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REVIEW ARTICLE

Is routine splenic flexure mobilization always necessary in laparotomic or laparoscopic anterior rectal resection? A systematic review and comprehensive meta-analysis

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Abstract

Splenic flexure mobilization (SFM) is one of the most difficult steps in laparoscopic colorectal surgery and its role is harshly debated. Some surgeons considered it routinely necessary to obtain a safe anastomosis and to respect oncologic criteria; for others SFM is frequently unnecessary, not ensuring the aspects mentioned above and increasing the risk of morbidity (splenic, bowel and vessels injury, lengthened procedure). We performed a systematic review and a comprehensive meta-analysis, without any language restriction, about the peri-operative and post-operative outcomes (anastomotic leakage, intra-operative complication, conversion rate, operative time, post-operative bleeding, intra-abdominal collection, prolonged ileus, wound infection, anastomotic stricture, overall complications, hospital stay, re-operation, post-operative mortality, R0 margin resection, local recurrence) in patients undergoing elective anterior rectal resection (ARR) with or without SFM, both in laparotomic (LT) and laparoscopic (LS) approach. Fourteen studies were meta-analyzed with a total amount of 42,221 patients. The comprehensive meta-analysis shows that the mobilization or the preservation (SFP) of the splenic flexure does not statistically influence the incidence of colorectal anastomotic leakage, conversion rate, post-operative bleeding, intra-abdominal collection, prolonged ileus, wound infection, anastomotic stricture, overall complications, hospital stay, re-operation, R0 margin resection, and local recurrence results. The operative time is significantly longer in every group of patients undergoing SFM. The incidence of intra-operative complication is statistically increased in overall patients and also in the LS subgroup of patients undergoing SFM, in which also higher incidence of wound infection and re-operation is shown. The meta-analysis shows that SFM may be considered not necessary to ensure better peri-operative and post-operative outcomes in both LT and LS ARR.

Keywords Colorectal cancer · Splenic flexure mobilization · Rectal resection · Laparoscopy · Robotic surgery

Abbreviations

SFM	Splenic flexure mobilization
RCT	Randomized controlled trial
ARR	Anterior rectal resection
SFP	Splenic flexure preservation
HRR	High rectal resection
LRR	Low rectal resection
LT	Laparotomic
LS	Laparoscopic

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Introduction

Splenic flexure mobilization (SFM) has been shown to be one of the most difficult steps to learn in laparoscopic colorectal surgery [1–4]. Sure enough, the study by Akiyoshi identified SFM as an independent predictor of difficulty of laparoscopic surgery for left-sided colon cancer and so of longer operative time on multivariate analysis [5].

SFM is considered by some surgeons routinely necessary in distal left colectomy and colonic anterior resection to obtain high ligation of the mesenteric vessels and maximized lymph node clearance, adequate specimen length, and a safe, well-perfused, tension-free anastomosis [6, 7]. These surgeons argue that the sigmoid colon should not be used in anastomoses because it is often thick-walled, diverticular, it has a poorer blood supply than the more proximal colon and it may have been exposed to radiotherapy [8].

Other surgeons oppose routine SFM asserting that it is frequently unnecessary (it is not a guarantee of a well-perfused and tension-free anastomosis, and the oncologic criteria can be respected even without it) and adds complexity and length to the operation, because of its difficulty especially during the laparoscopic approach, with a not negligible degree of morbidity including splenic injury [9, 10].

Moreover, SFM in an important issue when the robotic-assisted laparoscopic approach is adopted for colorectal resection. From one hand, SFM may result in a difficult and time-spending procedure because of the limited range of movement of the robotic arms and the need to change the position of the robotic docking (from the pelvis to the left hypochondrium), thus increasing the operative time.

From the other side, the disadvantage of redocking is compensated for by the improved ergonomics and vision of the robotic platform, which could make a challenging laparoscopic step as SFM much easier, by preventing splenic, bowel and vessels injuries. Moreover, the robotic system provides with the use of infrared vision which combined with the intravenous injection of indocyanine green allows to ascertain the bowel vascularity, thus ensuring an optimal blood supply to the anastomosis.

There are few publications and no randomized controlled trials (RCTs) comparing anterior rectal resection (ARR) with or without SFM, both with laparoscopic and laparotomic approach, and to date the results about the outcomes are not univocal. Three previous meta-analysis did not include all the available literature reports, did not focus on only anterior rectal resection, and did not distinguish the subgroup according to the height of the rectal resection and to the surgical approach [11–13]. For this reason, we conducted a systematic review and a comprehensive meta-analysis of all published studies about this issue.

Materials and methods

A systematic review and a meta-analysis were performed about the incidence of complications in patients undergoing elective ARR according to the SFM or splenic flexure preservation (SFP), both with open and laparoscopic procedure, both for malignant and benignant pathology.

The authors developed a protocol by detailing the objectives, criteria for study selection, approach to assess study quality, outcomes and statistical methods. Neither ethical committee approval nor written consent was needed.

Study outcomes

The primary outcome of the study was to assess the incidence of colorectal anastomotic leakage in patients who underwent ARR with or without SFM. The secondary outcomes were intra-operative complication, conversion rate, operative time, post-operative bleeding, intra-abdominal collection, prolonged ileus, wound infection, anastomotic stricture, overall complications, hospital stay, re-operation, post-operative mortality, R0 margin resection, and local recurrence.

Search strategy and eligibility criteria

An unrestricted search was performed in MEDLINE/PubMed, Scopus, EMBASE, Cochrane Library, Google Scholar and Research Gate up to 31st December 2020, without language restrictions. Research criteria included the terms "splenic flexure mobilization". Moreover, other relevant studies were manually searched among the reference lists of selected articles and review articles.

Two authors (F.R. and A.P.) independently performed the search and reviewed all the identified publications and abstracts for inclusion using the predetermined criteria. To be comprised in the meta-analysis, studies needed to report the number of patients undergoing the operation, details of the surgical procedure, clinical outcomes, separately detailed in the two subgroups of patients (SFM vs SFP). Disagreements were resolved by consensus with a third investigator (W.B.).

Data extraction and quality assessment

Two authors (F.R. and W.B.) independently extracted the data from the included studies using standardized extraction forms: general data (year, study design), characteristics of patients (number, sex, age, pre-operative BMI), clinical outcomes (anastomotic leakage, intra-operative complication, conversion rate, operative time, post-operative bleeding, intra-abdominal collection, prolonged ileus, wound infection, anastomotic stricture, overall complications, hospital stay, re-operation, post-operative mortality, R0 margin resection, local recurrence). Data were confirmed by both. Outcomes were reported as defined in the individual studies.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist was used [14]. The quality of cohort studies was evaluated using the Newcastle–Ottawa quality assessment scale [15].

Selection of studies for meta-analysis

Data about patients with or without study outcomes according to SFM or SFP were required to be included in the meta-analysis, thus allowing the creation of a 2 × 2 table.

Statistical analysis

Data were then pooled using the Mantel–Haenszel method. Meta-analyses of all outcomes were calculated according to fixed-effects model (in the absence of significant heterogeneity) and to random-effects model (in the presence of significant heterogeneity). Cochran's chi-squared test and I squared test for heterogeneity were used to assess in-between-study heterogeneity. Statistically significant heterogeneity was considered to be present when $p < 0.10$ and I squared > 50% [16]. Pooled odds ratios were reported with 95% confidence intervals (CIs). Publication biases were visually assessed using funnel plots [17]. We planned to perform separate subgroups meta-analyses according to the height and to the surgical approach of the ARR, comparing to SFM and SFP: high (HRR) versus low (LRR) ARR, laparotomic (LT) versus laparoscopic (LS) ARR, LT HRR versus LT LRR, and LS HRR versus LS LRR.

Analyses were performed using Review Manager 5.4 (The Cochrane Collaboration, Oxford, England).

