

Reflux and Belching After 270 Degree Versus 360 Degree Laparoscopic Posterior Fundoplication

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Objective: To investigate differences in effects of 270 degrees (270 degrees LPF) and 360 degrees laparoscopic posterior fundoplication (360 degrees LPF) on reflux characteristics and belching.

Background: Three hundred sixty degrees LPF greatly reduces the ability of the stomach to vent ingested air by gastric belching. This frequently leads to postoperative symptoms including inability to belch, gas bloating and increased flatulence. Two hundred seventy degrees LPF allegedly provides less effective reflux control compared with 360 degrees LPF, but theoretically may allow for gastric belches (GBs) with a limitation of gas-related symptoms.

Methods: Endoscopy, stationary esophageal manometry, and 24-hour impedance-pH monitoring off PPIs was performed before and 6 months after fundoplication for PPI-refractory gastroesophageal reflux disease (n = 14 270 degrees LPF vs. n = 28 360 degrees LPF). GBs were defined as gas components of pure gas and mixed reflux episodes reaching the proximal esophagus. Absolute reductions (Δ) were compared.

Results: Reflux symptoms and the 24-hour incidence of acid (Δ -77.6 vs. -76.7), weakly acidic (Δ -9.4 vs. -6.6), liquid (Δ -59.0 vs. -49.8) and mixed reflux episodes (Δ -28.0 vs. -33.5) were reduced to a similar extent after 270° LPF and 360° LPF, respectively. The reduction in proximal, mid-esophageal and distal reflux episodes were similar in both groups as well. Persistent symptoms were not related to acid or weakly acidic reflux. Two hundred seventy degrees LPF had no significant impact on the number of gas reflux episodes (Δ -3.6; $P = 0.363$), whereas 360 degrees LPF significantly reduced gas reflux episodes (Δ -17.0; $P = 0.002$). After 270 degrees LPF, GBs (Δ -29.3 vs. -50.6; $P = 0.026$) were significantly less reduced and the prevalence of gas bloating (7.1% vs. 21.4%; $P = 0.242$) and increased flatulence (7.1% vs. 42.9%; $P = 0.018$) was lower compared to 360 degrees LPF. Twenty-eight patients (67%) showed supragastric belches (SGBs) before and after surgery. The increase in SGBs without reflux (Δ +32.4 vs. +25.5) and the decrease in reflux-associated SGBs (Δ -12.1 vs. -14.0) were similar after 270 degrees LPF and 360 degrees LPF.

Conclusions: Two hundred seventy degrees LPF and 360 degrees LPF alter the belching pattern by reducing GBs (air venting from stomach) and increasing SGBs (no air venting from stomach). However, gas reflux and GBs are reduced less after 270 degrees LPF than after 360 degrees LPF, resulting in more air venting from the stomach and less gas bloating and flatulence, whereas reflux is reduced to a similar extent in the short-term.

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Laparoscopic fundoplication is the standard surgical treatment of gastroesophageal reflux disease (GERD).^{1–3} A fundoplication is created by wrapping the fundus of the stomach anteriorly or posteriorly around the esophagus. A recent meta-analysis has demonstrated that laparoscopic posterior fundoplication has superior reflux control compared with laparoscopic anterior fundoplication and should be considered the surgical therapy of choice.⁴ Recently published American guidelines for antireflux surgery recommend 360 degrees laparoscopic posterior fundoplication (360 degrees LPF) and 270 degrees laparoscopic posterior fundoplication (270 degrees LPF) as surgical procedures for GERD.⁵ Three hundred sixty degrees LPF provides excellent 10-year reflux control,¹ but 3 meta-analyses have recently demonstrated that 360 degrees LPF is associated with a high rate of gas-related symptoms.^{6–8} Fifteen percent of the patients develop inability to belch⁶, 19% suffer from gas bloating⁷ and 59% report increased flatulence after 360 degrees LPF.⁸

