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Gas-related symptoms after antireflux surgery

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Abstract
Background Gas-related symptoms such as bloating, flatulence, and impaired ability to belch are frequent after antireflux surgery, but it is not known how these symptoms affect patient satisfaction with the procedure or what determines the severity of these complaints. We aimed to assess the impact of gas-related symptoms on patient-perceived success of surgery and to determine whether the severity of gas-related complaints after antireflux surgery is associated with objectively measured abnormalities.
Methods Fifty-two patients were studied at a median of 27 months after antireflux surgery. The influence of gas-related symptoms on their quality of life and satisfaction with surgical outcome was assessed. The rates of air swallows and gastric and supragastric belches before and after surgery were assessed using impedance measurements.
Results Bloating and flatulence were associated with a decreased quality of life and less satisfaction with surgical outcome. Notably, 9 % of the patients would not opt for surgery again due to gas-related symptoms. Antireflux surgery decreased the total number of gastric belches but did not affect the number of air swallows. The severity of gas-related symptoms was not associated with an increased number of preoperative air swallows and/or belches or a larger postoperative decrease in the number of gastric belches.
Conclusion Gas-related symptoms are associated with less satisfaction with surgical outcome. The severity of gas-related symptoms is not determined by the number of preoperative air swallows or a more severe impairment of the ability to belch after surgery. Preoperative predictors of postoperative gas-related symptoms therefore could not be identified.

Keywords Gastroesophageal reflux disease · GERD · Antireflux surgery · Fundoplication · Gas-bloat syndrome · Belching · Bloating · Flatulence · Impedance

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Therapy for gastroesophageal reflux disease (GERD) consists of lifestyle modifications and the use of antacids, H_2-antagonists, and proton pump inhibitors (PPIs) [1]. However, a small group of GERD patients has refractory symptoms despite these therapeutic interventions. In this group of patients, antireflux surgery is the only remaining treatment option [2]. Since the first report on fundoplication by Nissen [3] in the 1950s, several variants of the procedure have been introduced. The two procedures that are currently most widely performed are the classical Nissen fundoplication, which consists of a 360° posterior

wrap around the esophagus, and the Toupet fundoplication, which consists of a 270° posterior wrap [4].

The outcome of antireflux surgery is at least comparable with that of medical treatment, and antireflux surgery is associated with high patient satisfaction rates [2, 5–7]. However, side effects such as dysphagia, abdominal bloating, flatulence, and an inability to belch are common side effects after surgery [4, 8]. The development of dysphagia after antireflux surgery has been studied extensively [9]. In contrast, little is known about gas-related symptoms such as bloating, flatulence, and the inability to belch after surgery. In particular, it is unknown to what extent the quality of life and patient satisfaction with the fundoplication are affected by these symptoms.

With each swallow, air enters the esophagus and is transported to the stomach. Distension of the stomach, such as that caused by swallowed air, triggers a vagally mediated reflex known as a transient lower esophageal sphincter relaxation (TLESR) [10]. During a TLESR, the lower esophageal sphincter (LES) relaxes and air is vented from the stomach into the esophagus after which it can be orally expelled. This type of belching, referred to as gastric belching, is the physiological mechanism that enables venting of this ingested gas from the stomach to the esophagus in order to prevent accumulation of intestinal gas [11]. With the use of esophageal impedance monitoring, a second mechanism of belching was identified, the so-called supragastric belch [12]. During a supragastric belch, air is sucked into the esophagus and expelled immediately thereafter (within 1 s), before it has reached the stomach [12]. Whereas the mechanisms of gastric and supragastric belching are completely different, the patient experiences these two types of belches in a similar fashion [13]. Although the pathophysiology of supragastric belching has not been elucidated fully, it has been suggested that patients start supragastric belching as an involuntary response to an unpleasant gastrointestinal (GI) sensation [14].

Bredenoord et al. [15] demonstrated that antireflux surgery results in a decreased rate of TLESRs and of gastric belches. Broeders et al. [16] showed that the incidence of air swallows is not affected by antireflux surgery. The combination of impaired air venting and unaltered air ingestion provides a plausible explanation for gas-related post-fundoplication symptoms such as bloating and flatulence. However, it is unclear why some patients develop severe gas-related symptoms after antireflux surgery and others do not. It can be hypothesized that patients with more severe postoperative gas-related symptoms exhibit more preoperative air swallows and gastric belches and have a larger decrease in gastric belches after surgery.

