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ORIGINAL ARTICLE

Reflux and Belching after Laparoscopic 270 degree Posterior Versus 180 degree Anterior Partial Fundoplication

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Abstract

Background Laparoscopic 270 degree posterior, or Toupet (LTF), and 180 degree anterior partial fundoplication (LAF) ensure equal reflux control and reduce the risk of gas-related symptoms compared to 360 degree (Nissen) fundoplication. It is unclear which type of partial fundoplication is superior in preventing gas-related side-effects. The aim of this study was to determine differences in effect of LTF and LAF on reflux characteristics and belching patterns.

Methods Upper gastrointestinal endoscopy, esophageal manometry, and 24-h combined pH-impedance monitoring were performed before and 6 months after fundoplication ($n = 10$, LTF vs. $n = 10$, LAF). Observed changes after surgery (Δ) were compared between the two procedures.

Results Symptomatic reflux control as well as the reduction in the mean number of acid (Δ − 58.5 vs. − 66.5; $P = 0.912$), liquid (Δ − 17.0 vs. − 43.5; $P = 0.247$), and mixed liquid gas reflux episodes (Δ − 38.0 vs. − 40.0; $P = 0.579$) were comparable following LTF and LAF. There were no differences in the mean number of weakly acidic reflux episodes after LTF and LAF (1.0 (0.8–4) vs. 1.0 (0–3), $P = 0.436$). The reduction in proximal ($P = 1.000$), mid-esophageal ($P = 0.063$), and distal reflux episodes ($P = 0.315$) was comparable. Both procedures equally reduced the number of gastric belches ($P = 0.278$) and supragastric belches ($P = 0.123$), with no significant reduction in the number of air swallows after either procedure ($P = 0.278$).

Conclusion LTF and LAF provide similar reflux control, with a comparable effect on acidic, liquid, and gas reflux. Both procedures equally reduced the number of belches and supragastric belches. This study provides the physiological evidence for the published randomized trials reporting similar symptomatic outcome after both types of partial fundoplication.

Keywords Laparoscopy · Fundoplication · Gastroesophageal reflux disease · Belching · Treatment outcome

Introduction

Laparoscopic fundoplication is an effective and definitive treatment for patients suffering from proton pump inhibitor (PPI) refractory gastroesophageal reflux disease (GERD), or for those who are unwilling to take life-long medication. Laparoscopic 360 degree total (Nissen) fundoplication (LNF) is the most frequently performed type of fundoplication worldwide, providing excellent reflux control with high and stable satisfaction rates.[1–3] However, an important problem associated with total fundoplication is the development of post-fundoplication symptoms, including dysphagia and gas-related symptoms, such as gas bloat and increased flatulence, caused by a supracompetent antireflux barrier.[4,5] The development of postoperative dysphagia and/or gas-related symptoms has a significant impact on patient-perceived success of surgery, resulting in lower postoperative satisfaction scores.[4–7]

To reduce the risk of postoperative dysphagia and gas-related symptoms, partial fundoplications have been developed. The two most frequently performed types of partial fundoplication include the laparoscopic 270 degree posterior or Toupet fundoplication (LTF) and the 180 degree anterior fundoplication (LAF).[4,8] Both are created by wrapping the

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fundus of the stomach partially around the distal esophagus, either posteriorly or anteriorly. Recent meta-analyses have demonstrated that both types of partial fundoplication, LTF and LAF, offer durable and comparable control of reflux symptoms, with a lower incidence of "post-fundoplication symptoms" compared with LNF.[4,8] Recently, our study group published the results of a multicenter randomized clinical trial comparing LTF and LAF for the treatment of GERD.[9] At 1 year, there were no differences in the presence and/or severity of heartburn, or in the incidence or severity of dysphagia for liquids or solids between the two groups. Additionally, routine upper gastrointestinal endoscopy, conventional 24-h pH monitoring, and esophageal manometry performed 3 months after surgery did not demonstrate any differences in the presence of esophagitis, total esophageal acid exposure, or lower esophageal resting pressure after both procedures.[9]

