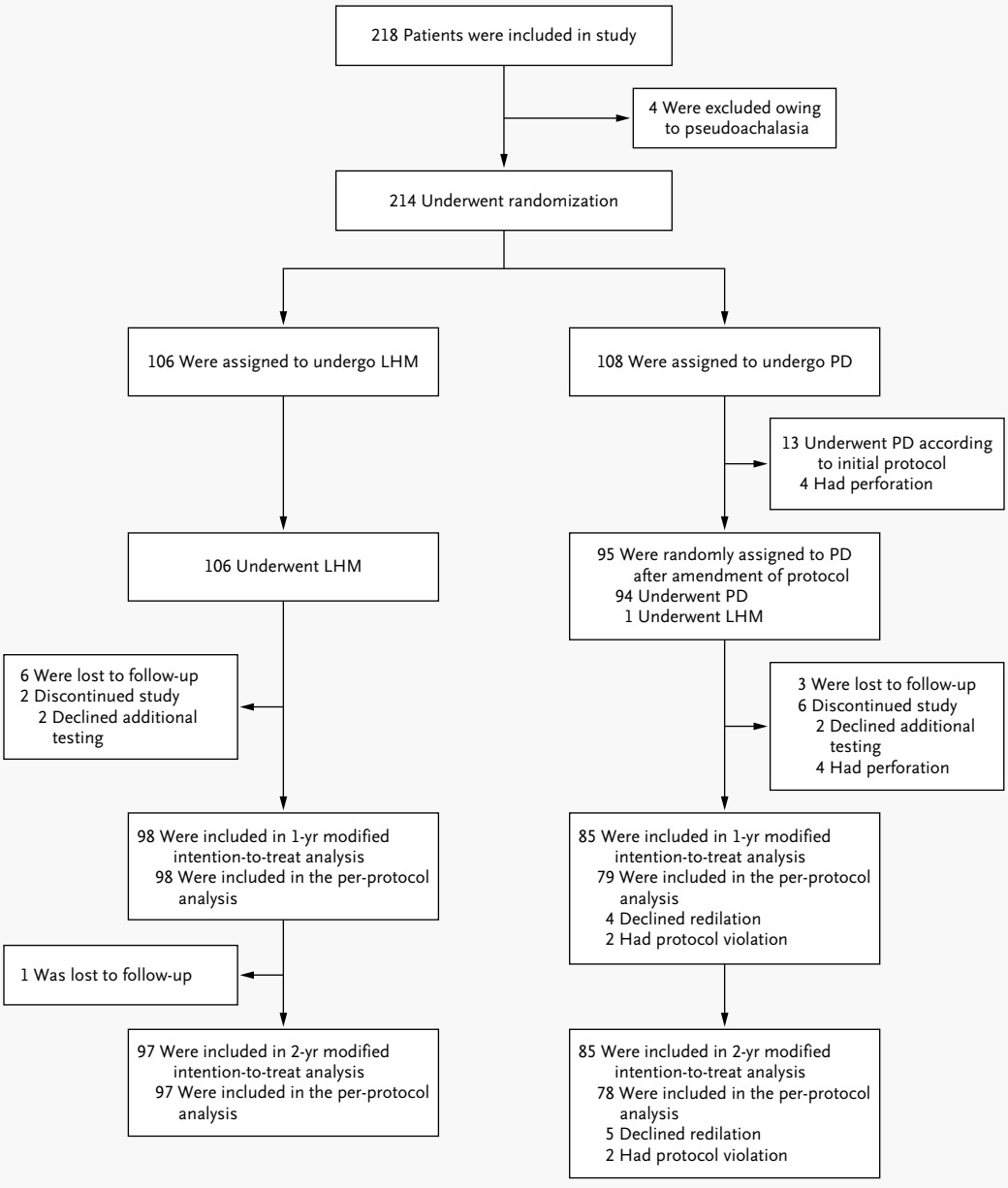

Figure 1. Enrollment, Randomization, and Follow-up.

One patient who was randomly assigned to the pneumatic-dilation (PD) group had to undergo a cholecystectomy, and the surgeon decided to perform a laparoscopic Heller's myotomy (LHM). This patient was included in the PD group in the modified intention-to-treat analysis but not in the per-protocol analysis.

ment, were identified as risk factors for redilation after pneumatic dilation.

COMPLICATIONS AND ADVERSE EVENTS

An esophageal perforation occurred in 4 of the 95 patients (4%) in the pneumatic-dilation group in whom dilation was initially performed with the use of a 30-mm balloon (3 when the first dilation was performed with the use of a 30-mm balloon and 1 when the second dilation was performed with the use of a 35-mm balloon). The patients in whom a perforation occurred were significantly

Table 1. Baseline Characteristics of the Patients.

