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SYSTEMATIC REVIEW

Single incision laparoscopic fundoplication: A systematic review of the literature

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Abstract

BACKGROUND

Fundoplication, was first introduced as a surgical treatment method of gastroesophageal reflux disease. Consequently, several modifications of this method have been described, whereas laparoscopic fundoplication was recently introduced. Although single incision (SI) fundoplication was considered as an alternative to the conventional laparoscopic approach, several studies reported an increased operation duration, and high rates of multiport conversion and incisional hernia.

AIM

To provide a current overview of the technical variations and the postoperative outcomes of patients submitted to SI fundoplication.

METHODS

The present systematic review of the literature was designed and conducted on the basis of the PRISMA guidelines. A systematic screening of the electronic scholar databases (Medline, Scopus and Web of Science) was performed.

RESULTS

Literature search resulted in the identification of 19 studies. Overall, 266, 137 and 110 SI Nissen, Dor and Toupet fundoplications were reported, respectively. In the majority of the trials, standard laparoscopic instruments were used. The left liver lobe was displayed through the use of forceps, graspers, retractors, drains or even glue. Both intra-corporeal and extracorporeal suturing was described. Mean operative time was 136.3 min. Overall complication rate was 5.2% and the rate of incisional hernia was 0.9%. No mortality was reported.

CONCLUSION

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Due to the methodological heterogeneity and the lack of high quality studies comparing multi to single access techniques and the several variations, we conclude that further well designed studies are necessary, in order to evaluate the role of SI fundoplication.

Key words: Single incision; Single port; Fundoplication; Nissen; Dor; Toupet

Core tip: This systematic review summarizes all available data about the use of single incision laparoscopic fundoplication. Although the technique is not yet standardized, this study validates the safety and efficacy of the single port approach compared to conventional multiport approach.

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INTRODUCTION

Fundoplication, the wrap of the gastric fundus around the distal part of the esophagus, was introduced by Nissen[1] in 1956, as a surgical treatment of gastroesophageal reflux disease (GERD), and is currently considered as the operation of choice, when conservative approaches fail[2]. Since the extent of the plication was correlated with postoperative functional complications, various modifications (*e.g.*, Hill, Toupet) of the original technique have been described[3-5]. Besides these, fundoplication has been, also, an important restoration element in other procedures, such as, Heller myotomy for esophageal achalasia[6].

The implementation of the minimal invasive principles in fundoplication, was justified under the auspice of a better cosmetic result, reduced postoperative pain and a faster recovery[7]. However, proponents of the open approach, linked laparoscopy to increased perioperative costs, pneumoperitoneum related complications, and technical difficulties leading to a steeper learning curve, such as, narrowing of the field of vision, fixed instrument positions and loss of loss of freedom degrees[8]. Due to the fact that subsequent studies, associated laparoscopic fundoplication with a reduced length of hospital stay (LOS), return to daily activities and overall morbidity, resulted in the establishment of laparoscopy as the gold standard approach[7,9].

In order to further enhance the advantages of minimally invasive operations, single incision (SI) laparoscopic surgery was introduced. Navarra *et al*[10], in 1997, reported the first SI cholecystectomy, whereas Hamzaoglu *et al*[11], performed the first single incision laparoscopic surgery (SILS) Nissen in 2010. Single port fundoplications, although characterized by minimization of postoperative scars and better cosmesis, are more demanding in terms of laparoscopic skills, due to the inert loss of triangulation and intraoperative instrument clashing[12]. Although, initial studies comparing SILS fundoplications to the conventional multiport approaches, reported that the two techniques were comparable in terms of efficacy and safety[13,14], the increased operative time and the high rate of conversion to multiport and port-site hernia were considered as inhibitory factors for the wider acceptance of the method[13].

Therefore, taking into consideration the above mentioned body of evidence, the present systematic review of the literature was designed and conducted. Our study, mainly, focuses in providing a comprehensive appraisal of the intraoperative technical variations and the postoperative outcomes in adult patients submitted to SI fundoplication.

MATERIALS AND METHODS

Study protocol

The PRISMA guidelines were utilized for the completion of this systematic review[15].