The exact physiological effects of both types of partial fundoplication and the relationship with the development of gas-related symptoms are scarcely described. To clarify the latter, combined pH-impedance monitoring is the esophageal function test of choice. This technique enables visualization of movements of gas and liquids through the esophagus,[10,11] providing valuable information regarding the effects of fundoplication on acidic and weakly acidic reflux, air swallows, gastric belches, and supragastric belches. These are important factors when evaluating the outcome of antireflux surgery. Weakly acidic reflux has been demonstrated to elicit typical reflux symptoms which cannot be detected by conventional 24-h pH monitoring and do not respond to acid-suppressing medication.[12,13] Gastric belching is a physiologic mechanism during which the stomach vents ingested air. It is hypothesized that gas-related symptoms are largely caused by an inability to belch[14,15] A previous study of our group used combined pH-impedance monitoring to compare reflux characteristics and belching patterns between LTF and LNF, and demonstrated that LTF reduces reflux to a similar extend compared with LNF, but with less reduction in gas reflux and gastric belches, resulting in a lower incidence of gas bloating and flatulence following LTF.[16]

The present study is the first to use combined pH-impedance monitoring to compare LTF and LAF, and determine differences in effects of both partial fundoplications on reflux characteristics and belching.

Materials and Methods

Study Design and Data Collection

Between January 2009 and March 2016, 20 patients diagnosed with GERD with pathological esophageal acid exposure and who were on the waiting list for primary LTF ($n = 10$) or LAF ($n = 10$) were prospectively included. Patients who had undergone previous antireflux surgery, hiatal hernia repair, or bariatric surgery were excluded. All patients were asked to complete structured questionnaires preoperatively and 6 months postoperatively, and were scheduled for routine pre- and postoperative esophageal manometry and 24-h combined pH-impedance monitoring. Baseline characteristics, including age, body mass index, and the presence of comorbidities, and pre- and postoperative symptomatic and objective outcome were prospectively entered into a digitalized database.

Symptomatic Outcome

All included patients were asked to complete structured questionnaires preoperatively and 6 months postoperatively by mail. The structured questionnaire focused on the presence and severity of typical GERD symptoms, dysphagia, and gas-related symptoms (the presence of bloating, inability to belch, and increased flatulence). The presence and intensity of reflux symptoms were assessed using the validated GERD Health-Related Quality of Life score (GERD-HRQoL).[17,18] The presence of and changes in dysphagia were analyzed using the validated European Organization for Research and Treatment of Cancer QLQ-OES 18 questionnaire.[19] The validated Short-Form 36 (SF-36) was used to assess the possible changes in health-related Quality of Life (QoL).[20] The presence of bloating, inability to belch, and increased flatulence were assessed using a binary scale (absent/present).

Endoscopy

Upper gastrointestinal endoscopy was not routinely performed, but based upon the preoperative presence of or clinical suspicion for esophagitis, Barrett's esophagus, or stenosis. Endoscopy was performed after 8 h of fasting. During endoscopy, postsurgical anatomy, healing of esophagitis, and/or the presence of any esophageal obstruction or hiatal hernia was assessed and scored according to the Los Angeles Classification.[21]

Esophageal Manometry

All patients were scheduled for pre- and postoperative esophageal manometry. Three days after cessation of medication that could possibly affect esophageal motility, manometry was performed using a multi-lumen water-perfused catheter with incorporated sleeve sensor (Dentsleeve International Ltd., Mississauga, Canada) and a low-compliance perfusion system. Following transnasal introduction, the position of the proximal part of the lower esophageal sphincter (LES) was determined by slowly withdrawing the catheter, and intraluminal esophageal pressures were registered at 5, 10, 15, 20, and 25 cm above the proximal border of the LES. Next, the manometric response to 10 standardized wet

swallows (5-mL water bolus) was recorded. The gastric baseline pressure was registered 2 cm below the distal margin of the sleeve sensor and used as the zero reference point.

Ambulatory 24-H Combined pH-Impedance Monitoring

Ambulatory 24-h combined pH-impedance monitoring was performed after cessation of acid-suppressing medication or medication which could influence esophageal motility, with PPIs being ceased for 7 days and H2-recepetor antagonists for 3 days before monitoring. Using transnasal introduction, the antimony pH electrode was placed 5 cm from the upper border of the manometrically determined proximal border of the LES, whereas the recording segments of the impedance catheter (VersaFlex, Alpine Biomed, Fountain Valley, CA, USA) were placed 2–4, 4–6, 6–8, 8–10-, 14–16, and 16–18 cm from the proximal border of the LES. The 24-h pH and impedance signals were recorded using a digital data recorder (Medical Measurements Systems, Enschede, The Netherlands) with a sampling frequency of 1 and 50 Hz respectively. [22] The presence of symptomatic episodes was assessed by asking patients to press a button on the digital data recorder. Furthermore, the patient registered the occurrence of all symptoms, the associated body position, and the relation with food and drink intake in a diary. If symptoms were recorded during a 24-h measurement, the symptom-index (SI) and symptom association probability index (SAP) were calculated for all reflux episodes, gastric belches, and supra gastric belches, with an SI of more than 50% and SAP of more than 95% regarded as being positive.[23,24]

