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ABSTRACT

Background Laparoscopic Nissen fundoplication (LNF) is the most frequently performed operation for gastro-oesophageal reflux disease (GORD). However, 12% of the patients have persistent reflux symptoms and 19% develop gas-related symptoms after LNF. Weakly acidic reflux and inability to belch have been alleged to cause these symptoms, respectively. The effect of LNF on weakly acidic reflux and (supra) gastric belching was evaluated.

Methods In 31 patients upper gastrointestinal endoscopy, stationary oesophageal manometry and 24-h impedance–pH monitoring off acid secretion inhibiting drugs was performed before and 6 months after primary LNF for GORD that was refractory to proton pump inhibitors. Patients filled out validated questionnaires on GERD-HRQoL before and 3, 6 and 12 months after surgery.

Results LNF reduced reflux symptoms (18.6→1.6; $p=0.015$). The procedure drastically reduced the incidence (number per 24 h) of acid (76.0→1.6; $p<0.001$) and weakly acidic (13.6→5.7; $p=0.001$) as well as liquid (53.4→5.4; $p<0.001$) and mixed reflux episodes (36.3→1.9; $p<0.001$). In contrast, gas reflux was reduced to lesser extent (35.6→25.7; $p=0.022$). Proximal, mid-oesophageal and distal reflux were reduced to a similar extent. Persistent GORD symptoms were neither preceded by acid nor by weakly acidic reflux. The number of air swallows did not change, but the number of gastric belches (GBs) was greatly reduced (68.5→23.9; $p<0.001$). Twenty-three patients had supragastric belches (SGBs), both before and after surgery, whereas eight patients had no SGBs at all. The majority of SGBs were not reflux associated and the frequency was greatly increased after LNF (20.8→46.0; $p=0.036$). Reflux-associated SGBs were abolished after surgery (14.0→0.4; $p<0.001$).

Conclusions LNF similarly controls acid and weakly acidic reflux, but gas reflux is reduced to lesser extent. Persistent reflux symptoms are neither caused by acid nor by weakly acidic reflux. LNF alters the belching pattern by reducing GBs (air venting from stomach) and increasing SGBs (no air venting from stomach). This explains the increase in belching experienced by some patients after LNF, despite the reduction in gastric belching. It can be hypothesised that the reduction in GBs after LNF incites patients to increase SGBs in a futile attempt to vent air from the stomach.

Significance of this study

What is already known about this subject?
- Laparoscopic Nissen fundoplication (LNF) is the most frequently performed operation for gastro-oesophageal reflux disease (GORD).
- It is controversial whether weakly acidic reflux causes reflux symptoms that persist in 12% of the patients.
- Nineteen per cent of patients develop gas-related symptoms after LNF, allegedly due to an inability to belch.

What are the new findings?
- LNF similarly controls acid and weakly acidic reflux, but gas reflux is reflux is reduced to lesser extent.
- Persistent symptoms are neither caused by acid nor weakly acidic reflux, but in one-third of the patients by belches.
- LNF alters the belching pattern by reducing gastric belches (GBs) and increasing supra-gastric belches (SGBs).
- This explains the increase in belching experienced by some patients after LNF, despite the reduction in gastric belching.

How might it impact on clinical practice in the foreseeable future?
- The diagnostic work-up of symptoms that persist after LNF should not be limited to acid and weakly acidic reflux and should include evaluation of belching.
- The results of this study might contribute to the decision to perform partial rather than complete fundoplication: smaller decrease in GBs and fewer gas-related symptoms.

INTRODUCTION

Laparoscopic Nissen fundoplication (LNF) is the most frequently performed operation for gastro-oesophageal reflux disease (GORD).[1] LNF has been recommended as the surgical therapy of choice by both the European Study Group for Antireflux Surgery[2] and the Society of American Gastrointestinal Endoscopic Surgeons.[3] However, a recent meta-analysis has demonstrated that 12% of the patients report refractory reflux symptoms after LNF.[4] Weakly acidic reflux has been alleged to be the main cause of persistent reflux complaints. In the last 3 years, four studies have been conducted that evaluated acid and weakly acidic reflux after fundoplication using 24 h combined intraluminal impedance–pH monitoring. However, results of the four previous studies are contradictory with regard the effect of fundoplication on weakly acidic reflux and its role as the main cause of refractory reflux symptoms.[5–8]