Gastric belching is a physiological mechanism that serves to vent ingested air from the stomach. It is commonly assumed that an inability to vent air from the stomach by gastric belching causes gas-related symptoms.^{9–15} A previous study indeed demonstrated that patients with an objective reduction of gastric belches (GBs) after fundoplication, have higher symptom scores for inability to belch and gas bloating, compared with patients who not have an objective reduction of GBs.¹⁶ Our group has recently demonstrated that after 360 degrees LPF the number of GBs is significantly reduced.¹⁷ Two hundred seventy degrees LPF has been hypothesized to reduce GBs to a lesser extent and may theoretically reduce gas-related symptoms compared with 360 degrees LPF. Until now, 2 studies have compared the effects of partial posterior and 360 degrees posterior fundoplication on belching. The results of these studies are contradictory and belches in these studies were measured with manometry by evaluating the so-called common cavity phenomenon.^{16,18} However, common cavities have been shown to be not very reliable for the detection of gastric belching.^{16,19} Esophageal impedance monitoring has made it possible to detect the passage of air through the esophagus directly and is much more reliable for detection of GBs during a prolonged period of time.^{20,21}

Several uncontrolled studies have reported less effective long-term reflux control after 270 degrees LPF, compared with 360 degrees LPF.^{22–25} However, the effect of 270 degrees LPF on weakly acidic reflux and proximal reflux extent has not yet been studied. These 2 factors are important in the evaluation of the effectiveness of antireflux surgery, because weakly acidic reflux can elicit reflux symptoms that do not respond to treatment with acid-suppressing drugs.^{26,27} In addition, weakly acidic reflux has been alleged to be the main cause of reflux complaints that persist after fundoplication.^{28,29} The proximal extent of the refluxate determines whether a reflux episode is perceived as a symptom by the patient.²⁶ Intraluminal impedance monitoring enables one to evaluate both acid and weakly acidic reflux, as well as proximal reflux extent.³⁰ Therefore, this study used this technique to investigate differences in effects of 270 degrees LPF and 360 degrees LPF on reflux characteristics and belching.

METHODS

Study Design and Data Collection

From January 2008 to April 2010 we prospectively included consecutive patients that underwent impedance-pH monitoring and were on the waiting list for primary laparoscopic fundoplication for proton pump inhibitor-refractory GERD with pathological acid exposure. Preoperative data, clinical outcome and the results of objective investigations were prospectively entered into a computerized database by an independent data manager (HGR). Patients who underwent 270 degrees LPF were matched to a 360 degrees LPF control group¹⁷ according to total esophageal acid exposure time on 24-hour impedance-pH monitoring before surgery (ratio 1:2).

Surgical Procedures

All laparoscopic fundoplications were performed between January 2008 and April 2010 either at the University Medical Center Utrecht (EJH and IAMJB) or another large teaching hospital; Meander Medical Center (IAMJB). The first series of patients all underwent 360 degrees LPF and the surgical therapy of choice for GERD in our centers was changed after a meta-analysis demonstrated that 270 degrees LPF reduces dysphagia.⁶ The 2 participating surgeons both contributed to both 270 degrees LPFs and 360 degrees LPFs and were well beyond the learning curve for both procedures at the start of the study, with 150 270 degrees LPFs plus 100 360 degrees LPFs (EJH) and 40 270 degrees LPFs plus 300 360 degrees LPFs (IAMJB), respectively.³¹ In all patients a standardized fundoplication was performed that aimed to create a loose valve to minimize postfundoplication symptoms. After full mobilization of the distal esophagus, surgeons verified that the gastroesophageal junction was placed in the abdomen without tension. The short gastric vessels were ligated and divided and it was made sure that the fundoplication was tension-free as well. A floppy fundoplication of 2.5 to 3.0 cm was constructed after posterior crural repair. A bougie was never used. Two hundred seventy degrees LPF was defined as a posterior fundoplication with a 270 degree circumference³² and 360 degrees LPF was defined as a posterior fundoplication with a circumference of 360 degrees.^{33–35} The margins of the 270 degrees wrap were fixed to the esophagus and to the crural arch anterosuperiorly and the wrap was fixed to the crural repair with 1 or 2 posterior sutures. One of the sutures of the 360 degrees wrap incorporated the esophageal wall and the posterior aspect of the wrap was fixed to the crural repair in an identical fashion to the 270 degrees wrap.