Surgical Procedures

All fundoplications were performed by a single experienced gastrointestinal surgeon specialized in antireflux surgery, who was well beyond his learning curve.[25] In all patients, a standardized fundoplication was performed that aimed to create a loose valve in order to minimize the development of post-fundoplication symptoms. The distal esophagus was fully mobilized and short gastric vessels were ligated and divided if considered necessary. The surgeon verified that the gastro-esophageal junction was placed in a tension-free position in the abdomen and the fundoplication was tension-free as well. Posterior crural repair was performed using non-absorbable sutures and without the use of a bougie, after which a floppy fundoplication of 2.5 to 3.0 cm was constructed. In case of LTF, the fundus was wrapped 270 degree behind the distal esophagus and attached to the esophagus on the right and left sides and to the hiatus on the right side, leaving the anterior esophagus uncovered. Constructing a LAF, the fundus was wrapped for 180 degrees around the anterior distal esophagus and sutured to the front of the esophagus and the diaphragmatic hiatus.[26]

The first group of 10 patients was allocated to LTF and the second group of 10 patients was allocated to LAF by the same surgeon, irrespective of preoperative symptoms, medical history, or outcome of upper gastrointestinal endoscopy or esophageal function tests.

Data Analysis

The classification of reflux characteristics, and gastric and supragastric belches has been described in detail in two previous studies from our research group examining the physiological effects of 360 degree LNF.[27,28] This also accounts for the used classification of air-containing swallows, gas, liquid, mixed, acid, and weakly acidic reflux episodes.[28] One single observer (JEO) manually analyzed all pre- and postoperative 24-h pH-impedance recordings of the included patients using a software program (MMS, Enschede, The Netherlands). In case of any uncertainty, two expert observers (JO and AJB) could be consulted, who were blinded for patient characteristics and pre- and postoperative status to minimize the risk of observer bias. The upper limit of the normal number of total, acid, and weakly acidic reflux episodes were 75, 50, and 33 episodes per 24 h, respectively.[29] The proximal extent in centimeters above the LES was determined for each reflux episode. The extent of liquid component of liquid-containing reflux episodes (pure liquid and mixed reflux) was classified as proximal (≥ 15 cm above LES), mid-esophageal (5–15 cm above LES), or distal reflux (≤ 5 cm above LES).[27] For liquid-containing reflux episodes, the total esophageal reflux distance (TERD), defined as the sum of the proximal extent above the LES of all reflux episodes in centimeters, and the mean proximal extent were calculated.[27]

Gastric belches included gas components of pure gas and mixed liquid gas reflux episodes that reached the most proximal channel.[30] Supragastric belches were identified using the criteria previously described by Bredenoord et al., defining supragastric belches as rapid increases in impedance (≥ 1000 Ω) moving in an abnormal direction and followed by a return to baseline moving from distal to proximal.[31] This was considered to indicate a pattern reflecting the expulsion air following rapid esophageal air ingestion. When a supragastric belch occurred prior (< 1 s) to the onset of a reflux episode or during a reflux episode, with the onset within 10 s after the start of the episode, it was considered to be a reflux-related supragastric belch.[32]

The number of air swallows, gastric and supragastric belches, as well as all reflux episodes were normalized to a 24-h period for adequate comparison, with exclusion of periods of meal consumption, based on the diary from the included patients.

Statistical Analysis, Ethics Approval, and Sample Size Calculation

Statistical analysis was performed using the statistical software package SPSS, version 20.0 (SPSS, Inc., Chicago, IL, USA). All continuous variables are presented as median ± interquartile range (IQR). Absolute differences (Δ) between pre- and postoperative values were used to express the effect of surgery on continuous variables. The Mann-Whitney *U* test was used to compare the absolute differences between the LTF group and the LAF group. In order to determine whether the effect of surgery was significant in either the LTF group or the LAF group, the Wilcoxon signed rank test was used. The x^2 test was used to compare groups for nominal variables. A *P* value < 0.05 was considered to be statistically significant.

The protocol of this study was approved by the research ethics committee of the participating hospital. All patients agreed on inclusion and prospectively collection and publication of their data. Based on the design and results of previous physiological studies using combined pH-impedance monitoring for analyzing outcome of different laparoscopic antireflux procedures of both our group and those of others,[16,33–35] a sample size of 20 patients (10 patients per group) was established.