Three meta-analyses demonstrated that gas-related symptoms are the most common complaint after LNF.[4 9 10] Fifteen per cent of the patients develop the inability to belch[4], 19% develop gas bloating[9] and 59% report flatulence after LNF.[10] Gastric belching is a physiological mechanism that serves to vent ingested air from the stomach. Accumulation of swallowed air[11] causes distention of the proximal stomach which results in a transient relaxation of the lower oesophageal sphincter (TLOSR) by a vagally mediated reflex.[12–15] During a TLOSR air can be vented from the stomach. It is commonly assumed that an inability to vent air from the stomach by gastric belching is the cause of the gas-related symptoms that frequently occur after LNF.[11 16–21] Others, however, have suggested that gas-related symptoms are due to excessive air swallowing after fundoplication.[22] Until now, belching after fundoplication has only been studied indirectly using measurement of belched gas volumes[20] or manometric evaluation of the so-called common cavity phenomenon.[17 23–25] Two papers from Adelaide, Australia, have described that patients who have undergone fundoplication often report that they are still able to belch in the absence of TLOSRs and common cavities.[17 23] Therefore, it was hypothesised that the mechanism of belching is different after fundoplication and that belches consisted of swallowed air that has been retained in the oesophagus due to failed peristalsis.[23]

Intraluminal impedance monitoring has made it possible to detect the passage of air through the oesophagus, either in the aboral or oral direction.[26 27] This technique enables one to identify all individual air swallows and belches during a prolonged period of time and to discriminate gastric belches (GBs) from supragastric belches (SGBs). GBs are accompanied by TLOSRs and result in venting of air from the stomach. Our group has demonstrated that SGBs originate from oesophageal air ingestion, usually brought about by creating a negative intrathoracic pressure while closing the glottis, followed by immediate expulsion of this air in oral direction.[28] In contrast to GBs, SGBs are not accompanied by TLOSRs and air venting from the stomach.[28] Excessive supragastric belching is a behavioural disorder which benefits from speech therapy.[29] We have subsequently shown that SGBs occur more frequently in patients with GORD than in healthy subjects and these belches often occur in close association with acid and weakly acidic reflux episodes. In fact, supragastric belching elicits reflux in some cases and is the patient's response to an unpleasant oesophageal sensation in others.[30] The four previous studies that addressed effect of LNF on weakly acidic reflux using impedance monitoring have yielded opposing results and have not evaluated the impact of LNF on belching.[5–8] Therefore, the current study aimed to evaluated the effect of LNF on weakly acidic reflux and gastric and supragastric belching.

METHODS

Study design and data collection

From January 2008 to December 2009, all patients who underwent impedance–pH monitoring and were on the waiting list for primary LNF were included prospectively. Preoperative data, clinical outcome and the results of objective investigations were prospectively entered into a computerised database by an independent data manager (HGR).

Surgical procedures

All LNFs were performed between January 2008 and December 2009. In all patients a standardised, floppy 360° LNF of 2.5–3.0 cm was constructed after ligation and division of the short gastric vessels, full mobilisation of the oesophagus and posterior crural repair.[31–33] LNF was performed by two surgeons beyond the learning curve for LNF,[34] either at the University Medical Center Utrecht (EJH and IAMJB) or the tertiary teaching hospital; Meander Medical Center (IAMJB).

Clinical assessment

Before surgery and at 3 months, 6 months and 12 months after surgery, patients were asked by telephone to complete validated questionnaires by mail. Reflux symptoms were assessed using the GERD Health-Related Quality of Life score (GERD-HRQoL) that has been validated[35] and compared to physiological parameters.[36] The European Organisation for Research and Treatment of Cancer QLQ-OES 18 questionnaire was used, as it has been validated for the detection of changes in dysphagia.[37] The validated Short-Form 36 (SF-36)[38] and a visual analogue scale (VAS) validated for quality of life (QoL) assessment after oesophageal surgery[39] were used to measure the impact on QoL.

Upper gastrointestinal endoscopy

Before surgery and 6 months after surgery, patients underwent upper gastrointestinal (GI) endoscopy at the department of Gastroenterology of the University Medical Center Utrecht. Hiatal hernia size and the Los Angeles classification oesophagitis grade[40] were determined endoscopically.

Stationary oesophageal manometry

All manometric recordings were conducted after suspending medication that potentially affects gastrointestinal motility 7 days in advance and were performed by two senior clinicians of the Gastrointestinal Research Unit of the University Medical Center Utrecht (JO and JS). A water-perfused system with a multiple-lumen catheter with an incorporated sleeve sensor was used (Dentsleeve International, Mississauga, Ontario, Canada). After transnasal introduction, the catheter was retracted to determine the proximal border of the lower oesophageal sphincter (LOS). The sleeve sensor was positioned at the level of the LOS and intraluminal oesophageal pressures were recorded at 5, 10, 15, 20 and 25 cm above the proximal margin. Thereafter, the manometric response to ten standardised wet swallows was studied (5 ml water bolus). The gastric baseline pressure was registered 2 cm below the distal margin of the sleeve sensor and served as the zero reference point.