The aim of this study was to assess the impact of gas-related symptoms on surgical outcome. Furthermore, we aimed to assess whether gas-related complaints after surgery are associated with an increased number of preoperative number of air swallows and/or gastric belches or a larger postoperative decrease in gastric belches.

Methods

Subjects

We contacted all patients who underwent an ambulatory pH-impedance measurement before antireflux surgery between 2008 and 2011 in the Meander Hospital in Amersfoort, the University Medical Centre in Utrecht, and the Academic Medical Centre in Amsterdam. For 42 of the 52 patients who met the criterion, results of pre- and postoperative esophageal impedance monitoring were available since impedance monitoring was performed as part of the follow-up of a study protocol. Part of these data has previously been described [16, 17].

Questionnaires

Questionnaires were completed by telephone interview more than 3 months after surgery. The post-procedural severity of bloating, flatulence, and the inability to belch compared to the severity of these symptoms before surgery was reported using a three-point scale that was defined as none to mild, moderate, or severe. Overall quality of life was assessed by the SF12v2, which consists of a physical- and a mental component summary (QualityMetric, Lincoln, RI, USA) [18]. Furthermore, patients were asked whether complaints of bloating, flatulence or an inability to belch decreased their satisfaction with the overall result of their fundoplication and whether their gas-related symptoms would make them opt out of surgery if the decision were to be made again.

pH-impedance measurements

pH-impedance measurements were performed using a combined pH/impedance catheter assembly which comprised six impedance segments and one ion-sensitive field effect transistor pH electrode (Unisensor AG, Attikon, Switzerland) that was placed 5 cm from the upper border of the manometrically localized LES. Impedance recording segments were located at 2–4, 4–6, 6–8, 8–10, 14–16, and 16–18 cm above the upper border of the LES. Impedance and pH signals were stored on a digital data logger (Ohmega ambulatory pH-impedance recorder, Medical Measurement Systems, Dover, NH, USA), using a sampling frequency of 50 Hz. Measurements were performed after cessation of PPI or H_2-antagonist and medication that could influence GI motility for 7 days.

Postoperative impedance measurements were performed in 42 of the 52 patients.

Esophageal manometry

Esophageal manometry measurements were performed using a water-perfused catheter with an incorporated sleeve sensor (Dentsleeve International Ltd., Mississauga, ON, Canada). 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. Thereafter, the manometric response to ten standardized wet swallows (5-mL water bolus) was studied. LES pressure and residual LES pressure were referenced to the gastric baseline which was registered 2 cm below the distal margin of the sleeve sensor.

Patients were measured while in the supine position, and measurements were performed after cessation of PPI or H_2-antagonist and medication which could influence GI motility for 7 days.

Surgical procedure

The surgical procedures performed in these patients have been previously described [16, 17]. In all patients, a standardized laparoscopic fundoplication was performed that aimed to create a loose valve to minimize postoperative 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 2.5–3.0 cm was constructed after posterior crural repair. A bougie was never used. A 270° laparoscopic posterior fundoplication (LPF) was defined as a posterior fundoplication with a 270° circumference [19] and 360° LPF was defined as a posterior fundoplication with a circumference of 360° [20]. The margins of the 270° wrap were fixed to the esophagus and to the crural arch anterosuperiorly and the wrap was fixed to the crural repair with one or two posterior sutures. One of the sutures of the 360° wrap incorporated the esophageal wall, and the posterior aspect of the wrap was fixed to the crural repair in a fashion identical to that of the 270° wrap.

Data analysis

All 24-h pH-impedance tracings were analyzed manually. Liquid-containing reflux events were identified in the impedance tracings according to previously described criteria [21]. The criteria used for classification of air-containing swallows (air swallows), gastric belches, supragastric belches, and liquid-containing reflux events have also been published before [12, 15, 22].

In summary, gastric belches were defined as a rapid retrograde rise in impedance of $\geq$3,000 Ω in at least two consecutive channels, reaching the most proximal impedance-recording segment [22]. A supragastric belch was defined as a quick antegrade movement of gas of $\geq$1,000 Ω followed by a quick expulsion of gas in the retrograde direction resulting in a return to the baseline impedance level in the retrograde direction [12].

