



# Choosing the right patient for laparoscopic fundoplication: a narrative review of preoperative predictors

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**Objective:** To determine the best preoperative predictors for a successful outcome after primary laparoscopic fundoplication.

**Background:** Anti-reflux surgery is a proven treatment modality for patients with debilitating reflux symptoms, or those with breakthrough symptoms or an intolerance to medical therapy. Studies show that 3–6% of patients undergoing primary anti-reflux surgery will ultimately need a revisional procedure, and this carries a higher morbidity and mortality rate than primary surgery. Given the risks associated with laparoscopic revisional fundoplication, it is imperative to select the right patient for a primary laparoscopic fundoplication.

**Methods:** A literature search was conducted of MEDLINE, Embase, Cochrane and ClinicalKey databases using the search terms “fundoplication”, “recurrent reflux”, “predictors of success” with “AND” and “OR” selected. English-written papers published between 1995 to 2020 were included. Abstracts and case reports of patients less than 18 years of age were excluded. Only studies with laparoscopic fundoplication were included. Open, endoscopic and revisional fundoplication studies were excluded, as well as any paper discussing hiatus hernias greater than 5 cm in size.

**Conclusions:** Best predictors for a good outcome after anti-reflux surgery include: male gender, BMI under 30 kg/m<sup>2</sup>, typical reflux symptoms, responders to anti-reflux medication, and abnormal reflux on 24-hour pH monitoring with positive symptom indices.

**Keywords:** Recurrent reflux; laparoscopic fundoplication; predictors of success

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## Introduction

Gastro-esophageal reflux disease (GERD or reflux disease) is defined by the Montreal consensus as a condition that develops when the reflux of gastric content into the esophagus causes troublesome symptoms or complications (1).

According to a review by Nirwan *et al.*, GERD has a global prevalence of 14% with significant variations between regions and countries. Whilst the prevalence of GERD in Australia and the United Kingdom is 10–15%, the prevalence in the United States of America is higher, at 30–35% (2).

Laparoscopic anti-reflux surgery is an accepted

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treatment for GERD (3-7). However, the published failure rate from laparoscopic fundoplication ranges from 10% to 20% (8-10), of which 3–6% of patients will require a revisional surgery (5,11-17). This small percentage of patients undergoing revisional fundoplication is significant considering the large number of fundoplication undertaken since the advent of laparoscopic anti-reflux surgery. A revisional fundoplication not only poses a greater technical challenge than a primary fundoplication, but it also results in higher complication rates ranging from 0–44% (18), and higher risk of mortality (1%) (19). As well, a further 10% of patients undergoing laparoscopic re-operative anti-reflux surgery may require another revisional procedure (20,21).

Given the risks associated with laparoscopic revisional fundoplication, it is imperative to select the right patient for a primary laparoscopic fundoplication. We aim to determine the best preoperative predictors which correspond to a successful outcome following laparoscopic fundoplication and present the article in accordance with the Narrative Review reporting checklist (available at <https://aoe.amegroups.com/article/view/10.21037/aoe-21-19/rc>).

## Methods

GERD is one of the most common benign disorders of the upper gastro-intestinal tract with non-specific symptoms, heterogeneous clinical presentation, and a varied diagnostic differential. Hence, making the correct diagnosis of reflux, and then making the correct treatment choice (i.e., medical versus surgical therapy) are both of the utmost importance.

An extensive literature search was conducted of MEDLINE, Embase, Cochrane and ClinicalKey databases using the search terms “fundoplication”, “recurrent reflux”, “predictors of success” with “AND” and “OR” selected. English-written papers published between 1995 to 2020 were included. Abstracts and case reports of patients less than 18 years of age were excluded. Only studies with laparoscopic fundoplication were included, and of those, only studies which focused on pre-operative patient predictors or investigations were included. Open, endoscopic and revisional fundoplication studies were excluded, as well as any paper discussing hiatus hernias greater than 5 cm in size.

## Discussion

### *Pre-operative patient predictors*

#### **Age**

Age as a predictor of outcome after laparoscopic

fundoplication for GERD patients has contradictory findings. Addo *et al.* in a retrospective study, demonstrated improved long-term quality of life amongst elderly patients undergoing laparoscopic fundoplication, even though the risk of intra-operative complications, length of stay, and re-operation rates were all higher compared to the younger age group (22). In a study involving review of a Californian database of 13,050 patients, multivariate analysis demonstrated significantly higher rates of re-operation among younger patients (hazard ratio, HR =3.56 for <30 years old; HR 1.89 for 30–50 years old; HR 1.65 for 50–65 years old) and female patients (HR =1.35) (23). Older patients had greater symptom improvement, a finding which is consistent across multiple studies (24–26).

Large population database studies have also revealed higher rates of re-operation in younger patients compared to patients more than 70 years of age (23,27). Although a large Swedish study, with up to 5 years follow-up, found older age was a risk factor for reflux recurrence (HR 1.41 for >61 years compared to <45 years). Though the redo fundoplication rate was similar in both groups (2.7% *vs.* 2.6%), the percentage of patients with post laparoscopic fundoplication recurrence treated with medication was higher in elderly group (19.2%) compared to the younger aged group (10.8%) (28). The Adelaide group reported similar findings of frequent anti-reflux medication use and re-operation rate (11%) with increasing age (29). In a multivariate analysis, age (<50 years), typical symptoms, and response to PPI had an exponential effect on positive outcome after laparoscopic fundoplication compared to outcome for older persons, age >50 years (30).