Ambulatory 24-h combined oesophageal impedance–pH monitoring

Ambulatory 24-h oesophageal impedance–pH testing was performed in the University Medical Center Utrecht. A combined impedance–pH catheter (VersaFlex; Alpine Biomed, Fountain Valley, California, USA) was introduced transnasally, after cessation of at least 7 days of all medication that affects gastrointestinal motility and secretion. This catheter has a single antimony pH electrode and eight ring electrodes for recording of impedance signals. The catheter was positioned with the pH electrode at 5 cm and the impedance recording segments at 2–4, 4–6, 6–8, 8–10, 14–16 and 16–18 cm above the manometrically determined upper margin of the LOS. The tracings were recorded in a digital data logger (Medical Measurements Systems, Enschede, The Netherlands), using a sampling frequency of 50 Hz.[41] Patients were instructed to register body position, GORD symptoms, meals and beverages in a diary. In addition, they were asked to press a button on the digital data logger at the beginning of each symptom episode. If the patients experienced symptoms during the measurement, the symptom

index (SI) was calculated separately for all reflux events, GBs and SGBs. A SI of at least 50% was considered to be positive.[42]

Data analysis

The analysis of the 24-h impedance–pH recordings was performed manually by a single observer (JAJLB) using a dedicated software program (MMS, Enschede, The Netherlands). In case of uncertainty another expert observer was consulted (AJB). To minimise observer bias, both observers were blinded for patient characteristics and preoperative or postoperative status. The criteria used for classification of air-containing swallows (air swallows), gas, liquid, mixed, acid and weakly acidic reflux have been published before.[5] Normal values for total, acid and weakly acidic reflux episodes were 75, 50 and 33 per 24 h respectively.[43] In addition, the proximal extent of the refluxate, in centimetres, above the LOS was determined for each individual reflux episode. Liquid-containing reflux episodes (pure liquid and mixed reflux) were classified as proximal (≥15 cm above LOS), mid-oesophageal (5–15 cm above LOS) or distal (≤5 cm above LOS), based on the extent of the liquid component. The mean proximal extent and the total oesophageal reflux distance (TORD) were calculated for liquid-containing reflux episodes. The latter is the sum of the proximal extent of all individual reflux episodes, in centimetres, above the LOS.

Gas-containing reflux episodes (pure gas and mixed liquid–gas reflux episodes) were regarded as GBs if the gas component reached the most proximal channel.[44] SGBs were identified using the criteria described by Bredenoord *et al*[28] A SGB was defined as a rapid rise in impedance (≥1000 Ω) moving in an aboral direction, followed by a return to baseline moving from distally to proximally. This pattern reflects expulsion of air after rapid oesophageal air ingestion. SGBs were considered to be related to reflux when a SGB occurred immediately prior (<1 s) to the onset of the reflux episode or during a reflux episode, with the onset of the SGB within 10 s after the start of the reflux episode.[30] The number of air swallows, reflux episodes and belches were normalised to a 24 h period. Periods of meal consumption were disregarded. Reference values for the number of air swallows, GBs and SGBs were those of healthy volunteers: 176, 33 and 2 per 24 h respectively.[30 44]

Statistical analysis

The statistical analysis was performed using SPSS version 15.0 (SPSS Inc). Continuous variables were expressed as mean±SEM unless stated otherwise. The Wilcoxon signed rank test was used to determine significant effects of surgery. Comparisons between the SGB− and SBG+ group for either pre- or postoperative data were performed using the Mann–Whitney U test. Differences with a $p<0.050$ were considered statistically significant.

RESULTS

Subjects

Thirty-one patients with PPI-refractory GORD with pathological acid exposure on pH monitoring were studied (11 men: mean age 48 years, range 26–67 years). Mean body mass index was 28.0 (1.1) and mean hiatal hernia size was 2.1 (0.4) cm at baseline.