The observer was blinded to patient characteristics and pre- or postoperative status when analyzing the impedance tracings.

Statistical analysis

Throughout this article data are presented as median (IQR). Statistical analysis was performed using Prism software version 5 (Graph Pad, La Jolla, CA, USA). Comparisons between the pre- and postoperative number of belches and air swallows were analyzed using the Wilcoxon signed-rank test. We performed the Kruskal–Wallis test to compare parameters between the three groups of severity of bloating and flatulence, and if a significant difference was found, this was followed by Dunn's post hoc analysis. Moderate and severe symptoms of an inability to belch were relatively rare; therefore, statistical analysis was performed between patients with none to mild symptoms and moderate to severe symptoms. The latter was analyzed using the Mann–Whitney test. Differences were considered statistically significant when $p < 0.05$.

Results

Subjects

Two of the 54 patients could not be contacted due to incorrect contact information. The remaining 52 patients [32 female, mean age = 52 years (26–70)] all completed the questionnaire. Of the patients who participated, 24 patients had undergone a Toupet fundoplication and 28 patients had undergone a Nissen fundoplication. Postoperative impedance measurements and manometry studies were performed in 42 patients. Questionnaire scores were assessed after a median of 27 months (19–31) after surgery.

Patients exhibited a median of 53 (31–79) liquid-containing reflux episodes before surgery and 7 (4–13) liquid-containing reflux episodes after surgery (Table 1) ($p < 0.001$). Esophageal acid exposure time (% time pH <4) significantly decreased from 13 % (9–18) to 0.5 % (0.0–1.9) ($p < 0.001$). The number of air swallows did not differ significantly before and after surgery [378 (260–523) vs. 360 (249–495)].

Table 1 Reflux and air movements through the esophagus, as measured with impedance monitoring, before and after antireflux surgery

	Preoperative	Postoperative	*p* value
Liquid-containing reflux episodes	53 (31–79)	7 (4–13)	<0.001
Acid exposure time	13 (9–18) %	0.5 (0.0–1.9) %	<0.001
Air swallows	378 (260–523)	360 (249–495)	NS
Gastric belches	60 (49–79)	12 (5–35)	<0.001
Supragastric belches	5 (0–33)	6 (0–51)	NS

Outcomes are presented as median (IQR)

NS not significant

The total number of gastric belches was significantly decreased after surgery [60 (49–79) vs. 12 (5–35), $p < 0.001$] (Table 1). This decrease in gastric belches was greater in patients who underwent a Nissen fundoplication than in patients who underwent a Toupet fundoplication [−52 (−64 to −29) vs. −38 (−55 to −18)]; however, this difference was not significant.

The total number of supragastric belches did not differ significantly before and after surgery [5 (0–33) vs. 6 (0–51)] (Table 1). Notably, 14 patients did not exhibit any supragastric belches before surgery and 13 patients did not exhibit any supragastric belches after surgery. In the patients who did exhibit supragastric belches preoperatively, the total number of supragastric belches increased from 25 (3–55) to 44 (5–58); however, this difference was not significant. Moreover, 17 patients exhibited an increase in the total number of supragastric belches whereas 12 patients exhibited a decrease in the total number of supragastric belches.

LES resting pressure was significantly increased after surgery [7.5 (4.1–13.5) vs. 15.0 (9.8–21.0), $p < 0.05$]. Residual LES pressure was also significantly increased after surgery [1.1 (0.0–2.3) vs. 5.3 (2.3–9.4), $p < 0.05$].

Subjective outcomes

Twenty-four patients reported none to mild bloating symptoms, 18 patients reported moderate bloating, and 10 patients reported severe bloating. Severe bloating was more common in patients who underwent a Nissen fundoplication than in those who underwent a Toupet fundoplication (25 vs. 13 %) (Table 2). A significant difference between the physical component of the quality-of-life questionnaire score of patients with none to mild bloating symptoms and patients with moderate or severe bloating symptoms [52 (39–55) vs. 37 (20–47) vs. 24 (20–46), $p < 0.05$] was found (Fig. 1; Table 3). However, the mental component of the quality-of-life questionnaire score did not differ significantly. Furthermore, satisfaction with the outcome after surgery was decreased due to bloating symptoms in 15 % of the patients.