#### **Gender**

The likelihood of a successful outcome following laparoscopic fundoplication for women may be lower than for men, although most will still have a good outcome. In a large prospectively collected database study, females were less satisfied with the outcomes after fundoplication, consequently having more revisional procedures compared to males (24). Observational studies confirm that female gender (OR 1.56,  $P < 0.0001$ ) is associated with increased risk for re-operation after fundoplication (23,27). In a Swedish study involving 2,655 patients, the overall recurrence rate of reflux symptoms in female patients was 22% *vs.* 14% in males, and the rate of redo fundoplication was 4% *vs.* 2% for males. The majority of patients with reflux recurrence were treated with medication with a median follow-up of 5.6 years (28).

### Body mass index (BMI)

Obesity is a recognized risk factor for the development for reflux. Studies evaluating BMI as a predictor for fundoplication outcome have classified patients into 3 categories: BMI <30 kg/m<sup>2</sup>, ≥30 to <35 kg/m<sup>2</sup>, and ≥35 kg/m<sup>2</sup>. While patients with a BMI ≥35 kg/m<sup>2</sup> are best suited to bariatric surgery (31), treatment for moderate obesity (middle BMI group) is more controversial. Poorer outcomes after laparoscopic fundoplication were seen in obese patients in some studies (32-35), whereas other studies found similar outcome regardless of patient BMI (36-43). Schietroma *et al.* compared outcomes for 201 patients based on BMI and found that although short term outcomes were similar for all groups, long term outcomes were not. After more than 10 years, reflux control was worse in the obese group compared to the non-obese group (44). A recent meta-analysis by Abdelrahman *et al.* concluded that although laparoscopic fundoplication can be safely performed in an obese patient, higher reflux recurrence is a risk (45). In a study analysing patterns of re-operation for failed fundoplication in 9,462 patients, the majority of patients (86%) who underwent conversion to Roux-en-Y gastric bypass were obese, whereas only 8% redo fundoplication patients were obese (27).

### Typical vs. atypical symptoms

Laparoscopic fundoplication achieves excellent outcomes in over 90% of GERD patients with typical symptoms, namely heartburn and acid regurgitation (11,33,46-48). However, the effectiveness of anti-reflux surgery for the resolution of atypical symptoms (i.e., cough, hoarseness, globus, odynophagia, sore throat, etc.) is less predictive (46,49,50). Therefore, patients with atypical reflux symptoms should have a concrete diagnosis of pathological reflux through validated objective tests to qualify for surgery and elevate the likelihood of good outcome post-surgery. A recent large retrospective study of patients with objectively diagnosed reflux associated with atypical symptoms (difficulty breathing, chronic cough, hoarseness, and globus sensation), with follow-up of 19±17 months after laparoscopic anti-reflux surgery, found significant post-operative benefits as assessed by four quality of life validated instruments (51). In the same cohort of study, complete resolution of chronic cough was found in 77% of respondents at follow-up (52).

### Response to anti-reflux medication

The majority of patients with reflux have resolution of reflux

symptoms with proton pump inhibitor (PPI) therapy and are termed as good responders. However, about 17–45% of patients complain of persistent reflux symptoms despite maximal PPI therapy, and are deemed poor responders (53-56). PPI response is predictive. Patients classified as PPI responders is one of the best predictors for an excellent outcome post laparoscopic fundoplication (11,57), while PPI non responders are considered as poor candidates for laparoscopic anti-reflux surgery. Hence, these patients form an important subgroup of GERD patients to be considered for further investigation prior to laparoscopic fundoplication. Studies comparing these two groups, indicate that the non-responders may still benefit from laparoscopic anti-reflux surgery, though not as much as PPI responders (58-60). Other smaller prospective studies report similar findings, with a fundoplication success rate averaging 85% for PPI non-responders (48,61,62).

PPI non-responders constitute the most common group of patients referred for laparoscopic fundoplication (39,63). A systematic review on PPI-refractory GERD patients found that at 10 years post laparoscopic fundoplication, nearly 35% of patients experienced recurrent heartburn, 30% reported regurgitation, and PPI use increased from 9% at 1 year to 18% at 10 years. Additionally, 10% of patients with PPI-refractory GERD required surgical intervention within 10 years of follow-up (64). The degree of circumferential extent of fundoplication failed to alter the outcomes for GERD patients refractory to PPI undergoing laparoscopic fundoplication (65-67). Frazzoni *et al.* found that for PPI-refractory GERD patients confirmed by impedance pH-study, cure of GERD was achieved in 34 of 38 patients (89%), in which 11 patients had an abnormal number of total reflux events as the only preoperative abnormality on ambulatory impedance-pH testing, suggesting weakly acidic reflux can play a role in the pathogenesis of PPI-refractory GERD (62). In 2018, an expert panel recommended that in PPI-refractory GERD patients undergoing impedance-pH monitoring while on PPI therapy, laparoscopic anti-reflux surgery should only be considered if there is abnormal reflux burden in the form of elevated distal esophageal acid exposure or regurgitation with positive symptom-reflux association and a large hiatus hernia (68). Future studies based on these indications for PPI-refractory GERD patients may help reduce the burden of revisional fundoplication.

### Pre-operative investigations

#### Endoscopy

Patients with reflux are divided into erosive and non-

erosive reflux disease based on endoscopy findings. Up to 70% of patients with reflux symptoms have no evidence of esophagitis at endoscopy (69). However, the pre-operative severity of esophagitis does not influence the outcomes of laparoscopic fundoplication (70,71). Studies comparing the outcomes of patients with or without erosive esophagitis, found a similar reduction in symptoms and anti-reflux medication use in both groups (72,73). However, another comparative study indicated that quality of life outcomes after laparoscopic fundoplication are worse in patients with non-erosive reflux disease, and one third of these patients will continue anti-reflux medication after surgery (74).

