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Impact of Splenic Flexure Mobilization and Inferior Mesenteric Artery Ligation Level on Surgical and Oncological Outcomes in Left-Sided Colorectal Cancer: A Systematic Review and Meta-Analysis

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Abstract

Purpose: To assess associations of splenic flexure mobilization (SFM) and inferior mesenteric artery (IMA) ligation level with surgical and oncological outcomes in left-sided colorectal cancer.

Methods: This PRISMA 2020 systematic review was registered in PROSPERO (CRD420261392853). MEDLINE/PubMed, Scopus, SciELO, Cochrane Library, Google Scholar, and references were searched on May 30, 2026, for comparative studies published during 2006–2025. Risk of bias was assessed using RoB 2 and ROBINS-I. Risk ratios (RRs) and mean differences (MDs) were synthesized separately for each intervention.

Results: Twenty-nine studies included 94,763 participants: three randomized trials, one prospective cohort, and 25 retrospective cohorts. SFM increased lymph-node yield (MD 0.67 nodes; 95% CI 0.05–1.29) and operative time (MD 35.36 minutes; 95% CI 19.69–51.03), without significant differences in R0 resection, blood loss, or hospital stay. The association with anastomotic leakage was borderline (RR 1.13; 95% CI 1.00–1.27) and susceptible to confounding by indication. High IMA ligation increased lymph-node yield (MD 1.26 nodes; 95% CI 0.61–1.91), without reducing leakage (RR 1.15; 95% CI 0.97–1.36). Two overall-survival hazard ratios were not pooled because of differences in adjustment and clinical context. Evidence certainty was low or very low.

Conclusion: Both maneuvers were associated with small increases in lymph-node yield; SFM prolonged surgery. No consistent survival advantage was established for high IMA ligation. Predominantly observational evidence limits causal interpretation and supports cautious, individualized decision-making.

Keywords: colorectal neoplasms; splenic flexure mobilization; inferior mesenteric artery; anastomotic leakage; lymph nodes; meta-analysis.

Abbreviations

Term	Definition	Term	Definition
ACS-NSQIP	American College of Surgeons National Surgical Quality Improvement Program	**LL**	Low ligation
AJCC	American Joint Committee on Cancer	**LLIMA**	Low ligation of the inferior mesenteric artery
IMA	Inferior mesenteric artery	**MeSH**	Medical Subject Headings
LCRC	Left-sided colorectal cancer	**NR**	Not reported
COPE	Committee on Publication Ethics	**O−E/V**	Observed minus expected / variance; statistics used in time-to-event analysis
DeCS	Health Sciences Descriptors	**PICO**	Population, exposure, comparator, and outcomes
SD	Standard deviation	**PRISMA**	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
MD	Mean difference	**PROSPERO**	International Prospective Register of Systematic Reviews
DOI	Digital object identifier	**BL**	Blood loss
LOS	Length of hospital stay	**R0**	Resection with microscopically negative margins
AL	Anastomotic leakage	**RDI-UTI**	Institutional Digital Repository of Universidad Tecnológica Indoamérica
GRADE	Grading of Recommendations Assessment, Development and Evaluation	**LNY**	Lymph-node yield
HL	High ligation	**RoB 2**	Cochrane Risk of Bias 2
HLIMA	High ligation of the inferior mesenteric artery	**ROBINS-I**	Risk Of Bias in Non-randomized Studies of Interventions
HR	Hazard ratio	**RR**	Risk ratio
I^2	Heterogeneity statistic	**SFM**	Splenic flexure mobilization
CI	Confidence interval	**OT**	Operative time
ISREC	International Study Group of Rectal Cancer		

Introduction

Left-sided colorectal cancer includes tumors of the descending colon, sigmoid colon, and rectum. Curative-intent surgery requires an adequate oncological resection, appropriate lymph-node assessment, and reconstruction that preserves perfusion and avoids excessive anastomotic tension. These objectives are influenced by tumor height, pelvic anatomy, the length and mobility of the remaining colon, the surgical approach, and the surgeon's intraoperative assessment [1–4].