Results

Included Patients

There were no differences in baseline characteristics between the patients who underwent LTF and LAF (Table 1), with comparable preoperative reflux symptoms assessed using the GERD-HRQoL score, similar total esophageal acid exposure, and comparable LES function between the two groups.

Upper Gastrointestinal Endoscopy and Esophageal Manometry

Eighteen patients (90%) had undergone preoperative gastrointestinal endoscopy. Of these patients, six (30%) were diagnosed with esophagitis, and 11 (55%) with a sliding hiatal hernia. There were no differences between the two groups in the prevalence of esophagitis or hiatal hernia before or after surgery.

Preoperative esophageal manometry was performed in all patients, with no differences in preoperative mean LES resting pressure between the two groups (LTF 0.95 kPa vs. LAF 0.80 kPa, $P = 0.472$) or distal contraction amplitude (7.65 vs. 8.30 kPa, $P = 0.520$). Postoperative manometry was performed in all but one patient (95%), with a median postoperative interval of 3.0 months after LTF and 4.0 months after LAF ($P = 0.866$). Neither LTF nor LAF caused a significant increase in LES resting pressure compared to the preoperative state (LTF Δ + 0.5 (− 0.2–1.1) kPa, $P = 0.240$; LAF + 0.4 (0.0–1.8) kPa, $P = 0.137$). LES relaxation pressure significantly increased after LTF, but the increase did not reach statistical significance after 180 degree LAF (LTF Δ + 0.3 (0.1–0.8) kPa, $P = 0.020$; LAF + 0.3 (0.0–0.6) kPa, $P = 0.093$). The distal contraction amplitude was not significantly altered by LTF (Δ + 1.7 (−0.9–2.8), $P = 0.721$) nor LAF (− 1.2 (− 2.3–4.0) kPa, $P = 0.441$).

Effect on Acidic and Weakly Acidic Reflux

All 20 patients underwent pre- and postoperative 24-h pH-impedance monitoring (Tables 2 and 3). The median interval between fundoplication and postoperative pH-impedance monitoring was 3.0 months after LTF and 3.5 months after LAF ($P = 0.969$). Both LTF and LAF led to a significant reduction in total esophageal acid exposure time, with no significant difference in absolute reduction between the two procedures (Δ − 10.8 (−

Table 1 Baseline characteristics of included patients according to fundoplication type

	LTF	LAF	*P* value
Patients (*n*)	10	10	–
Male/female	5/5	5/5	1.000
Age (years)	41.5 (24–62)	42.0 (37–51)	0.677
Body mass index (kg/m^2)	29.0 (24–33)	26.7 (24–30)	0.657
GERD-HRQoL score	22.0 (14–31)	19.5 (12–30)	0.769
LES resting pressure (kPa)	0.95 (0.5–2)	0.80 (0.2–1.6)	0.472
Distal contraction amplitude (kPa)	7.65 (5–11)	8.30 (7–13)	0.520
Total esophageal acid exposure (%)*	11.1 (10–19)	9.0 (7–13)	0.121

Values are given as number of patients or median (interquartile range)

LTF laparoscopic 270 degree posterior partial fundoplication, *LAF* laparoscopic 180 degree anterior partial fundoplication, *GERD-HRQoL* GERD Health-Related Quality of Life score, *LES* lower esophageal resting pressure

*Preoperative total esophageal acid exposure measured using 24-h combined pH-impedance monitoring

Table 2 Number of acidic and weakly acidic and liquid and mixed reflux episodes during 24-h monitoring after laparoscopic 270 degree posterior and 180 degree anterior partial fundoplication

	LTF			LAF		
	Preoperative	Postoperative	Δ	Preoperative	Postoperative	Δ
Total reflux episodes	76.0 (47–93)	1.0 (0.8–17)	− 65.0 (− 87–− 47)	101.0 (59–115)	1.0 (0–5)	− 101 (− 105–− 50)
Acid reflux	63.0 (40–89)	0.0 (0–6)	− 58.5 (− 83–− 40)	66.5 (51–91)	0.0 (0–4)	− 66.5 (− 80–− 45)
Weakly acidic reflux	6.0 (3–13)	1.0 (0.8–4)	− 4.0 (− 9–− 1)	12.5 (5–36)	1.0 (0–3)	− 12.0 (− 32–− 5)*
Liquid reflux	28.5 (16–43)	1.0 (0–13)	− 17.0 (− 42–− 13)	44.5 (22–69)	0.5 (0–4)	− 43.5 (− 57–− 22)
Acid reflux	21.5 (12–37)	0.0 (0–5)	− 19.0 (− 33–− 9)	33.0 (20–45)	0.0 (0–2)	− 30 (− 40–− 20)
Weakly acidic reflux	4.0 (0–6)	1.0 (0–3)	− 2.0 (− 5–0.3)	7.0 (2–18)	0.0 (0–2)	− 6.5 (− 17–− 2)
Mixed reflux	42.0 (34–57)	0.0 (0–3)	− 38.0 (− 56–− 34)	48.5 (32–53)	0.0 (0–1)	− 40.0 (− 52–− 20)
Acid reflux	39.0 (30–52)	0.0 (0–1)	− 35.0 (− 52–− 30)	37.5 (22–47)	0.0 (0–0.3)	− 37.5 (− 47–− 22)
Weakly acidic	4.0 (1–5)	0.0 (0–0.3)	− 4.0 (− 4–− 1)	5.5 (4–15)	0.0 (0–1)	− 5.5 (− 15–− 3)

