A physiologic clinical study of achalasia: Should Dor fundoplication be added to Heller myotomy?

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Read at the Eighty-fifth Annual Meeting of The American Association for Thoracic Surgery, San Francisco, Calif, April 10-13, 2005.

Received for publication March 25, 2005; revisions received July 19, 2005; accepted for publication July 26, 2005.

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J Thorac Cardiovasc Surg 2005;130:1593-600
0022-5223/\$30.00

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doi:10.1016/j.jtcvs.2005.07.027

Objective: Myotomy for achalasia disrupts the lower esophageal sphincter, improving emptying at the expense of reflux. We hypothesized that surgical palliation of achalasia requires balancing desirable improvement in esophageal emptying with undesirable production of gastroesophageal reflux. Therefore, we objectively studied the physiologic effects of adding Dor fundoplication to Heller myotomy.

Methods: From December 1996 to June 2004, 149 patients underwent Heller myotomy; 88 (59%) had additional Dor fundoplication. The adequacy of myotomy was assessed by premyotomy to postmyotomy change in lower esophageal sphincter pressures, esophageal emptying by change in timed barium esophagram, and gastroesophageal reflux by postoperative 24-hour pH monitoring.

Results: For adequacy of myotomy, postmyotomy resting lower esophageal sphincter pressure was higher with (median, 18 mm Hg) than without (median, 13 mm Hg) Dor fundoplication ($P = .002$), as was residual lower esophageal sphincter pressure (median, 4.6 vs 1.8 mm Hg; $P = .01$). For esophageal emptying, postmyotomy barium height and width were similar with or without Dor fundoplication ($P > .1$). For gastroesophageal reflux, percentage of upright time with a pH of less than 4 was lower with (median, 0.4%) than without (median, 2.9%) Dor fundoplication ($P = .005$), and percentage of supine time with a pH of less than 4 was lower with (median, 0%) than without (median, 5.8%) Dor fundoplication ($P = .007$).

Conclusions: The addition of Dor fundoplication reduces the adequacy of myotomy without impairing emptying and reduces reflux. Heller myotomy and Dor fundoplication balance emptying and reflux and therefore should be the surgical treatment of choice for achalasia.

The aim of surgical myotomy in palliation of achalasia is improvement of esophageal emptying through destruction of the lower esophageal sphincter (LES). Although the more extensive the myotomy, the better the emptying,¹ this may produce gastroesophageal reflux. A recent randomized trial demonstrated that adding Dor fundoplication to Heller myotomy reduces the risk of reflux.² However, the trial did not address the possible mitigation of the benefits of myotomy by reducing esophageal emptying. Thus, it remains debatable whether fundoplication should accompany myotomy.

Abbreviations and Acronyms

LES = lower esophageal sphincter

We hypothesized that surgical palliation of achalasia requires balancing desirable improvement in esophageal emptying with undesirable production of gastroesophageal reflux. Therefore, we objectively studied the physiologic effects of adding Dor fundoplication to Heller myotomy.

Patients and Methods

One hundred forty-nine patients with achalasia who had Heller myotomy between December 1996 and July 2004 were identified from the Cleveland Clinic's Thoracic Surgical Database, which the institutional review board has approved for use in research. Dor fundoplication was added to Heller myotomy in 88 (59%) patients (Electronic Appendix 1).

Of the 149 patients, 92 (62%) had prior nonsurgical treatments: 22 (15%) had Botox injection, 70 (48%) had pneumatic dilatation, and 19 (13%) had bougienage. The mean age was 49 ± 16 years, and 83 (56%) were men.

Operative Technique

All but one operation commenced laparoscopically, and 5 were converted to laparotomy. Heller myotomy was conducted similarly for all patients and extended onto the stomach by at least 2 cm.³ In the 61 patients who did not have Dor fundoplication, at the completion of myotomy, the right and left myotomy edges were sutured to the right and left crura of the esophageal hiatus, respectively, close to their superior margins. Dor fundoplication was constructed as previously described.³

Adequacy of Myotomy

The adequacy of myotomy was assessed by means of esophageal manometry. This was performed with a low-compliance, pneumohydraulic water infusion system (Arndorfer Medical Specialties, Milwaukee, Wis), an 8-lumen manometry catheter (Arndorfer Medical Specialties), and an 8-channel polygraph (Synectics Medical AB, Stockholm, Sweden). Mean LES resting pressure was the average of baseline measurement before 5 swallows. Mean LES residual pressure was the average of the lowest pressure measured after each of 5 swallows. (Maximum amplitude of tertiary waves in the esophageal body was also recorded and is described in Electronic Appendix 2.) Normative values in our laboratory are LES resting pressure of 10 to 45 mm Hg and LES residual pressure of 0 mm Hg.