Table 2 Severity of bloating, flatulence, and inability to belch in patients who underwent a Nissen- and/or a Toupet fundoplications

	Toupet ($n = 24$)	Nissen ($n = 28$)	Total	*p* value
Bloating				
None to mild	12 (50)	12 (43)	24 (46)	
Moderate	9 (38)	9 (32)	18 (35)	NS
Severe	3 (13)	7 (25)	10 (19)	
Flatulence				
None to mild	7 (29)	7 (25)	14 (27)	
Moderate	11 (46)	5 (18)	16 (31)	<0.05
Severe	6 (25)	16 (57)	22 (42)	
Inability to belch				
None to mild	17 (71)	24 (86)	41 (79)	
Moderate	4 (17)	1 (4)	5 (10)	NS
Severe	3 (13)	3 (11)	6 (12)	
Time after surgery	19 (15–28)	30 (22–38)	27 (19–31)	<0.05

Time after surgery represents the time (months) between surgery and the questionnaire and is presented as median (IQR). Data on the prevalence of gas-related symptoms are presented as number (percentage)

NS not significant

Fourteen patients reported none to mild flatulence symptoms, 16 patients reported moderate flatulence, and 22 patients reported severe flatulence. Severe flatulence

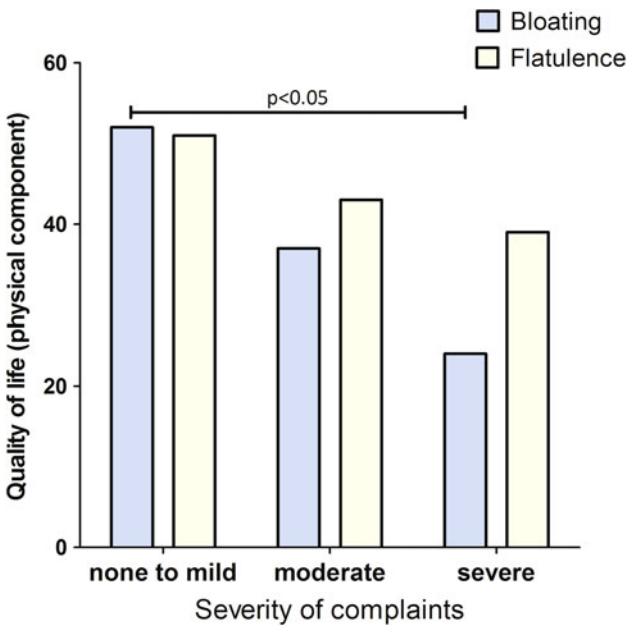

Fig. 1 Impact of symptoms of bloating and flatulence on the physical component of the quality-of-life questionnaire score

Table 3 Quality-of-life scores relative to the severity of gas-related symptoms

	Severity of symptoms			*p* value
	None to mild	Moderate	Severe	
Bloating				
Mental component	59 (54–63)	54 (36–59)	58 (38–64)	NS
Physical component	52 (39–55)	37 (20–47)	24 (20–46)	<0.05
Flatulence				
Mental component	60 (45–65)	60 (54–63)	55 (34–58)	NS
Physical component	51 (33–56)	43 (35–50)	39 (23–54)	NS
Inability to belch				
Mental component	57 (50–63)	54 (40–59)		NS
Physical component	43 (25–54)	45 (34–50)		NS

Data are presented as median (IQR)

NS not significant

symptoms were more common after Nissen fundoplication than after Toupet fundoplication (57 vs. 25 %) (Table 2). No significant differences between the physical or mental component of the quality-of-life questionnaire scores were found between patients with none to mild, moderate, or severe flatulence symptoms (Fig. 1; Table 3). Although not significant, patients with severe flatulence had a lower score for the physical component of their quality-of-life questionnaire than patients with moderate or none to mild symptoms [51 (33–56) vs. 43 (35–50) vs. 39 (23–54)]. Moreover, 19 % of the patients were less satisfied with the outcome after surgery due to flatulence symptoms.

Forty-one patients reported none to mild symptoms of an impaired ability to belch, 5 patients rated their impaired ability to belch as moderate, and 6 patients as severe. The prevalence of severe inability to belch was similar in patients who underwent a Nissen fundoplication compared to a Toupet fundoplication (Table 2). No significant differences between the physical or mental component of the quality-of-life questionnaire scores was found between patients with none to mild and moderate to severe belch impairment (Table 3). Furthermore, 6 % of the patients were less satisfied with the outcome after surgery due to their impaired ability to belch. Notably, the time after surgery was shorter in patients with moderate to severe inability to belch compared patients with none to mild symptoms.

