Surgical Endoscopy (2020) 34:510–520
https://doi.org/10.1007/s00464-019-07208-9

REVIEW ARTICLE

Assessing the efficacy and safety of laparoscopic antireflux procedures for the management of gastroesophageal reflux disease: a systematic review with network meta-analysis

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Received: 28 February 2019 / Accepted: 9 October 2019 / Published online: 18 October 2019

Abstract

Background Despite the extensive literature on laparoscopic antireflux surgery, comparative evidence across different procedures is scarce. The aim of this study was to assess and rank the most efficacious and safe laparoscopic procedures for the management of gastroesophageal reflux disease.

Methods Medline, Embase, AMED, CINAHL, CENTRAL, and OpenGrey databases were queried for randomized trials comparing two or more laparoscopic antireflux procedures with each other or with medical treatment for the management of gastroesophageal reflux disease. Pairwise meta-analyses were conducted for each pair of interventions using a random-effects model. Network meta-analysis was employed to assess the relative efficacy and safety of laparoscopic antireflux procedures for the management of gastroesophageal reflux disease.

Results Forty-four publications reporting 29 randomized trials which included 1892 patients were identified. The network of treatments was sparse with only a closed loop between different types of wraps; 270°, 360°, anterior 180° and anterior 90°; and star network between 360° and other treatments; and between anterior 180° and other treatments. Laparoscopic 270° (odds ratio, OR 1.19, 95% confidence interval, CI 0.64–2.22), anterior 180°, and anterior 90° were equally effective as 360° for control of heartburn, although this finding was supported by low quality of evidence according to GRADE modification for NMA. The odds for dysphagia were lower after 270° (OR 0.38, 95%, CI 0.24–0.60), anterior 90° (moderate quality evidence), and anterior 180° (low-quality evidence) compared to 360°. The odds for gas-bloat were lower after 270° (OR 0.51, 95% CI 0.27, 0.95) and after anterior 90° compared to 360° (low-quality evidence). Regurgitation, morbidity, and reoperation were similar across treatments, albeit these were associated with very low-quality evidence.

Conclusion Laparoscopic 270° fundoplication achieves a better outcome than 360° total fundoplication, especially in terms of postoperative dysphagia, although other types of partial fundoplication might be equally effective.

Registration no. CRD42017074783.

Keywords Fundoplication · Antireflux surgery · GERD · Network meta-analysis

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00464-019-07208-9) contains supplementary material, which is available to authorized users.

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Gastroesophageal reflux disease (GERD) is a common condition which impacts significantly quality of life [1, 2]. Medical management is effective for most patients, although up to one-third will experience persistent reflux symptoms [3]. Surgical treatment was popularized after the advent of minimally invasive procedures [4]. Laparoscopic fundoplication is highly effective for controlling typical reflux symptoms, but can be associated with side effects, primarily new onset dysphagia, and gas-bloating [5]. Modifications to the original 360° procedure described by Nissen have been suggested to provide both effective reflux control and concurrently to minimize post-fundoplication side effects.

Meta-analyses have compared pairs of antireflux procedures and provide high-level evidence for two-way comparisons [6–8]. Comparing multiple procedures in the same meta-analytical model via network meta-analysis allows a combination of direct (pairwise) and indirect (via a common comparator) evidence. Network meta-analysis provides more precise effect estimates, allows ranking of different treatment options and delivers more conclusive evidence prior to conventional meta-analysis [9–12]. A recently published network meta-analysis of surgical management of gastroesophageal reflux disease in adults is of limited external validity due to inclusion of open surgery and obsolete approaches, such as the Angelchik prosthesis [13].

As laparoscopic approaches are now standard for antireflux surgery, this systematic review and network meta-analysis aimed to investigate the relative efficacy of currently available procedures, and provide a treatment ranking for the different types of laparoscopic antireflux procedures currently in use for the treatment of GERD.

Methods

Protocol and registration

This project was methodologically supported by the European Association for Endoscopic Surgery Research Committee. The review protocol was registered at the International Prospective Register of Systematic Reviews (CRD42017074783) and conformed to PRISMA-NMA reporting standards [14]. Following commencement of the study, there were no amendments and no deviations from the protocol. Institutional review board approval or written consent was not required as this was a systematic review project.