Upper GI endoscopy and stationary oesophageal manometry

Before surgery, 15 patients had oesophagitis and 16 patients had non-erosive GORD. After LNF, oesophagitis was found to be healed in all but five patients, one patient refused postoperative upper GI endoscopy (table 1). These six patients all had a total oesophageal acid exposure time of <1.5% and fewer than 11 reflux episodes on postoperative impedance–pH monitoring. All patients underwent pre- and postoperative manometry. LNF increased LOS resting pressure (1.2 (0.1) to 2.0 (0.2) kPa; p=0.002) and LOS relaxation nadir pressure (0.2 (0.0) to 0.9 (0.1) kPa; p<0.001), but distal contraction amplitude did not increase significantly (9.2 (0.5) to 10.5 (1.0) kPa; NS).

Table 1 Grade of oesophagitis

Grade	Preoperative (n=31)	Postoperative (n=30)
None	16	25
Grade A	8	3
Grade B	4	2
Grade C	2	0
Grade D	1	0

Control of acid and weakly acidic reflux

All patients completed pre- and postoperative oesophageal impedance–pH testing. LNF reduced upright (15.5 (1.3) to 1.5 (0.4); p<0.001), supine (11.3 (2.3) to 0.8 (0.6); p<0.001) and total (13.8 (1.3) to 1.1 (0.4); p<0.001) acid exposure time. Impedance–pH monitoring demonstrated that LNF led to an impressive decrease in total number of reflux episodes below normal values (−92%; 89.6 (6.7) to 7.3 (0.9); p<0.001), with a similar reduction of acid (76.0 (5.5) to 1.6 (0.7); p<0.001) and weakly acidic reflux (13.6 (2.8) to 5.7 (0.7); p=0.001). LNF greatly decreased liquid (−90%; 53.4 (5.1) to 5.4 (0.8); p<0.001) and mixed reflux (−95%; 36.3 (3.8) to 1.9 (0.5); p<0.001), with no differences in control of acid and weakly acidic reflux. The decrease in gas reflux was far less pronounced, albeit statistically significant (−28%; 35.6 (3.9) to 25.7 (5.7); p=0.022). Details on reflux events are given in table 2.

The reduction in proximal (−93%; 34.0 (4.8) to 2.4 (0.4); p<0.001), mid-oesophageal (−91%; 49.9 (4.5) to 4.4 (0.7); p<0.001) and distal reflux was similar (−91%; 5.6 (0.9) to 0.5 (0.3); p<0.001), with no differences between acid and weakly acidic reflux. LNF greatly reduced the TORD (−92%; 1025 (88.8) cm to 78.9 (9.5) cm; p<0.001) and the proportional reduction was the same as the reduction in total reflux episodes (−92%). Surgery did not change mean proximal reflux extent (−4.4%; 11.3 (0.3) cm to 10.8 (0.6) cm; NS). Details on reflux extent are given in table 3.

Belching

There were two patients who developed excessive air swallowing and gastric belching after surgery; these patients have been marked in figure 1A,B. The number of air swallows was

Table 2 Number of liquid, mixed and gas reflux events per 24 h

Event	Preoperative (n=31)	Postoperative (n=31)	Change (%)	p Value
Total reflux episodes	**89.6 (6.7)**	**7.3 (0.9)**	**−92**	**<0.001**
Acid reflux	76.0 (5.5)	1.6 (0.7)		<0.001
Weakly acidic reflux	13.6 (2.8)	5.7 (0.7)		0.001
Liquid reflux	**53.4 (5.1)**	**5.4 (0.8)**	**−90**	**<0.001**
Acid reflux	44.6 (4.4)	1.3 (0.6)		<0.001
Weakly acidic reflux	8.7 (1.9)	4.2 (0.6)		0.017
Mixed reflux	**36.3 (3.8)**	**1.9 (0.5)**	**−95**	**<0.001**
Acid reflux	31.3 (2.9)	0.4 (0.2)		<0.001
Weakly acidic reflux	4.9 (1.5)	1.5 (0.4)		0.002
Gas reflux	**35.6 (3.9)**	**25.7 (5.7)**	**−28**	**0.022**

Table 3 Extent of liquid-containing reflux events per 24 h, total oesophageal reflux distance (TORD) and mean proximal reflux extent