Eight patients reported severe dysphagia, 11 patients reported moderate dysphagia symptoms, and 33 patients reported no symptoms of dysphagia. Severe dysphagia was most often associated with severe bloating (38 %) than with mild symptoms (27 %) or no symptoms of dysphagia (12 %). Furthermore, severe dysphagia was also most often associated with severe flatulence (50 vs. 36 and 39 %) but not a more severely impaired ability to belch.

Notably, 9.6 % of the patients would not opt for surgery again due to gas-related symptoms.

Associations with pre- and postoperative air movement patterns or LES pressure

No significant differences between the preoperative number of gastric belches, supragastric belches, and air swallows were found between patients with none to mild, moderate, or severe bloating symptoms (Table 4). Likewise, no association was found between the preoperative belching and air-swallowing patterns and postoperative flatulence and inability to belch.

Analysis of the association between postoperative air movement patterns (gastric and supragastric belches and air swallows) and the severity of gas-related symptoms (bloating, flatulence, and inability to belch) showed that there were no statistically significant relationships (Table 5). Furthermore, no association was found between the severity of gas-related complaints and the postoperative LES resting pressure or postoperative residual LES pressure.

Discussion

This is the first study in which the impact of gas-related symptoms on the outcome of fundoplication was studied, in conjunction with an analysis of the association between these symptoms and objective pre- and postoperative parameters. We specifically aimed to determine whether postoperative gas-related symptoms are associated with a specific preoperative belching or air-swallowing behavior.

The main contributor to intragastric air is swallowing of air and the main mechanism of venting this ingested air is by gastric belching. We hypothesized that patients with gas-related symptoms after surgery had a greater number of preoperative air swallows and gastric belches or a more severely impaired ability to belch after surgery. However, gas-related symptoms after surgery were not associated

Table 4 Preoperative incidence of gastric belches and air swallows in relationship to the severity of postoperative gas-related symptoms

	Preoperative analysis			*p* value
	None to mild	Moderate	Severe	
Bloating				
Gastric belches	56 (42–75)	72 (54–97)	57 (35–83)	NS
Supragastric belches	11 (4–65)	26 (8–28)	12 (2–44)	NS
Air swallows	300 (239–450)	343 (240–599)	427 (245–523)	NS
Flatulence				
Gastric belches	65 (51–87)	56 (48–68)	64 (47–80)	NS
Supragastric belches	23 (4–62)	28 (5–70)	11 (2–29)	NS
Air swallows	324 (263–501)	254 (180–461)	411 (271–507)	NS
Inability to belch				
Gastric belches	57 (52–77)	75 (27–112)		NS
Supragastric belches	21 (2–59)	17 (7–26)		NS
Air swallows	323 (257–491)	284 (164–561)		NS

Data are presented as median (IQR)

NS not significant

with a greater number of preoperative air swallows or belches. Furthermore, gas-related symptoms were not associated with a lower number of postoperative gastric belches or a larger decrease in the number of gastric belches. These findings suggest that the preoperative incidence of gastric belches or air swallows cannot be used as a predictor of the development of gas-related symptoms after fundoplication.

The LOTUS trial found that postoperative bloating and flatulence occurred in 40 and 57 % of the patients, respectively [23]. Although the data from the LOTUS trial do not assess symptoms of flatulence and bloating using a three-point scale, our data also show a relatively high incidence of gas-related symptoms after surgery, which is comparable to that of the much larger population of the LOTUS trial.

The presence of bloating and flatulence after surgery decreases the satisfaction with surgical outcome and is associated with a decreased quality of life. Moreover, 9 % of the patients who were included in this study would not opt for surgery again due to gas-related symptoms. These findings suggest that gas-related symptoms can have a major impact on surgical outcome. Patients should therefore be carefully informed about the implications and incidence of gas-related symptoms after surgery and the fact that these cannot be predicted beforehand.