Outcome measures

Primary: Symptoms—dysphagia, gas-bloat, heartburn, and regurgitation.

Secondary: Esophagitis, deMeester score, quality of life score, surgical re-interventions, use of proton pump inhibitors (PPIs), 30-day or in-hospital morbidity and mortality.

Eligibility criteria

Randomized controlled trials (RCTs) comparing two or more laparoscopic antireflux procedures with each other or with medical treatment in adult patients with GERD.

Information sources

Medline, Embase, AMED, and CINAHL via OpenAthens Eduserv, CENTRAL via Wiley Online Library, and OpenGrey via Exalead were searched until May 2018. The search syntax is provided as Supplementary material (Table S1). No date, language, article type, or other restrictions were applied. Titles and abstracts were screened by two authors in a blinded manner and disagreements were resolved by discussion or arbitration by the senior author. The same process was applied to the full texts of records deemed to be potentially eligible.

Data extraction

Data were collected from the abstract, main manuscript, tables, supplementary material, or graphs using PlotDigitizer [15]. Article authors were contacted via e-mail and were requested to cross-check extracted data and complete missing information, if any. Data of interest were abstracted by the first author and cross-checked by the senior author (Supplementary material Table S2). Symptom-related data were considered as responses to yes/no questions when available or in the context of scales; the lowest (typically a zero) value was considered as absence of the symptom. Data at different follow-up assessments were collected but only data at the longest follow-up time point were considered for analysis. The follow-up duration for morbidity data was typically not defined. An electronic datasheet based on the Cochrane Consumers and Communication Review Group's data extraction template was constructed and pilot-tested on the three most recent studies and refined accordingly in liaison with the senior author.

Risk of bias

The Cochrane Collaboration's Tool for assessment of risk of bias was employed. More specifically the following criteria were assessed: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other sources of bias. An industry-sponsored study on pharmacological treatment was conventionally

considered to be at high risk of bias under the domain "other bias." The risk of bias assessment was summarized using Review Manager 5.3 [16].

Transitivity

The fundamental, for NMA, assumption of transitivity requires that the distribution of effect modifiers is similar across comparisons in the network. Inclusion criteria, length of follow-up, use of bougie, and division of short gastric vessels were assessed. Open procedures were discarded as this was considered to be a significant effect modifier and to reduce external validity. Transitivity often manifests itself statistically via differences between direct and indirect estimates (consistency assumption).

Statistical synthesis

Pairwise meta-analyses for each pair of interventions were performed using a random-effects model in Stata/SE (StataCorp/LP, TX, USA). Relative treatment effects were estimated using odds ratios (OR) and 95% confidence intervals (CI). The restricted maximum likelihood method was used to estimate heterogeneity.

Network meta-analysis was performed in Stata using the *network package* [17] and self-programmed Stata routines [18, 19]. The restricted maximum likelihood method was used to estimate heterogeneity assuming a common estimate for heterogeneity across the different comparisons.

Differences between direct and indirect evidence for the same comparisons were explored by comparing direct and indirect estimates and computing the inconsistency factor within each closed loop of evidence [20]. The node-splitting approach, which compares the direct estimate for each comparison to the respective indirect one once this comparison had been removed from the network, was also employed [21]. To check the assumption of consistency in the entire network, the 'design-by-treatment' model was used as described by Higgins et al. [22].

Small-study effects within each treatment comparison when compared in at least 10 studies were explored using funnel plot. Contour-enhanced funnel plots were used in an attempt to disentangle publication bias from small-study effects [23, 24].

The ranking probabilities for all treatments of being at each possible rank for each intervention were estimated using the *netrank* command in Stata. A hierarchy of the competing interventions was obtained using rankograms, the surface under the cumulative ranking curve (SUCRA), and mean ranks [25]. Relevant plots were produced using the suite of Stata commands by Chaimani et al. [19].

Statistical methodology is detailed in the Supplementary (Text S1).

Assessment of the quality of evidence

The quality of evidence was assessed using GRADE-based assessments for network meta-analysis and was tabulated using the CINeMA software [26, 27]. Clinically important size of effect was considered an OR of more than 1.2 (or less than 0.83) across outcomes.