Results

Overall 306 studies were found, 14 met the criteria for the inclusion in the meta-analysis [18–31].

The flow diagram for research and inclusion is shown in Fig. 1.

Thirteen studies were retro-prospective cohort, one was prospective (Table 1). A minimum of 80 and a maximum of 28,316 patients were included in the studies for a total amount of 42,221 patients. The characteristics and the outcomes of the study populations are shown in Table 1.

Anastomotic leakage

The meta-analysis of the data from all the 14 studies (42,221 patients) showed that the incidence of colorectal anastomotic leakage did not statistically differ between the patient undergoing SFM and those undergoing SFP (OR 1.03; 95%CI 0.92–1.15; $p = 0.59$; $I^2 = 0\%$) [18–31] (Fig. 2).

Meta-analyzing the subgroups, the leakage resulted statistically increased in HRR with SFM compared to this with SFP (OR 2.74; 95%CI 1.04–7.22; $p = 0.04$; $I^2 = 0\%$), while there was no difference in LRR (OR 1.55; 95%CI 0.91–2.64; $p = 0.10$; $I^2 = 0\%$) [19–22, 24, 25, 29, 30].

No statistically significant difference was observed both in laparotomic (LT) and laparoscopic (LS) comprehensive

Fig. 1 Flowchart of the retrieved studies

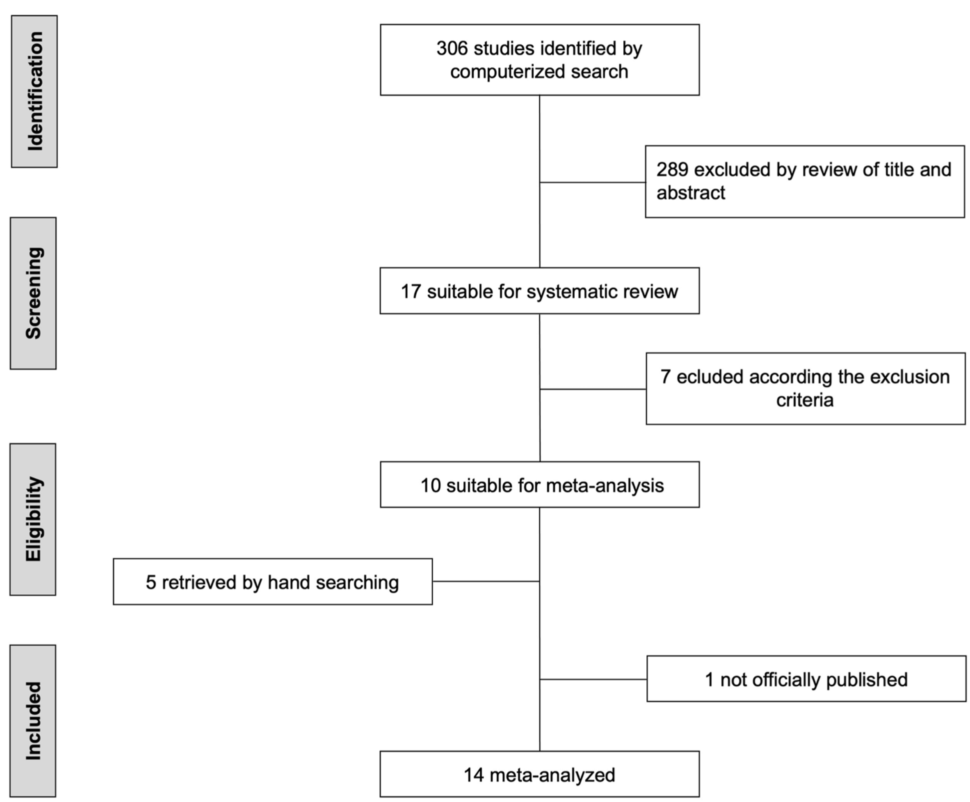

Table 1 Characteristics of the included studies

Author	Brennan et al.	Katory et al.	Akasu et al.	Marsden et al.		Gezen et al.	Carlson et al. Database ACS-NSQIP (2005–09)	Gouvas et al.		Hayden et al.	Bostrom et al.	Chernikovsky et al.
Year	2007	2007	2010	2011		2012	2014	2014		2014	2015	2016
Study design	Retrospective	Retrospective	Retrospective	Prospective		Prospective	Retrospective	Retrospective		Retrospective	Retrospective	Retrospective
Newcastle–Ottawa scale	5	6	6	6		5	6	6		6	6	5
Patients (n)	100	707	98	128	88	122	11,112	208		121	722	126
SFM (M/F)	26 (16/10)	176 (82/94)	35	LS 17 (8/9)–LT 22 (14/8)	LS 27 (17/10)–LT 31 (21/10)	86 (57/29)	3890 (1876/2014)	58 (28/30)	81 (46/35)	62	356	32 (22/10)
SFP (M/F)	74 (46/28)	531 (272/259)	63	LS 67 (38/29)–LT 22 (14/8)	LS 27 (21/6) -LT 3 (3/0)	36 (20/16) (partial SFM)	7222 (3528/3694)	51 (29/22)	18 (4/14)	59	366	94 (56/38)
Age mean (range, SD)												
SFM	62 (48–84)	66 (33–93)	N.A.	LS 76–LT 70	LS 73–LT 71	59.3 (±13.0)	60.1 (±13.3)*	64.6 (±2.5)	65.4 (±0.9)	N.A.	N.A.	N.A.
SFP	64 (44–79)	66 (22–92)		LS 68–LT 71.5	LS 66–LT 68	55.5 (±13.2)	61.3 (±13.7)*	63.9 (±2.4)	64.4(±11.3)	N.A.	N.A.	
BMI												
SFM	N.A.	N.A.	N.A.	LS 25.5–LT 27	LS 28–LT 26	N.A.	28.4 (±6.6)	27.5 (±1.9)	28.2 (±0.1)	N.A.	N.A.	27 (20–46)
SFP				LS 27–LT 27.5	LS 24–LT 25		28.1 (±7.0)	27.7 (±4.2)	28.0 (±5.6)	N.A.	N.A.	31 (23–39)
Indication												
SFM SFP	Rectal cancer	Sigmoid and rectal cancer	Rectal cancer	Rectal cancer		Rectal cancer	Benign/malignant	Sigmoid and rectal cancer		Rectal cancer	Rectal cancer	Rectal cancer
Neoadjuvant RT/CHRT												
SFM	5 (19.2%)*	N.A.	N.A.	LS 0–LT 4 (18%)	LS 4–LT 5	54 (62.8%)	N.A.	N.A.		N.A.	N.A.	N.A.
SFP	23 (31.1%)*			LS 0–LT 0	LS 3–LT 1	20 (55.5%)						
Surgical procedure												
SFM	ARR (high and low)	ARR (high)	ARR (very low)	ARR		ARR (low)	ARR (high and low)	ARR		ARR (low)	ARR (high and low)	ARR (high and low)
SFP				high	low			High	Low			
Surgical approach												
SFM	LT	LT	LT	LS 17–LT 22	LS 27–LT 31	LS	LS 1939–LT 1951*	LS		LS and LT (N.A.)	LT	LS
SFP	LT	LT	LT	LS 67–LT 22	LS 27–LT 3	LS	LS 2849–LT 4373*	LS			LT	LS

Table 1 (continued)