All data are expressed as median (interquartile range)

LTF laparoscopic 270 degree posterior partial fundoplication, *LAF* laparoscopic 180 degree anterior partial fundoplication

*$P = 0.023$ vs. LTF

16.1–− 10.8) vs. − 7.9 (−11.9–− 6.2), $P = 0.497$). Both procedures significantly reduced the number of reflux episodes ($P = 0.005$ compared to preoperative state), with no difference in absolute reduction between the two groups (Δ − 65.0 (− 87–− 47) vs. − 100.5 (− 105–− 50), $P = 0.218$), and an equal and significant reduction in acid reflux episodes (Δ − 58.5 (− 83–− 40] vs. − 66.5 (− 80–− 45), $P = 0.912$). Preoperatively, there was a trend towards a higher number of weakly acidic reflux episodes in the LAF group (6.0 (3.3–12.5) vs. 12.5 (5.0–36.3), $P = 0.105$). Therefore, the total number of weakly acidic reflux episodes was reduced to a greater extend by LAF (Δ − 12.0 (− 32.0–− 4.8)) compared to LTF (Δ − 4.0 (− 9.3–− 1.3), $P = 0.023$), with no significant difference in the total number of postoperative weakly acidic reflux episodes (1.0 (0.8–4.0) vs. 1.0 (0.0–2.5), $P = 0.436$). Both liquid and mixed reflux episodes were significantly reduced by LTF and LAF, respectively, with no significant differences in absolute reduction (Table 2). Furthermore, there were no significant differences in the reduction of acid and weakly acidic liquid or mixed gas-liquid reflux episodes. The total number of gas reflux episodes was significantly reduced in both groups, but to a greater extend by LAF (Δ − 3.0 (− 11.5–1.5) vs. − 15.0 (− 29.5–− 12.5), $P = 0.010$, Fig. 1). This was most likely caused by a significantly higher number of preoperative gas reflux episodes in the LAF group compared to the LTF group (7.0 (4.0–14.5) vs. (18.0 (13.3–36.5), $P = 0.011$).

Both LTF and LAF led to an equal reduction in proximal (Δ − 36.0 (− 64.0–− 16.3) vs. − 38.0 (− 49.0–− 19.5, $P = 1.000$), mid (Δ − 19.5 (− 26.8–0.8) vs. − 28.0 (− 74–− 20), $P = 0.063$), and distal reflux (Δ − 1.0 (− 5.0–0.0) vs. − 2.0 (− 8.8–− 1.0), $P = 0.315$). Both procedures significantly reduced TERD, with no difference in absolute reduction between the two groups (Δ − 1026.5 (− 1268.8–− 675.0] vs. − 1427.5 (− 1658.8–− 665.0), $P = 0.247$).

Table 3 Number of air swallows and gastric and supragastric belches during 24-h monitoring before and after laparoscopic 270 degree posterior and 180 degree anterior partial fundoplication

	LTF			LAF		
	Preoperative	Postoperative	Δ	Preoperative	Postoperative	Δ
Air swallows	213 (149–363)	266 (185–360)	46.0 (23–68)	382 (338–488)	332 (261–432)	− 31.0 (− 156–81)
Gastric belches	66.0 (50–86)	19.0 (10–30)	− 41.0 (− 64–− 26)	117 (70–130)	37.0 (20–61)	− 76.0 (− 103–− 35)
SGBs without reflux	0.0 (0.0–1.)	0.5 (0–25)	0.5 (0–23)	0.5 (0–12)	7.5 (0–26)	4.0 (0–12)
SGBs with reflux	0.0 (0–3)	0.0 (0–9)	0.0 (0–5)	0.0 (0–27)	0.0 (0–2)	0.0 (− 19–1)
SGB before reflux	0.0 (0–1)	0.0 (0–7)	0.0 (0–6)	0.0 (0–13)	0.0 (0–1)	0.0 (− 8–0)
SGB during reflux	0.0 (0–1)	0.0 (0–0.3)	0.0 (− 0.3–0)	0.0 (0–6)	0.0 (0–0.3)	0.0 (− 5–0)