Results

Study selection and network plot

A total of 44 articles reporting outcomes from 29 RCTs which included 1892 patients were identified [28–71]. The study selection is summarized in Fig. 1. The network of treatments formed a closed loop between 270°, 360°, and anterior 180°; and star network between 360° and other treatments; and also between anterior 180° and other treatments (Fig. 2). Network plots for individual outcomes are provided as Supplementary material (Figs. S1–S6).

Study characteristics and transitivity

Studies were published between 1997 and 2017 (median year of publication, 2008) and publications originated from Europe (23), Australia (10), the USA/Canada (5), China (3), and South Africa (3). GERD was the criterion for inclusion across studies, whereas no trials considered patients with large hernias. One RCT considered patients with esophageal dysmotility and 8 RCTs excluded patients with dysmotility disorders. The latter exclusion criterion was well distributed across comparisons and was not considered to challenge transitivity. The use of a bougie was not disclosed in about one-third of RCTs. A bougie was used in most 360° fundoplications, and represented a potential source of intransitivity. Short gastric vessels were divided in about one-fourth of RCTs and this was another potential source of intransitivity. Duration of follow-up ranged between 1 and 12 years (typically 5 years), and this was another potential source of inconsistency. Study characteristics and individual study outcomes are detailed in Table 1 and as Supplementary material (Tables S3–S6).

Evidence synthesis

Dysphagia

All interventions were associated with lower odds for dysphagia compared to 360° total fundoplication. Anterior 120° fundoplication was ranked the highest among treatments (OR 7.92, 95% CI 2.32–27.00; compared to 360° fundoplication). Total 360° fundoplication was associated