Author	Brennan et al.	Katory et al.	Akasu et al.	Marsden et al.		Gezen et al.	Carlson et al. Database ACS-NSQIP (2005–09)	Gouvas et al.		Hayden et al.	Bostrom et al.	Chernikovsky et al.
Colorectal anastomosis												
SFM	23 stapled/3 handsewn	N.A.	N.A.	N.A.		Stapled colorectal or handsewn coloanal	N.A.	N.A.		N.A.	N.A.	N.A.
SFP	64 stapled/10 handsewn											
Fecal diversion												
SFM	10 (38.5%)	N.A.	N.A.	LS 6(35%)–LT 14 (64%)	LS 27 (100%)–LT 31 (100%)	86 (100%)	N.A.	N.A.		N.A.	N.A.	N.A.
SFP	26 (35.1%)			LS 16 (24%)–LT 8 (36%)	LS 27 (100%)–LT 3 (100%)	36 (100%)						
Conversion rate												
SFM	N.A.	N.A.	N.A.	LS 0	LS 2 (7.4%)	7 (8.1%)*	N.A.	N.A.		N.A.	N.A.	N.A.
SFP				LS 3 (4.5%)	LS 0	8 (22.2%)*						
Intra-operative complication												
SFM	0	N.A.	N.A.	N.A.		N.A.	N.A.	6 (10.3%)	0	N.A.	N.A.	1 (3.1%)
SFP	0							0	0			0
Operative time mean (range, SD)												
SFM	167 (130–200)*	N.A.	N.A.	LS 210 (110–340)–LT N.A.	LS 260 (180–410)–LT N.A.	225.6 (± 55.2)	204.0 (± 86.9)*	134.7 (± 11.4)*	176.5 (± 1.6)	N.A.	N.A.	188 (120–270)
SFP	120 (95–180)*			LS 165 (110–260)–LT N.A.	LS 245.5 (180–320)–LT N.A.	224.2 (± 52.4)	172.2 (± 81.9)*	105.8 (± 8.5)*	164.2 (± 23.2)			167 (90–360)
Anastomotic leakage												
SFM	1 (3.8%)	3 (1.7%)	5 (14.3%)	LS 2 (12%)–LT 2 (9%)	LS 0–LT 1 (3.2%)	17 (19.8%)	45 (1.2%)	3 (5.2%)	15 (18.5%)	5 (8.1)	47 (13.2%)	2 (6.3%)
SFP	3 (4.0%)	2 (0.4%)	8 (12.7%)	LS 1 (1.5%)–LT 2 (9%)	LS 0–LT 0	2 (5.6%)	93 (1.3%)	1 (2.0%)	3 (16.7%)	4 (6.8%)	35 (9.6%)	8 (8.5%)
Anastomotic stricture												
SFM	N.A.	0	N.A.	N.A.		N.A.	N.A.	N.A.		15 (24.2%)	N.A.	N.A.
SFP		2 (0.4%)								8 (13.6%)		

Table 1 (continued)

Author	Brennan et al.	Katory et al.	Akasu et al.	Marsden et al.		Gezen et al.	Carlson et al. Database ACS-NSQIP (2005–09)	Gouvas et al.		Hayden et al.	Bostrom et al.	Chernikovsky et al.
Post-operative bleeding												
SFM	N.A.	N.A.	N.A.	N.A.		4 (4.7%)	N.A.	N.A.		N.A.	N.A.	N.A.
SFP						1 (2.8%)						
Intra-abdominal collection/abscess												
SFM	N.A.	N.A.	N.A.	LS 0–LT 0	LS 2 (7.4%)–LT 1 (3.2%)	N.A.	152 (3.9%)	3 (5.2%)	5 (6.2%)	N.A.	N.A.	N.A
SFP				LS 0–LT 1 (4.5%)	LS 1 (3.7%)–LT 1 (33.3%)		270 (3.7%)	2 (3.9%)	0			
Wound infection												
SFM	3 (11.5%)	5 (2.8%)	N.A.	LS 1 (5.9%)–LT 0	LS 1 (3.7%)–LT 1 (3.2%)	10 (11.6%)	457 (11.7%)*	N.A.		N.A.	N.A.	N.A.
SFP	8 (10.8%)	19 (3.6%)		LS 0–LT 1 (4.5%)	LS 0–LT 0	1 (2.8%)	699 (9.7%)*					
Prolonged ileus												
SFM	N.A.	N.A.	N.A.	N.A.		5 (5.8%)	N.A.	8 (13.8%)	10 (12.3%)	N.A.	N.A.	N.A.
SFP						4 (11.1%)		5 (9.8%)	3 (16.7%)			
Overall complications (n Pt)												
SFM	9 (34.6%)	N.A.	N.A.	LS 4 (2.3%)–LT 3 (13.6%)	LS 6 (22.2%)–LT 7 (22.6%)	31 (36.0%)	N.A.	11 (19.0%)	27 (33.3%)	N.A.	N.A.	N.A.
SFP	25 (33.8%)			LS 9 (13.4%)–LT 5 (22.7%)	LS 7 (25.9%)–LT 1 (33.3%)	8 (22.2%)		11 (21.6%)	11 (61.1%)			
Hospital stay												
SFM	12 (9–39)	N.A.	N.A.	LS 4 (2–21)–LT 13.5 (5–48)	LS 6 (3–30)–LT 11 (5–67)	8.6 (±7.1)	6.9 (±5.6)	N.A.		N.A.	N.A.	10 (6–14)
SFP	12 (8–147)			LS 4 (2–33)–LT 10 (3–45)	LS 6 (3–50)–LT 21 (14–34)	9.9 (±9.4)	7.1 (±6.7)					10.5 (5–16)

Table 1 (continued)

Author	Brennan et al.	Katory et al.	Akasu et al.	Marsden et al.		Gezen et al.	Carlson et al. Database ACS-NSQIP (2005–09)	Gouvas et al.	Hayden et al.	Bostrom et al.	Chernikovsky et al.
Post-operative mortality											
SFM	1 (3.8%)	4 (2.3%)	N.A.	LS 0–LT 0	LS 1 (3.7%)–LS 0	5 (5.8%)	29 (0.7%)	N.A.	N.A.	N.A.	N.A.
SFP	1 (1.4%)	5 (0.9%)		LS 0–LT 0	LS 0–LT 0	2 (5.6%)	87 (1.2%)				
Re-operation											
SFM	1 (3.8%)	N.A.	N.A.	LS 3 (17.6%)-LT 3 (13.6%)	LS 1 (3.7%)–LT 2 (6.4%)	5 (5.8%)	184 (4.7%)	N.A.	N.A.	N.A.	N.A.
SFP	3 (4.0%)			LS 1 (1.5%)–LT 2 (9.1%)	LS 0–LT 1 (33.3%)	0	381 (5.3%)				
Harvested lymph nodes											
SFM	11 (5–20)	13 (0–53)	N.A.	LS 16 (6–27)–LT 10.5 (2–31)	LS 12 (4–31)–LT 13 (4–34)	12.2 (±6.2)	N.A.	N.A.	N.A.	N.A.	13.7
SFP	11 (4–23)	12.5 (0–58)		LS 11 (3–30)–LT 10.5 (2–24)	LS 11 (3–34)–LT 13 (13–16)	10.2 (±6.2)					12.6
R0 margin resection											
SFM		176 (100%)		LS 15 (100%)–LT 16 (88.9%)	LS 20 (100%)–LT 28 (96.5%)	82/84 (97.6%)					
SFP		531 (100%)		LS 59 (98.3%)–LT 21 (100%)	LS 26 (96.3%)–LT 3 (100%)	31/32 (96.9%)					
Local recurrence rate											
SFM	2 (7.7%)	N.A.	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
SFP	5 (6.8%)										

Author	Ferrara et al		Tulina et al	Mouw et al		Dilday et al
				Database ACS-NSQIP (2009–2016)		Database COL-NSQIP (2012–16)
Year	2018		2018	2019		2019
Study design	Retrospective		Retrospective	Retrospective		Retrospective
Newcastle–Ottawa scale	6		6	6		6
Patients (n)	112	*82*	115	146		28,316
SFM (M/F)	47 (26/21)	*40 (22/18)*	15 (6/9)	14 (6/8)	54 (30/24)	12,914 (N.A.)