Eligibility criteria

All human trials that reported results on SI fundoplication, with an adult study population, whose outcomes of interest were reported in English and were retrievable, were considered as eligible. Eligible studies should provide perioperative results (*i.e.*, complication, mortality or conversion rates, operation duration and follow up) on SI fundoplication. Exclusion criteria for this systematic review were studies: (1) with a pediatric study sample; (2) with no outcome of interest; (3) with inadequate outcome data; (4) without human objects; or (5) in the form of reviews, editorials, letters, conference abstracts and expert opinions.

Literature search

A systematic screening of the literature available in the electronic scholar databases (Medline, Scopus and Web of Science) was performed. The last search date was 2/1/2019. The following keywords were used: "SILS", "single site", "single port", "single incision", "laparoendoscopic single site", "fundoplication".

Study selection and data collection

After the completion of the literature search, the duplicate entries were identified and removed. The next step included the screening of titles and abstracts. Finally, the remaining articles were submitted to a full text review, in order to assess consistency with the above mentioned eligibility criteria. All electronic search, study selection and data extraction were performed in duplicate and blindly by two independent investigators (PK and SC). In case of a discrepancy, through mutual discussion and revision, a consensus was reached. If the disagreement was not resolved, the opinion of a third investigator was considered (BI).

Data extraction included the recording of data regarding the included studies(first author, country and type of study, follow up, number and experience of surgeons, sample size and gender, age and body mass index (BMI) allocation of the patients), patient characteristics (ASA score, previous operations and surgery indication), technical characteristics (single port device, instrument type, liver retraction method, dissection device, boogie size, suturing method and pneumoperitoneum pressure) and perioperative outcomes (operation duration LOS, blood loss and conversion, complications, recurrence mortality and incisional hernia rates).

Only the information available in the full text article of the trials were reported. In case that the mean and the standard deviation (SD) of the continuous variables were not provided, then they were estimated from the respective median, range or interquartile range, according to the formula by Hozo *et al*[16]. Moreover, outcome percentages were calculated according to the following formula: Total number of events regarding a specific complication/Sum of patients sample of studies reporting the specific complication.

RESULTS

Study selection

The application of the search algorithm resulted in the identification of 2040 records (Figure 1). More specifically, 746, 1102 and 192 citations were retrieved through Medline, Web of Science and Scopus, respectively. After the removal of the duplicate entries, 1444 titles and abstracts were screened. In this phase, 1404 records (5 conference abstracts or letters, 10 non human studies, 86 reviews or meta-analyses and 1303 irrelevant studies) were excluded. The next step included the full text screening of the remaining 40 articles, on the basis of the inclusion criteria. In total 21 full text articles were not considered as eligible (2 trials with inadequate data, 8 trials with duplicate patient data and 11 irrelevant studies). Therefore, 19 studies[11,12,14,17-32] were included in our systematic review.

Study characteristics

The characteristics of the included studies are summarized in Table 1. Publication year ranged from 2010[11] to 2016[14,30]. Although initial references consisted of case reports[11,12,18,23,27,29], subsequent trials included retrospective[14,19-22,24-26,30,31] and prospective[17,32] studies. All eligible trials were performed in a single institution. Regarding the operation type, 14 studies[11,12,17-26,30,31] reported on Nissen fundoplication, whereas Dor and Toupet fundoplication was performed in 6[14,25,27-29,32] and 1 trial[17], respectively. Although the number of operating surgeons ranged from 1[22,24,27] to multiple[14,19,30,32], experience in laparoendoscopic techniques was documented only in 3[24,26,27] studies. In total, 513 patients were submitted to a SI laparoscopic fundoplication. More specifically, 266, 137 and 110 SI Nissen, Heller and Dor and