Splenic flexure mobilization (SFM) releases the lateral attachments of the left colon and can provide additional length for a colorectal or coloanal anastomosis. The maneuver also adds dissection, operative time, and manipulation near the spleen and pancreas. Its selective use is often determined by a low anastomosis, a short mesocolon, a narrow pelvis, or anticipated tension. Consequently, an observed association between SFM and anastomotic leakage may reflect the indication for SFM and the baseline complexity of the operation, rather than a direct harmful effect of the maneuver [5–8].

The level of inferior mesenteric artery (IMA) ligation represents a separate technical and oncological question. High ligation permits central vascular dissection and may retrieve apical lymph nodes, whereas low ligation preserves the left colic artery and may protect perfusion and autonomic nerve function. However, apical lymphadenectomy can be performed while preserving the left colic artery; therefore, a higher ligation level does not necessarily imply a more complete lymph-node dissection [9–12].

Previous studies have reported inconsistent effects of both maneuvers, and the literature includes randomized controlled trials (RCTs), prospective cohorts, single-center retrospective series, and national databases. We therefore conducted a systematic review and meta-analysis of comparative studies, retaining SFM and IMA ligation level as independent intervention questions and treating survival as a time-to-event outcome when valid hazard ratios (HRs) were available.

Methods

Reporting and registration

The review was conducted in accordance with PRISMA 2020. The protocol was registered in PROSPERO under CRD420261392853 (https://www.crd.york.ac.uk/PROSPERO/view/CRD420261392853). No changes were made to the objectives, eligibility criteria, primary outcomes, or synthesis methods specified in the registered protocol.

Eligibility criteria

Primary comparative studies of adults with left-sided colorectal adenocarcinoma undergoing curative-intent resection were included. Eligible designs were RCTs and prospective or retrospective comparative cohorts evaluating SFM versus no SFM or selective SFM, or high versus low IMA ligation. Open, laparoscopic, robotic, and other minimally invasive approaches were eligible when the intervention comparison was identifiable. At least one prespecified surgical or oncological outcome and full-text availability were required. Case reports, noncomparative series, expert opinions, narrative or systematic reviews, meta-analyses, protocols, conference abstracts, pediatric studies, duplicate publications, and reports without an eligible comparator or extractable outcome were excluded.

When several publications originated from the same cohort or trial, they were treated as linked reports. For each outcome, the report with the most complete data or the longest relevant follow-up was used, and participants were not counted twice within a meta-analysis. Reviews and meta-analyses were used only to identify primary studies and contextualize the evidence.

Search strategy and study selection

MEDLINE via PubMed, Scopus, SciELO, Cochrane Library, and Google Scholar were searched on May 30, 2026, to identify records published between January 1, 2006, and December 31, 2025. The main concepts were left-sided colorectal cancer, SFM, and IMA ligation level. The general SFM strategy was ("colorectal cancer" OR "rectal cancer" OR "sigmoid cancer" OR "left-sided colorectal cancer") AND ("splenic flexure mobilisation" OR "splenic flexure mobilization") AND ("anastomotic leak" OR "anastomotic leakage" OR "lymph node yield" OR "operative time" OR "blood loss" OR "hospital stay" OR "oncological outcomes"). The IMA strategy was ("colorectal cancer" OR "rectal cancer" OR "sigmoid cancer") AND ("inferior mesenteric artery" OR "IMA") AND ("high ligation" OR "high tie") AND ("low ligation" OR "low tie" OR "low-tie") AND ("lymph node yield" OR "anastomotic leakage" OR "overall survival" OR "disease-free survival" OR "recurrence" OR "oncological outcomes"). Syntax and fields were adapted to each database. Complete strategies and retrieval counts are presented in Supplementary Table S1.