Table 1 (continued)

Author	Ferrara et al		Tulina et al	Mouw et al		Dilday et al
				Database ACS-NSQIP (2009–2016)		Database COL-NSQIP (2012–16)
SFP (M/F)	65 (36/29)	*42 (24/18)*	100 (55/45)	21 (12/9)	57 (36/21)	15,402 (N.A.)
Age mean (range, SD)						
SFM	76	*73.5*	62.3 (± 7.8)	65.6	61.5	N.A.
SFP	72	*68.5*	60.8 (± 10.5)	63.4	65.4	N.A.
BMI						
SFM	24.2	*24.2*	26.1 (± 4.1)	25.4	28.0	N.A.
SFP	24.4	*24.2*	26.9 (± 3.8)	32.6	27.7	N.A.
Indication						
SFM	rectal cancer		rectal cancer	rectal cancer		benign/malignant
SFP						
Neoadjuvant RT/CHRT						
SFM	11 (23.4%)	*10 (25%)*	2 (13.3%)	0	30 (55.5%)	N.A.
SFP	16 (24.6%)	*14 (33.3%)*	23 (23%)	0	36 (63.2%)	
Surgical procedure						
SFM	ARR (high and low)		ARR (low)	ARR		ARR (high and low)
SFP				high	low	
Surgical approach						
SFM	LS 40–LT 7	*LS*	LS 7–LT 8	LS and LT (N.A.)		LS and LT (N.A.)
SFP	LS 42–LT 23	*LS*	LS 42–LT 58			
Colorectal anastomosis						
SFM	N.A.	*N.A.*	5 end to end/10 side to side	N.A.		N.A.
SFP			69 end to end/31 side to side			
Fecal diversion						
SFM	31 (66.0%)	*26 (65%)*	15 (100%)	Yes (N.A.)		None
SFP	34 (52.3%)	*16 (38.1%)*	100 (100%)	Yes (N.A.)		
Conversion rate						
SFM	N.A.	*18 (45%)*	N.A.	N.A.		N.A.
SFP		*11 (26.3%)*				
Intra-operative complication						
SFM	N.A.	*N.A.*	0	N.A.		N.A.
SFP			0			
Operative time mean (range, SD)						
SFM	225 (± 57.9)#	*222.5 (± 58.2)#*	286.7 (± 84.2)	N.A.		228.6 (± 101.8)
SFP	190 (± 65.6)#	*205.5 (± 56.2)#*	253.5 (± 76.6)			197.9 (± 94.5)

Table 1 (continued)

Author	Ferrara et al		Tulina et al	Mouw et al		Dilday et al
				Database ACS-NSQIP (2009–2016)		Database COL-NSQIP (2012–16)
Anastomotic leakage						
SFM	1 (2.1%)#	*1 (2.5%)#*	2 (13.3%)	0	7 (13.0%)	466 (3.6%)
SFP	4 (6.1%)#	*3 (7.1%)#*	8 (8%)	1 (4.8%)	6 (10.5%)	561 (3.7%)
Anastomotic stricture						
SFM	N.A.	*N.A.*	N.A.	N.A.		N.A.
SFP						
Post-operative bleeding						
SFM	1 (2.1%)#	*1 (2.5%)#*	N.A.	N.A.		N.A.
SFP	4 (6.1%)#	*3 (7.1%)#*				
Intra-abdominal collection/abscess						
SFM	1 (2%)#	*1 (2.5%)#*	N.A.	N.A.		593 (4.6%)
SFP	1 (1.5%)#	*1 (2.4%)#*				669 (4.3%)
Wound infection						
SFM	3 (6.4%)#	*2 (5%)#*	N.A.	N.A.		665 (5.2%)
SFP	2 (3.1%)#	*0#*				831 (5.4%)
Prolonged ileus						
SFM	1 (2.1%)#	*0#*	3 (20%)	N.A.		N.A.
SFP	3 (4.6%)#	*1 (2.4%)#*	8 (8%)			
Overall complications (n Pt)						
SFM	18 (38.3%)	*15 (37.5%)#*	6 (40%)	N.A.		1975 (15.3%)
SFP	23 (35.4%)	*10 (23.8%)#*	49 (49%)			2420 (15.7%)
Hospital stay						
SFM	11 (±5.6)#	*10 (±4.3)#*	15 (±5.3)	N.A.		N.A.
SFP	10 (±4.3)#	*9 (±3.2)#*	15 (±6.6)			
Post-operative mortality						
SFM	1 (2.1%)	*1 (2.5%)#*	0	6 (42.9%)	9 (16.7%)	58 (0.5%)
SFP	3 (4.6%)	*1 (2.4%)#*	0	7 (33.3%)	12 (21.0%)	142 (0.9%)
Re-operation						
SFM	6 (12.8%)#	*N.A.*	N.A.	N.A.		245 (1.9%)
SFP	9 (13.8%)#					310 (2.0%)

Table 1 (continued)

Author	Ferrara et al		Tulina et al	Mouw et al	Dilday et al
				Database ACS-NSQIP (2009–2016)	Database COL-NSQIP (2012–16)
Harvested lymph nodes					
SFM	14	*14*	N.A.	N.A.	N.A.
SFP	13	*13*			
R0 margin resection					
SFM	40 (100%)	*N.A.*			
SFP	47 (94%)				
Local recurrence rate					
SFM	1 (2.1%)#	*1 (2.5%)#*	N.A.	N.A.	N.A.
SFP	4 (6.1%)#	*2 (4.8%)#*			

ARR: anterio rectal resection; #: data extracted from Author's database

In *Italics*: data extracted from Author's database about only laparoscopic procedures

subgroups of patients (OR 1.42; 95%CI 0.94–2.11; $p=0.09$; $I^2=0\%$ and OR 1.91; 95%CI 1.00–3.64; $p=0.05$; $I^2=24\%$, respectively), as in LT HRR (OR 2.26; 95%CI 0.59–8.55; $p=0.23$; $I^2=17\%$), in LT LRR (OR 1.03; 95%CI 0.33–3.24; $p=0.96$; $I^2=0\%$), in LS HRR (OR 4.31; 95%CI 0.77–24.16; $p=0.10$; $I^2=0\%$), and in LS LRR (OR 2.24; 95%CI 0.83–6.03; $p=0.11$; $I^2=38\%$) [18–22, 24, 26–28].

Intra-operative complication

The meta-analysis of the data from four studies (549 patients) showed that the incidence of intra-operative complication statistically increased in patients undergoing SFM (OR 11.47; 95%CI 1.25–105.18; $p=0.03$; $I^2=0\%$) [18, 24, 27, 29].

The available data did not allow the analysis of HRR, LRR, and LT subgroups. Conversely, LS comprehensive patients reported a statistically significant increasing of intra-operative complication rate when SFM was performed (OR 11.33; 95%CI 1.23–104.09; $p=0.03$; $I^2=0\%$) compared to SFP [24, 27] (Fig. 3).

Conversion rate

The meta-analysis of the data from three studies (342 patients) showed that the incidence of conversion rate did not statistically differ between the SFM and SFP groups (OR 1.05; 95%CI 0.26–4.29; $p=0.95$; $I^2=66\%$) [21, 22, 28].

No statistically significant difference was observed in the LRR (OR 0.90; 95%CI 0.06–14.45; $p=0.94$; $I^2=67\%$), comprehensive LS (OR 1.00; 95%CI 0.25–3.97; $p=0.99$; $I^2=74\%$), and LS LRR (OR 0.90; 95%CI 0.06–14.45; $p=0.94$; $I^2=67\%$) subgroups [21, 22, 28]. The remaining subgroups were not calculable.

Operative time

The meta-analysis of the data from six studies (39,985 patients) showed that the operative time was statistically longer in patients undergoing SFM compared to those undergoing SFP (OR 27.56; 95%CI 23.21–31.92; $p<0.00001$; $I^2=70\%$) [22–24, 28, 29, 31].