All data are expressed as median (interquartile range)

LTF laparoscopic 270 degree posterior partial fundoplication, *LAF* laparoscopic 180 degree anterior partial fundoplication, *SGBs* supragastric belches

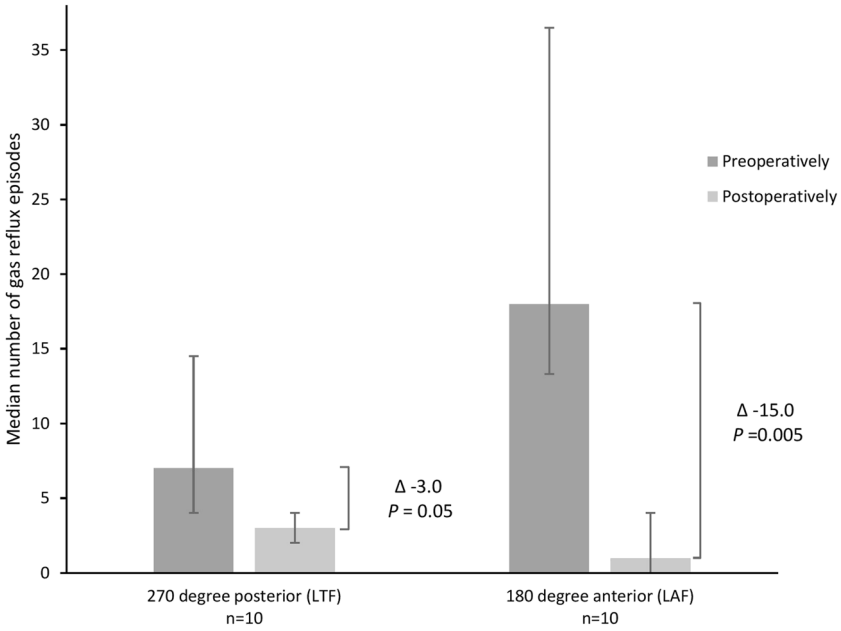

Fig. 1 Median number of gas reflux episodes during 24-h monitoring after 270 degree posterior and 180 degree anterior partial fundoplication

Effect on Belching

There was no difference in the effect of LTF compared to LAF on the number of air swallows during 24-h monitoring (Δ + 46.0 (23–86) vs. − 31.0 (− 156–81), $P = 0.278$), with both procedures not significantly altering the number of air swallows (Table 3). Gastric belches were present in all patients both pre- and postoperatively. Both LTF and LAF significantly decreased the number of gastric belches ($P = 0.008$ and $P = 0.007$, respectively) compared to the preoperative state, with no difference in absolute reduction between the two procedures ($P = 0.278$; Fig. 2).

Supragastric belching, either associated with reflux or not, was present preoperatively in nine patients (45%), with no difference in prevalence between the two groups (Table 3). Twelve patients (60%) demonstrated supragastric belches during the postoperative measurements, of whom three did not demonstrate supragastric belches before surgery. Both LTF and LAF led to a significant and equal increase in supragastric belches not associated with reflux. There was no significant difference in the effect of LTF on the prevalence of supragastric belches associated with reflux, either prior to or during reflux, compared to LAF ($P = 0.123$, $P = 0.075$, and $P = 0.684$, respectively).