Endoscopy remains a vital investigation prior to revisional fundoplication (19,75). Ideally, it should be undertaken by the operating surgeon as it provides a blueprint for the mechanism of failure and a management plan (76).

### pH studies

Ambulatory pH or pH-impedance monitoring is the gold standard for quantifying esophageal acid exposure and establishing a relationship with symptoms in patients with GERD (77,78). In a multivariate analysis conducted by Campos *et al.* for 199 GERD patients who underwent a laparoscopic Nissen fundoplication, the strongest predictor of good or excellent outcome was the 24-hour pH monitoring score with an odds ratio of 5.4. In contrast, patients with typical symptoms, responsive to anti-reflux medications, but with normal pH score had only a fair or poor outcome after surgery (39). The value of routine preoperative pH testing was confirmed in another study in which significantly worse subjective outcomes after Nissen fundoplication were found in patients with normal compared with abnormal preoperative 24-hour pH test results (79). In cases of a strong clinical suspicion yet previous negative reflux pH testing, prolonged 48-hour Bravo™ wireless pH monitoring can be considered to improve the diagnostic yield (80-83). The subgroup of patients diagnosed with esophageal hypersensitivity to acid reflux (i.e., those with a positive symptom association probability but physiological levels of esophageal acid exposure) are equally good candidates for laparoscopic anti-reflux surgery as patients with pathological acid exposure (84).

Postoperatively, pH monitoring can also be used to identify fundoplication failures for patients with recurrent symptoms. Esophageal multichannel intraluminal impedance (MII) monitoring in combination with pH monitoring (MII-pH) in patients either on or off acid

suppression medications can detect all types of reflux events (acidic, weakly acidic or non-acidic) recording the retrograde movement of refluxate by impedance and degree of acidity by pH (85). The role of ambulatory impedance monitoring in selecting patients for anti-reflux surgery is evolving. A study by Glasgow *et al.* urged caution in the use of abnormal impedance values in the context of normal esophageal acid exposure for the selection of patients for anti-reflux operation. The study found that patients who underwent anti-reflux surgery who had abnormal impedance monitoring but physiologically normal esophageal acid exposure (DeMeester score <14.7), post-operatively had poor control of heartburn; more frequent new onset dysphagia (23% *vs.* 5%); and significantly more likelihood of continuing PPI medications after surgery (86). In a study by Francis *et al.* of 27 patients with pathological GERD but atypical symptoms refractory to PPI who underwent LARS, predictors of improvement of atypical symptom post-operatively were the presence of heartburn with or without regurgitation concomitant to their primary extra-esophageal symptom and distal esophageal pH <4 more than 12% over 24 hours. The probability of extra-esophageal symptom improvement was 90% if both conditions were present. Impedance-pH parameters performed on PPI therapy were not predictive of improvement of atypical symptom after fundoplication (87).

### Manometry

(I) Esophageal motility: manometric assessment of esophageal motility is considered standard practice for pre-operative work-up of GERD patients being considered for primary or revisional anti-reflux surgery (88-90). Abnormalities of motility may contraindicate or modify planned anti-reflux surgery. The importance of undertaking preoperative manometry is shown by Chan *et al.*, who found 2.5% of 1,081 patients referred for anti-reflux surgery had obstructive lower esophageal sphincter (LES) pathophysiology (1% achalasia and 2.5% incomplete LES relaxation) and 4.5% had significant esophageal body hypomotility, which included aperistalsis in 3.2% and severe hypomotility in 1.3% of patients (91). Impaired esophageal motility is a frequent finding on manometry in GERD patients, however it is not a disease specific finding (92-98). Tailoring of the fundoplication in patients with ineffective esophageal motility and GERD has long been debated, yet several studies show that esophageal motility does



**Table 1** Predictors assessed for laparoscopic fundoplication outcome

Pre-operative factors	Predictive strength for a good outcome
1. Age	None
2. Gender	Male gender*
3. Body mass index	BMI <30 kg/m <sup>2</sup> *
4. Typical vs. atypical symptoms	Typical symptoms***
5. Response to anti-reflux medications	Good responder***
6. Endoscopy	None
7. pH studies	Positive pH study***
8. Manometry studies	None
9. Barium esophagogram	None

Strength of predictor: \*, some evidence; \*\*\*, strong evidence.

not influence the outcome after laparoscopic anti-reflux surgery (99-102). Randomized controlled trials comparing laparoscopic Nissen *vs.* Toupet in patients with GERD based on esophageal body motility, failed to find any differences in symptomatic outcomes (103,104). Some patients with GERD and ineffective esophageal motility show normalization of peristalsis and increase in gastro-esophageal junction (GEJ) pressure after laparoscopic fundoplication (105-107). A cohort study using a large database comparing the outcomes of 2,040 patients based on the wrap type and preoperative motility with a follow-up of 5 years demonstrated that ineffective esophageal motility based on conventional manometry did not predict postoperative dysphagia; and tailoring the degree of fundoplication based on preoperative motility had no impact on long-term postoperative dysphagia (108). Nevertheless, current common practice is to perform a partial fundoplication in patients with poor pre-operative motility as this yields good post-operative reflux control with high patient satisfaction (109).