Also in the HRR and LRR subgroups the operative time resulted statically longer when SFM was performed (OR 28.90; 95%CI 25.15–32.65; $p<0.00001$ and OR 10.98; 95%CI 1.66–20.30; $p=0.02$; $I^2=0\%$, respectively) [22, 24, 29]. Similarly, in the LS comprehensive patients undergoing SPM this outcome was statically longer (OR 16.73; 95%CI 3.18–30.29; $p=0.02$; $I^2=79\%$) as in LS LRR subgroup (OR 10.00; 95%CI 0.47–19.52; $p=0.04$; $I^2=0\%$) [22, 24, 28]. No available data about the remaining subgroups.

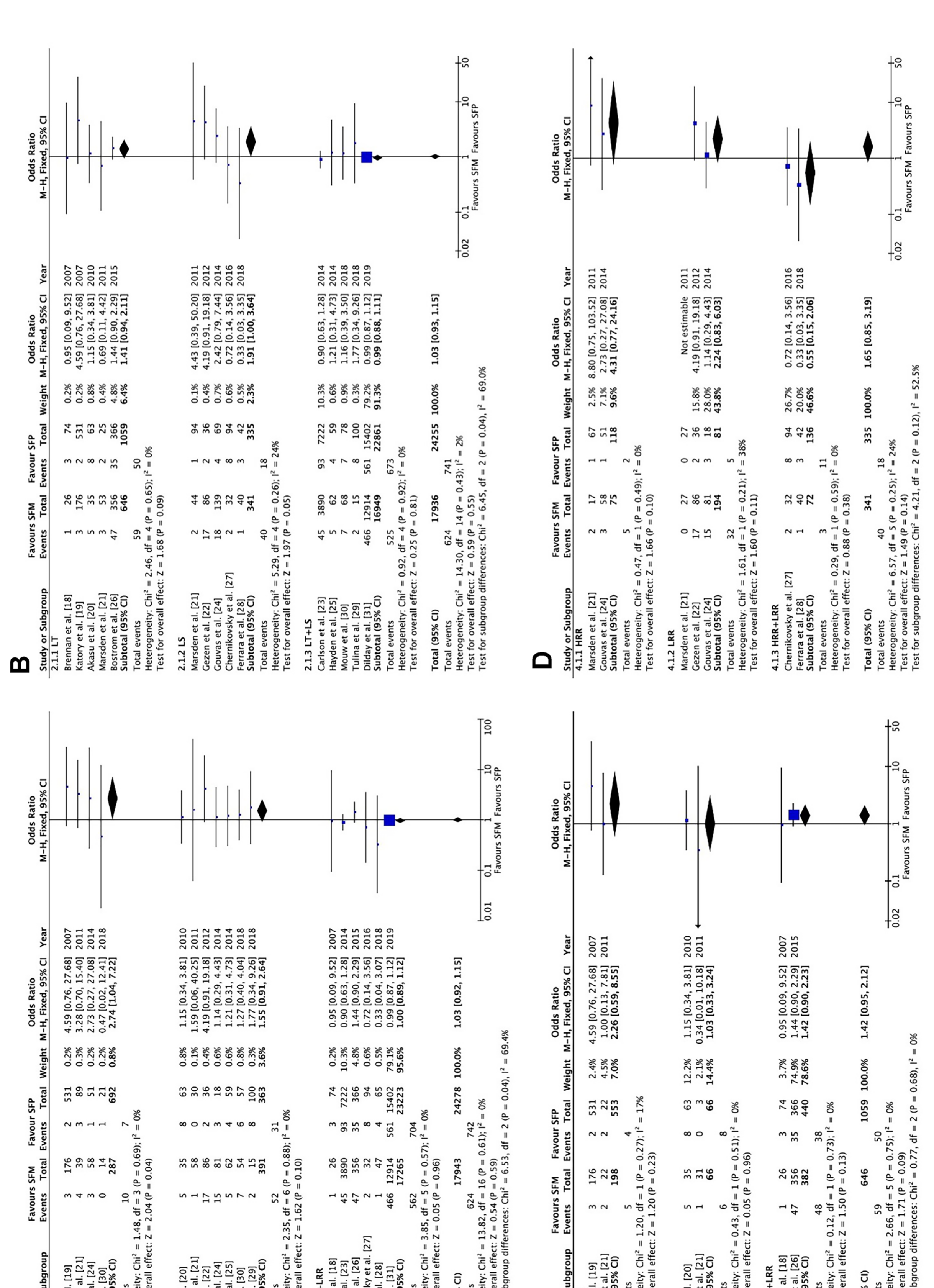

Fig. 2 Forest plot of the meta-analysis of the incidence of anastomotic leakage. **A** All the studies with HRR and LRR subgroups. **B** LT and LS studies. **C** HRR and LRR subgroups in LT. **D** HRR and LRR subgroup in LS

Post-operative bleeding

The meta-analysis of the data from only two studies (234 patients) showed no statistically significant difference between SFM and SFP about post-operative bleeding (OR 0.73; 95%CI 0.18–2.93; $p=0.66$; $I^2=4\%$) [22, 28].

The available data did not allow the analysis of HRR, LRR and LT subgroups, while in the LS comprehensive patients no statistically significant difference resulted between SPM and SFP (OR 0.77; 95%CI 0.19–3.23; $p=0.72$; $I^2=0\%$) [22, 28].

Intra-abdominal collection

The meta-analysis of the data from five studies (39,964 patients) showed no statistically significant difference between SFM and SFP about intra-abdominal collection (OR 1.06; 95%CI 0.96–1.17; $p=0.24$; $I^2=0\%$) [21, 23, 24, 28, 31].

Also in the HRR and LRR subgroups the incidence of this outcome did not statically differ between SFM (OR 1.15; 95%CI 0.24–5.49; $p=0.86$; $I^2=0\%$) and SFP (OR 2.68; 95%CI 0.32–22.43; $p=0.36$; $I^2=0\%$) [21, 24]. The same for the LS comprehensive (OR 2.17; 95%CI 0.66–7.13; $p=0.20$; $I^2=0\%$) and for the LS LRR (OR 2.34; 95%CI 0.35–15.45; $p=0.38$; $I^2=0\%$) subgroups [21, 24, 28]. The remaining subgroups were not calculable.

Prolonged ileus

The meta-analysis of the data from four studies (557 patients) showed no statistically significant differences about the incidence of prolonged ileus between SPM and SFP patients (OR 1.00; 95%CI 0.52–1.91; $p=1.00$; $I^2=3\%$) [22, 24, 28, 29].

Similarly, the incidence of this outcome did not statistically differ between SFM and SFP in LRR subgroup (OR 0.93; 95%CI 0.40–2.14; $p=0.86$; $I^2=39\%$) [22, 24, 29]. The same for the LS comprehensive (OR 0.85; 95%CI 0.42–1.74; $p=0.66$; $I^2=0\%$) and for the LS LRR (OR 0.59; 95%CI 0.22–1.56; $p=0.29$; $I^2=0\%$) subgroups [22, 24, 28]. The remaining subgroups were not calculable.

Wound infection

The meta-analysis of the data from seven studies (40,685 patients) showed that the incidence of wound infection did not statically differ between SFM and SFP groups (OR 1.10; 95%CI 0.89–1.36; $p=0.36$; $I^2=49\%$) [18, 19, 21–24, 28, 31].

Also in the HRR and LRR subgroups the incidence of this outcome did not statistically differ between SFM (OR 0.89; 95%CI 0.35–2.28; $p=0.81$; $I^2=0\%$) and SFP (OR 3.89; 95%CI 0.69–21.91; $p=0.12$; $I^2=0\%$, respectively) [19, 21, 22].

Conversely, in the LS subgroup the wound infection rate resulted significantly lower in patients undergoing SFP compared to those undergoing SFM (OR 5.96; 95%CI 1.32–26.84; $p=0.02$; $I^2=0\%$) [21, 22, 28]. No difference was observed in the comprehensive LT (OR 0.83; 95%CI 0.38–1.82; $p=0.65$; $I^2=0\%$) and in the LS LRR (OR 4.19; 95%CI 0.72–24.34; $p=0.11$; $I^2=0\%$) subgroups [18, 19, 21]. The remaining subgroups were not calculable (Fig. 4).