Clinical Assessment

Patients were asked by telephone to complete validated questionnaires by mail, preoperatively and 6 months postoperatively. The GERD Health-Related Quality of Life score (GERD-HRQoL) that has been validated³⁶ and compared with physiologic parameters,³⁷ was used to evaluate reflux symptoms. Changes in dysphagia were detected with the validated European Organization for Research and Treatment of Cancer QLQ-OES 18 questionnaire.³⁸ Health-related Quality of Life (QoL) was assessed using the validated Short-Form 36 (SF-36)³⁹. In addition, patients were asked to indicate the presence of inability to belch, gas bloating and increased flatulence in comparison with their preoperative state on a binary scale (absent/present).

Upper GI Endoscopy

Hiatal hernia size and esophagitis according to the Los Angeles classification⁴⁰ were determined endoscopically at the department of Gastroenterology of the University Medical Center Utrecht.

Stationary Esophageal Manometry

Manometry was performed at the Gastrointestinal Research Unit of the University Medical Center Utrecht, after suspending medication that potentially affects gastrointestinal motility 7 days in advance. A multiple-lumen water-perfused catheter with an incorporated sleeve sensor (Dentsleeve International Ltd, Mississauga, Canada) and a low-compliance perfusion system was used. The catheter was slowly withdrawn to determine the proximal border of the lower esophageal sphincter (LES) after transnasal introduction. Next, the sleeve sensor was positioned at the level of the LES and intraluminal esophageal pressures were recorded at 5, 10, 15, 20, and 25 cm above the proximal margin. Subsequently, the manometric response to 10 standardized wet swallows (5-mL water bolus) was studied. The gastric baseline pressure (registered 2 cm below the distal margin of the sleeve sensor) served as the zero reference point.

Ambulatory 24-hour Combined Esophageal Impedance-pH Monitoring

Ambulatory 24-hour esophageal impedance-pH testing was performed at the Gastrointestinal Research Unit of the University Medical Center Utrecht. After cessation of at least 7 days of all medication that could affect gastrointestinal motility and secretion, a combined impedance-pH catheter (VersaFlex, Alpine Biomed, Fountain Valley, CA, USA) was introduced transnasally. The catheter had 8 ring electrodes for recording of impedance signals and a single antimony pH electrode. The catheter was positioned with the impedance recording segments at 2–4, 4–6, 6–8, 8–10, 14–16, and 16–18 cm and the pH electrode at 5 cm and above the manometrically determined upper margin of the LES. A digital data logger (Medical Measurements Systems, Enschede, The Netherlands), with a sampling frequency of 50 Hz recorded the tracings.⁴¹ Patients were asked to press a button on the digital data logger at the beginning of each symptom episode and to register body position, GERD symptoms, meals and beverages in a diary. The symptom index (SI) was calculated separately for all reflux events, GBs and supra gastric belches (SGBs), if symptoms were recorded during the measurement. A SI of at least 50 per cent was regarded to be positive.⁴²

Data Analysis

The classification of reflux characteristics, gastric and supra-gastric belches used was identical to the classification described in 2 of our studies that compared these parameters before and after 360 degrees LPF.^{17,43} The 24-h impedance-pH tracings were manually analyzed by a single observer (JALB) but facilitated by a dedicated software program (MMS, Enschede, The Netherlands). Another expert observer was consulted in case of uncertainty (AJB). To minimize observer bias, both observers were blinded for patient characteristics and pre- or postoperative status. Criteria for the classification of air-containing swallows (air swallows), gas, liquid, mixed, acid and weakly acidic reflux episodes have been published earlier.⁴³ Normal values for the number of total, acid and weakly acidic reflux episodes were 75, 50, and 33 per 24-hour respectively.⁴⁴ For each individual reflux episode the proximal extent of the refluxate in centimeters above the LES was determined. The extent of the liquid component of liquid-containing reflux episodes (pure liquid and mixed reflux) determined classification as proximal (≥ 15 cm above LES), mid-esophageal (5–15 cm above LES) or distal reflux (≤ 5 cm above LES).¹⁷ The total esophageal reflux distance (TERD) and mean proximal extent were calculated for liquid-containing reflux episodes. The TERD was defined as the sum of the proximal extent above the LES of all individual reflux episodes in centimeters.¹⁷

Gas components of pure gas and mixed liquid-gas reflux episodes that reached the most proximal channel were regarded as GBs.⁴⁵ The criteria described by Bredenoord et al were used to identify SGBs.⁴⁶ SGBs were defined as rapid increases in impedance ($\geq 1000 \Omega$) moving in an aboral direction, followed by a return to baseline moving from distal to proximal. This indicated a pattern that reflects expulsion of air after rapid esophageal air ingestion. A SGB was considered to be related to reflux when it occurred immediately prior (< 1 s) to the onset of the reflux episode or when occurring during a reflux episode, with onset within 10 seconds after the start of the reflux episode.⁴⁷ Periods of meal consumption were disregarded and the total number of reflux episodes, air swallows and belches were normalized to a 24-hour period.