- (II) GEJ: the GEJ consists of the intrinsic LES pressure and extrinsic crural diaphragm pressure. For many years, manometric studies reported findings for LES luminal pressure before and/or after fundoplication, failing to recognize the contribution of crural diaphragm pressure. Regardless, many GERD patients show mechanically impaired LES competence with or without low crural diaphragm pressure, in the presence or absence of a hiatus hernia (110-112). Other studies

show that normotensive or increased LES or GEJ pressure in GERD patients prior to surgery, has no effect on the outcome after laparoscopic total or partial fundoplication (33,111,113-115). However, one study with a median follow-up of 14 months (6–81 months) found that patients with a normal LES had a six-fold increase in the risk of developing dysphagia compared to those with an abnormal LES (relative risk 5.8) (116). A small minority of patients with GERD have a hypertensive LES. Studies, albeit with smaller samples, have confirmed that this subset of patients have a good outcome after laparoscopic fundoplication (117-119).

### *Barium esophagogram*

Studies to date indicate a limited role for barium esophagogram (or barium swallow) in the preoperative work up of GERD patients (120,121). However, the Esophageal Diagnostic Advisory Panel recommends barium studies in all patients during the work-up for laparoscopic fundoplication (88). Preoperatively, barium esophagogram is used to differentiate between a type III paraesophageal (mixed) hernia and the more common type I sliding hernia, as endoscopy can be inaccurate in this context (122). Barium swallow may identify a foreshortened esophagus associated with a large (>5 cm) hiatus hernia; a non-reducible hiatal hernia (i.e., does not reduce when the patient is upright); and a distal esophageal stricture.

In symptomatic post fundoplication patients, barium esophagogram is essential in predicting the anatomical cause of a failed fundoplication. It provides information concerning the integrity of the fundoplication, the state of motility, and the presence of reflux in GERD patients with recurrent symptoms post fundoplication (123). The role of barium is useful for planning primary or redo fundoplication, as a road map for operative intervention for large hiatal hernia or laparoscopic revisional fundoplication (124).

### **Conclusions**

*Table 1* summarizes the findings from our literature review. Best predictors for a good outcome after anti-reflux surgery include: male gender, BMI under 30 kg/m<sup>2</sup>, typical reflux symptoms, responders to anti-reflux medication, and abnormal reflux on 24-hour pH monitoring with positive symptom indices.

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## References

1. Vakil N, van Zanten SV, Kahrilas P, et al. The Montreal definition and classification of gastroesophageal reflux disease: a global evidence-based consensus. *Am J Gastroenterol* 2006;101:1900-20; quiz 43.
2. Nirwan JS, Hasan SS, Babar ZU, et al. Global Prevalence and Risk Factors of Gastro-oesophageal Reflux Disease (GORD): Systematic Review with Meta-analysis. *Sci Rep* 2020;10:5814.
3. Anvari M, Allen C. Five-year comprehensive outcomes evaluation in 181 patients after laparoscopic Nissen fundoplication. *J Am Coll Surg* 2003;196:51-7; discussion 7-8; author reply 8-9.
4. Bammer T, Hinder RA, Klaus A, et al. Five- to eight-year outcome of the first laparoscopic Nissen fundoplications. *J Gastrointest Surg* 2001;5:42-8.
5. Catarci M, Gentileschi P, Papi C, et al. Evidence-based appraisal of antireflux fundoplication. *Ann Surg* 2004;239:325-37.
6. Dassinger MS, Torquati A, Houston HL, et al. Laparoscopic fundoplication: 5-year follow-up. *Am Surg* 2004;70:691-4; discussion 4-5.
7. Lamb PJ, Myers JC, Jamieson GG, et al. Long-term outcomes of revisional surgery following laparoscopic fundoplication. *Br J Surg* 2009;96:391-7.
8. Zaninotto G, Portale G, Costantini M, et al. Long-term results (6-10 years) of laparoscopic fundoplication. *J Gastrointest Surg* 2007;11:1138-45.
9. Humphries LA, Hernandez JM, Clark W, et al. Causes of dissatisfaction after laparoscopic fundoplication: the impact of new symptoms, recurrent symptoms, and the patient experience. *Surg Endosc* 2013;27:1537-45.
10. Morgenthal CB, Shane MD, Stival A, et al. The durability of laparoscopic Nissen fundoplication: 11-year outcomes. *J Gastrointest Surg* 2007;11:693-700.
11. Dallemagne B, Weerts J, Markiewicz S, et al. Clinical results of laparoscopic fundoplication at ten years after surgery. *Surg Endosc* 2006;20:159-65.
12. Lafullarde T, Watson DI, Jamieson GG, et al. Laparoscopic Nissen fundoplication: five-year results and beyond. *Arch Surg* 2001;136:180-4.
13. Carlson MA, Frantzides CT. Complications and results of primary minimally invasive antireflux procedures: a review of 10,735 reported cases. *J Am Coll Surg* 2001;193:428-39.
14. Hunter JG, Smith CD, Branum GD, et al. Laparoscopic fundoplication failures: patterns of failure and response to fundoplication revision. *Ann Surg* 1999;230:595-604;