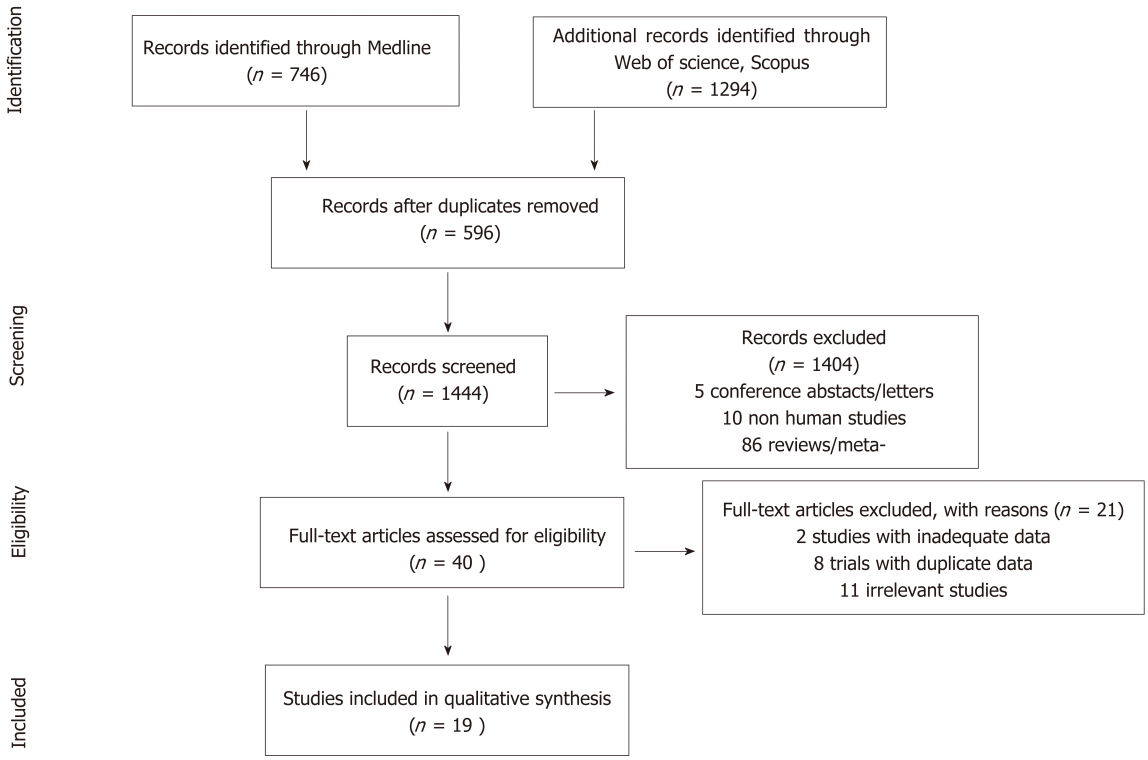

Figure 1 Study flow diagram.

Toupet fundoplications were recorded, respectively. Mean age, gender and BMI allocation is, also, displayed in Table 1. Mean follow up period extended from 1 wk[11] to 60 mo[26].

Data considering the ASA classification of the included patients were systematically not provided (Table 2). The indications for performing surgery were hiatus hernia[18,25] and GERD[11,12,17,19-24,26,30,31] for the Nissen and Toupet fundoplication and achalasia[14,27-29,32] for the Heller myotomy and Dor fundoplication. Reports were inconsistent, regarding the included patients that had undergone a previous abdominal operation.

Despite the fact that, in the majority of the included studies (Table 3), a commercial SP device, such as SILS™[11,18-22], Triport Plus™[32], Wrapdisk™[28], X-CONE[19], or EZ Access™[14], was applied, several trials[12,14,19,20,23,25,29,32] reported the introduction of conventional or low profile trocars through a single abdominal incision. In most operations[14,21,22,25,28,30], conventional laparoscopic instruments were used. However, the application of articulating[11,12,18,21,27,32] or curved[23] instruments has, also, been described. Heterogeneity in terms of the liver retraction method was identified. Several techniques, such as, the use of forceps[14], graspers[23], retractors[11,17,19,20,24,32], drains[28,29] or even glue[25], have been documented for the elevation and displacement of the liver left lobe. In the larger part of the included trials[11,12,14,17,18,20,22,25,27,32], commercial energy devices were applied for tissue dissection. A transesophageal boogie was used only in 4 studies[12,22,23,29], and the respective diameter ranged from 32Fr[22] to 60Fr[12]. Intracorporeal suturing with conventional sutures was documented in 4 trials[23,25,29,32]. In the remaining trials, extracorporeal suturing[22], Endostich™[12,17,18,20,32], SILS STICH[11], or V Lock™ sutures[17] were applied. The intraabdominal pneumoperitoneum pressure spanned from 8 mmHg[28] to 15 mmHg[12,26].

Although no conversion to open was reported, the multiport conversion rates for Nissen and Dor fundoplications were 9.8% and 14%, respectively (Table 4). Mean overall operation duration was 136.3 min. The mean operative time for Nissen fundoplication was 130.7 min. Similarly pooled LOS was 2.49 d. Mean intraoperative blood loss was retained at very low levels (17.04 mL). Overall morbidity rate was estimated at the rate of 5.2%. No mortality event was documented. In all subgroups, recurrence of primary symptoms was minimal (0%). The rate of postoperative incisional hernia was calculated at the level of 0.9%.