Event	Preoperative (n=31)	Postoperative (n=31)	Change (%)	p Value
Proximal reflux	**34.0 (4.8)**	**2.4 (0.4)**	**−93**	**<0.001**
Acid reflux	29.2 (3.6)	0.4 (0.2)		<0.001
Weakly acidic reflux	4.8 (2.0)	2.0 (0.4)		0.034
Mid-oesophageal reflux	**49.9 (4.5)**	**4.4 (0.7)**	**−91**	**<0.001**
Acid reflux	42.5 (4.0)	0.9 (0.4)		<0.001
Weakly acidic reflux	7.5 (1.3)	3.5 (0.5)		0.004
Distal reflux	**5.6 (0.9)**	**0.5 (0.3)**	**−91**	**<0.001**
Acid reflux	4.3 (0.7)	0.3 (0.2)		<0.001
Weakly acidic reflux	1.3 (0.4)	0.2 (0.1)		0.003
TORD (cm)	**1025 (89)**	**78.9 (9.5)**	**−92**	**<0.001**
Mean proximal reflux extent (cm)	**11.3 (0.3)**	**10.8 (0.6)**	**−4.4**	**0.281**

higher than the reference value and was not affected by the operation (figure 1A: 432 (33) to 430 (48); NS). GBs were present in all patients before surgery and were completely abolished in three patients after surgery. Before surgery the number of GBs was higher than the normal value and decreased markedly below the reference value after surgery (figure 1B: −65%; 68.5 (4.3) to 23.9 (5.8); p<0.001). Supragastric belching was patient dependent: 23 patients had SGBs both before and after LNF (SGB+), whereas eight patients did not exhibit any SGBs, neither before nor after LNF (SGB−). Post-hoc analysis of the patients with and without SGBs did not reveal any differences in demographics: hiatal hernia size, oesophagitis grade, manometry parameters, air swallows and reflux episodes. The only difference between patients with SGBs and without SGBs was a lower number of GBs (63.5 (4.5) vs 82.9 (8.9); p=0.043) and gas reflux (29.6 (3.9) vs (52.9 (7.3); p=0.010) before LNF in SGB+ patients, compared to SGB− patients. In SGB+ patients, SGBs were well above normal values before and after surgery. Preoperatively, the majority of the SGBs was not reflux associated. The number of SGBs not associated with reflux doubled after fundoplication (figure 1C: +121%; 20.8 (6.3) to 46.0 (18); p=0.036). Reflux-associated SGBs were virtually abolished by LNF: both SGBs immediately preceding reflux episodes (−96%; 5.0 (1.4) to 0.2 (0.1); p=0.001) and SGBs during reflux episodes (−98%; 9.0 (2.3) to 0.2 (0.2); p<0.001) were eliminated almost completely by LNF. Details on belching are given in table 4.

Table 4 Air swallows, gastric belches and supragastric belches (SGBs) per 24 h

	Preoperative	Postoperative	Change (%)	p Value
Air swallows (n=31)	432 (33)	430 (48)	−0.6	0.185
Gastric belches (n=31)	68.5 (4.3)	23.9 (5.8)	−65	<0.001
SGBs not associated with reflux (n=24)	20.8 (6.3)	46.0 (18)	+121	0.036
SGBs associated with reflux (n=24)				
SGBs preceding reflux episode	5.0 (1.4)	0.2 (0.1)	−96	0.001
SGBs during reflux episode	9.0 (2.3)	0.2 (0.2)	−98	<0.001

Symptomatic outcome

LNF reduced reflux symptoms (GERD-QoL: 18.6 (2.7) to 1.6 (0.7); p=0.015) and dysphagia (34.4 (2.1) to 22.4 (1.2); p=0.018). QoL increased after LNF according to the VAS score (50.2 (5.2) to 71.5 (4.0); p=0.051) and the SF-36 score (54.4 (5.6) to 72.1 (4.8); p=0.021). Details on symptomatic outcome are given in table 5. There were 15 patients who reported persistant GORD symptoms during postoperative impedance−pH monitoring, whereas 16 patients were asymptomatic. The 15 patients reported 86 symptoms of which only two were related to acid reflux and one was related to weakly acidic reflux. None of the patients had a positive SI for acid and weakly acidic reflux after LNF. Of the 83 symptoms that were not reflux related, 13 belch symptoms and two heartburn symptoms were related to GBs. Of the 83 symptoms, another 20 belching symptoms and four heartburn symptoms were related to SGBs. As a result, three out of 15 patients had a positive SI for belch symptoms and GBs and another two out of 15 patients had a positive SI for belch symptoms and SGBs after LNF. Only one of those five patients reported belching symptoms before surgery. The two patients who developed excessive air swallowing and gastric belching after surgery (marked in figure 1A,B), both had a positive symptom index for belching symptoms and GBs. Both patients developed belching symptoms and hyperflatulence and one of the two also had gas bloating symptoms after surgery.