- discussion -6.
15. Furnee EJ, Draaisma WA, Broeders IA, et al. Surgical reintervention after failed antireflux surgery: a systematic review of the literature. *J Gastrointest Surg* 2009;13:1539-49.
  16. Smith CD, McClusky DA, Rajad MA, et al. When fundoplication fails: redo? *Ann Surg* 2005;241:861-9; discussion 9-71.
  17. Hatch KF, Daily MF, Christensen BJ, et al. Failed fundoplications. *Am J Surg* 2004;188:786-91.
  18. Symons NR, Purkayastha S, Dillemans B, et al. Laparoscopic revision of failed antireflux surgery: a systematic review. *Am J Surg* 2011;202:336-43.
  19. Iqbal A, Awad Z, Simkins J, et al. Repair of 104 failed anti-reflux operations. *Ann Surg* 2006;244:42-51.
  20. Awais O, Luketich JD, Schuchert MJ, et al. Reoperative antireflux surgery for failed fundoplication: an analysis of outcomes in 275 patients. *Ann Thorac Surg* 2011;92:1083-9; discussion 9-90.
  21. Deschamps C, Trastek VF, Allen MS, et al. Long-term results after reoperation for failed antireflux procedures. *J Thorac Cardiovasc Surg* 1997;113:545-50; discussion 50-1.
  22. Addo A, Sanford Z, Broda A, et al. Age-related outcomes in laparoscopic hiatal hernia repair: Is there a "too old" for antireflux surgery? *Surg Endosc* 2021;35:429-36.
  23. Zhou T, Harnsberger C, Broderick R, et al. Reoperation rates after laparoscopic fundoplication. *Surg Endosc* 2015;29:510-4.
  24. Beck PE, Watson DI, Devitt PG, et al. Impact of gender and age on the long-term outcome of laparoscopic fundoplication. *World J Surg* 2009;33:2620-6.
  25. Cowgill SM, Arnaoutakis D, Villadolid D, et al. Results after laparoscopic fundoplication: does age matter? *Am Surg* 2006;72:778-83; discussion 83-4.
  26. Pizza F, Rossetti G, Limongelli P, et al. Influence of age on outcome of total laparoscopic fundoplication for gastroesophageal reflux disease. *World J Gastroenterol* 2007;13:740-7.
  27. Obeid NR, Altieri MS, Yang J, et al. Patterns of reoperation after failed fundoplication: an analysis of 9462 patients. *Surg Endosc* 2018;32:345-50.
  28. Maret-Ouda J, Wahlin K, El-Serag HB, et al. Association Between Laparoscopic Antireflux Surgery and Recurrence of Gastroesophageal Reflux. *JAMA* 2017;318:939-46.
  29. Wijnhoven BP, Lally CJ, Kelly JJ, et al. Use of antireflux medication after antireflux surgery. *J Gastrointest Surg* 2008;12:510-7.
  30. Jackson PG, Gleiber MA, Askari R, et al. Predictors of outcome in 100 consecutive laparoscopic antireflux procedures. *Am J Surg* 2001;181:231-5.
  31. Mechanick JI, Youdim A, Jones DB, et al. Clinical practice guidelines for the perioperative nutritional, metabolic, and nonsurgical support of the bariatric surgery patient--2013 update: cosponsored by American Association of Clinical Endocrinologists, the Obesity Society, and American Society for Metabolic & Bariatric Surgery. *Endocr Pract* 2013;19:337-72.
  32. Perez AR, Moncure AC, Rattner DW. Obesity adversely affects the outcome of antireflux operations. *Surg Endosc* 2001;15:986-9.
  33. Morgenthal CB, Lin E, Shane MD, et al. Who will fail laparoscopic Nissen fundoplication? Preoperative prediction of long-term outcomes. *Surg Endosc* 2007;21:1978-84.
  34. Hahnloser D, Schumacher M, Cavin R, et al. Risk factors for complications of laparoscopic Nissen fundoplication. *Surg Endosc* 2002;16:43-7.
  35. Andolfi C, Vigneswaran Y, Kavitt RT, et al. Laparoscopic Antireflux Surgery: Importance of Patient's Selection and Preoperative Workup. *J Laparoendosc Adv Surg Tech A* 2017;27:101-5.
  36. D'Alessio MJ, Arnaoutakis D, Giarelli N, et al. Obesity is not a contraindication to laparoscopic Nissen fundoplication. *J Gastrointest Surg* 2005;9:949-54.
  37. Winslow ER, Frisella MM, Soper NJ, et al. Obesity does not adversely affect the outcome of laparoscopic antireflux surgery (LARS). *Surg Endosc* 2003;17:2003-11.
  38. Fraser J, Watson DI, O'Boyle CJ, et al. Obesity and its effect on outcome of laparoscopic Nissen fundoplication. *Dis Esophagus* 2001;14:50-3.
  39. Campos GM, Peters JH, DeMeester TR, et al. Multivariate analysis of factors predicting outcome after laparoscopic Nissen fundoplication. *J Gastrointest Surg* 1999;3:292-300.
  40. Anvari M, Bamehriz F. Outcome of laparoscopic Nissen fundoplication in patients with body mass index  $\geq 35$ . *Surg Endosc* 2006;20:230-4.
  41. Ng VV, Booth MI, Stratford JJ, et al. Laparoscopic antireflux surgery is effective in obese patients with gastroesophageal reflux disease. *Ann R Coll Surg Engl* 2007;89:696-702.
  42. Chisholm JA, Jamieson GG, Lally CJ, et al. The effect of obesity on the outcome of laparoscopic antireflux surgery. *J Gastrointest Surg* 2009;13:1064-70.
  43. Tekin K, Toydemir T, Yerdel MA. Is laparoscopic antireflux surgery safe and effective in obese patients? *Surg Endosc* 2012;26:86-95.