Esophageal manometry was performed (1) before myotomy to confirm the diagnosis of achalasia and record premyotomy values (data were available from our institution on 140 patients at a median of 34 days before myotomy) and (2) 8 weeks after myotomy (data were available for 72 patients at a median of 69 days after myotomy).

Esophageal Emptying

Esophageal emptying was assessed by using a timed barium esophagram.⁴ While standing, patients were instructed to drink up

to 250 mL of a low-density barium sulfate suspension (45% weight in volume) within 35 to 45 seconds. With the patient in a slightly left posterior oblique position, three-on-one spot films of the esophagus were made 1, 2, and 5 minutes after the last swallow of barium. The height of the barium column was measured from the tip of the distal esophageal waist to the top of the solid barium column (not including foam), and width was measured as the maximum diameter of the barium column.

Timed barium esophagraphy was performed (1) before myotomy (data were available from our institution on 146 patients at a median of 33 days before myotomy) and (2) after myotomy (data were available for 133 patients at a median of 64 days after myotomy).

Gastroesophageal Reflux

Gastroesophageal reflux was assessed by means of ambulatory 24-hour esophageal pH monitoring. This was performed with a 2.1-mm monocrySTALLINE pH catheter with one antimony electrode (Synectics, Irving, Tex). The pH electrode was connected to a portable digital data recorder (Mark 2 Gold, Synectics), and patients returned home encouraged to perform their normal daily activities. There were no dietary restrictions. After 18 to 24 hours, the catheter was removed, and data were analyzed with Gastrosoft (Gastrosoft, Irvin, Tex). The percentage of upright and supine time with a pH of less than 4, the number of upright and supine reflux episodes, and the longest (minutes) upright and supine episodes were recorded.

Twenty-four-hour pH monitoring was performed in 71 patients at a median of 68 days after myotomy only, because premyotomy measurements are confounded by natural acidity of food, fermentation, and lactic acid production in the obstructed esophagus.⁵

Data Analysis

To fairly compare results of myotomy alone with myotomy plus Dor fundoplication, a propensity score was developed using logistic regression analysis to adjust for differences in patient characteristics between these 2 groups.^{6,7} First, a parsimonious model was obtained using the variables in Appendix 1, and this model was amplified by factors from each class of variables not included (saturated model). From this, a propensity score was calculated for each patient, representing the probability of undergoing Dor fundoplication. The propensity score was forced into all multivariable analyses to ensure balance of patient differences in modeling end points.

Adequacy of myotomy. Linear regression was used to identify variables associated with LES resting and residual pressures. Selection of risk factors used bootstrap bagging,⁸ with automated analysis of 1000 resampling data sets using a retention criterion of a $P \leq .05$. This was followed by tabulation of the frequency of occurrence of both single factors and closely related clusters of factors (aggregation), which represents the reliability with which factors can be said to have a $P \leq .05$. All models included premyotomy LES pressure and the indicator for Dor fundoplication. After identifying main effects for the model, interactions of variables with Dor fundoplication were sought. Finally, for fair comparison, the propensity score was added to the fully developed model. The square root of resting pressure was used to meet analysis assumptions.

Esophageal emptying. Although barium height and width are continuous, their distribution was skewed, and the majority of patients had complete emptying. Therefore, 2 separate analyses were performed: (1) incomplete emptying (dichotomous) and (2)

Figure 1. Adequacy of myotomy assessed by lower esophageal sphincter resting and residual pressures before and after myotomy with and without Dor fundoplication. Each patient's pre-myotomy and postmyotomy values are connected by a line, and horizontal bars are median values.

degree of incomplete emptying (residual barium in patients with incomplete emptying). The generalized estimating equation and mixed modeling were used to account for repeated time assessments. Each model included its 1-minute premyotomy value, the indicator for Dor fundoplication, interaction between variables associated with outcome and Dor fundoplication, time (1, 2, and 5 minutes), and propensity score.