Characteristic	Laparoscopic Heller's Myotomy (N=106)	Pneumatic Dilation (N=95)*	P Value
Sex — no.			0.18
Male	57	60	
Female	49	35	
Age — yr			0.68
Mean	45.5	46.4	
95% CI	42.8–48.3	43.2–49.6	
Age >40 yr — no. (%)	67 (63)	59 (62)	0.88
Weight — kg			0.92
Mean	73.5	73.3	
95% CI	70.5–76.5	70.3–76.3	
Body-mass index†			0.49
Mean	25.0	24.6	
95% CI	24.0–26.0	23.8–25.4	

* This number includes patients who were randomly assigned to pneumatic dilation after an amendment to the protocol specified that a smaller balloon should be used for the first pneumatic dilation (a 30-mm balloon instead of the 35-mm balloon previously used for the first dilation), followed 1 to 3 weeks later by dilation with a 35-mm balloon.

† The body-mass index is the weight in kilograms divided by the square of the height in meters.

older than the patients in whom a perforation did not occur (61 years of age [95% CI, 56 to 65] vs. 46 years of age [95% CI, 43 to 50], P=0.003 with the use of Student's t-test). The perforations were treated conservatively (i.e., total restriction of food and drink and intravenous antibiotic therapy) in the case of 2 patients and surgically in the case of the other 2 patients; all the patients recovered well. As noted in the Methods section, the perforation rate was significantly higher when a 35-mm balloon was used for the first dilation (a rate of 31%, P=0.001 with the use of the chi-square test).

A total of 13 of the 106 patients in the LHM group (12%) had a mucosal tear, which was corrected immediately during the procedure. Conversion to an open procedure was required in only 1 case. Patients with a perioperative mucosal tear had a rate of treatment success that was similar to that of patients without a mucosal tear (92% and 87%, respectively; P=0.69 with the use of Fisher's exact test).

One year after treatment, 24-hour pH-metry was performed in 132 of the 172 eligible patients (i.e., all patients who were available for follow-up, excluding patients who had treatment failure). Acid exposure (the percentage of time in which the pH was <4) did not differ significantly between the groups (2.1% [95% CI, 2.2 to 4.5] in the pneumatic-dilation group and 3.3% [95% CI, 2.2 to 4.5] in the LHM group, P=0.09). Abnormal exposure to gastric acid, which was defined as a pH of less than 4 for more than 4.5% of the time, was observed in 15% of the patients in the pneumatic-dilation group (among whom the pH was <4 for 5 to 13% of the time) and 23% of the patients in the LHM groups (among whom the pH was <4 for 5 to 23% of the time) (P=0.28 with the use of Fisher's exact test). Endoscopy was performed 1 year after treatment in 150 of 172 eligible patients. Esophagitis was observed in 19% of the patients in the pneumatic-dilation group (10% with grade A, 6% with grade B, and 3% with grade C esophagitis, according to the Los Angeles classification) and 21% of the patients in the LHM group (11% with grade A, 7% with grade B, 1% with grade C, and 1% with grade D esophagitis) (P=0.84 with the use of Fisher's exact test).

DISCUSSION

Pneumatic dilation and LHM are both effective treatments for achalasia. On the basis of excellent results with LHM from single-center studies, there is growing enthusiasm in favor of laparoscopic surgery.[9-11] We conducted a randomized trial comparing LHM (with Dor's fundoplication) with pneumatic dilation and found that the primary outcome, the rate of treatment success, was similar with the two treatments. Using a reduction in Eckardt symptom score to 3 or less as the criterion for treatment success, we found that the success rate after 1 and 2 years of follow-up was 93% and 90%, respectively, with LHM, as compared with 90% and 86%, respectively, with pneumatic dilation. Our results are in line with one smaller randomized study (involving 51 patients) that also showed no significant between-group difference in the success rate in the intention-to-treat analysis.[12] A cross-sectional follow-up evaluation of an achalasia cohort at the Cleveland Clinic Foundation also showed similar rates of treatment success with pneumatic dilation and LHM.[13] In contrast, in an older randomized study, open Heller's myotomy was superior to pneumatic dilation; how-

ever, the dilation protocol used in that study was probably suboptimal.[14] In line with the primary outcomes, we observed no significant between-group difference in quality of life or esophageal function. On the basis of our data, we conclude that LHM with Dor's fundoplication does not result in rates of therapeutic success that are superior to those with pneumatic dilation for the primary treatment for achalasia, at least after a mean follow-up period of 43 months.