DISCUSSION

Laparoscopic Nissen fundoplication (LNF) is the most frequently performed operation for GORD.[1] However, recent meta-analyses have demonstrated that a substantial number of patients report

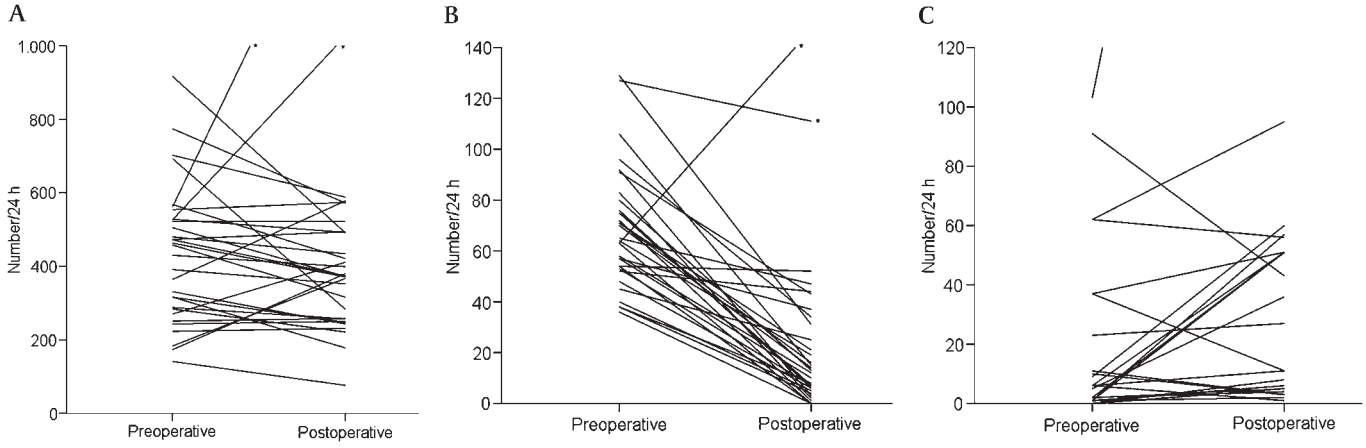

Figure 1 Number of air swallows (n=31), gastric belches (n=31) and supragastric belches not associated with reflux (n=24). (A) Air swallows. *The two patients who developed excessive air swallowing and gastric belching after surgery. (B) Gastric belches. *The two patients who developed excessive air swallowing and gastric belching after surgery. (C) Supragastric belches not associated with reflux.

Table 5 Reflux symptoms (GERD-HRQoL), dysphagia (QLQ-OES 18) and quality of life (Short-Form 36 and VAS score)

	Preoperative	3 months	6 months	12 months
Reflux symptoms				
GERD-HRQoL	18.6 (2.7)	4.3 (1.6)*	2.4 (1.0)*	1.6 (0.7)*
Dysphagia				
QLQ-OES18	34.4 (2.1)	29.2 (1.7)*	27.3 (1.7)*	24.4 (1.2)*
Quality of life				
VAS score	50.2 (5.2)	52.2 (4.3)	54.6 (5.1)	71.5 (4.0)†
Short-Form 36	54.4 (5.6)	64.3 (4.3)	70.1 (5.2)	72.1 (4.8)*

*$p<0.050$ versus preoperative.
†$p=0.051$ versus preoperative.
GERD-HRQoL, GERD Health-Related Quality of Life score; VAS, visual analogue scale.

gas-related symptoms and persistent refractory reflux symptoms after this procedure.[4 9 10] Inability to belch has been postulated to cause the gas-related symptoms, but the impact of fundoplication on belching has only been evaluated indirectly.[17 20 23–25] Weakly acidic reflux has been alleged to be the main cause of persistent reflux complaints. Until now, four studies have evaluated the effect of fundoplication on acid and weakly acidic reflux. The results of these studies are contradictory, as two studies[7 8] report that the operation mainly reduces acid reflux and that the persistence of weakly acidic reflux causes postoperative reflux symptoms, whereas the other two studies[5 6] demonstrate a similar reduction in acid and weakly acidic reflux episodes.

The four previous studies have distinct limitations. The first study did not evaluate the effect of fundoplication on acid and weakly acidic reflux, as preoperative impedance–pH monitoring was not performed (n=36).[8] The two subsequent studies had limited sample sizes (n=14 and n=15)[5 6] and the fourth study did not analyse reflux events manually (n=38).[7] Since automated analysis of impedance signals is not yet sufficiently reliable, manual evaluation of oesophageal impedance tracings is the 'gold standard' for diagnosing GORD.[45] To resolve the controversy regarding control of acid and weakly acidic reflux, the current study combined preoperative and postoperative impedance recordings, manual analysis and an adequate sample size.