44. Schietroma M, Piccione F, Clementi M, et al. Short- and Long-Term, 11-22 Years, Results after Laparoscopic Nissen Fundoplication in Obese versus Nonobese Patients. *J Obes* 2017;2017:7589408.
45. Abdelrahman T, Latif A, Chan DS, et al. Outcomes after laparoscopic anti-reflux surgery related to obesity: A systematic review and meta-analysis. *Int J Surg* 2018;51:76-82.
46. Kaufman JA, Houghland JE, Quiroga E, et al. Long-term outcomes of laparoscopic antireflux surgery for gastroesophageal reflux disease (GERD)-related airway disorder. *Surg Endosc* 2006;20:1824-30.
47. Granderath FA, Kamolz T, Schweiger UM, et al. Quality of life and symptomatic outcome three to five years after laparoscopic Toupet fundoplication in gastroesophageal reflux disease patients with impaired esophageal motility. *Am J Surg* 2002;183:110-6.
48. Brillantino A, Schettino M, Torelli F, et al. Laparoscopic Nissen-Rossetti fundoplication is a safe and effective treatment for both Acid and bile gastroesophageal reflux in patients poorly responsive to proton pump inhibitor. *Surg Innov* 2011;18:387-93.
49. Iqbal M, Batch AJ, Spychal RT, et al. Outcome of surgical fundoplication for extraesophageal (atypical) manifestations of gastroesophageal reflux disease in adults: a systematic review. *J Laparoendosc Adv Surg Tech A* 2008;18:789-96.
50. Lugaresi M, Aramini B, Daddi N, et al. Effectiveness of antireflux surgery for the cure of chronic cough associated with gastroesophageal reflux disease. *World J Surg* 2015;39:208-15.
51. Weltz AS, Addo A, Broda A, et al. The impact of laparoscopic anti-reflux surgery on quality of life: do patients with atypical symptoms benefit? *Surg Endosc* 2021;35:2515-22.
52. Park A, Weltz AS, Sanford Z, et al. Laparoscopic antireflux surgery (LARS) is highly effective in the treatment of select patients with chronic cough. *Surgery* 2019;166:34-40.
53. El-Serag H, Becher A, Jones R. Systematic review: persistent reflux symptoms on proton pump inhibitor therapy in primary care and community studies. *Aliment Pharmacol Ther* 2010;32:720-37.
54. Donnellan C, Sharma N, Preston C, et al. Medical treatments for the maintenance therapy of reflux oesophagitis and endoscopic negative reflux disease. *Cochrane Database Syst Rev* 2005;(2):CD003245.
55. Becher A, El-Serag H. Systematic review: the association between symptomatic response to proton pump inhibitors and health-related quality of life in patients with gastro-oesophageal reflux disease. *Aliment Pharmacol Ther* 2011;34:618-27.
56. Fass R, Shapiro M, Dekel R, et al. Systematic review: proton-pump inhibitor failure in gastro-oesophageal reflux disease--where next? *Aliment Pharmacol Ther* 2005;22:79-94.
57. Galmiche JP, Hatlebakk J, Attwood S, et al. Laparoscopic antireflux surgery vs esomeprazole treatment for chronic GERD: the LOTUS randomized clinical trial. *JAMA* 2011;305:1969-77.
58. Borie F, Zazavadjian le Bian A, Millat B. Long-term quality of life in gastroesophageal reflux disease after NISSEN fundoplication: does it depend on preoperative responsiveness to proton pump inhibitors? *Surg Laparosc Endosc Percutan Tech* 2014;24:332-6.
59. Hamdy E, El Nakeeb A, Hamed H, et al. Outcome of laparoscopic Nissen fundoplication for gastroesophageal reflux disease in non-responders to proton pump inhibitors. *J Gastrointest Surg* 2014;18:1557-62.
60. Wilkerson PM, Stratford J, Jones L, et al. A poor response to proton pump inhibition is not a contraindication for laparoscopic antireflux surgery for gastro esophageal reflux disease. *Surg Endosc* 2005;19:1272-7.
61. Antoniou SA, Delivorias P, Antoniou GA, et al. Symptom-focused results after laparoscopic fundoplication for refractory gastroesophageal reflux disease--a prospective study. *Langenbecks Arch Surg* 2008;393:979-84.
62. Frazzoni M, Piccoli M, Conigliaro R, et al. Refractory gastroesophageal reflux disease as diagnosed by impedance-pH monitoring can be cured by laparoscopic fundoplication. *Surg Endosc* 2013;27:2940-6.
63. Rosenthal R, Peterli R, Guenin MO, et al. Laparoscopic antireflux surgery: long-term outcomes and quality of life. *J Laparoendosc Adv Surg Tech A* 2006;16:557-61.
64. Hillman L, Yadlapati R, Whitsett M, et al. Review of antireflux procedures for proton pump inhibitor nonresponsive gastroesophageal reflux disease. *Dis Esophagus* 2017;30:1-14.
65. Lal P, Leekha N, Chander J, et al. A prospective nonrandomized comparison of laparoscopic Nissen fundoplication and laparoscopic Toupet fundoplication in Indian population using detailed objective and subjective criteria. *J Minim Access Surg* 2012;8:39-44.
66. Cao Z, Cai W, Qin M, et al. Randomized clinical trial of laparoscopic anterior 180 degrees partial versus 360 degrees Nissen fundoplication: 5-year results. *Dis Esophagus* 2012;25:114-20.
67. Pessaux P, Arnaud JP, Delattre JF, et al. Laparoscopic antireflux surgery: five-year results and beyond in 1340