Anastomotic stricture

The meta-analysis of the data from only two studies (828 patients) showed that there was no statically significant difference about the incidence of anastomotic stricture according to SFM versus SFP patients (OR 1.80; 95%CI 0.75–4.32; $p=0.19$; $I^2=0\%$) [19, 25]. The available data did not allow the analysis of HRR, LRR, LT, and LS subgroups.

Overall complications

The meta-analysis of the data from seven studies (29,189 patients) showed that the incidence of overall complications did not statically differ between the patients undergoing SFM or SFP (OR 0.97; 95%CI 0.91–1.03; $p=0.31$; $I^2=0\%$) [18, 21, 22, 24, 28, 29, 31].

Similarly, the incidence of this outcome did not statistically differ between SFM and SFP both in the HRR (OR 0.99; 95%CI 0.50–1.96; $p=0.97$; $I^2=0\%$) and in the LRR (OR 0.79; 95%CI 0.37–1.71; $p=0.55$; $I^2=56\%$) subgroups [21, 22, 24, 29], moreover, both in the LT (OR 0.91; 95%CI 0.44–1.88; $p=0.79$; $I^2=0\%$) and in the LS comprehensive (OR 1.26; 95%CI 0.84–1.88; $p=0.26$; $I^2=0\%$) subgroups [18, 21, 22, 24, 28], and both in the LS HRR (OR 1.14; 95%CI 0.52–2.50; $p=0.75$; $I^2=5\%$) and in the LS LRR (OR 0.82; 95%CI 0.27–2.52; $p=0.73$; $I^2=70\%$) subgroups [21, 22, 24]. The remaining subgroups were not calculable.

Hospital stay

The meta-analysis of the data from four studies (11,461 patients) showed that the length of the hospital stay did not statistically differ between the SFM and SFP groups (OR − 0.19; 95%CI − 0.42 to 0.04; $p=0.11$; $I^2=0\%$) [22, 23, 28, 29].

The available data allowed only the analysis of LRR subgroup which revealed no statistically difference between the SFM and SFP groups (OR − 0.56; 95%CI − 2.81 to 1.68; $p=0.12$; $I^2=33\%$) [23, 28], as the LS comprehensive subgroup (OR 0.57; 95%CI − 0.92 to 2.05; $p=0.45$; $I^2=29\%$) [22, 28]. The remaining subgroups were not calculable.

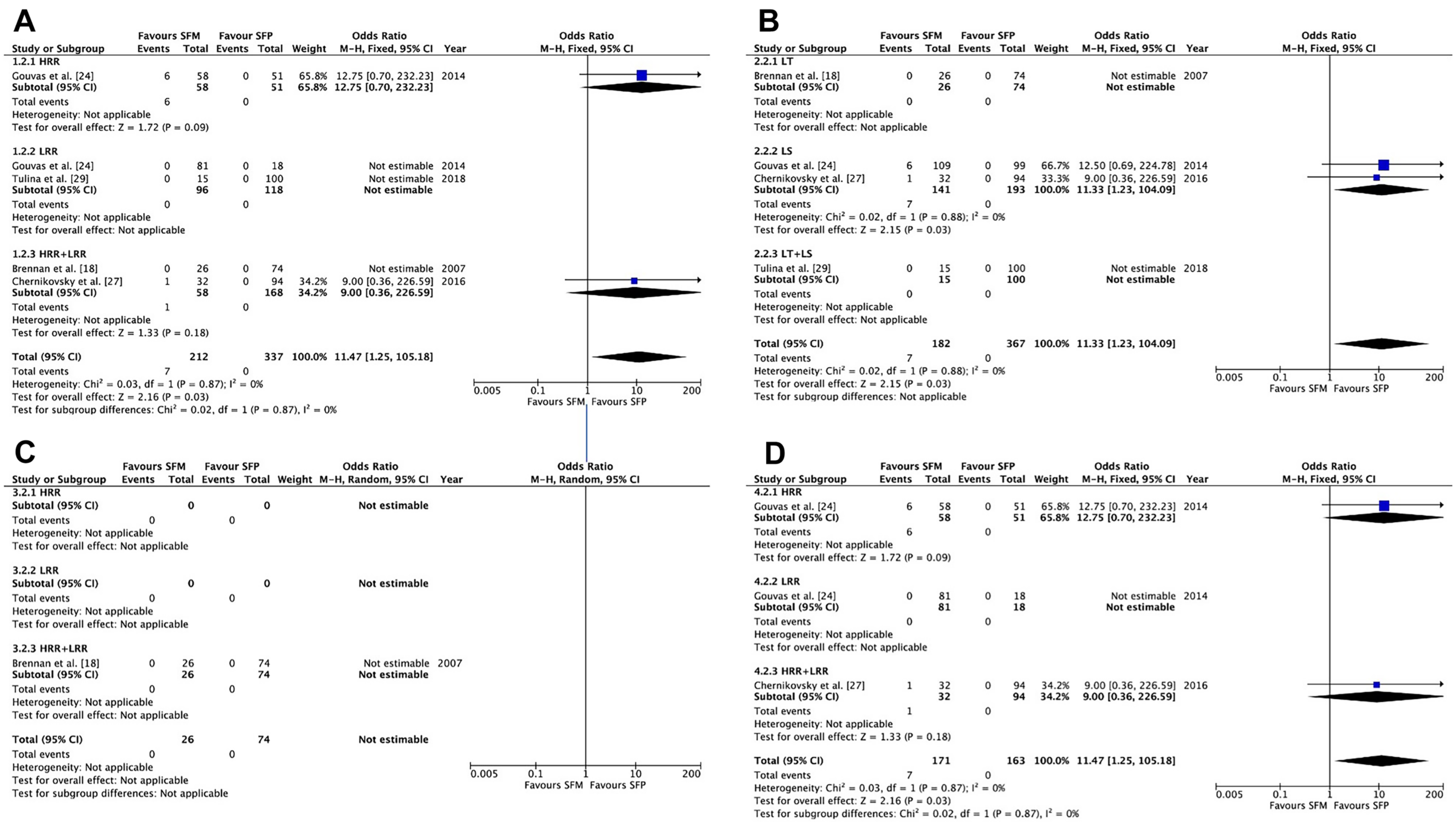

Fig. 3 Forest plot of the meta-analysis of the incidence of intra-operative complication. **A** All the studies with HRR and LRR subgroups. **B** LT and LS studies. **C** HRR and LRR subgroups in LT. **D** HRR and LRR subgroup in LS