Table 1 Included studies

Included studies

ID	Ref.	Country	Type of study	Center	Year	Operation type	Surgeons	Experience	Sample	Gender (M/F)	Age	BMI	Follow up
27417943	Buckley *et al*[30]	United States	Retrospective	Single center	2016	Nissen	3	No	21	n/a	n/a	n/a	34 (8.3) mo
26350663	Sukharamwala *et al*[17]	United States	Prospective	Single center	2015	Nissen	n/a	n/a	190	67/123	55(14.7)	27(3.9)	n/a
24960483	Agaba *et al*[26]	United States	Retrospective	Single center	2014	Nissen	2	Yes	3	n/a	n/a	n/a	60 mo
24686364	Galvani *et al*[24]	United States	Retrospective	Single center	2014	Nissen	1	Yes	2	0/2	43.4 (4)	22(3)	n/a
24615563	Wu *et al*[25]	China	Retrospective	Single center	2014	Nissen	n/a	n/a	5	n/a	n/a	n/a	1 mo
23585169	Strzalka *et al*[31]	Poland	Retrospective	Single center	2013	Nissen	n/a	n/a	1	n/a	n/a	n/a	n/a
10.5336/medsci.2012-31954	Yilmaz *et al*[22]	Turkey	Retrospective	Single center	2013	Nissen	1	n/a	10	3/7	35(8.5)	24.6 (3)	n/a
22146016	Eyuboglu *et al*[20]	Turkey	Retrospective	Single center	2012	Nissen	n/a	n/a	22	5/17	28(5.75)	n/a	8 mo
20306152	Miyazaki *et al*[19][1]	Japan	Retrospective	Single center	2012	Nissen	Surgical team	n/a	4	2/2	52.5 (11.7)	20.9 (1.1)	n/a
22278618	Mizuno *et al*[21][2]	Japan	Retrospective	Single center	2012	Nissen	n/a	n/a	2	1/1	65.5 (13.4)	30.5 (0.7)	18 mo
21991503	Barbaros *et al*[18]	Turkey	Case report	Single center	2011	Nissen	n/a	n/a	1	1/0	29	n/a	n/a
21059609	Dapri *et al*[23]	Belgium	Case report	Single center	2011	Nissen	n/a	n/a	1	0/1	21	n/a	6 mo
21471786	Hawasli *et al*[12]	United States	Case report	Single center	2011	Nissen	n/a	n/a	1	0/1	36	29	1 wk
20306152	Hamzaoglu *et al*[11]	Turkey	Case series	Single center	2010	Nissen	n/a	n/a	3	1/2	40(17.5)	26.3 (4.93)	1 wk
Total									266	79/156	51.05	26.75	19.27
26315292	Fukuda *et al*[14]	Japan	Retrospective	Single center	2016	Heller and Dor	Surgical team	No	10	1/9	53.6 (18.3)	19.7 (2)	n/a
24615563	Wu *et al*[25]	China	Retrospective	Single center	2014	Heller and Dor	n/a	n/a	4	n/a	n/a	n/a	1 mo
23896255	Ross *et al*[32]	United States	Prospective	Single center	2013	Heller and Dor	Surgical team	No	120	56/64	53(17.4)	25(4.7)	33 (7.9) mo
23088902	Yamada *et al*[28]	Japan	Case report	Single center	2013	Heller and Dor	n/a	n/a	1	0/1	56	n/a	12 mo
22218875	Yano *et al*[29]	Japan	Case report	sIngle center	2012	Heller and Dor	n/a	n/a	1	1/0	31	n/a	n/a
21969159	Nakajima *et al*[27]	Japan	Case report	Single center	2011	Heller and Dor	1	yes	1	1/0	58	n/a	1 mo
Total									137	59/74	52.9	24.59	31.5
26350663	Sukharamwala *et al*[17]	United States	Prospective	Single center	2015	Toupet	n/a	n/a	110	28/82	66(13.2)	26(3.8)	n/a
Total									513	166/312	55.01	25.9	27.6

[1]Only data for Nissen extracted- Heller and Dor data duplicate;
[2]In the study of Mizuno *et al*[21] only data from adult patients extracted. n/a: Not available.