The current study demonstrates that fundoplication similarly reduces acid and weakly acidic reflux and therefore rejects the hypothesis that persisting reflux symptoms are mainly caused by weakly acidic reflux. In addition, the current results show that refractory GORD symptoms are neither caused by acid nor by weakly acidic reflux. Belching seems to be a more important cause of persistent complaints, as one-third of the symptomatic patients have a positive relationship between post-fundoplication symptoms and GBs or SGBs.

The previous studies are also contradictory regarding the effect of fundoplication on gas- and liquid-containing reflux. One study found that fundoplication selectively reduces reflux episodes as the reduction in liquid-containing reflux episodes was larger than the reduction in gas episodes.[5] However, the two other studies that evaluated gas reflux did not support this observation.[6 8] Our findings support the results of the first study as the reduction of liquid-containing reflux was three times larger than the reduction of pure gas reflux. This finding is in line with a study that demonstrated that gas passes the oesophagogastric junction more easily than liquids.[46]

Not every reflux episode is perceived as a symptom by the patient and the reduction of the number of reflux episodes is not the only factor that determines the effectiveness of anti-reflux surgery: the proximal extent of a reflux is important as well.[47] Only one study has evaluated the effect of fundoplication on proximal and distal reflux.[5] The current report combined the quantity and extent of the reflux episodes by calculating the TORD. The reduction in TORD and the reduction in total reflux episodes were similar, indicating that the effect of surgery was not selective for proximal or distal reflux. This was confirmed by the fact that the reductions in proximal, mid-oesophageal and distal reflux were comparable as well, with a similar mean proximal reflux extent before and after surgery. The reduction in reflux episodes lead to the elimination SGBs associated with reflux after surgery. Both SGBs that elicit reflux (SGBs immediately preceding reflux episodes) and SGBs in response to unpleasant oesophageal sensations (SGBs during reflux episodes) were abolished.

The four studies that evaluated the effect of fundoplication using impedance monitoring did not evaluate the effect of fundoplication on belching.[5–8] Previous studies that evaluated belching after fundoplication were methodologically limited by the fact that belches were recorded indirectly, using an experimental method to quantify belched volumes[20] or manometric common cavities.[17 23–25] Four of these studies[20 23–25] evaluated post-fundoplication patients and only one study[17] compared belching before and after surgery. As a result, the current report is the first study to directly evaluate the impact of fundoplication on belching. In addition, previous studies provoked belching by gas insufflation and recorded belches for less than an hour.[17 20 23–25] Rapid air infusion of a large volume of air (750–1200 ml) into the stomach does not resemble normal physiology in which swallows transport small volumes of air to the stomach. In contrast, the current study evaluated the effect on belching for 24 h in a physiological setting, without gastric distention.

It has long remained unclear why patients who had undergone fundoplication reported the ability to belch, while TLOSRs and common cavities were found to be absent in these patients.[17 23] The absent correlation between subjective and objective belching was not understood either.[17 20 23 25] The first part of the hypothesis that has been formulated to explain this discrepancy has been confirmed by the current results, by demonstrating that fundoplication alters the belching pattern from GBs to SGBs.[23] Our results demonstrate that patients with SGBs have fewer GBs before surgery, compared to patients without SGBs. On the intra-patient level, the reduction in GBs by LNF is accompanied by an increase in SGBs after surgery. Since GBs allow air to be vented from the stomach whereas SGBs do not and fundoplication reduces gastric belching and does not alter the number of air swallows, gas bloating and flatulence are increased after fundoplication. It can be hypothesised that the gas bloating induced by a decrease in GBs elicits post-fundoplication patients to actively increase the number of SGBs in a futile attempt to vent gas. This behaviour can be explained by the fact that patients associate all belches with relief of gas bloating, as they cannot discriminate GBs (air venting from stomach) from SGBs (no air venting from stomach). This hypothesis needs to be confirmed by a large study that focuses on impedance patterns and gastric air volumes postoperatively and compares symptomatic and asymptomatic patients.

TLOSRs are the major mechanism permitting the venting of air from the stomach and fundoplication reduces of the number of TLOSRs triggered by the proximal stomach.[5] It has previously been demonstrated that the TLOSR rate is higher after partial fundoplication compared to total fundoplication.[48] A study on manometric common cavities demonstrated that the reduction of GBs is less after Toupet (posterior partial) fundoplication,

compared to Nissen (posterior total) fundoplication.[24] A recent meta-analysis has demonstrated that reflux control is similar after Toupet and Nissen fundoplication.[4] Toupet fundoplication is likely to be associated with a smaller decrease in GBs and fewer severe gas-related symptoms after surgery. An impedance study that directly compares the effect of Toupet and Nissen fundoplication on GBs has yet to confirm this potential benefit of partial fundoplication.