Gastroesophageal reflux. Upright and supine pH monitoring data were analyzed separately. Because data were right skewed and heavily weighted by zeros, each pH variable was independently regrouped into ordinal outcomes, and ordinal logistic regression anal-

ysis was used. The percentage of upright time with a pH of less than 4 was regrouped into 4 levels: 0%, greater than 0% to 3%, greater than 3% to 10%, and greater than 10%. The percentage of supine time was likewise regrouped into 4 levels: 0%, greater than 0% to 6%, greater than 6% to 16%, and greater than 16%. Upright and supine numbers of episodes of pH less than 4 were regrouped into 3 levels: 0, 1 to 40, and greater than 40. The longest episode of pH less than 4, both upright and supine, was regrouped into 3 levels: 0 minutes, greater than 0 to 20 minutes, and greater than 20 minutes.

Results

Adequacy of Myotomy

The addition of Dor fundoplication to Heller myotomy was associated with increased postmyotomy LES resting pressure ($P = .002$, Figure 1 and Table 1). Other factors less reliably associated with increased postmyotomy LES resting pressure

TABLE 1. Factors associated with higher postmyotomy lower esophageal sphincter resting pressure

Factor	Coefficient $\pm$ SE	P value	Reliability (%) [*]
Dor fundoplication	2.7 ± 0.83	.002	80
Propensity score for Dor fundoplication	0.58 ± 0.72	.4†	
Higher premyotomy LES resting pressure‡	-0.58 ± 0.23	.02	44
Older age and no Dor fundoplication	0.048 ± 0.014	.001	67
Interaction of age and Dor fundoplication	0.010 ± 0.0090	.3	
Prior pneumatic dilatation	0.66 ± 0.26	.01	52

SE, Standard error; LES, lower esophageal sphincter. ^{*}Percentage of bootstrap analyses in which factor was identified with a P value of .05 or less. †Nonsignificant P value for propensity score implies that the variables in this model account for differences between groups with respect to this outcome. ‡ $[35/(\text{premyotomy resting pressure} + 1)]$, inverse transformation.

TABLE 2. Factors associated with incomplete esophageal emptying on postmyotomy timed barium esophagram

Factor	Coefficient $\pm$ SE	P value
Dor fundoplication	-0.20 ± 0.35	.6
Propensity score for Dor fundoplication	1.35 ± 1.08	.2
Premyotomy barium height at 1 min	0.014 ± 0.021	.5
Wider premyotomy barium width at 1 min	0.25 ± 0.085	.003
Measurement time (1, 2, 5 min) [*]	-0.27 ± 0.049	<.0001
Prior pneumatic dilatation	1.22 ± 0.37	.001
Lower amplitude tertiary wave‡	0.61 ± 0.31	.05

SE, Standard error. ^{*}Emptying increased with time of assessment, as expected. ‡30/premyotomy amplitude tertiary wave, inverse transformation.

Figure 2. Esophageal emptying assessed by timed barium esophagram before and after myotomy at 1 and 5 minutes with and without Dor fundoplication. Format of the graph is as in Figure 1. A, Height. B, Width.

were higher premyotomy LES resting pressure ($P = .02$), older age in patients without Dor fundoplication ($P = .001$), and prior pneumatic dilatation ($P = .01$).

The addition of Dor fundoplication to Heller myotomy was associated with increased postmyotomy residual pressure ($P = .01$, Figure 1). No other associations were identified.

Esophageal Emptying

The addition of Dor fundoplication to Heller myotomy did not impair esophageal emptying ($P = .6$, Table 2). Of the 134 patients with postmyotomy studies, complete esophageal emptying was observed in 47 (35%) at 1 minute (35%

with Dor fundoplication and 34% without Dor fundoplication) and 78 (59%) at 5 minutes (58% with Dor fundoplication and 60% without Dor fundoplication). Incomplete emptying was associated with prior pneumatic dilatation; at 1 and 5 minutes, 46 (73%) and 33 (52%) patients who had undergone this procedure had incomplete emptying versus 39 (57%) and 20 (29%) of those who had not. Higher premyotomy amplitude of tertiary wave was also associated with incomplete emptying.

In general, the height of the residual barium column was greater in patients with higher premyotomy LES residual pres-

Figure 3. Gastroesophageal reflux assessed by means of 24-hour pH monitoring postmyotomy with and without Dor fundoplication, upright and supine measurements. *Boxes indicate 70% of observations, horizontal bar is median measurement, and whiskers are 90% of observations. A, Percent time. B, Number of episodes. C, Longest episode.*

sure ($P = .001$; Figure 2, A), and the width of the residual barium column was greater in patients with greater premyotomy width ($P < .0001$; Fig 2, B). However, in 6 patients there was an increase in LES pressures but improved emptying. In another patient with decreased LES pressure, emptying worsened.