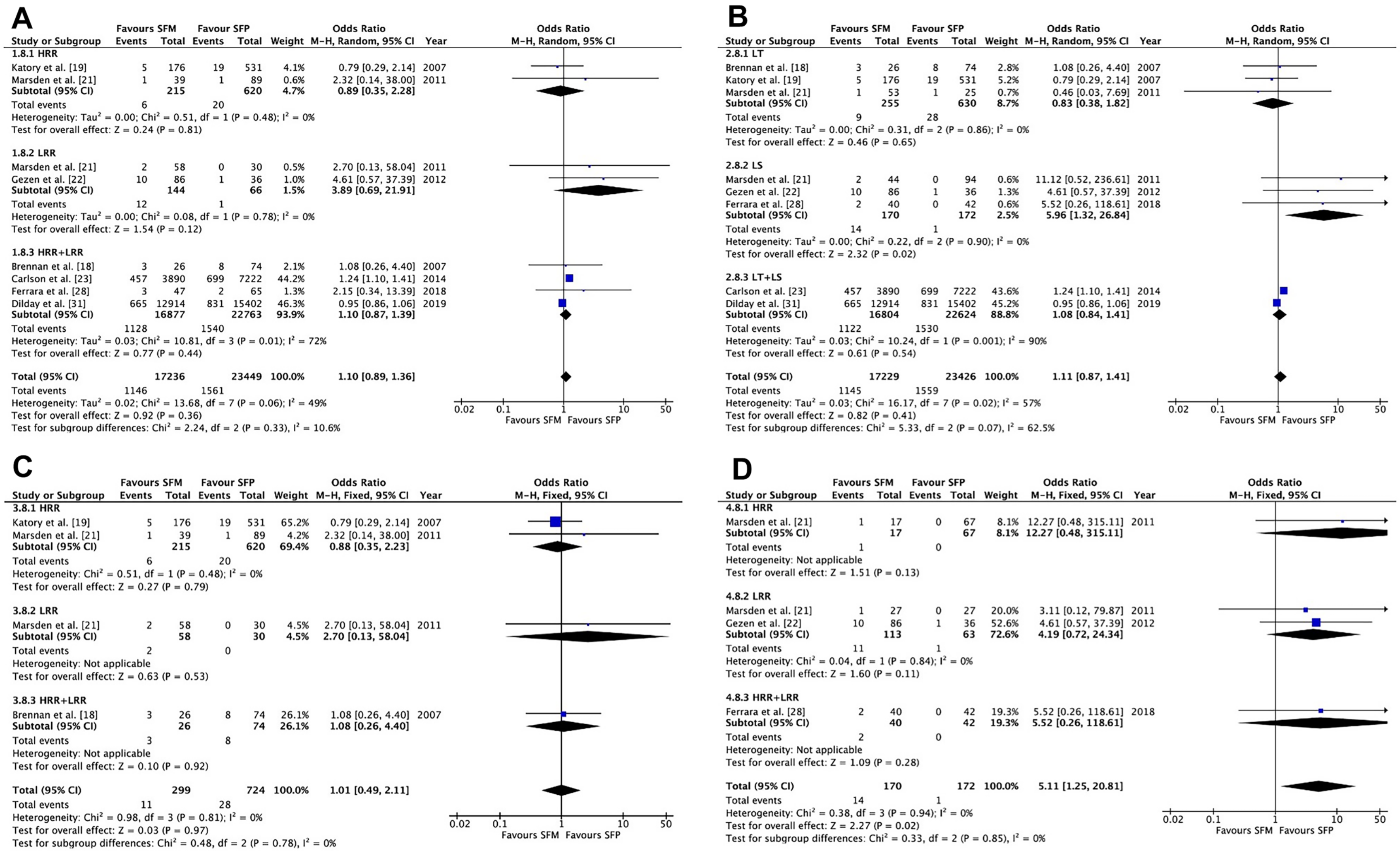

Fig. 4 Forest plot of the meta-analysis of the incidence of wound infection. **A** All the studies with HRR and LRR subgroups. **B** LT and LS studies. **C** HRR and LRR subgroups in LT. **D** HRR and LRR subgroup in LS

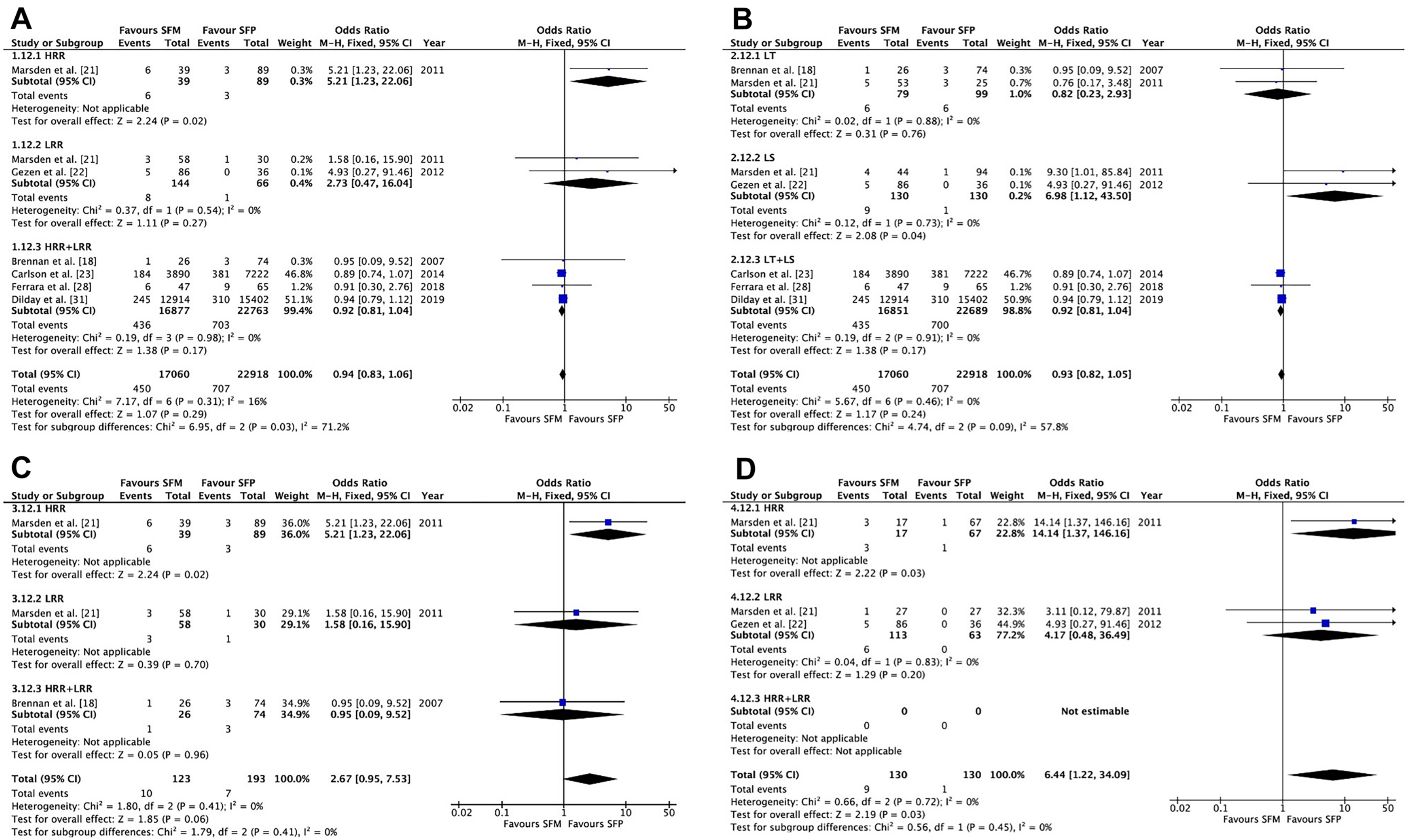

Fig. 5 Forest plot of the meta-analysis of the incidence of re-operation. **A** All the studies with HRR and LRR subgroups. **B** LT and LS studies. **C** HRR and LRR subgroups in LT. **D** HRR and LRR subgroup in LS

Re-operation

The meta-analysis of the data from seven studies (39,978 patients) showed that the re-operation rate did not differ between the SFM and SFP groups (OR 0.94; 95%CI 0.83–1.04; $p=0.29$; $I^2=16\%$) [18, 21–23, 28, 30, 31]. No statistically difference was observed in the LRR subgroup (OR 2.73; 95%CI 0.47–16.04; $p=0.54$; $I^2=0\%$) [21, 22, 30].

In LS comprehensive subgroup the incidence of the outcome was significantly higher in SFM patients (OR 6.98; 95%CI 1.12–43.50; $p=0.03$; $I^2=0\%$), while it was not in the LT comprehensive subgroup (OR 0.82; 95%CI 0.23–2.93; $p=0.76$; $I^2=0\%$) [18, 21, 22], as in LS LRR subgroup (OR 4.17; 95%CI 0.48–36.49; $p=0.12$; $I^2=0\%$) [21, 22]. The remaining subgroups were not calculable (Fig. 5).