Statistical Analysis

Continuous variables were expressed as mean \pm standard error of the mean (SEM) unless stated otherwise. Effects of surgery on continuous variables were expressed as absolute differences between pre- and postoperative values (Δ). Comparison of absolute differences and preoperative values between the 270 degrees LPF and the 360 degrees LPF group were performed using the Mann-Whitney *U*-test. The Wilcoxon signed rank test was used to determine significant effects of surgery in either the 270 degrees LPF or the 360 degrees LPF group. The χ^2 test was used to compare groups for nominal variables. $P < 0.05$ was considered statistically significant. The statistical analysis was performed using SPSS version 15.0 (SPSS Inc. Chicago, IL).

RESULTS

Subjects

Fourteen patients that underwent 270 degrees LPF were compared to 28 360 degrees LPF controls who were matched based on total esophageal acid exposure (16.0 [2.3] versus 14.3 [1.3]%; $P = 0.626$). There were no patients with prominent laryngopharyngeal reflux. Baseline characteristics were comparable for both groups (Table 1).

Upper GI Endoscopy and Stationary Esophageal Manometry

In both groups, half of the patients had esophagitis and the other half had non-erosive GERD before surgery. The prevalence of esophagitis was 2 of 12 [17%] after 270 degrees LPF and 5 of 27 [19%] after 360 degrees LPF. All patients completed pre- and postoperative manometry. Two hundred and seventy degrees LPF and 360 degrees LPF increased both LES resting pressure ($\Delta + 0.5$ [0.3] kPa vs. $+ 0.8$ [0.2] kPa) and LES relaxation nadir pressure ($\Delta + 0.4$

[0.2] kPa vs. $+ 0.7$ [0.1] kPa) to a similar extent, but did not alter distal contraction amplitude ($\Delta + 0.8$ [0.6] kPa vs. $+ 1.4$ [0.8] kPa).

Control of Acid and Weakly Acidic Reflux

All patients completed pre- and postoperative esophageal impedance-pH testing. Total acid exposure time was reduced after 270 degrees LPF and 360 degrees LPF to a similar extent ($\Delta - 13.5$ [2.0]% vs. $- 13.0$ [1.3]%). The reduction in total number of reflux episodes was similar after 270 degrees LPF and 360 degrees LPF ($\Delta - 87.0$ [8.5] vs. $- 83.4$ [6.3]), with a similar reduction in acid ($\Delta - 77.6$ [6.5] vs. $- 76.7$ [5.7]) and weakly acidic reflux episodes ($\Delta - 9.4$ [4.7] vs. $- 6.6$ [1.9]). Two hundred seventy degrees LPF and 360 degrees LPF greatly decreased liquid ($\Delta - 59.0$ [9.2] vs. $- 49.8$ [5.3]) and mixed reflux episodes ($\Delta - 28.0$ [5.9] vs. $- 33.5$ [2.9]), with no differences in control of acid and weakly acidic reflux episodes (Table 2). Two hundred and seventy degrees LPF had no significant impact on number of gas reflux episodes ($\Delta - 3.6$; $P = 0.363$), whereas 360 degrees LPF significantly reduced the number of gas reflux episodes ($\Delta - 17.0$; $P = 0.002$). Details on gas reflux events are given in Figure 1.

The reduction in proximal reflux was significantly higher after 270 degrees LPF ($\Delta - 44.1$ [6.5] vs. $- 29.9$ [3.6]; $P = 0.038$). This was probably because of the significantly higher number of proximal reflux episodes before 270 degrees LPF, compared with the 360 degrees LPF group (49.4 [6.5] vs. 32.3 [3.7]; $P = 0.017$). The reduction in mid-esophageal ($\Delta - 38.2$ [5.1] vs. $- 48.0$ [4.6]) and distal reflux ($\Delta - 4.6$ [1.9] vs. $- 5.4$ [1.0]) were similar after 270 degrees LPF and 360 degrees LPF. Two hundred seventy degrees LPF and 360 degrees LPF reduced the TERD to a similar extent ($\Delta - 1094$ [118] cm vs. $- 940$ [73] cm) and did not change mean proximal reflux extent ($\Delta - 2.1$ [0.7] cm vs. $- 0.1$ [0.6] cm).