Success rates reported in the literature vary widely depending on the criteria used to define success. In particular, if efficacy is defined as the lack of need for any subsequent intervention,[15] the success rate with pneumatic dilation is much lower than that with surgery. The use of repeated dilations to treat recurrent symptoms is, however, a generally accepted strategy in clinical practice and leads to excellent control of symptoms, even during long-term follow-up.[16-18] In line with these studies, we allowed patients who were randomly assigned to pneumatic dilation to undergo additional pneumatic dilations if symptoms recurred. The number of pneumatic dilations was limited to a maximum of three series of dilations, each comprising up to two or three dilation procedures, but the third and final series was allowed only if it took place more than 2 years after the second series. One might argue, therefore, that with longer follow-up, more than three series of dilations may be required to control symptoms, thus leading to lower success rates with pneumatic dilation. On the other hand, differences in the dilation protocol between our study and the study at the Cleveland Clinic Foundation (in which the balloon pressure was increased up to 10 to 12 PSI to obliterate the balloon waist)[13] and differences in the length of the cut in the myotomy between our study and a 2003 study (in which the length of the cut extended up to 3 cm in the stomach)[19] may have led to differences in the rates of therapeutic success. Nevertheless, the treatment protocols included in our study are internationally accepted and widely used in clinical practice.

Previous studies have identified baseline chest pain (as assessed on a scale of 0 to 5, with 0 indicating no pain and 5 indicating daily pain), basal pressure at the lower esophageal sphincter above 30 mm Hg, a sigmoid esophagus, and a long duration of symptoms as predictors of a negative outcome with laparoscopic surgery in multivariate analyses.[20,21] On the other hand, younger age (<40 years) and higher pressure at the lower esophageal sphincter after treatment have been reported as predictors of a negative outcome with pneumatic dilation.[17,22] In our study, preexisting daily chest pain, the height of the barium-contrast column 5 minutes after ingestion of barium, and a width of the esophagus of less than 4 cm before treatment were identified as predictors of treatment failure in a Cox regres-

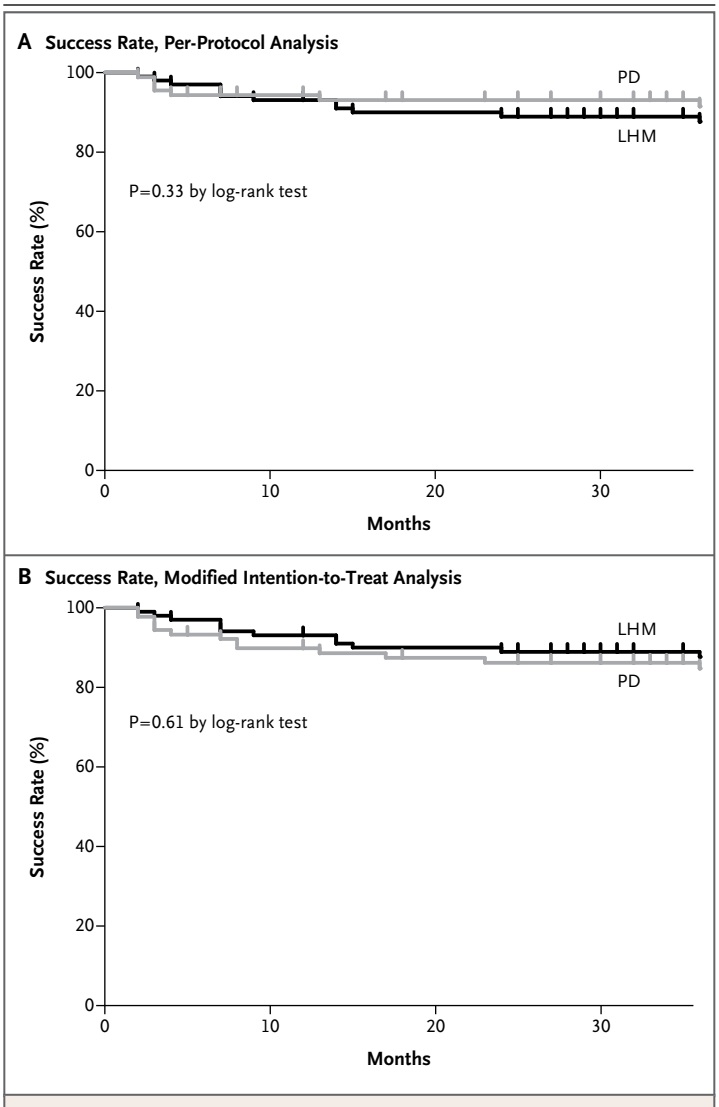

Figure 2. Kaplan–Meier Curves for the Rate of Treatment Success.
Kaplan–Meier survival curves show the rate of treatment success with pneumatic dilation (PD) as compared with laparoscopic Heller's myotomy (LHM) with Dor's fundoplication in the per-protocol analysis (Panel A) and the modified intention-to-treat analysis (Panel B).