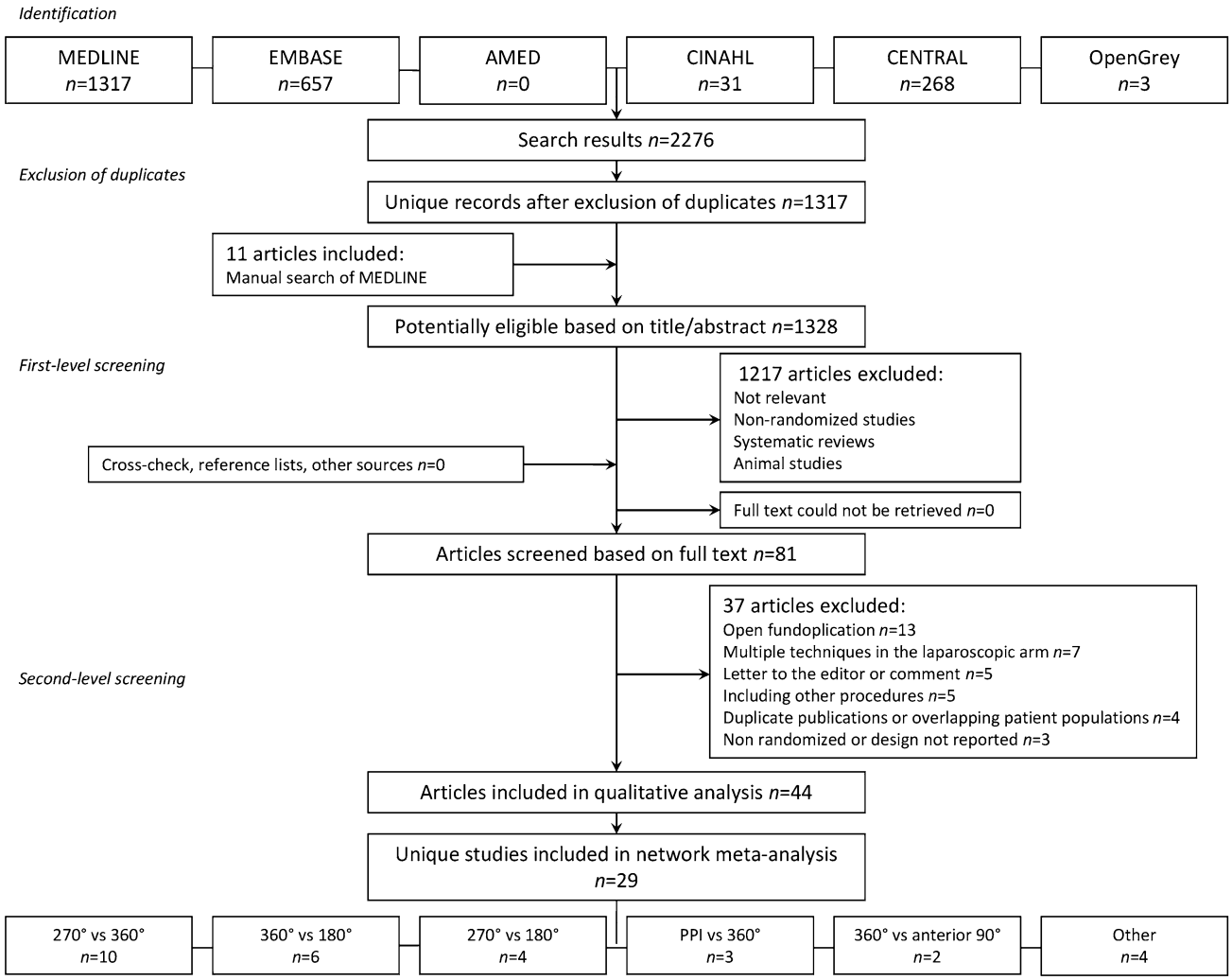

Fig. 1 Flow chart of search history

with a 2.6-fold increased odds for dysphagia (OR 2.62, 95% CI 1.65–4.16). No statistically significant differences were found among other interventions (Table 1; Supplementary material Fig. S7).

Gas-bloat

Anterior 90° (OR 2.44, 95% CI 1.16–5.12) and 270° (OR 1.96, 95% CI 1.05–3.65) had lower odds for gas-bloat symptoms compared to 360° fundoplication. No other significant differences were found; however, estimates were very imprecise. (Table 2; Supplementary material Fig. S8).

Heartburn

PPIs were less effective than 360° fundoplication in terms of heartburn control (OR 0.21, 95% CI 0.05–0.91). No differences were found for other interventions, although estimates were very imprecise (Table 3; Supplementary material Fig. S9).

Regurgitation

PPIs compared to 360° (OR 0.15, 95% CI 0.02–0.87) and 270° fundoplication (OR 0.08, 95% CI 0.01–0.60), and anterior 180° compared to 270° fundoplication (OR 0.37, 95%

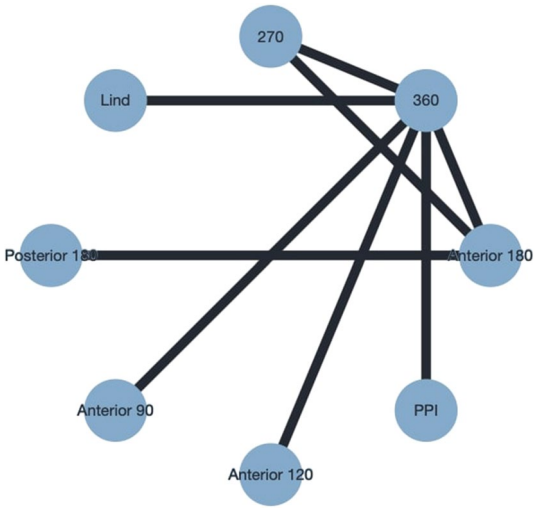

Fig. 2 Network plot of comparisons

CI 0.14–0.92) were less effective for controlling regurgitation. No further differences were found; however, estimates were very imprecise (Table 4; Supplementary material Fig. S10).

Morbidity

No differences across treatments was found for morbidity; however, both confidence and predictive intervals were wide (Table 5; Supplementary material Fig. S11).

Reoperation

No differences were found for reoperations, although interval estimates were generally wide (Table 6; Supplementary material Fig. S12).

Rankograms with predictive probabilities are provided in the Supplementary (Figs. S13–S18).

Inconsistency

There was no evidence of inconsistency according to inconsistency factors but differences between direct and indirect evidence were large for regurgitation and reoperation. The node-splitting approach showed that there was some evidence of inconsistency between direct and indirect evidence in outcomes regurgitation and reoperation (see Supplementary material Tables S7–S13).