Belching

Fundoplication did not affect the numbers of air swallows, with no differences between 270 degrees LPF and 360 degrees LPF ($\Delta - 4.8$ [33] vs. $- 51.7$ [28]). The number of GBs before surgery was similar in the 270 degrees LPF group and the 360 degrees LPF group (57.8 [9.5] vs. 67.8 [4.0]; $P = 0.140$). GBs were present in all patients before surgery and were completely abolished in 2 patients in the 360 degrees LPF group. Both 270 degrees LPF and 360 degrees LPF reduced the number of GBs. However, the number of GBs was significantly less reduced after 270 degrees LPF, compared with 360 degrees LPF ($\Delta - 29.3$ [8.8] vs. $- 50.6$ [4.6]; $P = 0.026$). Details on GBs are given in Figure 2. Supragastric belching only occurred in specific patients; it was observed in 7 patients in the 270 degrees LPF group and in 21 patients in the 360 degrees LPF group both before and after surgery (SGB +), whereas 7 patients in each group did not exhibit any SGBs, neither before nor after fundoplication (SGB -). The number of SGBs not associated with reflux increased to a similar extent after 270 degrees LPF and 360 degrees LPF ($\Delta + 32.4$ [7.1] vs. $+ 25.5$ [16]). The reduction in reflux-associated SGBs, both SGBs immediately preceding reflux episodes and SGBs during reflux episodes, was similar after 270 degrees LPF and 360 degrees LPF ($\Delta - 12.1$ [7.8] vs. $- 14.0$ [3.6]). Details on air swallows and SGBs are given in Table 3.

Symptomatic Outcome

The prevalence of inability to belch (0/14 [0%] vs. 2/28 [7.1%]; $P = 0.306$), gas bloating (1/14 [7.1%] vs. 6/28 [21.4%]; $P = 0.242$) and increased flatulence (1/14 [7.1%] vs. 12/28 [42.9%]; $P = 0.018$) was lower after 270 degrees LPF than after 360 degrees LPF. The reduction in reflux symptoms (GERD-QoL: from 20.6 [2.3] to 4.2 [1.7] vs. from 17.6 [2.4] to 3.6 [0.9]) and dysphagia (QLQ-OES 18: from 35.0 [3.9] to 26.0 [2.3] vs. from 33.8 [1.4] to 27.6 [1.4]) and

TABLE 1. Baseline Characteristics of Patients According to Treatment Group After 270 degrees LPF and 360 degrees LPF

	270 degrees LPF	360 degrees LPF
Patients (n)	14	28
Age [range]	47.4 [23–64]	48.5 [26–67]
Male/female sex	7/7	11/17
Body mass index (kg/m ²)*	29.8 (1.2)	28.3 (1.2)
Hiatal hernia (cm)*	2.1 (0.7)	2.3 (0.4)
Total esophageal acid exposure (%)*	16.0 (2.3)	14.3 (1.3)

*Values are given as mean (SEM).

TABLE 2. Total Number of liquid-Containing Reflux Episodes and Number of Liquid and Mixed Reflux Events Per 24 Hour After 270 Degrees LPF and 360 Degrees LPF