The inter-observer agreement between experienced reviewers for the evaluation of total reflux episodes, weakly acidic reflux and proximal reflux extent are k 0.80, k 0.70 and k 0.76 respectively.[49 50] In the present study and a similar study[5] it was sometimes difficult to interpret impedance tracings, in particular postoperatively. In 70% of the patients the second reviewer was consulted, in the majority of the cases (50%) more than once in the same patient. It was sometimes particularly difficult to distinguish weakly acidic reflux from small elevation of the sphincter complex without reflux, which may have contributed to the high rate of weakly acidic reflux in some of the previous impedances studies post-fundoplication. The inter-observer agreement for impedance–pH monitoring post-surgery and for differentiating gastric and supragastric belching has not been reported so far. The identification of GBs and SGBs was not particularly difficult, due to the marked rise in impedance ($\geq$1000 Ω) we used as cut-off point and the high sample frequency.[28] The sample frequency is of particular importance to distinguish events with high propagation velocity, such as GBs and SGBs. A minimum sample frequency of 50 Hz enables aboral movement of gas to be distinguished from oral movement in 100% of the belches.[41]

In conclusion, LNF similarly controls acid and weakly acidic reflux, but gas reflux is reduced to lesser extent. Persistent reflux symptoms are caused neither by acid nor by weakly acidic reflux. However, one-third of the symptomatic patients have a positive relationship between post-fundoplication symptoms and GBs or SGBs. LNF alters the belching pattern by reducing GBs (air venting from stomach) and increasing SGBs (no air venting from stomach). This explains the increase in belching experienced by some patients after LNF, despite the reduction in gastric belching. It can be hypothesised that the reduction in GBs after LNF incites patients to increase SGBs in a futile attempt to vent air from the stomach to reduce postoperative bloating.

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Editor's quiz: GI snapshot

An unusual elevated lesion of the oesophagus

CLINICAL PRESENTATION

A 44-year-old man with a history of gastric cancer that was treated with distal gastrectomy 4 years ago underwent upper endoscopic examination in a follow-up study. The endoscopic examination revealed an elevated lesion 8 mm in size in the lower oesophagus (figure 1A) and narrow band imaging (NBI) endoscopy showed vascular augmentation as brownish spots on the surface of the elevated lesion (figure 1B). There was no abnormality in the stomach and oesophagus—squamous junction. Physical examination and a routine blood test, including tumour markers, showed no abnormal findings. Whole body computed tomography (CT) detected no abnormalities. A biopsy of the lesion was performed.

QUESTION

What is the diagnosis?

See page 516 for answer

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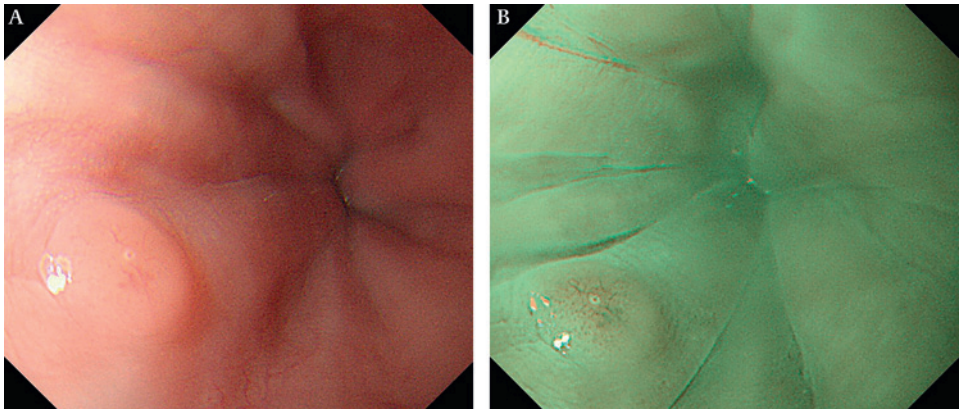

Figure 1 (A) Endoscopic photograph of the lower oesophagus showing an elevated lesion. (B) Narrow band imaging (NBI) endoscopy displaying brownish spots on the surface of the lesion.

Effects of anti-reflux surgery on weakly acidic reflux and belching

J A J L Broeders, A J Bredenoord, E J Hazebroek, et al.

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