DISCUSSION

The pooled overall complication rate in SI fundoplication was calculated at the level of 5.2%, validating thus the safety profile of the single port approach. This is in accordance to the current literature, where morbidity rate of minimal invasive fundoplication is estimated at 7%-12%[7,33]. In addition to this, a very small percentage (0.9%) of the operated patients developed incisional hernia at the port site. Based on

Table 2 Patient characteristics

Patient characteristics							
Ref.	**Operation type**	**ASA I**	**ASA II**	**ASA III**	**ASA IV**	**Previous operation**	**Indication**
Buckley *et al*[30]	Nissen	n/a	n/a	n/a	n/a	n/a	GERD
Sukharamwala *et al*[17]	Nissen	n/a	n/a	n/a	n/a	14	GERD
Agaba *et al*[26]	Nissen	n/a	n/a	n/a	n/a	n/a	GERD
Galvani *et al*[24]	Nissen	n/a	n/a	n/a	n/a	n/a	GERD
Wu *et al*[25]	Nissen	n/a	n/a	n/a	n/a	n/a	Hiatus Hernia
Strzalka *et al*[31]	Nissen	n/a	n/a	n/a	n/a	n/a	GERD
Yilmaz *et al*[22]	Nissen	n/a	n/a	n/a	n/a	n/a	GERD
Eyuboglu *et al*[20]	Nissen	n/a	n/a	n/a	n/a	n/a	GERD
Miyazaki *et al*[19] *	Nissen	n/a	n/a	n/a	n/a	n/a	GERD
Mizuno *et al*[21]**	Nissen	n/a	n/a	n/a	n/a	n/a	GERD
Barbaros *et al*[18]	Nissen	n/a	n/a	n/a	n/a	n/a	Hiatus Hernia
Dapri *et al*[23]	Nissen	n/a	n/a	n/a	n/a	n/a	GERD
Hawasli *et al*[12]	Nissen	n/a	n/a	n/a	n/a	n/a	GERD
Hamzaoglu *et al*[11]	Nissen	n/a	n/a	n/a	n/a	n/a	GERD
Fukuda *et al*[14]	Heller and Dor	n/a	n/a	n/a	n/a	n/a	Achalasia
Wu *et al*[25]	Heller and Dor	n/a	n/a	n/a	n/a	n/a	Achalasia
Ross *et al*[32]	Heller and Dor	n/a	n/a	n/a	n/a	5	Achalasia
Yamada *et al*[28]	Heller and Dor	n/a	n/a	n/a	n/a	n/a	Achalasia
Yano *et al*[29]	Heller and Dor	n/a	n/a	n/a	n/a	n/a	Achalasia
Nakajima *et al*[27]	Heller and Dor	n/a	n/a	n/a	n/a	n/a	Achalasia
Sukharamwala *et al*[17]	Toupet	n/a	n/a	n/a	n/a	14	GERD

n/a: Not available; ASA: American Society of Anesthesiologists; GERD: Gastroesophageal reflux disease.

the included studies, the mean operative time was 136.3 minutes. Although SI Nissen and Dor operative times were comparable (130.71 and 138.3, respectively), the duration of SI Toupet procedure was longer (145 min). According to the study of Peters *et al*[7], the mean operative time of laparoscopic fundoplication was 112.59 minutes. These results, validate the elongation of the procedure time, when the SI approach is implemented. The high multiport conversion rate, reported in previous trials[14], was not confirmed in our review (12.9%). More specifically, Rao *et al*[34], reported that the multiport conversion rate in SI surgery ranges from 2% to 40%. In contrast to the considerable treatment failure rates (14.4%) in laparoscopic fundoplication[7], in our review, recurrence of symptoms in SI, were minimal. Similarly our findings show a comparable LOS (2.49 ds) in SI fundoplication, considering the respective hospitalization duration (4 d) in the multi port approach[7].

Despite the advantages derived from laparoscopy, minimal invasive techniques require the completion, of a steeper learning curve by the operating surgeon, in order to be performed safely and efficiently[35-37]. Through systematic repetition of the operative steps, the surgeon accumulates the necessary technical skills and achieves proficiency[36,37]. The clinical relevance of these, is that the operative volume and the location of an individual on the learning curve is directly associated with postoperative outcomes[38]. More specifically, in laparoscopic fundoplication the estimated learning curve cut-off value is approximately 20 patients[39,40]. SI fundoplication is technically more demanding and as so, a larger number of cases would be regarded as necessary for achieving adequacy. According to Ross *et al*[32], multiport conversion rates in SI Dor fundoplication were minimized after 60 patients, whereas the learning curve for SI Nissen and Toupet fundoplication was calculated at 25 cases[41]. In our review, single port adequacy, was scarcely reported[24,26,27]. Since previous experience is linked to perioperative endpoints, like operative time, conversion rate and morbidity, future studies should systematically report the learning curve status of the surgical team.