	270 Degrees LPF			360 Degrees LPF		
	Pre-Op (n = 14)	Post-Op (n = 14)	Δ	Pre-Op (n = 28)	Post-Op (n = 28)	Δ
Total reflux episodes	105.5 (8.7)	18.5 (6.1)	- 87.0 (8.5)	90.7 (6.3)	7.4 (1.0)	- 83.4 (6.3)
Acid reflux	89.6 (7.4)	12.1 (5.7)	- 77.6 (6.5)	78.5 (5.6)	1.8 (0.8)	- 76.7 (5.7)
Weakly acidic reflux	15.9 (4.7)	6.4 (1.4)	- 9.4 (4.7)	12.3 (2.2)	5.6 (0.7)	- 6.6 (1.9)
Liquid reflux	72.9 (10)	13.9 (3.6)	- 59.0 (9.2)	55.4 (5.4)	5.6 (0.8)	- 49.8 (5.3)
Acid reflux	61.4 (8.4)	8.7 (3.4)		47.0 (4.7)	1.4 (0.7)	
Weakly acidic reflux	11.6 (3.3)	5.2 (1.2)		8.4 (1.9)	4.3 (0.6)	
Mixed reflux	32.6 (4.5)	4.6 (2.9)	- 28.0 (5.9)	35.3 (2.9)	1.8 (0.5)	- 33.5 (2.9)
Acid reflux	28.3 (4.3)	3.4 (2.5)		31.5 (2.6)	0.4 (0.2)	
Weakly acidic reflux	4.3 (2.0)	1.2 (0.5)		3.8 (0.6)	1.4 (0.4)	

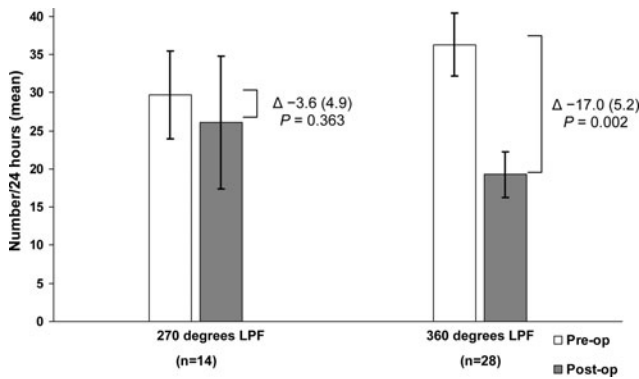


FIGURE 1. Mean number of gas reflux events per 24 hour after 270 degrees LPF and 360 degrees LPF.

the increase in QoL (SF-36: from 58.1 [7.3] to 69.7 [6.6] vs. from 54.6 [5.1] to 67.3 [4.8]) were similar after 270 degrees LPF and 360 degrees LPF.

None of the 23 patients with symptoms during postoperative impedance-pH monitoring had a positive SI for acid and/or weakly acidic reflux after surgery. Only 5 of 127 symptoms were preceded by acid reflux or weakly acidic reflux. One patient in the 360 degrees LPF group had a positive SI for belching symptoms and GBs and 2 patients in each group had a positive SI for belching symptoms and SGBs.

DISCUSSION

This study demonstrates that 360 degrees LPF and 270 degrees LPF reduce reflux to a similar extent in the short-term, but that there are distinct differences in gastric belching after both procedures. In line with previous studies in 360 degrees LPF patients,^{17,43} the current results show that fundoplication has no impact on the number of air swallows. This study demonstrates that both 270 degrees LPF and 360 degrees LPF alter the belching pattern by reducing GBs and increasing SGBs. The first serve to vent ingested air from the stomach, whereas the latter are esophageal belches that do not allow air ventilation from the stomach.⁴⁶ Consequently, fundoplication reduces air venting, which causes gas-related symptoms. However, gas reflux and GBs are reduced less after 270 degrees LPF, resulting in more air venting and less gas bloating and flatulence compared with 360 degrees LPF.

The results of the 2 studies that have previously evaluated differences in GBs between partial posterior and 360 degrees poste-

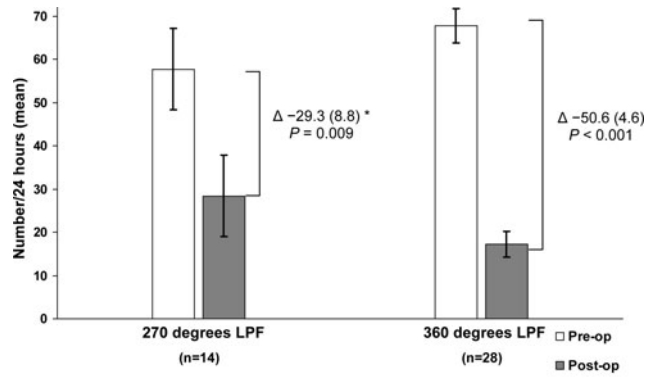


FIGURE 2. Mean number of gastric belches per 24 hour after 270 degrees LPF and 360 degrees LPF. * P = 0.026 versus Δ 360° LPF group