Table 2. Primary and Secondary Outcomes at 1 and 2 Years of Follow-up, According to Treatment.*

Outcome	Baseline			1 Yr				2 Yr			
	LHM (N=106)	PD (N=95)	P Value	LHM (N=98)	PD (N=85)	Percentage-Point Difference, LHM–PD	P Value	LHM (N=97)	PD (N=85)	Percentage-Point Difference, LHM–PD	P Value
Treatment success — mean % (95% CI)											
Modified ITT analysis				93 (88 to 98)	90 (84 to 96)	3 (–4 to 11)		90 (84 to 96)	86 (77 to 93)	4 (–6 to 13)	0.46
Per-protocol analysis				93 (88 to 98)	93 (88 to 99)	0 (–7 to 7)		90 (84 to 96)	93 (88 to 99)	3 (–5 to 11)	0.33
Eckardt score†											
Mean (95% CI)	7.4 (7.0 to 7.8)	7.0 (6.7 to 7.4)	0.15	1.2 (1.0 to 1.5)	1.4 (1.1 to 1.7)		0.28	1.1 (0.9 to 1.3)	1.5 (1.2 to 1.8)		0.06
Range	4–12	4–10		0–3	0–5			0–3	0–4		
LES — mean mm Hg (95% CI)	31 (28 to 33)	33 (30 to 37)	0.17	10 (8.8 to 12)	14 (12 to 16)		0.003	10 (8.7 to 12)	12 (9.7 to 14)		0.27
Height of barium-contrast column after 5 min — cm‡			0.91				0.95				0.21
Median	12	12		0	0			1.9	3.7		
Interquartile range	8.1 to 18	7.9 to 17		0 to 6.5	0 to 6.0			0 to 6.8	0 to 8.8		
Quality of life — mean score (95% CI)											
QLQ-OES24§	39 (36 to 42)	36 (34 to 39)	0.14	13 (11 to 15)	15 (12 to 17)		0.28	12 (10 to 14)	14 (11 to 16)		0.28
SF-36¶											
Physical component summary	48 (46 to 50)	48 (46 to 50)	0.81	54 (53 to 56)	52 (50 to 54)		0.12	53 (51 to 55)	52 (50 to 54)		0.31
Mental component summary	42 (40 to 44)	43 (41 to 46)	0.41	49 (47 to 51)	49 (47 to 51)		0.96	50 (48 to 52)	48 (46 to 51)		0.35

* Data for the two treatment groups were compared at the different time points with the use of Student's t-test, except for the data on the height of the barium-contrast column after 5 minutes, which were compared with the use of the Mann–Whitney U test. No significant between-group differences were seen except for pressure at the lower esophageal sphincter (LES) after 1 year, which was higher in the pneumatic dilation (PD) group than in the laparoscopic Heller's myotomy (LHM) group (P=0.003 with the use of Student's t-test). ITT denotes intention-to-treat, QLQ-OES24 European Organisation for Research and Treatment of Cancer disease-specific questionnaire module for assessing quality of life in patients with esophageal cancer, and SF-36 Medical Outcomes Study 36-Item Short-Form Health Survey.

† The Eckardt score is the sum of the symptom scores for dysphagia, regurgitation, and chest pain (with 0 indicating the absence of symptoms, 1 indicating occasional symptoms, 2 indicating daily symptoms, and 3 indicating symptoms at each meal) and weight loss (with 0 indicating no weight loss, 1 indicating a loss of <5 kg, 2 indicating a loss of 5 to 10 kg, and 3 indicating a loss of >10 kg)[4]; thus, the maximum score on the Eckardt scale, indicating the most pronounced symptoms, is 12.

‡ The height of the barium-contrast column in the esophagus on a timed barium esophagogram, measured 5 minutes after barium ingestion, is a measure of esophageal emptying.

§ The QLQ-OES24[6] assesses several items of esophageal function. Scores range from 0 to 100, with lower scores indicating better function.