Although fundoplication is considered by many as a straightforward procedure, the respective minimal invasive application requires the possession of advanced skills, like laparoscopic suturing. Secure laparoscopic knot tying is a difficultly acquired dexterity and it can make the difference between an uneventful postoperative period and an increased morbidity rate[42,43]. Therefore, in order to

Table 3 Technical characteristics

Technical characteristics

Ref.	Operation type	Single port device	Instruments	Liver retraction	Dissection device	Boogie	Suturing	Gas	Gas pressure
Buckley *et al*[30]	Nissen	SILS™	Conventional	n/a	n/a	n/a	n/a	n/a	n/a
Sukharamwala *et al*[17]	Nissen	SILS™	n/a	Pretzel Retractor	Monopolar or Ultrasonic dissectors	n/a	Endostich™ or V Lock™	n/a	n/a
Agaba *et al*[26]	Nissen	SILS™	n/a	n/a	n/a	n/a	n/a	n/a	15mmHg
Galvani *et al*[24]	Nissen	n/a	n/a	CINCH™ retractor	n/a	n/a	n/a	n/a	n/a
Wu *et al*[25]	Nissen	Conventional trocars in a single incision	Conventional	Cyanoacrylate glue	Harmonic™	n/a	Intracorporeal	n/a	n/a
Strzalka *et al*[31]	Nissen	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Yilmaz *et al*[22]	Nissen	SILS™	Conventional	Berk technique	Harmonic™	32Fr	Extracorporeal	CO2	13mmHg
Eyuboglu *et al*[20]	Nissen	Conventional trocars in a single incision or SILS™	n/a	Cerrahpasa retractor	Ligasure™ or Monopolar	n/a	Endostich™	n/a	n/a
Miyazaki *et al*[19] *	Nissen	Conventional trocars in a single incision or SILS™ or X-CONE™	n/a	Loop Retractor	n/a	n/a	n/a	n/a	n/a
Mizuno *et al*[21]**	Nissen	SILS™	ProSeed™ and Conventional	Loop Retractor	n/a	n/a	n/a	CO2	8mmHg
Barbaros *et al*[18]	Nissen	SILS™	Roticulating	Snowden Pencer™	Ligasure™	n/a	Endostich™	n/a	14mmHg
Dapri *et al*[23]	Nissen	Conventional trocars in a single incision	Dapri™ Karl Storz	Grasper	n/a	34Fr	Intracorporeal	n/a	n/a
Hawasli *et al*[12]	Nissen	Conventional trocars in a single incision	Roticulating	Veress	Sono-surg™	60FR	Endostich™	CO2	15mmHg
Hamzaoglu *et al*[11]	Nissen	SILS™	Roticulating	Instanbul Technique	Harmonic™	no	SILS™ STICH	n/a	n/a
Fukuda *et al*[14]	Heller and Dor	Conventional trocars in a single incision or SILS™ or EZ Access™	Conventional	Mini loop Retractor™ or Forceps	Harmonic™	n/a	n/a	CO2	n/a
Wu *et al*[25]	Heller and Dor	Conventional trocars in a single incision	Conventional	Cyanoacrylate glue	Harmonic™	n/a	Intracorporeal	n/a	n/a
Ross *et al*[32]	Heller and Dor	Conventional trocars in a single incision or SILS™ or Triport Plus™	Roticulating	Retractor	Bipolar or Ultrasonic dissectors	n/a	Intracorporeal or Endostich™	CO2	n/a
Yamada *et al*[28]	Heller and Dor	Wrapdisk™	Conventional	Silicon drain	Monopolar	n/a	n/a	CO2	8mmHg
Yano *et al*[29]	Heller and Dor	Conventional trocars in a single incision	n/a	Penrose drain	Monopolar	56Fr	Intracorporeal	CO2	12mmHg
Nakajima *et al*[27]	Heller and Dor	SILS™	Roticulating	Endo Close™	Monopolar or Enseal™	n/a	n/a	n/a	10mmHg
Sukharamwala *et al*[17]	Toupet	SILS™	n/a	Pretzel Retractor	Monopolar or Ultrasonic dissectors	n/a	Endostich™ or V Lock™	n/a	n/a

n/a: Not available.