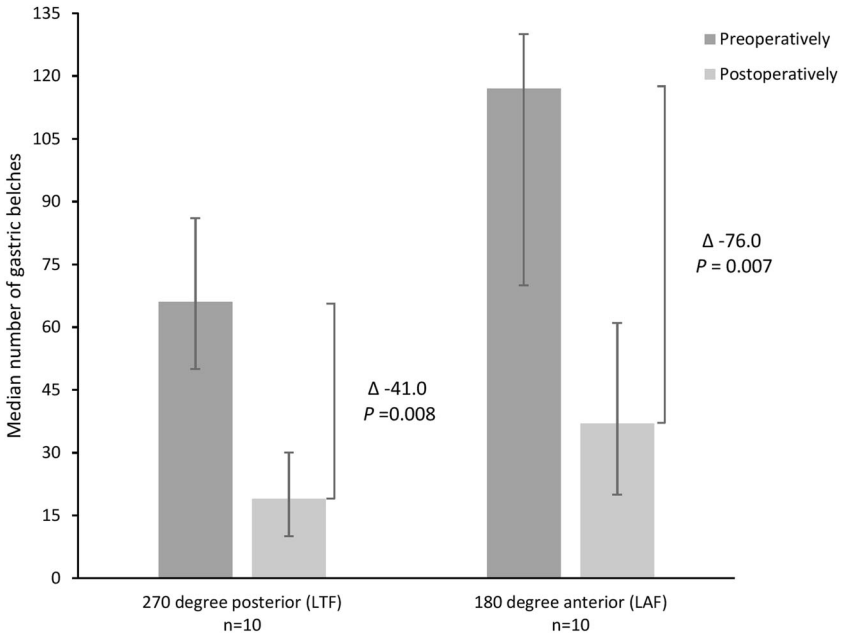

Fig. 2 Median number of gastric belches during 24-h monitoring after 270 degree posterior and 180 degree anterior partial fundoplication

Symptomatic Outcome

Both procedures significantly reduced reflux symptoms, assessed using the GERD-HRQoL-score, with the absolute reduction not differing between the two procedures (Δ − 20.0 (− 29.0–− 12.0) vs. − 17.5 (− 23.3–− 12.3), $P = 0.536$). Postoperatively, all patients reported > 50% improvement in total GERD-HRQoL-score compared to the preoperative state, indicative of a successful therapeutic outcome.[17,18] The presence and severity of postoperative dysphagia, assessed using the QLQ-OES 18 questionnaire, did not differ between the two groups (23.5 (21.5–25.8) vs. 22.0 (21.0–25.5), $P = 0.579$), with both groups demonstrating a significant and comparable reduction compared to the preoperative state ($P = 0.018$ and $P = 0.008$, respectively). The prevalence of inability to belch, gas bloating, and increased flatulence did not differ after LTF or LAF ($P = 0.242$, $P = 0.367$, and $P = 0.304$, respectively). Compared to the preoperative state, the health-related QoL significantly increased after both LTF (Δ + 17.5 (12.2–29.0), $P = 0.018$) and LAF (Δ + 21.1 (3.4–38.9), $P = 0.022$), with no significant differences between the two procedures ($P = 0.792$).

Fourteen of the 20 patients reported symptoms during postoperative 24-h pH-impedance monitoring, of whom none had a positive SI or SAP for acid or weakly acidic reflux. Only four of the 49 reported symptoms (8.2%) were preceded by weakly acidic reflux episodes.

Discussion

Laparoscopic fundoplication yields excellent results with regard to reflux control.[36] However, troublesome side-effects, of which dysphagia and gas-related symptoms are the most important, pose a significant challenge to both the clinician and patient, since they significantly reduce patient satisfaction.[7] This study demonstrates that LTF and LAF significantly reduce esophageal acid exposure and the total number of acidic and weakly acidic reflux episodes, with no difference in reduction between the two procedures. This is the first study to use combined pH-impedance monitoring to evaluate differences in reflux control and belching patterns after the two most frequently performed types of partial fundoplication. While the absolute reduction in the number of weakly acidic reflux episodes and gas reflux episodes is greater after LAF compared to LTF, there was no difference in the total number of postoperative weakly acidic and gas reflux episodes between the two procedures. Additionally, there was no difference in symptomatic reflux control between LTF and LAF.

The reduction in gastric belches following fundoplication results in reduced air venting from the stomach, and is therefore held responsible for the development of postoperative gas-related symptoms.[31] The number of belches was significantly reduced by both types of fundoplication, with no difference in absolute reduction. Additionally, there was no difference in the prevalence of postoperative bloating or inability to belch between the two procedures. Previous studies have used combined pH-impedance monitoring to compare the influence of LTF and LNF on gastric belching, with contradictory results. Two studies provoked belching by insufflating gas into the stomach, with one study reporting a superior reduction in gastric belches after partial fundoplication[37] and the other reporting similar numbers of gastric belches after posterior partial and total fundoplication.[38] Broeders et al. were the first to compare belching patterns after LTF and LNF using combined pH-impedance monitoring during an entire 24-h period and without insufflation of gas.[16] As stated before, the study of Broeders et al. reported an equal reduction in both acid and weakly acidic reflux episodes, with a significantly lower reduction in gas reflux and gastric belches after LTF compared to LNF, thereby providing the physiological explanation for the reduced incidence of gas-related symptoms after LTF demonstrated by a recent meta-analysis.[4]