Gastroesophageal Reflux

Adding Dor fundoplication to Heller myotomy reduced percentage of time (upright, $P = .005$; supine, $P = .007$), number of episodes (upright, $P = .01$; supine, $P = .04$), and longest episode (upright, $P = .17$; supine, $P = .004$) with a pH of less than 4 (Figure 3 and Table 3). In patients without Dor fundoplication, lower premyotomy LES resting and residual pressures were associated with increased reflux, as measured by number of episodes and percentage of time with a pH of less than 4 upright, respectively.

Discussion

General

Palliation of achalasia requires disrupting the denervated LES to facilitate esophageal emptying. However, this sacrifices the most important mechanism for preventing gastroesophageal reflux. Injury from gastroesophageal reflux is heightened in patients with achalasia because loss of propulsive contractions in the esophagus results in inability to clear the refluxate. Adding an antireflux procedure to Heller myotomy should reduce gastroesophageal reflux, but might counter the adequacy of myotomy, reducing esophageal emptying. Ideal palliation of achalasia requires balancing esophageal emptying and gastroesophageal reflux. Objective physiologic measurements must be used to assess this balance because subjective criteria (patient's symptoms) have proved to be unreliable.^{4,9,10}

Adequacy of Myotomy

An aggressive myotomy that destroys the entire LES is most likely to improve esophageal emptying in patients with achalasia. Extending the myotomy for 3 cm onto the stomach is superior to a lesser myotomy.¹ An adequate myotomy, as assessed by LES resting pressure, is most probable in a young patient with low preoperative LES resting pressure in whom the first treatment is myotomy; that is, younger, less contracted, less scarred esophageal muscle is most likely to be completely disrupted. In contrast, Arain and colleagues¹¹ report that higher LES resting pressure is associated with better relief of dysphagia after myotomy; however, they did not perform postmyotomy manometry. This highlights the dissociation between subjective measures (symptoms) and objective measures (physiology) after treatment of achalasia. Also, in contrast to Bonavina and colleagues,¹² we found that prior pneumatic dilatation adversely affects the adequacy of myotomy.

Importantly, addition of Dor fundoplication to an effective myotomy increases both resting and residual LES pressures, reducing the adequacy of myotomy.

Esophageal Emptying

The maximal adverse effect on the balance between emptying and reflux occurs with the addition of Nissen fundoplication to Heller myotomy.¹³ In 17 patients, 13 with achalasia and 4 with

TABLE 3. Factors associated with more gastroesophageal reflux on postmyotomy pH monitoring

Factor	Coefficient $\pm$ SE	P value
Percent time with pH <4, upright		
Dor fundoplication	-3.0 ± 1.08	.005
Propensity score for Dor fundoplication	-0.048 ± 1.23	.97
Lower premyotomy LES residual pressure and no Dor fundoplication	-0.20 ± 0.068	.003
Interaction of premyotomy LES residual pressure and Dor fundoplication	-0.00058 ± 0.048	.99
Percent time with pH <4, supine		
Dor fundoplication	-1.37 ± 0.51	.007
Propensity score for Dor fundoplication	0.80 ± 1.30	.5
Lower premyotomy LES resting pressure	-0.92 ± 0.54	.09
No. of episodes of pH <4, upright		
Dor fundoplication	-3.1 ± 1.27	.01
Propensity score for Dor fundoplication	-2.0 ± 1.48	.17
Lower premyotomy LES resting pressure and no Dor fundoplication*	-0.73 ± 0.28	.008
Interaction of Dor fundoplication and premyotomy LES resting pressure	0.19 ± 0.24	.4
No. of episodes of pH <4, supine		
Dor fundoplication	-1.04 ± 0.51	.04
Propensity score for Dor fundoplication	0.21 ± 1.26	.9
Higher premyotomy amplitude of tertiary wave†	-0.62 ± 0.33	.06
Longest episode of pH <4, upright		
Dor fundoplication	-0.71 ± 0.52	.17
Propensity score for Dor fundoplication	0.13 ± 1.26	.9
Longest episode of pH <4, supine		
Dor fundoplication	-1.50 ± 0.52	.004
Propensity score for Dor fundoplication	0.70 ± 1.27	.6

SE, Standard error; LES, lower esophageal sphincter. *exp(LES resting pressure/35), exponential transformation. †30/premyotomy amplitude of tertiary wave, inverse transformation.

diffuse esophageal spasm, this combination failed to improve esophageal emptying immediately after myotomy. Furthermore, esophageal emptying worsened over time, with 29% of patients requiring takedown of the Nissen fundoplication.