Post-operative mortality

The meta-analysis of the data from eight studies (40,831 patients) showed that the incidence of post-operative mortality was statistically significant higher in patients undergoing SFP compared to those undergoing SFM (OR 0.59; 95%CI 0.47–0.74; $p<0.00001$; $I^2=21\%$) [18, 19, 21–23, 28, 30].

The meta-analysis of the HRR and LRR subgroups did not report any statistically significant difference between SFM and SFP (OR 1.91; 95%CI 0.73–5.02; $p=0.19$; $I^2=0\%$ and OR 0.85; 95%CI 0.38–1.89; $p=0.69$; $I^2=0\%$, respectively) [19, 21, 22, 30]. The same about the LT (OR 2.53; 95%CI 0.76–8.38; $p=0.13$; $I^2=0\%$), the LS comprehensive (OR 1.48; 95%CI 0.41–5.43; $p=0.55$; $I^2=0\%$) subgroups [18, 19, 21, 22, 28], and the LS LRR subgroup (OR 1.36; 95%CI 0.31–6.03; $p=0.68$; $I^2=0\%$) [21, 22]. The remaining subgroups were not calculable.

R0 margin resection

The meta-analysis of the data from four studies (1120 patients) showed that the achievement of the R0 resection of the rectal margin did not differ between SFM and SFP groups (OR 0.82; 95%CI 0.36–1.87; $p=0.63$; $I^2=14\%$) [19, 21, 22, 28].

Similarly, the incidence of this outcome did not statistically differ between SFM and SFP both in the HRR and in the LRR subgroups (OR 0.44; 95%CI 0.15–1.23; $p=0.12$ and OR 1.46; 95%CI 0.23–9.11; $p=0.69$; $I^2=0\%$, respectively) [19, 21, 22]. The same for the LT comprehensive (OR 0.26; 95%CI 0.01–5.23; $p=0.38$) [19, 21] and for the LS comprehensive (OR 1.62; 95%CI 0.25–10.45; $p=0.61$; $I^2=0\%$) subgroups [19, 21]. The remaining subgroups were not calculable.

Local recurrence

The meta-analysis of the data from only two studies (212 patients) showed that the local recurrence rate did not statically differ between SFM and SFP groups (OR 0.68; 95%CI 0.18–2.56; $p=0.57$; $I^2=0\%$) [18, 28]. The available data did not allow the analysis of HRR, LRR, LT, and LS subgroups.

Discussion

Anastomotic leakage is one of the most serious complications in colorectal surgery and it is associated with increased morbidity, mortality, and prolonged hospital stay [32, 33]. The incidence of leakage ranges from 2 to 39% and depends on the type of surgical procedure, level or resection, and surgical experience [34–36]. There are well-founded factors that influence the colorectal anastomotic leakage: male sex, smoke, distance of the anastomosis from the anal verge, presence of a fecal diversion [37–40]. Moreover, there are other factors whose role in affecting anastomotic leakage is still debatable: pre-operative radiotherapy, type of anastomosis, type of reconstruction, pelvic drainage, nutritional state, BMI, and splenic flexure mobilization [7, 20, 41–43]. There are many studies in literature about SFM, but only few papers have really compared ARR with or without SFM.

Recently, Park compared the outcomes of patients who underwent laparoscopic or open rectal anterior resection, all performed without SFM [44]. The complication rate was lower in the laparoscopic group than in the open one (10% vs 25.5%, $p=0.043$). Moreover, local recurrence rates were similar (0.8% in the laparoscopic group compared to 2.1% in the open one). Interestingly, less than 15% of all patients considered for laparoscopic surgery underwent SFM. The author reported that routine SFM in cases of rectal or sigmoid cancer yields no oncologic benefits, although it may result in an increase of the total length of the specimen [44].

Recently, Gezen assessed that the dissection of gastrocolic and pancreatic-mesocolic attachments, in addition to phrenicocolic and splenocolic ligaments, is needed for the complete mobilization of the colon and he found that when the splenic flexure is completely mobilized it is simpler to construct a reservoir [22].

As further proof, a recent cadaveric study by Thum-Umnuaysuk showed that SFM added only an average of 3 cm of length compared to high ligation of the inferior mesenteric artery alone [45].

Akiyoshi, in a series of 260 patients undergoing laparoscopic left colon resections for cancer, found that SFM was associated with longer operative time, greater intra-operative blood loss, and increased intra-operative complications, but also with larger distal tumor margin, on multivariate analysis [5].

Given this, the meta-analysis was performed including all published observational studies comparing ARR with or without SFM, focusing on the laparotomic versus laparoscopic approach and on the height of the resection. Unfortunately, there are no RCT about this topic available in literature to date.

The comprehensive meta-analysis shows that the mobilization or the preservation of the splenic flexure does not statistically influence the incidence of colorectal anastomotic leakage. Moreover, the incidence of conversion rate, post-operative bleeding, intra-abdominal collection, prolonged ileus, wound infection, anastomotic stricture, overall complications, hospital stay, re-operation, R0 margin resection, and local recurrence results do not differ between SFM and SFP. The operative time is significantly longer in every group of patients undergoing SFM compared to those undergoing SFP. The incidence of intra-operative complication is statistically increased in overall patients and also in the LS subgroup of patients undergoing SFM, in which also higher incidence of wound infection and re-operation is shown. These findings may be explained with the difficulty of SFM tied to the risk of damaging the adjacent structures, and with the longer operative time, especially in laparoscopy. The post-operative mortality is statistically higher in patients undergoing SFP compared to those undergoing SFM at the comprehensive meta-analysis, but there are no differences in the subgroups.

Several limitations must be taken into account in this meta-analysis. First, the meta-analysis includes only observational studies.

Second, the meta-analyzed studies differ due to some non-negligible parameters. Only six authors mentioned whether the included patients underwent neoadjuvant radiotherapy or radio-chemotherapy and their number, but undistinguishing their outcomes from the total population of the study [18, 21, 22, 28–30]. The same happened for the description of the technique in performing the colorectal anastomosis [18, 22, 29] and the presence of the fecal diversion [18, 21, 22, 28–30]. About the surgical approach, three authors included patient underwent both LT and LS procedure without separating the data [25, 30, 31]. If the detailed data above were available, subgroups meta-analyses could be performed with very interesting results.

Third, data about some outcomes were available only in just a few studies, especially when the subgroup meta-analyses were calculated, thus resulting in meta-analyzing over a small number of patients. Therefore, these results must be critically considered and need further studies to be extensively analyzed.

Fourth, the meta-analyzed studies differ for the number of patients and rate of complications: the number of included patients ranged from 88 to 28,316 and the overall complications rate ranged from 2.3 to 61.1%. Moreover, the method of classification and report of the complications were not available in every included studies.

All these aspects must be carefully considered when it comes to discussing the results of the meta-analysis. Therefore, although the results of the meta-analysis may be considered clear enough, well-designed RCTs with homogenous groups of patients (according to neoadjuvant treatment, surgical approach, type of colorectal anastomosis, presence of fecal diversion, and classification of peri-operative complications) are needed to definitively assess the role of routine SFM in both laparoscopic and robotic-assisted rectal resection.

In conclusion, SFM does not seem to be routinely recommended, but it may be let up to surgeon's decision according to intra-operative features (difficult mobilization of left colon, obese patient, need to respect oncologic criteria, retracted mesentery, neoadjuvant chemotherapy). This is a very important aspect when mini-invasive laparoscopic or robotic-assisted approach is performed: a difficult procedure as SFM should not be carried out if not strictly necessary, thus avoiding the lengthening of operative time (especially in robotic-assisted colorectal resection) and the risk of potential splenic, bowel and vessels injury.

Declarations

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

Research involving human participants and/or animals Data were extracted from published series; not applicable.

Informed consent Not applicable.

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