¶ The SF-36 physical and mental component summaries measure general aspects of health quality of life. Scores range from 0 to 100, with higher scores representing better well-being.

sion analysis. These data confirm that monitoring esophageal emptying after treatment is a helpful tool for predicting recurrence[23] and for deciding whether further dilation is required. The reason that a diameter of the esophagus less than 4 cm before treatment is associated with treatment failure is unclear, unless it may be indicative of vigorous achalasia, which is known to have a worse outcome.[24] Finally, our data indicate that chest pain is a difficult symptom to resolve with either treatment and contributes substantially to the need for retreatment and to patient dissatisfaction.[25] Although age was not a predictive factor for clinical success with either treatment, we did observe a greater need for redilation in patients younger than 40 years of age in the pneumatic-dilation group. This finding seems to support the recommendation[26] that younger patients (especially men) should be treated preferentially with LHM.

In the first 13 patients randomly assigned to pneumatic dilation, the initial pneumatic dilation was performed with the use of a 35-mm balloon, with the result that perforations occurred in 4 of the patients. As a consequence, the distention protocol was amended to specify that the first pneumatic dilation should be performed with a 30-mm balloon; this amendment led to a substantial reduction in the rate of perforation, to 4%. No other risk factor for perforation other than balloon size and older age could be identified. The significantly higher perforation rate associated with the use of a 35-mm balloon for the first dilation argues in favor of a graded distention protocol in which a 30-mm balloon is used during the initial pneumatic dilation, with a larger balloon for subsequent dilations. In the surgery group, mucosal tears, which were repaired immediately during surgery, occurred in 12% of the patients, a rate that is similar to that previously reported.[27] The clinical outcome was not affected by this complication. The most frequent complication of both treatments was gastroesophageal reflux.[15,27-29] Abnormal exposure to esophageal acid was observed in 15% of the patients treated with pneumatic dilation and 23% of the patients treated with LHD. These data raise the question of whether proper screening and treatment of increased acid exposure are required to avoid long-term complications such as Barrett's esophagus, stenosis, or even esophageal carcinoma.[29,30]

Table 3. Association of Various Factors Leading to the Need for Redilation in the Pneumatic-Dilation Group.*

Factor	Adjusted Hazard Ratio (95% CI)	P Value
Age ≥40 yr vs. <40 yr	0.23 (0.09–0.56)	0.001
Daily chest pain vs. no or less-than-daily chest pain	4.3 (1.6–11.4)	0.004
LES pressure 3 mo after treatment		0.08
<10 mm Hg	3.3 (0.98–11.5)	
10–20 mm Hg	1.1 (0.30–4.0)	
>20 mm Hg	Reference	
Height of barium-contrast column 3 mo after treatment†		0.07
<5 cm	Reference	
5–10 cm	1.7 (0.5–5.6)	
>10 cm	5.3 (1.3–22)	
Male vs. female sex	1.1 (0.34–3.3)	0.92

* Hazard ratios were estimated with the use of a Cox proportional-hazards model. LES denotes lower esophageal sphincter.

† The height of the barium-contrast column in the esophagus was measured 5 minutes after barium ingestion, on a timed barium esophagogram, as a measure of esophageal emptying.

The strengths of our study include the large number of patients enrolled; the fact that the study was performed at 14 study centers in five European countries, making our conclusions widely applicable (probably in the United States as well); the fact that objective measures were used for the assessment of clinical success and functional improvement in the case of both treatments; and the fact that randomization was stratified according to center. Our data showed that LHM was not associated with rates of therapeutic success that were superior to those with pneumatic dilation and suggest that graded dilation starting with a 30-mm balloon is a reasonable protocol for pneumatic dilation.

Dr. Boeckxstaens is supported by a grant (G.0905.08) from the Odysseus program, Fonds Wetenschappelijk Onderzoek, of the Flemish Government.

Dr. Bruley des Varannes reports receiving payment for board membership from Janssen Cilag, IPRAD Laboratories, Cephalon, and Mayoly Spindler Laboratories, consulting fees from Given Imaging, Novartis, and Danone, and lecture fees from AstraZeneca, Takeda Pharmaceuticals, and Nycomed; Dr. Elizalde, consulting fees from AstraZeneca; and Dr. Tack, payment for board membership from the Rome Foundation, consulting fees from XenoPort, Movetis (now part of Shire), Almirall, AstraZeneca, Danone, Menarini, Nycomed, SK Life Sciences, Theravance, Zeria Pharmaceuticals, ARYx Therapeutics, Ipsen, Ocera Therapeutics, Rose Pharma, Tranzyme Pharma, Norgine, Pfizer, Cargill, Forest

Laboratories, and Ironwood Pharmaceuticals, grant support from Novartis, AstraZeneca, and Movetis, lecture fees from Abbott, AstraZeneca, Movetis, Nycomed, Novartis, Menarini, and Ipsen, and payment for the development of educational presentations from Menarini and the Rome Foundation. No other potential conflict of interest relevant to this article was reported.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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