Broeders et al. [17] reported that patients who underwent a Nissen fundoplication developed bloating and flatulence more often than patients who underwent a Toupet fundoplication. The patients who underwent a Nissen fundoplication in our study exhibited a twofold increase in the prevalence of severe bloating and flatulence compared to patients who underwent a Toupet fundoplication. However, this reached significance only for flatulence. This suggests that patients who undergo a Nissen fundoplication are more at risk to develop postoperative gas-related symptoms than patients who undergo a Toupet fundoplication. Gas-related symptoms tend to decrease with time after fundoplication. Since the time interval between the telephone interview and the operation date was longer in the group of patients who underwent a Nissen fundoplication compared to patients who underwent a Toupet fundoplication, these results could even be an underestimation of the increased risk to develop gas-related symptoms after Nissen fundoplication. In theory, a different technique to create a fundoplication, such as with the guidance of an endoscopically placed bougie, could influence the occurrence of gas-related symptoms. However, such an analysis is not possible with our available data.

It has previously been suggested that supragastric belching could be a response to an unpleasant retrosternal or abdominal sensation [14]. Furthermore, it has been suggested that supragastric belching is exhibited by patients who underwent antireflux surgery in a futile attempt to vent air from the stomach [16]. It is thus possible that patients could exhibit an increased number of supragastric belches after antireflux surgery. However, the patients in our study did not exhibit an increase in the total number of supragastric belches after surgery. Furthermore, more severe gas-related symptoms were not associated with a larger number of supragastric belches or an increase in the number of supragastric belches. Therefore, supragastric belches do not appear to be associated with gas-related symptoms after antireflux surgery.

Despite that objective findings do not correlate with the severity of gas-related symptoms, antireflux surgery does

Table 5 Results of postoperative impedance monitoring and manometry relative to the severity of gas-related symptoms

	Postoperative analysis			*p* value
	None to mild	Moderate	Severe	
Bloating				
Gastric belches	7 (4–15)	21 (8–47)	8 (4–77)	NS
Δ Gastric belches	−44 (−62 to −20)	−58 (−64 to −32)	−30 (−53 to −20)	NS
Supragastric belches	5 (0–51)	11 (0–61)	8 (1–55)	NS
Δ Supragastric belches	0 (−14 to 3)	0 (0–33)	2 (−10 to 42)	NS
Air swallows	274 (244–417)	380 (283–498)	371 (238–774)	NS
Δ Air swallows	−31 (−86 to 16)	−23 (−198 to 41)	−39 (−95 to 265)	NS
LES pressure	10.5 (7.5–18.0)	18.8 (10.5–22.5)	18.8 (9.4–21.8)	NS
Residual LES pressure	4.5 (1.9–6.8)	5.3 (3.0–10.5)	6.8 (1.5–11.6)	NS
Flatulence				
Gastric belches	10 (3–41)	10 (4–30)	15 (6–39)	NS
Δ Gastric belches	−35 (−19 to −60)	−41 (−13 to −63)	−47 (−21 to −56)	NS
Supragastric belches	28 (0–58)	3 (0–54)	7 (0–51)	NS
Δ Supragastric belches	0 (−14 to 5)	0 (−3 to 8)	1 (−7 to 31)	NS
Air swallows	350 (246–515)	370 (227–474)	338 (264–515)	NS
Δ Air swallows	−58 (−127 to 8)	−1 (−121 to 162)	−35 (−128 to 23)	NS
LES pressure	14.6 (8.1–22.5)	15.8 (9.9–21.6)	13.1 (7.9–20.6)	NS
Residual LES pressure	6.8 (2.6–10.5)	3.4 (0.0–7.3)	6.4 (3.4–9.6)	NS
Inability to belch				
Gastric belches	10 (5–28)	21 (7–102)		NS
Δ Gastric belches	−45 (−62 to −28)	−32 (−61 to −10)		NS
Supragastric belches	8 (1–56)	0 (0–11)		NS
Δ Supragastric belches	0 (−11 to −11)	0 (0–4)		NS
Air swallows	324 (247–434)	494 (255–572)		NS
Δ Air swallows	−31 (−114 to 41)	−11 (−198 to 21)		NS
LES pressure	15 (9.4–20.3)	15 (12.8–22.5)		NS
Residual LES pressure	5.3 (2.6–7.9)	9.0 (2.3–12.8)		NS

Data are presented as median (IQR). LES pressure and residual LES pressure is presented as mmHg