Adding partial fundoplication should be less obstructive and promote a better balance. We found that esophageal emptying was optimal in a patient without prior therapy who had a less dilated esophagus with low-amplitude tertiary contractions; that is, the myotomized esophagus functions best as a passive conduit if it is operated on early and without previous pneumatic dilatation.

Thus, adding a Dor fundoplication to an effective myotomy has no adverse effect on esophageal emptying.

Gastroesophageal Reflux

The potential imbalance between esophageal emptying and gastroesophageal reflux is best appreciated in supine pH studies, which eliminate passive emptying of refluxed acid by gravity; this is not the case in upright pH studies. Supine reflux was abnormal for patients with myotomy alone. With the addition of Dor fundoplication, it was within the “normal range.” In contrast, the median of upright reflux measures was within the “normal range” for both patient groups. In long-term follow-up of patients receiving transthoracic myotomy without fundoplication, Lindenmann and colleagues¹⁴ reported that

45% of patients had abnormal pH studies. Because of the inability of the postmyotomy aperistaltic esophagus to clear acid, the goal should be to achieve no reflux (all pH values near zero).

Although Dor fundoplication reduced all measures of gastroesophageal reflux, it did not eliminate it in all patients. Lower premyotomy LES pressure was associated with both better myotomy and increased reflux. Thus, all patients are instructed to avoid supine reflux precipitators, such as eating just before going to bed and sleeping supine.

Adding Dor fundoplication to an adequate myotomy brings results of pH studies into the “normal range.”

Strengths and Limitations

This is a single-institution nonrandomized study. A propensity score was used to minimize selection bias and match the 2 surgical groups. However, Dor fundoplication was incorporated into our practice in an evolutionary fashion, which we have addressed by use of temporal trend analyses. Early results do not necessarily predict long-term outcome,¹⁵ but it is assumed that deterioration should be similar for both groups. Surgical intervention was performed by one surgeon, and assessment was made by our swallowing center team, ensuring (to the best of our ability) uniform treatment and assessment.

Physiologic assessments were not available in all patients in large part because of the evolution of our routine clinical protocol for follow-up of patients with achalasia. Initially, postmyotomy follow-up was with timed barium esophagram, which was easy to obtain after myotomy because it is fast, simple, and well tolerated. Thus, data were most complete for esophageal emptying. Subsequently, we added esophageal manometry and 24-hour pH monitoring to routine follow-up because of the growing appreciation of the disparity between symptoms and physiologic measurement. Physiologic assessment was therefore neither selective nor based on symptoms. We dealt with missing data by analyzing all patients available for each type of assessment, using propensity scores extensively, and adjusting for the preoperative values of each test.

In the future, physiologic tests to better assess balance of emptying and reflux might be developed, such as esophageal impedance studies, and could further refine treatment. Similarly, there might be better, less disruptive treatments (neural regeneration) that address both the LES and the aperistaltic esophageal body.

Recommendations

Because neither medical nor surgical treatment of achalasia addresses important problems of peristalsis and a functioning LES, only failure of relaxation of the LES, the goal of palliation of achalasia is symptom relief and preservation of the esophagus as a passive conduit. This requires balancing emptying with reflux. To the best of our knowledge, this balance is achieved by adding a partial (Dor) fundoplication to Heller myotomy. However, for an individual patient, Dor fundoplication might adversely effect esophageal emptying, and freedom from reflux is not ensured. Therefore, lifelong physiologic follow-up is needed to identify patients requiring retreatment to relieve symptoms and preserve the esophagus as a passive conduit.

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Appendix 1: Variables used in analyses

Demographic

Sex, age.

Procedure

Botox injection, number of Botox injections, pneumatic dilatation, number of pneumatic dilatations, simple dilatations, number of simple dilatations.

Preoperative Timed Barium Esophagram

Barium height at 1, 2, and 5 minutes; barium width at 1, 2, and 5 minutes.