Table 4 Perioperative outcomes

Perioperative outcomes										
Ref.	Operation type	Open conversion	Multiport conversion	Operation duration	LOS	Blood loss	Complications	Recurrence	Mortality	Incisional hernia
Buckley *et al*[30]	Nissen	0	n/a	n/a	n/a	n/a	2	0	0	2
Sukharamwala *et al*[17]	Nissen	n/a	n/a	130 (42.7)	2 (1.1)	n/a	n/a	n/a	n/a	n/a
Agaba *et al*[26]	Nissen	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Galvani *et al*[24]	Nissen	0	1	164 (83)	n/a	23 (4)	n/a	n/a	n/a	n/a
Wu *et al*[25]	Nissen	0	0	146 (13)	n/a	n/a	0	0	0	0
Strzalka *et al*[31]	Nissen	0	0	100	1	n/a	0	n/a	0	0
Yilmaz *et al*[22]	Nissen	0	2	93 (14.1)	2.2(0.9)	n/a	0	0	0	0
Eyuboglu *et al*[20]	Nissen	0	0	n/a	1	n/a	0	0	0	0
Miyazaki *et al*[19] *	Nissen	0	2	202.7 (61.1)	15.5 (10.6)	25 (23)	0	0	0	0
Mizuno *et al*[21]**	Nissen	0	0	147.5 (45.9)	10 (2)	10 (7)	0	0	0	0
Barbaros *et al*[18]	Nissen	0	0	120	1	n/a	0	0	0	0
Dapri *et al*[23]	Nissen	n/a	n/a	122	2	0	0	0	0	0
Hawasli *et al*[12]	Nissen	0	0	52	1	n/a	0	0	0	0
Hamzaoglu *et al*[11]	Nissen	0	0	190 (17.3)	2	30 (17.3)	0	0	0	0
		0 (0%)	5 (9.8%)	130.71	2.2	21.3	2 (2.8%)	0 (0%)	0 (0%)	2 (2.8%)
Fukuda *et al*[14]	Heller and Dor	0	7	223.5 (46.3)	9.7(2.4)	16 (17.8)	0	0	0	0
Wu *et al*[25]	Heller and Dor	0	0	133 (20)	n/a	n/a	0	0	0	0
Ross *et al*[32]	Heller and Dor	0	12	129 (39.2)	2 (2.7)	n/a	9	n/a	0	0
Yamada *et al*[28]	Heller and Dor	n/a	n/a	248	2	0	0	0	0	0
Yano *et al*[29]	Heller and Dor	n/a	n/a	236	4	0	0	0	0	0
Nakajima *et al*[27]	Heller and Dor	0	0	220	4	10	0	0	0	0
		0 (0%)	19 (14%)	138.3	2.6	13.07	9 (6.5%)	0 (0%)	0 (0%)	0 (0%)
Sukharamwala *et al*[17]	Toupet	n/a	n/a	145 (58.4)	3 (5.2)	n/a	n/a	n/a	n/a	n/a
Total		0 (0%)	24 (12.9%)	136.3	2.49	17.04	11 (5.2%)	0 (0%)	0 (0%)	2 (0.9%)

n/a: Not available.

reduce operative time and complement the inexperience of younger surgeons in intracorporeal knotting, endoscopic suturing devices have been imported in clinical practice, with comparable results[44-46]. In SILS, the limited working area, the restricted vision, the minimization of the manipulation angle and the parallelization of the optics and hand instruments increases the overall difficulty level[47,48]. In single port fundoplication, intracorporeal suturing has been extensively performed[17,23,25,29,32] with various techniques, like side-winding and the utilization of articulating graspers and needle holders[49]. Alternative approaches were the extracorporeal formation of a knot, with the subsequent completion through a suture passer[22] and the use of suturing devices[11,12,17,18,20].