Table 1 League table demonstrating the relative effectiveness for each pair of comparison for dysphagia

	PPI	Anterior 90°	Anterior 120°	Anterior 180°	270°	360°	Lind	Posterior 180°
PPI	*64.5 (5.8%)*	1.34 (0.42, 4.34)	0.44 (0.09, 2.06)	2.00 (0.68, 5.92)	1.33 (0.46, 3.79)	**3.47 (1.35, 8.90°)**	0.54 (0.05, 6.12)	2.16 (0.28, 16.52)
Anterior 90°		*51.3 (0.9%)*	0.33 (0.08, 1.34)	1.49 (0.61, 3.62)	0.99 (0.43, 2.27)	**2.58 (1.28, 5.18)**	0.40 (0.04, 4.18)	1.60 (0.23, 11.15)
Anterior 120°			*88.9 (49.1%)*	**4.57 (1.20, 17.43)**	3.03 (0.82, 11.23)	**7.92 (2.32, 27.00)**	1.24 (0.10, 15.81)	4.92 (0.56, 43.65)
Anterior 180°				*29.3 (0.0%)*	0.66 (0.36, 1.22)	**1.73 (1.01, 2.96)**	0.27 (0.03, 2.69)	1.08 (0.19, 6.04)
270°					*52.4 (0.3%)*	**2.62 (1.65, 4.16)**	0.41 (0.04, 4.00)	1.63 (0.26, 10.14)
360°						*5.5 (0.0%)*	0.16 (0.02, 1.46)	0.62 (0.10, 3.78)
Lind							*75.9 (40.4%)*	3.97 (0.23, 69.86)
Posterior 180°								*32.3 (3.4%)*

Estimates are presented as OR with 95% CI in parentheses. ORs above 1 suggest that the treatment listed in the left column is superior; ORs below 1 suggest that the treatment listed in the upper row is superior. The table lists network meta-analysis outcomes. The dashed diagonal (in italic) lists SUCRA values and the probability of each treatment being the best in parentheses. Significant values are given in bold

Table 2 League table demonstrating the relative effectiveness for each pair of comparison for gas-bloat

	Anterior 90°	Anterior 180°	270°	360°	Lind	Posterior 180°
Anterior 90°	*65.7 (12.6%)*	1.41 (0.50, 4.03)	1.25 (0.46, 3.35)	**2.44 (1.16, 5.12)**	0.41 (0.02, 10.15)	1.51 (0.02, 92.99)
Anterior 180°		*46.0 (3.2%)*	0.88 (0.40, 1.94)	1.73 (0.84, 3.56)	0.29 (0.01, 7.16)	1.07 (0.02, 57.51)
270°			*54.6 (5.2%)*	**1.96 (1.05, 3.65)**	0.33 (0.01, , 7.94)	1.21 (0.02, 70.35)
360°				*12.7 (0.0%)*	0.17 (0.01, 3.82)	0.62 (0.01, 35.54)
Lind					*75.8 (54.4%)*	3.66 (0.02, 608.21)
Posterior 180°						*45.2 (24.6%)*

Estimates are presented as OR with 95% CI in parentheses. ORs above 1 suggest that the treatment listed in the left column is superior; ORs below 1 suggest that the treatment listed in the upper row is superior. The table lists network meta-analysis outcomes. The dashed diagonal (in italic) lists SUCRA values and the probability of each treatment being the best in parentheses. Significant values are given in bold

Table 3 League table demonstrating the relative effectiveness for each pair of comparison for heartburn

	PPI	Anterior 90°	Anterior 120°	Anterior 180°	270°	360°	Lind	Posterior 180°
PPI	*20.0 (0.6%)*	0.36 (0.05, 2.49)	0.99 (0.11, 9.18)	0.34 (0.06, 1.83)	0.25 (0.05, 1.23)	**0.21 (0.05, 0.91)**	1.06 (0.06, 20.04)	0.13 (0.01, 1.76)
Anterior 90°		*52.5 (8.4%)*	2.75 (0.33, 22.76)	0.94 (0.20, 4.38)	0.70 (0.17, 2.92)	0.59 (0.17, 2.12)	2.96 (0.17, 51.16)	0.37 (0.03, 4.45)
Anterior 120°			21.5 (1.2%)	0.34 (0.05, 2.26)	0.26 (0.04, 1.54)	0.22 (0.04, 1.16)	1.08 (0.05, 22.83)	0.14 (0.01, 2.04)
Anterior 180°				*52.3 (1.5%)*	0.75 (0.33, 1.69)	0.63 (0.27, 1.48)	3.15 (0.21, 46.28)	0.40 (0.06, 2.77)
270°					*67.9 (7.3%)*	0.84 (0.45, 1.57)	4.21 (0.31, 58.05)	0.53 (0.06, 4.37)
360°						*78.8 (16.3%)*	5.00 (0.39, 63.90)	0.63 (0.07, 5.26)
Lind							*24.8 (5.3%)*	0.13 (0.00, 3.47)
Posterior 180°								*82.2 (59.5%)*