rior fundoplication are contradictory.^{16,18} One study reported a lower incidence of GBs after 360 degrees posterior fundoplication than after partial posterior fundoplication,¹⁸ whereas the other study found similar numbers of GBs after both procedures.¹⁶ Both studies did not evaluate the reduction in belches after fundoplication, provoked belching by gas insufflation and recorded belches for less than 30 minutes.^{16,18} Rapid infusion of a large volume of air (750 mL) into the stomach does not resemble normal physiology in which swallows transport small volumes of air to the stomach. In contrast, this study evaluated the effect on belching for 24 hours in a physiological setting, without gastric distention. In addition, the studies are methodologically limited by the fact that belches were recorded indirectly, using manometric common cavities.^{16,18} This is a distinct limitation because common cavities are absent in more than half of the gas reflux episodes detected by impedance.¹⁹ The low number of common cavities observed in manometric studies (0.4¹⁸ and 2.3¹⁶ per 30 minutes) are in contrast with the numbers observed with direct evaluation of GBs using 24-hour impedance monitoring (20.4).¹⁷ The rates of gas-related symptoms of this study are similar to the rates of inability to belch (7.8% vs. 15.7%) and gas bloating (22.5% vs. 35.9%) reported by a recent meta-analysis comparing 270 degrees and 360 degrees LPF⁶ and the prevalence of increased flatulence was also similar to the results of the only randomized trial that compared increased flatulence after 270 degrees and 360 degrees LPF (67.2% vs. 74.6%).⁴⁸

Previous studies have evaluated reflux after 360 degrees LPF using impedance monitoring.^{17,28,29,43,49} These studies have

TABLE 3. Air Swallows and Supragastric Belches (SGBs) Per 24 Hour After 270 Degrees LPF and 360 Degrees LPF

	270 Degrees LPF			360 Degrees LPF		
	Pre-Op	Post-Op	Δ	Pre-Op	Post-Op	Δ
Air swallows (270 degrees n = 14, 360 degrees n = 28)	418 (80)	414 (84)	-4.8 (33)	415 (35)	363 (24)	-51.7 (28)
SGBs without reflux (270 degrees n = 7, 360 degrees n = 21)	11.3 (4.1)	43.7 (9.2)	+32.4 (7.1)	19.8 (6.6)	45.3 (20)	+25.5 (16)
SGBs with reflux (270 degrees n = 7, 360 degrees n = 21)	21.9 (6.3)	9.7 (4.2)	-12.1 (7.8)	14.4 (3.6)	0.5 (0.2)	-14.0 (3.6)
SGBs before reflux	7.6 (3.6)	7.3 (3.8)		4.9 (1.5)	0.2 (0.1)	
SGBs during reflux	14.3 (3.9)	2.4 (1.5)		9.6 (2.4)	0.2 (0.2)	

demonstrated that 360 degrees LPF selectively reduces reflux episodes as the reduction in liquid-containing reflux episodes is larger than the reduction in gas episodes. This study is the first study that evaluated the effect of 270 degrees LPF on weakly acidic reflux and proximal extent of the reflux episodes. Our study demonstrates that 270 degrees LPF reduces acid and weakly acidic reflux to a similar extent as 360 degrees LPF. Two hundred seventy degrees LPF reduced liquid-containing reflux, but had no impact on pure gas reflux and the reduction in liquid-containing reflux after 360 degrees LPF was 5 times larger than the reduction in pure gas reflux. This does not imply that the gastroesophageal junction is an intelligent sphincter. Flow through the esophagus is highly dependent on both the cross-sectional area of its lumen and the viscosity of the fluid flowing through it.⁵⁰ The low viscosity of gaseous substances allows passage of a highly compliant esophagogastric junction more easily than liquids.⁵¹ This observation potentially explains the ability of 270 degrees LPF to provide similar reduction of liquid-containing reflux compared with 360 degrees LPF, without reducing gas reflux. A difference in distensibility of the cross-sectional area of the lumen after 270 degrees and 360 degrees LPF is another potential explanation for the difference in handling of gas and liquids.^{50,51} The latter explanation is more likely as a cadaver study has demonstrated that 270 degrees posterior fundoplication is not entirely competent at low intragastric pressures, allowing belching to occur, whereas 360 degrees posterior fundoplication is completely competent.⁵² The effectiveness of antireflux surgery is not only determined by reduction in the number of reflux episodes, the proximal reflux extent is important as well.²⁶ The current report combined the quantity and extent of the reflux episodes by calculating the TERD.¹⁷ The reduction in TERD, proximal, mid-esophageal and distal reflux were similar after 270 degrees and 360 degrees LPF. The improvement of reflux symptoms was similar after 270 degrees and 360 degrees LPF as well. In addition, the current results show that refractory GERD symptoms are neither caused by acid nor by weakly acidic reflux. Belching seems to be a more important cause of persistent complaints, as one-fifth of the symptomatic patients had a positive relationship between postfundoplication symptoms and belches. The reduction of reflux lead to a great decrease in the number of SGBs associated with reflux after surgery.