Besides experience with the minimal invasive techniques, successful completion of the intracorporeal laparoscopic operative steps, like suturing or dissection, is associated with the intraoperative setting of the hand instruments. In single port surgery, the access point is usually umbilicus, through which the working ports are introduced[34]. As a result, the working angle, which should optimally be at about 60°, is significantly reduced[50,51]. Moreover, in operations like fundoplication, where the distance between the operating site and the access point is increased, the working angle further decreases, and with the synchronous alterations of the elevation angle, the derived ergonomic stress further escalates[48,49]. Therefore, in order to technically increase the manipulation angle, pre bent and articulating instruments have been introduced. Despite the fact that, simulation studies displayed a difficulty of novice surgeons in using articulating instruments[52], the combination of an dynamically bending and a pre bent tool minimizes the task completion time[53]. In the setting of SI fundoplication, both the standard[14,21,22,27,28,30] and the articulating setup[11,12,18,27,32] has been applied. Dapri *et al*[23,54], proposed the use of specialized reusable pre bent instruments that enabled intracorporeal and extracorporeal triangulation, thus avoiding conflict between the instruments and the scope.

Moreover, adequate exposure of the working field is another important factor for the performance of the operative tasks. The efficient displacement of the left liver lobe is a crucial step in SI fundoplication and therefore numerous techniques have been devised. The most simple method, is the use of a working instrument such as forceps[14] or graspers[23]. Commercially available retractors have been extensively utilized[17,18,32]. A long Veress needle has been, also, used as a retractor[12]. Similarly, relocating of left lobe by silicon drains and elastic loops was described in various cases[14,19,21,28,29]. Nakajima *et al*[27], after applying a silk thread in the left triangular ligament with a suturing device, suspended the liver lobe in the epigastric region. Furthermore, Galvani *et al*[24], used an internal retraction device, which after applying the retraction clip in the pars flaccida, the hook part was placed in the falciform ligament or the parietal peritoneum. The role of cyanoacrylate glue as a retracting method has been also studied[25]. According to Wu *et al*[25], the adhesion of the left liver lobe on the diaphragm, using cyanoacrylate glue, is a fast, safe and totally reversible technique.

Since our study is a systematic review of previously published trials, the validity of its estimations is inherently influenced by the methodology of the eligible studies. In this case, the majority of the included trials consisted of, either case reports, or retrospective analyses and only a few prospective studies were identified. In addition to this, most of these series incorporated a small sample size, thus inhibiting the strength of our results. Due to the fact that the learning curve is directly associated with the postoperative outcomes, another bias introducing factor could possibly be the inconsistent reporting of the number of the operating surgeons and their experience in single port surgery. Finally, although the identification of the various technical methodologies was considered as an endpoint in our study, the existence of these variations contributes in the overall heterogeneity levels.

Our study is an attempt to provide an overview regarding the application of SI fundoplication. Pooled results validate the safety and efficacy of the single port approach, although the technique is not yet standardized and many methodological variations have been described. The majority of the trials reporting on SI fundoplication were case reports and studies of a low quality level, without a comparison arm of the conventional multi port procedure and other methodological variations. Therefore, further randomized controlled trials, of a larger sample size are required, in order to draw a safe conclusion considering the application of SI fundoplication.

ARTICLE HIGHLIGHTS

Research background

The implementation of the minimal invasive principles in fundoplication resulted in reduced length of hospital stay, overall morbidity, and earlier return to daily activities. In order to further enhance the advantages of minimally invasive operations, single incision (SI) laparoscopic fundoplication was introduced.

Research motivation

Several studies comparing SI laparoscopic fundoplications to the conventional multiport approaches reported an increased operation duration, and high rates of multiport conversion and incisional hernia.

Research objectives

This study was designed in order to provide a comprehensive appraisal of the intraoperative

technical variations and the postoperative outcomes in patients submitted to SI fundoplication.

Research methods
A systematic review of the literature available, in the electronic scholar databases (Medline, Scopus and Web of Science) was performed. All human trials that reported results on SI fundoplication, with an adult study population were considered eligible to be included in the study.

Research results
In total, 19 studies were included in this systematic review, comprising 266, 137 and 110 SI Nissen, Heller and Dor and Toupet fundoplications, respectively. Mean overall operation duration was 136.3 min. The total conversion rate to multiport laparoscopic fundoplication was 12.9%. Overall complication rate was 5.2%, while the rate of incisional hernia was 0.9%.

Research conclusions
The results of this systematic review confirm the safety and efficacy of the single port laparoscopic fundoplication, although the technique is not yet standardized.

Research perspectives
Due to the lack of high-quality studies, further well designed studies are necessary to determine the role of SI fundoplication.

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