Recently, our group published the results of a randomized clinical trial comparing LTF and LAF, in which 94 patients were included and underwent routine pre- and postoperative upper gastrointestinal endoscopy, esophageal manometry, and conventional 24-h pH monitoring.[9] One year after surgery, there were no significant differences between the two procedures in terms of subjective and objective reflux control, postoperative dysphagia, or incidence of gas-related symptoms. By using combined pH-impedance monitoring, the present study confirms our previous findings from the randomized clinical trial and demonstrates that LTF and LAF not only have a comparable short-term effect on acidic reflux, but also on the total amount of acidic and weakly acidic reflux and belching, providing physiological support for the equal symptomatic outcome after both types of partial fundoplication. Both types of partial fundoplication did not completely eliminate reflux, but significantly reduced the number of reflux episodes, thereby rendering patients asymptomatic during the described follow-up period. As is the case with every type of antireflux procedure, long-term follow-up of both physiological studies and randomized clinical trials needs to determine whether this effect is sustained.

The present study has several limitations. First, patients were not randomized to either LTF or LAF, with the potential for confounding as a result. However, the first group of 10 patients was allocated to LTF and the second group of 10 patients was allocated to LAF by the same surgeon. The transition of LTF to LAF was not based on superiority of either one of the procedures, or on preoperative patient characteristics. Hence, there was no selection whether a patient was treated with a posterior or anterior partial fundoplication. Additionally, baseline characteristics of patients undergoing LTF and LAF were identical, including both the presence

and severity of reflux symptoms (GERD-HRQoL score) as well as the preoperative presence of esophagitis, preoperative total esophageal acid exposure, LES resting pressure, or distal contraction amplitude. However, this does not completely eliminate the risk of confounding by unmeasured clinical factors.

Another limitation of the present study is the relatively small sample size and the fact that no sample size calculation was performed. Based on sample sizes reported in recently published studies using combined pH-impedance monitoring for the assessment of possible differences in outcome of laparoscopic fundoplication, including the study of Broeders et al., a sample size of 20 patients was established.[16,33–35] The fact that in the present study no differences in reflux or belching were found between the two procedures makes it unlikely that increasing our sample size would change these results. The physiological study of Broeders et al. with a comparable sample size and identical pre- and postoperative objective studies, outcome measures, and statistics as we describe in the present study, was able to demonstrate significant differences between the two fundoplications (360 degree total versus 270 degree posterior partial fundoplication).[16] Additionally, our group recently compared the clinical outcome of LTF and LAF in a randomized clinical trial in which 94 patients were included, and of which the results are in line with the outcome of the present physiological study, demonstrating no significant differences in symptomatic outcome, including a comparable incidence of gas-related symptoms, or in objective outcome (routine upper gastrointestinal endoscopy, esophageal manometry, and 24-h pH monitoring) between the two procedures.[9] In the present study, all fundoplications were performed by a single surgeon, with experience in performing both types of partial fundoplication. Therefore, the risk of bias based on experience is low.

Another possible limitation is the fact that the physiological effects of both types of partial fundoplication were not directly compared to those of LNF. However, this has previously been performed by Broeders et al., who directly compared the outcome LTF versus LNF using 24-h combined pH-impedance monitoring,[16] and two recent meta-analyses comparing the outcome of LTF with LNF[4] and LAF with LNF.[8] Due to the superior outcome of LTF and LAF compared to LNF with regard to the postoperative incidence of dysphagia and gas-related symptoms, and equivalent reflux control demonstrated by these level Ia studies, LNF is no longer being regarded the procedure of choice for primary antireflux surgery in the Netherlands.

Conclusion

In conclusion, this study demonstrates that LTF and LAF provide equal reflux control, with a comparable effect on reflux episodes and belching. Both procedures equally reduced the number of belches and supragastric belches. The present study provides the physiological evidence for the previously published randomized trials reporting equal symptomatic outcome after both types of partial fundoplication.[9,39] The choice for performing LTF or LAF should be based on the surgeon's experience with either procedure. Long-term follow-up of both randomized clinical trials as well as physiological studies comparing LTF and LAF need to confirm equivalence of both partial fundoplications at the long term.

Author Contribution Authors J.E. Oor, J.A. Broeders, D.J. Roks, J.M. Oors, B.L. Weusten, A.J. Bredenoord, and E.J. Hazebroek made substantial contributions to the conception and design of the work, acquisition, analysis and interpretation of data for the work, drafting and revising it critically for important intellectual content, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Compliance with Ethical Standards

The protocol of this study was approved by the research ethics committee of the participating hospital.

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