Records were exported to Rayyan, where duplicates were removed before independent title and abstract screening. Full texts were assessed against the eligibility criteria, and disagreements were resolved by consensus or by a third reviewer. The corrected PRISMA flow diagram is shown in Fig. 1.

Data extraction and outcomes

Two reviewers independently extracted study identifiers, design, setting, tumor location, procedure, intervention and comparison group sizes, and outcome data. Continuous outcomes were extracted as means, standard deviations (SDs), and group sizes. Medians and interquartile ranges were converted only when necessary and are identified in the study audit; medians were not implicitly interpreted as means. Dichotomous outcomes were extracted as events and totals. The primary outcomes were lymph-node yield, R0 resection, anastomotic leakage, blood loss, length of hospital stay, operative time, and overall survival.

Anastomotic leakage was analyzed as reported in each study. When the ISREC classification was available, grade A was defined as requiring no change in management, grade B as requiring active treatment without reoperation, and grade C as requiring reoperation [13]. Because studies did not consistently report grade-specific counts, the quantitative synthesis combined leakage of any reported grade. An ISREC grade was not assigned retrospectively when the source article provided insufficient information about management.

Overall survival was treated as a time-to-event outcome. HRs and their 95% confidence intervals (CIs) were extracted from Cox models when reported. When an HR was unavailable, log-rank O−E and V statistics or a valid Kaplan–Meier reconstruction using reported numbers at risk were sought. Five-year survival percentages were not converted into events or HRs because censoring and follow-up times were insufficiently characterized. When an HR could not be obtained or validated, survival was presented descriptively as five-year Kaplan–Meier survival probabilities.

Risk of bias and certainty of evidence

Two reviewers independently assessed risk of bias. RoB 2 was used for RCTs and ROBINS-I for nonrandomized studies. ROBINS-I domains were confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result. RoB 2 domains were randomization, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result.

Disagreements were resolved by consensus or by a third reviewer. The overall judgment followed the domain with the highest risk.

GRADE was applied separately to each outcome. Evidence from RCTs started at high certainty and evidence from nonrandomized studies at low certainty. Certainty was downgraded for risk of bias, inconsistency, indirectness, imprecision, and publication bias, and was upgraded only when a prespecified GRADE criterion was clearly met.

Statistical analysis

SFM and IMA ligation were synthesized in separate meta-analyses. RRs with 95% CIs were used for dichotomous outcomes, MDs with 95% CIs for continuous outcomes measured on the same scale, and HRs with 95% CIs for time-to-event outcomes. Heterogeneity was summarized using I^2 and 95% prediction intervals. I^2 values below 30%, between 30% and 60%, and above 60% were interpreted descriptively as low, moderate, and high heterogeneity, respectively.

Exploratory subgroup analyses were attempted only when study classifications and outcome data were available. Stratification by open versus minimally invasive approach, rectal versus sigmoid cancer, low anterior resection versus left colectomy, or routine versus selective SFM was not possible because several studies combined categories or did not report outcomes within each category. These analyses were post hoc, limited, and not adjusted for multiplicity.

Small-study effects were assessed using funnel plots and Egger's test when at least 10 studies contributed to a meta-analysis. Egger's test was not performed for outcomes with fewer than 10 studies or for survival without a pooled estimate. Analyses were performed in RStudio; the complete extraction and sensitivity audit are provided as supplementary material.

Results

Study selection and characteristics

The search identified 260 database records and 24 additional records through reference checking and manual searching. After removing 87 database records before screening, 173 records underwent title and abstract screening. Seventy database reports and 21 reports identified through other methods were assessed for eligibility. Forty-four database reports and 18 reports from other methods were excluded, leaving 29 included studies: 16 evaluated SFM and 13 evaluated IMA ligation level (Fig. 1).

The 29 studies included 94,763 participants. Three were RCTs, one was a prospective cohort, and 25 were retrospective cohorts. The SFM studies included one RCT, one prospective cohort, and 14 retrospective cohorts. The IMA ligation studies included two RCTs and 11 retrospective cohorts. Tumor location, surgical approach, setting, and reported outcomes were not uniformly distributed. Study-level classifications are summarized in Table 1.