Estimates are presented as OR with 95% CI in parentheses. ORs above 1 suggest that the treatment listed in the left column is superior; ORs below 1 suggest that the treatment listed in the upper row is superior. The table lists network meta-analysis outcomes. The dashed diagonal (in italic) lists SUCRA values and the probability of each treatment being the best in parentheses. Significant values are given in bold

Table 4 League table demonstrating the relative effectiveness for each pair of comparison for regurgitation

	PPI	Anterior 90°	Anterior 120°	Anterior 180°	270°	360°	Lind	Posterior 180°
PPI	*10.2 (0.1%)*	0.12 (0.01, 1.56)	0.47 (0.04, 5.93)	0.22 (0.03, 1.62)	**0.08 (0.01, 0.60)**	**0.15 (0.02, 0.87)**	0.04 (0.00, 2.22)	0.24 (0.01, 9.87)
Anterior 90°		*63.3 (14.0%)*	3.97 (0.30, 53.39)	1.87 (0.24, 14.79)	0.68 (0.08, 5.48)	1.24 (0.19, 8.04)	0.36 (0.01, 19.58)	2.00 (0.05, 87.16)
Anterior 120°			*24.7 (0.9%)*	0.47 (0.06, 3.52)	0.17 (0.02, 1.30)	0.31 (0.05, 1.90°)	0.09 (0.00, 4.79)	0.50 (0.01, 21.27)
Anterior 180°				*41.2 (0.1%)*	**0.37 (0.14, 0.92)**	0.67 (0.27, 1.62)	0.19 (0.01, 7.38)	1.07 (0.05, 25.18)
270°					*79.6 (17.8%)*	1.82 (0.72, 4.58)	0.53 (0.01, 20.34)	2.93 (0.11, 78.72)
360°						*57.9 (0.6%)*	0.29 (0.01, 9.92)	1.61 (0.06, 42.81)
Lind							*78.1 (53.8%)*	5.55 (0.04, 688.57)
Posterior 180°								*45.0 (12.7%)*

Estimates are presented as OR with 95% CI in parentheses. ORs above 1 suggest that the treatment listed in the left column is superior; ORs below 1 suggest that the treatment listed in the upper row is superior. The table lists network meta-analysis outcomes. The dashed diagonal (in italic) lists SUCRA values and the probability of each treatment being the best in parentheses. Significant values are given in bold

Table 5 League table demonstrating the relative effectiveness for each pair of comparison for morbidity

	PPI	Anterior 90°	Anterior 180°	270°	360°	Hill	Lind	Posterior 180°
PPI	*65.9 (15.4%)*	0.90° (0.20, 4.19)	2.08 (0.40, 10.72)	1.46 (0.39, 5.47)	1.59 (0.62, 4.07)	1.86 (0.33, 10.67)	0.94 (0.14, 6.49)	1.25 (0.11, 13.58)
Anterior 90°		*68.8 (24.0%)*	2.29 (0.38, 13.92)	1.61 (0.35, 7.45)	1.76 (0.52, 5.91)	2.06 (0.31, 13.85)	1.04 (0.13, 8.30)	1.38 (0.11, 16.82)
Anterior 180°			*28.2 (1.1%)*	0.70 (0.23, 2.17)	0.77 (0.20, 2.95)	0.90° (0.12, 6.59)	0.45 (0.05, 3.92)	0.60 (0.11, 3.41)
270°				*46.3 (2.7%)*	1.09 (0.43, 2.76)	1.28 (0.22, 7.27)	0.64 (0.09, 4.42)	0.85 (0.11, 6.76)
360°					*38.4 (0.1%)*	1.17 (0.27, 5.09)	0.59 (0.11, 3.19)	0.78 (0.09, 7.04)
Hill						*35.0 (5.8%)*	0.50 (0.05, 4.73)	0.67 (0.05, 9.39)
Lind							*64.1 (28.1%)*	1.33 (0.08, 21.23)
Posterior 180°								*53.3 (22.9%)*