- patients. *Arch Surg* 2005;140:946-51.
68. Yadlapati R, Vaezi MF, Vela MF, et al. Management options for patients with GERD and persistent symptoms on proton pump inhibitors: recommendations from an expert panel. *Am J Gastroenterol* 2018;113:980-6.
  69. Lind T, Havelund T, Carlsson R, et al. Heartburn without oesophagitis: efficacy of omeprazole therapy and features determining therapeutic response. *Scand J Gastroenterol* 1997;32:974-9.
  70. Watson DI, Foreman D, Devitt PG, et al. Preoperative endoscopic grading of esophagitis versus outcome after laparoscopic Nissen fundoplication. *Am J Gastroenterol* 1997;92:222-5.
  71. Desai KM, Frisella MM, Soper NJ. Clinical outcomes after laparoscopic antireflux surgery in patients with and without preoperative endoscopic esophagitis. *J Gastrointest Surg* 2003;7:44-52.
  72. Broeders JA, Draaisma WA, Bredenoord AJ, et al. Long-term outcome of Nissen fundoplication in non-erosive and erosive gastro-oesophageal reflux disease. *Br J Surg* 2010;97:845-52.
  73. Kamolz T, Granderath FA, Schweiger UM, et al. Laparoscopic Nissen fundoplication in patients with nonerosive reflux disease. Long-term quality-of-life assessment and surgical outcome. *Surg Endosc* 2005;19:494-500.
  74. Thibault R, Coron E, Sebillé V, et al. Antireflux surgery for non-erosive and erosive reflux disease in community practice. *Aliment Pharmacol Ther* 2006;24:621-32.
  75. Jobe BA, Kahrilas PJ, Vernon AH, et al. Endoscopic appraisal of the gastroesophageal valve after antireflux surgery. *Am J Gastroenterol* 2004;99:233-43.
  76. Juhasz A, Sundaram A, Hoshino M, et al. Endoscopic assessment of failed fundoplication: a case for standardization. *Surg Endosc* 2011;25:3761-6.
  77. Kahrilas PJ, Shaheen NJ, Vaezi MF, et al. American Gastroenterological Association Institute technical review on the management of gastroesophageal reflux disease. *Gastroenterology* 2008;135:1392-413, 413 e1-5.
  78. Richter JE, Pandolfino JE, Vela MF, et al. Utilization of wireless pH monitoring technologies: a summary of the proceedings from the esophageal diagnostic working group. *Dis Esophagus* 2013;26:755-65.
  79. Khajanchee YS, Hong D, Hansen PD, et al. Outcomes of antireflux surgery in patients with normal preoperative 24-hour pH test results. *Am J Surg* 2004;187:599-603.
  80. Penagini R, Sweis R, Mauro A, et al. Inconsistency in the Diagnosis of Functional Heartburn: Usefulness of Prolonged Wireless pH Monitoring in Patients With Proton Pump Inhibitor Refractory Gastroesophageal Reflux Disease. *J Neurogastroenterol Motil* 2015;21:265-72.
  81. Tseng D, Rizvi AZ, Fennerty MB, et al. Forty-eight-hour pH monitoring increases sensitivity in detecting abnormal esophageal acid exposure. *J Gastrointest Surg* 2005;9:1043-51; discussion 51-2.
  82. Prakash C, Clouse RE. Value of extended recording time with wireless pH monitoring in evaluating gastroesophageal reflux disease. *Clin Gastroenterol Hepatol* 2005;3:329-34.
  83. Pandolfino JE, Richter JE, Ours T, et al. Ambulatory esophageal pH monitoring using a wireless system. *Am J Gastroenterol* 2003;98:740-9.
  84. Broeders JA, Draaisma WA, Bredenoord AJ, et al. Oesophageal acid hypersensitivity is not a contraindication to Nissen fundoplication. *Br J Surg* 2009;96:1023-30.
  85. Agrawal A, Castell DO. Clinical importance of impedance measurements. *J Clin Gastroenterol* 2008;42:579-83.
  86. Glasgow ME, Dunst CM, Abdelmoaty WF, et al. The outcome of fundoplication in patients with GERD based on abnormal impedance testing. *Surg Endosc* 2020;34:2601-7.
  87. Francis DO, Goutte M, Slaughter JC, et al. Traditional reflux parameters and not impedance monitoring predict outcome after fundoplication in extraesophageal reflux. *Laryngoscope* 2011;121:1902-9.
  88. Jobe BA, Richter JE, Hoppo T, et al. Preoperative diagnostic workup before antireflux surgery: an evidence and experience-based consensus of the Esophageal Diagnostic Advisory Panel. *J Am Coll Surg* 2013;217:586-97.
  89. Patti MG, Allaix ME, Fisichella PM. Analysis of the Causes of Failed Antireflux Surgery and the Principles of Treatment: A Review. *JAMA Surg* 2015;150:585-90.
  90. Keller J. What Is the Impact of High-Resolution Manometry in the Functional Diagnostic Workup of Gastroesophageal Reflux Disease? *Visc Med* 2018;34:101-8.
  91. Chan WW, Haroian LR, Gyawali CP. Value of preoperative esophageal function studies before laparoscopic antireflux surgery. *Surg Endosc* 2011;25:2943-9.
  92. Leite LP, Johnston BT, Barrett J, et al. Ineffective esophageal motility (IEM): the primary finding in patients with nonspecific esophageal motility disorder. *Dig Dis Sci* 1997;42:1859-65.
  93. Tutuian R, Castell DO. Combined multichannel intraluminal impedance and manometry clarifies esophageal function abnormalities: study in 350 patients.