Risk of bias in included studies

Of the 29 included studies, 26 were nonrandomized and assessed using ROBINS-I, whereas three studies—Polovinkin and Pryn (2022), Fujii et al. (2018), and Matsuda et al. (2017)—were assessed using RoB 2. Among nonrandomized studies, 10 (38.5%) had moderate overall risk of bias and 16 (61.5%) had serious risk; none was classified as having low or critical overall risk.

The main determinant of risk of bias was confounding by indication, particularly nonrandom allocation to SFM or IMA ligation level. Factors such as tumor location and stage, anastomotic height, vascular anatomy, anticipated tension, surgical approach, procedural complexity, and surgeon experience were not uniformly controlled.

Among SFM studies, four nonrandomized studies had moderate overall risk of bias and 11 had serious risk. Among IMA ligation studies, six had moderate risk and five had serious risk. Studies with serious risk were mainly limited by retrospective design, between-group imbalances, and insufficient adjustment for prognostic and technical factors.

All three studies assessed using RoB 2 had some concerns overall, mainly because of incomplete information about randomization, follow-up, or selection of the reported results. Overall, the evidence was limited by the predominance of retrospective studies and the possibility of residual confounding; observed associations between surgical techniques and outcomes should therefore be interpreted cautiously and should not necessarily be considered causal. The risk-of-bias assessment is presented in Table 2.