Estimates are presented as OR with 95% CI in parentheses. ORs above 1 suggest that the treatment listed in the left column is superior; ORs below 1 suggest that the treatment listed in the upper row is superior. The table lists network meta-analysis outcomes. The dashed diagonal (in italic) lists SUCRA values and the probability of each treatment being the best in parentheses. Significant values are given in bold

Risk of bias

The risk of bias was unclear for many RCTs and high in a few trials (Fig. 3). Analytical judgments on risk of bias with proportional contributions to individual comparisons for each outcome are provided as Supplementary material (Figs. S19–S25). Visual assessment of contour-enhanced funnel plots was suggestive of publication bias

Table 6 League table demonstrating the relative effectiveness for each pair of comparison for reoperation

	Anterior 90°	Anterior 120°	Anterior 180°	270°	360°	Hill	Lind
Anterior 90°	*54.8 (18.6%)*	0.97 (0.01, 93.10)	1.96 (0.20, 19.68)	1.04 (0.12, 9.17)	0.91 (0.15, 5.56)	1.19 (0.13, 10.55)	1.10 (0.07, 17.72)
Anterior 120°		*53.1 (37.0%)*	2.03 (0.02, 169.09)	1.08 (0.01, 83.00)	0.94 (0.01, 61.91)	1.23 (0.02, 95.45)	1.14 (0.01, 123.89)
Anterior 180°			*28.0 (2.9%)*	0.53 (0.09, 3.25)	0.46 (0.11, 1.90°)	0.61 (0.10, 3.77)	0.56 (0.04, 7.08)
270°				*53.7 (9.9%)*	0.87 (0.28, 2.74)	1.14 (0.30, 4.31)	1.06 (0.10, 11.62)
360°					*62.2 (5.9%)*	1.31 (0.41, 4.23)	1.22 (0.15, 9.97)
Hill						*47.0 (6.6%)*	0.93 (0.08, 10.27)
Lind							*51.1 (19.2%)*

Estimates are presented as OR with 95% CI in parentheses. ORs above 1 suggest that the treatment listed in the left column is superior; ORs below 1 suggest that the treatment listed in the upper row is superior. The table lists network meta-analysis outcomes. The dashed diagonal (in italic) lists SUCRA values and the probability of each treatment being the best in parentheses. Significant values are given in bold

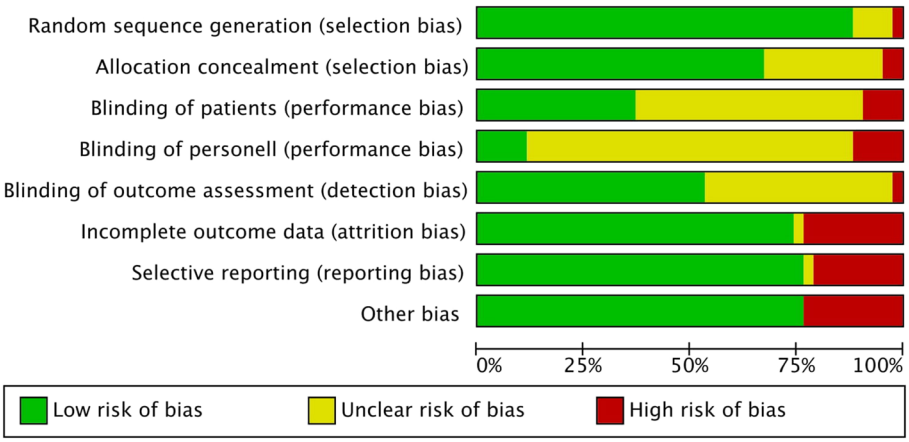

Fig. 3 Summary risk of bias graph

for the outcome dysphagia (Supplementary material Figs. S26–S31).

Quality of evidence

Judgements about the quality of evidence under consideration of GRADE items and additional network meta-analysis parameters are provided as Supplementary material (Tables S14–S19).