- Am J Gastroenterol 2004;99:1011-9.
94. Conchillo JM, Nguyen NQ, Samsom M, et al. Multichannel intraluminal impedance monitoring in the evaluation of patients with non-obstructive Dysphagia. *Am J Gastroenterol* 2005;100:2624-32.
  95. Diener U, Patti MG, Molena D, et al. Esophageal dysmotility and gastroesophageal reflux disease. *J Gastrointest Surg* 2001;5:260-5.
  96. Lee J, Anggiansah A, Anggiansah R, et al. Effects of age on the gastroesophageal junction, esophageal motility, and reflux disease. *Clin Gastroenterol Hepatol* 2007;5:1392-8.
  97. Fouad YM, Katz PO, Hatlebakk JG, et al. Ineffective esophageal motility: the most common motility abnormality in patients with GERD-associated respiratory symptoms. *Am J Gastroenterol* 1999;94:1464-7.
  98. Smout A, Fox M. Weak and absent peristalsis. *Neurogastroenterol Motil* 2012;24 Suppl 1:40-7.
  99. Booth M, Stratford J, Dehn TC. Preoperative esophageal body motility does not influence the outcome of laparoscopic Nissen fundoplication for gastroesophageal reflux disease. *Dis Esophagus* 2002;15:57-60.
  100. Cole SJ, van den Bogaerde JB, van der Walt H. Preoperative esophageal manometry does not predict postoperative dysphagia following anti-reflux surgery. *Dis Esophagus* 2005;18:51-6.
  101. Zornig C, Strate U, Fibbe C, et al. Nissen vs Toupet laparoscopic fundoplication. *Surg Endosc* 2002;16:758-66.
  102. Munitiz V, Ortiz A, Martinez de Haro LF, et al. Ineffective oesophageal motility does not affect the clinical outcome of open Nissen fundoplication. *Br J Surg* 2004;91:1010-4.
  103. Booth MI, Stratford J, Jones L, et al. Randomized clinical trial of laparoscopic total (Nissen) versus posterior partial (Toupet) fundoplication for gastro-oesophageal reflux disease based on preoperative oesophageal manometry. *Br J Surg* 2008;95:57-63.
  104. Strate U, Emmermann A, Fibbe C, et al. Laparoscopic fundoplication: Nissen versus Toupet two-year outcome of a prospective randomized study of 200 patients regarding preoperative esophageal motility. *Surg Endosc* 2008;22:21-30.
  105. Herbella FA, Tedesco P, Nipomnick I, et al. Effect of partial and total laparoscopic fundoplication on esophageal body motility. *Surg Endosc* 2007;21:285-8.
  106. Pizza F, Rossetti G, Del Genio G, et al. Influence of esophageal motility on the outcome of laparoscopic total fundoplication. *Dis Esophagus* 2008;21:78-85.
  107. Tsereteli Z, Sporn E, Astudillo JA, et al. Laparoscopic Nissen fundoplication is a good option in patients with abnormal esophageal motility. *Surg Endosc* 2009;23:2292-5.
  108. Broeders JA, Sportel IG, Jamieson GG, et al. Impact of ineffective oesophageal motility and wrap type on dysphagia after laparoscopic fundoplication. *Br J Surg* 2011;98:1414-21.
  109. Armijo PR, Hennings D, Leon M, et al. Surgical Management of Gastroesophageal Reflux Disease in Patients with Severe Esophageal Dysmotility. *J Gastrointest Surg* 2019;23:36-42.
  110. Cowgill SM, Bloomston M, Al-Saadi S, et al. Normal lower esophageal sphincter pressure and length does not impact outcome after laparoscopic Nissen fundoplication. *J Gastrointest Surg* 2007;11:701-7.
  111. Patti MG, Perretta S, Fisichella PM, et al. Laparoscopic antireflux surgery: preoperative lower esophageal sphincter pressure does not affect outcome. *Surg Endosc* 2003;17:386-9.
  112. Ritter MP, Peters JH, DeMeester TR, et al. Outcome after laparoscopic fundoplication is not dependent on a structurally defective lower esophageal sphincter. *J Gastrointest Surg* 1998;2:567-72.
  113. Riedl O, Gadenstatter M, Lechner W, et al. Preoperative lower esophageal sphincter manometry data neither impact manifestations of GERD nor outcome after laparoscopic Nissen fundoplication. *J Gastrointest Surg* 2009;13:1189-97.
  114. Fibbe C, Layer P, Keller J, et al. Esophageal motility in reflux disease before and after fundoplication: a prospective, randomized, clinical, and manometric study. *Gastroenterology* 2001;121:5-14.
  115. Wills VL, Hunt DR. Dysphagia after antireflux surgery. *Br J Surg* 2001;88:486-99.
  116. Blom D, Peters JH, DeMeester TR, et al. Physiologic mechanism and preoperative prediction of new-onset dysphagia after laparoscopic Nissen fundoplication. *J Gastrointest Surg* 2002;6:22-7; discussion 7-8.
  117. Tamhankar AP, Almogy G, Arain MA, et al. Surgical management of hypertensive lower esophageal sphincter with dysphagia or chest pain. *J Gastrointest Surg* 2003;7:990-6; discussion 6.
  118. Varga G, Kiraly A, Cseke L, et al. Effect of laparoscopic fundoplication on hypertensive lower esophageal sphincter associated with gastroesophageal reflux. *J Gastrointest Surg* 2008;12:304-7.
  119. Barreca M, Oelschlager BK, Pellegrini CA. Outcomes of laparoscopic Nissen fundoplication in patients with the "hypercontractile esophagus". *Arch Surg* 2002;137:724-8, discussion 9.

120. Mittal SK, Awad ZT, Tasset M, et al. The preoperative predictability of the short esophagus in patients with stricture or paraesophageal hernia. *Surg Endosc* 2000;14:464-8.
121. Linke GR, Borovicka J, Schneider P, et al. Is a barium swallow complementary to endoscopy essential in the preoperative assessment of laparoscopic antireflux and hiatal hernia surgery? *Surg Endosc* 2008;22:96-100.
122. Kahrilas PJ. The role of hiatus hernia in GERD. *Yale J Biol Med* 1999;72:101-11.
123. Baker ME, Einstein DM. Barium esophagram: does it have a role in gastroesophageal reflux disease? *Gastroenterol Clin North Am* 2014;43:47-68.
124. Dempsey DT. Barium upper GI series in adults: a surgeon's perspective. *Abdom Radiol (NY)* 2018;43:1323-8.

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