Manometry

Lower esophageal sphincter resting pressures and amplitude of tertiary wave.

Discussion

Dr Steven R. DeMeester (Los Angeles, Calif). I congratulate Dr Rice and his colleagues on an excellent article and on moving beyond the subjective evaluation of treatment outcome in patients with achalasia.

These patients are well known to have a charmed deception because their swallowing is so poor that any improvement is wonderful for them. Nonetheless, achalasia is an incurable benign disease, and symptomatic improvement in dysphagia is all we have to offer these patients; thus, symptoms are a critical part of the outcome evaluation. As good as this article is, I think it would be even better with the inclusion of symptomatic outcome data. This article, as well as the randomized trial recently published by Richards and colleagues, clearly demonstrates that an antireflux procedure after myotomy significantly reduces reflux. Furthermore, this article extends the work of Richards and colleagues by demonstrating with the timed barium swallow study that the addition of a Dor fundoplication does not impair esophageal emptying. Hopefully, the issue of whether a fundoplication should be added to a myotomy for achalasia is now put to rest. Perhaps the next critical

issue to focus on is the performance of the myotomy and use of objective timed barium data to address such issues as where to place the myotomy and how long it should be to sufficiently disrupt the clasp and sling fibers and thereby maximally relieve lower esophageal sphincter (LES) outflow obstruction. I again congratulate Dr Rice and colleagues on really emphasizing the physiologic evaluation of these patients after myotomy with their timed barium studies and manometry. In this regard, though, I have several questions for the authors, who kindly provided me with a copy of the article well in advance of this meeting.

First, although resting LES pressure decreased after myotomy in nearly all patients, it increased in some even without the Dor fundoplication. Likewise, esophageal emptying in some patients was worse after myotomy with or without the Dor fundoplication than before the operation. How do the authors explain this, were these the same patients, and did the operation provide symptomatic improvement in these patients?

Dr Rice. Unfortunately, even with the myotomy and addition of the Dor fundoplication, some patients do not improve and some worsen. I presume this is due to postoperative fibrosis and stricturing and perhaps a result of suturing. It is disturbing but not totally preventable in our experience.

Dr DeMeester. Were these the same patients? In other words, the patients who had an increased LES pressure after the operation, were they the same ones who had the worsened timed barium emptying studies?

Dr Rice. Yes, the same patients.

Dr DeMeester. Second, only 59% of patients had complete esophageal emptying by the timed barium study at 5 minutes after the operation. What is concerning is that previous reports from the Cleveland Clinic after balloon dilatation for achalasia have indicated that every patient with incomplete emptying, 100% of them, on timed barium study had recurrence of their dysphagia. In other words, only those patients who had complete emptying on the timed barium study after the pneumatic dilatation had long-term successful palliation of their dysphagia. Dr Rice, can you elaborate on the successful long-term palliation of dysphagia in your patients with incomplete esophageal emptying after myotomy? Did you offer any additional therapy to those patients with incomplete emptying on the timed barium study? Did the emptying in these patients improve or worsen over time? Do you think that there is room for improvement, perhaps by altering where or how the myotomy is performed to increase that percentage of complete emptying on timed barium study?

Dr Rice. We strive to have our patients completely emptied by 5 minutes; however, surgically, that is only possible in about 60%, and therefore 40% of our patients have persistent barium at 5 minutes. I will have to analyze the long-term results to answer most of your questions.

Dr DeMeester. Third, the authors noted that the postmyotomy height of the barium column on timed barium study was higher in patients with higher premyotomy LES residual pressure. Logically, it would seem that postmyotomy LES pressures should be most indicative of esophageal emptying on the timed barium study. Can you comment on the association between postoperative manometric findings and esophageal emptying on the timed barium study?

Dr Rice. Once again, do you want me to—

Dr DeMeester. The question is, can you comment on the association between improvement in manometry, decreased LES residual and resting pressures after myotomy, and improvement on the timed barium study? In the article the only correlation that you found was with premyotomy LES pressures, but logically, it would seem that postmyotomy LES pressures should correlate best with esophageal emptying, and I am asking whether there was such a correlation or association made.

Dr Rice. We did not compare our postmyotomy results with outcome. I will check with Gene Blackstone and make sure that is legitimate.

Dr DeMeester. Thank you.

Dr Mark J. Krasna (Baltimore, Md). Tom, excellent presentation, as always.