Discussion

Despite the extensive literature on different types of fundoplication, selection of the optimal surgical treatment is still debatable. In this study, we aimed to provide comparative evidence with robust evidence synthesis methodology and quality of evidence appraisal to aid drawing a meaningful conclusion that can guide care and patients with the optimal techniques to treat GERD.

This study was the first to implement network meta-analysis focusing on laparoscopic antireflux surgery. The main finding was that 360° total fundoplication was associated with higher odds for dysphagia and gas-bloat symptoms, and equivalent heartburn and regurgitation control, compared to all partial fundoplications. The quality of evidence on dysphagia was moderate for 270° posterior and 90° anterior fundoplication compared to 360° total fundoplication, and low for gas-bloat symptoms and heartburn, owing primarily to imprecision. Further, the 270° posterior fundoplication was effective with less odds for regurgitation compared to PPIs, although this outcome was informed only by indirect comparisons. An anterior 180° fundoplication (for which there is robust direct and indirect evidence) might be less effective than the 270° posterior fundoplication for controlling regurgitation, but this comparison was associated with very low quality of evidence, mainly due to discordance between direct and indirect evidence (incoherence). Evidence for anterior 90°, posterior 180°, anterior 120°, and Lind posterior 300° is limited due to the small number of studies and patients per comparison, and this is reflected in the wide interval estimates. No conclusions can be drawn on these interventions, except for consistent evidence of lower odds for dysphagia following all partial wraps.

When considering the full breadth of the above findings, including the network geometry, the highest-level evidence

suggests that 270° posterior partial fundoplication is the most effective procedure providing the best balance of reflux symptom control versus side effects. Current clinical practice guidelines do not provide clear recommendations about the selection of specific antireflux procedures for the treatment of GERD and anecdotal data suggest that surgical practices vary across institutions [72, 73]. Both direct and indirect evidence seem consistently in the direction of outcomes in favoring the 270° posterior partial fundoplication. The concordance of the results of this network meta-analysis with a similar work encompassing both open and laparoscopic procedures suggests that there are fundamental differences in the antireflux neo-barrier generated by 360° and 270° fundoplications, and these impact symptom outcomes [13]. Guideline developers, healthcare providers and institutions, and practicing surgeons need to take this consistent evidence into account when making decisions about what type of fundoplication to construct for patients with GERD.

Transitivity was challenged in some levels, including heterogeneity for surgical practice across comparisons (use of bougie, division of short gastric vessels) and the length of follow-up, although different durations of follow-up were well distributed across the closed loop of 360°, 270°, and anterior 180° fundoplications. In addition, duration of follow-up was over 5 years for less than half of the RCTs in the closed loop of comparisons and as such conclusions about long-term efficacy cannot be drawn. Another substantive limitation was the lack of reporting on quality parameters of RCTs (risk of bias items) in a significant proportion of studies, which is reflected in the assigned levels of evidence. Direct and indirect evidence was generally consistent, which amplified the effect estimates for the 3 interventions forming a closed loop. Several other treatment options, such as endoscopic plication and magnetic sphincter augmentation, were not considered. This was because most relevant studies usually include patients with mild GERD only. Furthermore, to the best of our knowledge, no RCTs comparing these procedures with fundoplication have been performed.

Network outcomes for perioperative morbidity and reoperation could not be adequately addressed because of the rarity of events. Functional and endoscopic outcomes were poorly reported, as was the use of PPI medication at follow-up. Most importantly, quality of life parameters were inconsistently reported across RCTs. The above have precluded network meta-analysis on those parameters.

Conclusion

Highest quality evidence suggests that laparoscopic 270° posterior partial fundoplication may be preferable over 360° total fundoplication for the treatment of GERD, although other partial anterior and posterior fundoplication variants might be equally effective. Future research needs to address the comparative effect of both anterior and posterior partial fundoplications and should further focus on reporting quality of life parameters.

Acknowledgements This study was methodologically supported by the European Association for Endoscopic Surgery Research Committee.

Funding None.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interest.

Disclosures Prof. David I. Watson received funding support for RCTs included in this meta-analysis in the form of Research Project Grants from the National Health and Medical Research Council (NHMRC) of Australia - Grant nos. 375111 and 1022722. Mr Alexandros Andreou, Prof. Dimitrios Mavridis, Prof. Nader K. Francis, and Dr. Stavros A. Antoniou do not have any conflicts of interest or financial ties to disclose.

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