NS non-significant

trigger the development of gas-related symptoms. Abdominal distension, which can be caused by increased intestinal gas, is an objective finding. In contrast, abdominal bloating refers to the subjective sensation of abdominal distension. In healthy subjects, normal gut transit and evacuation prevent gas pooling and symptoms since air in the gut triggers a distension-related reflex [24, 25]. However, when this protective mechanism fails, subjective symptoms, predominantly bloating, may develop in healthy volunteers [24, 25]. Furthermore, the perception of symptoms depends on the motor response of the gut rather than on the volume of retention [26, 27]. Similar to patients who underwent antireflux surgery, patients with irritable bowel syndrome (IBS) often experience troublesome symptoms of bloating [28]. Serra et al. [29] demonstrated that patients with IBS have impaired transit and intolerance to intestinal gas loads which are tolerated by healthy subjects. This impaired gas handling and reduced tolerance could underlie bloating symptoms in patients with IBS.

Our observations suggest that gas-related symptoms after surgery are more likely to be related to impaired gas handling than increased air swallowing or more impaired gastric belching. Therefore, symptomatic patients may be hypersensitive to the increased intestinal gas after surgery due to impaired gas handling. In contrast, non-symptomatic patients may exhibit an adequate gut response which prevents symptoms. This was shown to be even more likely by a retrospective study in which an association was observed between preoperative IBS symptoms such as constipation and diarrhea and postoperative bloating [30].

The main limitation of our study is its retrospective nature, where prospectively collected data from another study were analyzed for the current study. Therefore, no sample size analysis was done before the start of the study. Since the

available data were limited by the number of measurements performed, a type II error could have been made. However, our data show great overlap between the outcomes of the different groups of severity and relatively similar median values. Therefore, we believe that increasing the population is unlikely to result in the identification of preoperative predictors for gas-bloat symptoms based on preoperative impedance measurements. A notable exception is the association between severity of flatulence complaints and quality of life, which shows a trend toward a significant association, and we therefore speculate that a type II error is likely in this analysis. We believe that a type I error in this study is unlikely since inclusion was based on the availability of the measurement and not on the severity of complaints. Furthermore, the decision to perform a pH-impedance measurement was also not based on the presence or severity of symptoms, and the incidence of gas-related symptoms is similar to that in other studies that assessed the severity of gas-related symptoms, thereby further preventing a types I or II error.

A second limitation of this study is the lack of the use of a calibration bougie during the fundoplication procedures that were performed in our study population. A large proportion of surgeons use an intraoperative bougie during the procedure to prevent postoperative complications such as dysphagia [31]. Several studies that have studied the effect of an intraoperative bougie focused mainly on postoperative dysphagia and found conflicting evidence of whether the use of a bougie affected the occurrence of dysphagia [32]. It is currently not clear whether an intraoperative bougie has an effect on the occurrence of gas-related complaints, but it could, in theory, result in a reduction of gas-related complaints. Therefore, future studies on the effect of the use of a bougie on gas-related complaints are warranted.

The pathophysiology of gas-related symptoms is currently not known. Therefore, further research on the pathophysiology of gas-related symptoms after antireflux surgery is warranted. In theory, a patient's preoperative gas intolerance could be a marker for the development of postoperative gas-related symptoms. Future studies should therefore assess the clinical value of a preoperative gas challenge test [25]. Furthermore, there is currently no therapy available that can reduce gas-related symptoms after antireflux surgery. However, our results suggest that reducing the severity and incidence of gas-related symptoms will improve surgical outcome. Prokinetics can reduce gas-related symptoms in IBS patients and patients with functional bloating [33]. In theory, the effect of prokinetics on gas-related symptoms after fundoplication could have similar effects. Therefore, future studies should also assess the application of prokinetics in patients with gas-related symptoms after fundoplication.

In conclusion, our data suggest that severe gas-related symptoms are not associated with a specific belching or air-swallowing behavior but are most likely determined by impaired intestinal gas handling and hypersensitivity to gas-induced distention in response to impaired gastric air venting. Gas-related symptoms result in less satisfaction with surgical outcome and a decrease in the quality of life. Preoperative impedance monitoring cannot be used to predict the development of postoperative gas-related symptoms. Patients should therefore be carefully informed about the implications and incidence of gas-related symptoms after surgery and the fact that these cannot be predicted beforehand.

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