This physiological study was too small to provide evidence that 270 degrees LPF significantly reduces inability to belch and gas bloating compared with 360 degrees LPF, but the meta-analyses have previously shown that 270 degrees LPF reduces these gas-related symptoms.^{6,7} Another limitation of the study was the lack of randomization, though a randomized design is less critical in physiological studies than in studies that focus on clinical endpoints. The first patients that participated in this consecutive study underwent 360 degrees LPF and the surgical therapy of choice for GERD was changed after a meta-analysis demonstrated that 270 degrees LPF reduces dysphagia.⁶ Therefore, preoperative characteristics did not determine whether 270 degrees or 360 degrees LPF was performed.

The absence of selection bias is illustrated by the fact that the groups were similar at baseline. Surgeon experience has probably not biased the results because both surgeons completed the learning curve for both procedures³¹ and 1 surgeon had more experience in 270 degrees LPF (EJH) whereas the other was more experienced in 360 degrees LPF (IAMJ).

The current results demonstrate no differences in the short-term reduction of acid and weakly acidic reflux after 270 degrees and 360 degrees LPF. Limited amounts of reflux are part of the normal physiology of the gastroesophageal junction. Two hundred seventy degrees and 360 degrees LPF did not eliminate reflux but reduced the total number of reflux episodes to a similar extent and well below the normal value. Consequently, both procedures rendered patients asymptomatic in the short-term. Time is the enemy of both procedures and consequently a difference in reflux control between 270 degrees and 360 degrees LPF could potentially develop with extension of follow-up. On the basis of the results of 7 randomized trials, 2 recent meta-analyses^{6,53} and the American guidelines for antireflux surgery⁵ concluded that reflux control is similar up to 5 years after 270 degrees and 360 degrees LPF. However, comparative studies with follow-up beyond 5 years have demonstrated that reflux symptoms are more frequent after 270 degrees LPF than after 360 degrees LPF.²²⁻²⁵ It is likely that these uncontrolled studies advocated 270 degrees LPF in patients with poor esophageal peristalsis in an attempt to reduce post-operative dysphagia. This is a potential source of bias, because poor esophageal peristalsis has recently been identified as an independent predictor of recurrent reflux disease after fundoplication.⁵⁴ Therefore, the long-term results of the 7 randomized trials will have to confirm that the reduction of reflux remains similar after 270 degrees and 360 degrees LPF with extension of follow-up beyond 5 years. The 20-year follow-up of a randomized trial comparing open posterior partial and total fundoplication reports comparable reflux control.⁵⁵ Until equivalent long-term reflux control has been demonstrated for the laparoscopic variants of these fundoplications, both procedures are appropriate for the surgical treatment of GERD. Patients should be informed about the higher rate of gas-related symptoms after 360 degrees LPF and the potentially higher rate of reflux after 5 years associated with 270 degrees LPF. The decision to perform 270 degrees or 360 degrees LPF must be made after a conversation between surgeon and patient that explores these cons and pros.

In conclusion, the reduction in acid reflux and weakly acidic reflux and proximal reflux extent are similar after 270 degrees and 360 degrees LPF. Persistent reflux symptoms are neither caused by acid nor by weakly acidic reflux. Both procedures alter the belching pattern by reducing GBs (air venting from stomach) and increasing SGBs (no air venting from stomach). However, gas reflux and GBs are reduced less after 270 degrees LPF than after 360 degrees LPF, resulting in more air venting from the stomach and less gas bloating and flatulence, whereas reflux is reduced to a similar extent in the short-term.

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