I have 2 quick questions. You did mention to us the pre-LES pressure, and I am wondering, because not all the patients had exactly the same operation, namely those with and without, is it that part of that group had a lower LES pressure beforehand and that affected the decision of the surgeon whether to do it?

The second question is regarding the esophageal clearance measurement technique. You have obviously popularized the timed barium emptying study. There was an excellent presentation yesterday by Finley's group on using a nuclear medicine study, which gives you perhaps a more quantitative measure for esophageal clearance. I am wondering whether you have tried that yet at the Cleveland Clinic and whether you think there is any value to that in addition to or instead of timed barium emptying.

Dr Rice. What you see is an evolution of our thought process in treating these patients. Therefore, LES pressure did not dictate—

Dr Krasna. Consecutive patients?

Dr Rice. Yes, consecutive patients. Therefore, it did not dictate the operation that we chose.

We find that the timed barium esophagram is an easy test to perform, and I think it is easier to interpret because you have the anatomic evaluation; you can tell where the esophagus ends and the stomach begins. I think that is the shortcoming of nuclear medicine studies.

Dr Claude Deschamps (Rochester, Minn). Congratulations, Tom, on a nice article.

Did you choose to do a Dor fundoplication because of an irrational bias, or do you just not like the Toupet? Could you tell us your thinking there?

Second, I bet your drawings are almost nicer than the operation itself. Those are wonderful drawings. I noticed on your drawings that there are stitches on the diaphragmatic crura, and that raises the concern that you are shooting yourself in the foot with providing more obstruction. Would you just comment on this?

Dr Rice. I think a Toupet fundoplication is a little bit more of a fundoplication than a Dor, and I do not like the angulation that you get with a Toupet as you push the stomach in behind the esophagus. I try to minimally mobilize the esophageal hiatus. I do not take down short gastrics, and I am mobilizing less and less, but I do circumferentially mobilize the esophagus and try to mobilize the hiatus minimally. Ten percent to 15% of patients with achalasia will have a hiatal hernia, and therefore in those patients I fix it, and if the hiatus looks big to my judgment, I will put a stitch in it.

Thank you very much.

Electronic Appendix 1. Premyotomy patient and physiologic characteristics

Characteristic	No Dor fundoplication (n = 61)		Dor fundoplication (n = 88)		P value
	n*	No. (%)	n*	No. (%)	
Female	61	25 (41)	88	41 (47)	.5
Age at operation (y)†	61	51 ± 14	88	48 ± 17	.2
Botox injection	61	3 (4.9)	87	19 (22)	.004
Simple dilatation	61	5 (8.2)	86	14 (16)	.15
Pneumatic dilatation	61	32 (52)	86	38 (44)	.3
Barium height at 1 min†	60	17 ± 9.1	85	18 ± 8.2	.4
Barium height at 2 min†	48	15 ± 9.4	71	16 ± 7.7	.10
Barium height at 5 min†	60	12 ± 9.0	85	12 ± 7.8	.6
Barium width at 1 min†	60	6.0 ± 2.6	85	6.0 ± 2.3	.8
Barium width at 2 min†	48	5.6 ± 2.9	71	5.4 ± 2.3	.9
Barium width at 5 min†	60	5.1 ± 2.8	84	5.1 ± 2.6	.9
Body amplitude (mm Hg)†	47	31 ± 22	76	31 ± 30	.5

*Data available. †Mean ± standard deviation.

Electronic Appendix 2. Results: Amplitude of tertiary wave

Risk factor	Coefficient ± SE	P value	Reliability (%)
Dor fundoplication	0.25 ± 0.13	.06	38
Propensity score for Dor fundoplication	−0.30 ± 0.34	.4	—
Higher premyotomy amplitude of tertiary wave*	0.45 ± 0.13	.0007	91
Lower premyotomy barium width at 5 min	−0.088 ± 0.029	.004	53
Higher premyotomy barium height at 1 min*	0.43 ± 0.14	.003	82

Premyotomy amplitude of the tertiary wave was positively associated with postmyotomy values, premyotomy barium width at 5 minutes was negatively associated with postmyotomy amplitude of the tertiary wave, premyotomy barium height at 1 minute was positively associated with amplitude of the tertiary wave, and patients undergoing Dor fundoplication had higher postmyotomy amplitude of the tertiary wave than patients not undergoing Dor fundoplication. SE, Standard error. *Logarithmic transformation.