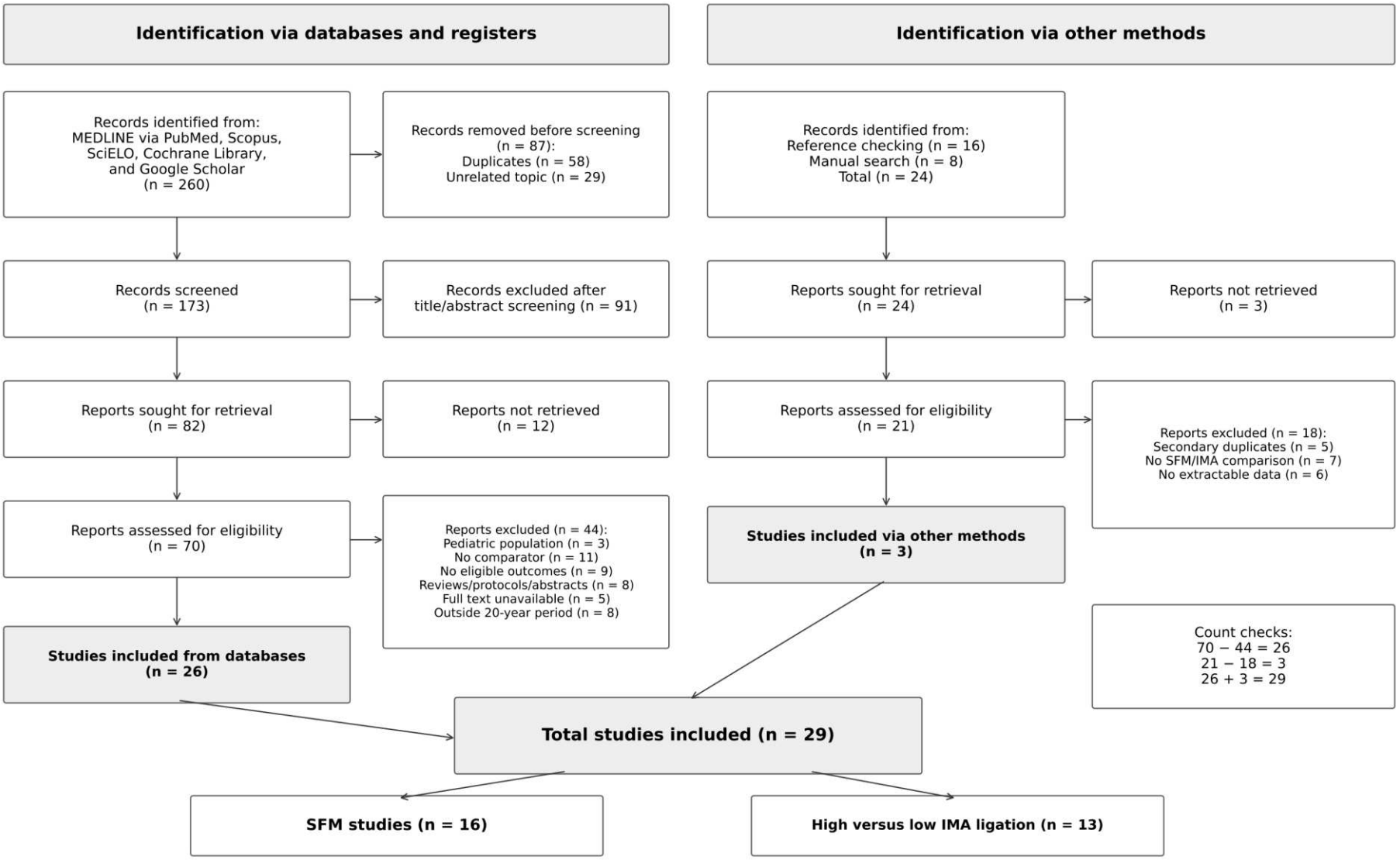


Fig. 1 PRISMA 2020 flow diagram. The counts are: 260 database records − 87 records removed before screening = 173 screened; 24 additional records − 3 reports not retrieved = 21 assessed through other methods; 26 + 3 = 29 included studies

Table 1 Characteristics of the 29 included comparative studies

Study	Design	Setting	Population procedure and comparison	n intervention / control
Polovinkin and Pryn (2022) [14]	RCT	Single-center	Rectal resection; routine versus selective SFM	156 / 67
Chernikovsky et al. (2017) [15]	Retrospective cohort	Single-center	Rectal resection; SFM versus no SFM	32 / 94
Ouaissi et al. (2013) [16]	Retrospective cohort	Multicenter (as reported)	Sigmoid cancer; left colectomy	53 / 27
Mann et al. (2023) [8]	Retrospective cohort	Single-center	Anterior resection; SFM versus no SFM	49 / 68
Ferrara et al. (2018) [17]	Retrospective cohort	Single-center	Rectal cancer; anterior resection	47 / 65
Syed et al. (2024) [18]	Retrospective cohort	Single-center	Anterior resection; routine SFM versus no SFM	65 / 29
Meyer et al. (2023) [19]	Prospective cohort	Single-center	Rectal cancer; robotic anterior resection	121 / 315
Dilday et al. (2020) [20]	Retrospective cohort	National ACS-NSQIP database	Distal colectomy with anastomosis; routine SFM	27,475 / 38,593
Mouw et al. (2019) [21]	Retrospective cohort	Multiple cohorts; ACS-NSQIP used for leakage	Low anterior resection; routine SFM	3,083 / 4,286
Tulina et al. (2018) [22]	Retrospective cohort	Multicenter (as reported)	TME and low colorectal anastomosis; selective SFM	15 / 100
Gezen et al. (2012) [23]	Retrospective cohort	Single-center	Rectal LAR; complete versus partial SFM	86 / 36
Marsden et al. (2011) [24]	Retrospective cohort	Single-center	Anterior resection; selective SFM	97 / 119
Katory et al. (2007) [25]	Retrospective cohort	Multicenter (as reported)	High anterior resection; colorectal malignancy	176 / 531
Brennan et al. (2007) [26]	Retrospective cohort	Single-center	Rectal cancer; anterior resection	26 / 74
Rutegård et al. (2023) [5]	Retrospective cohort	Multicenter	Rectal cancer; anterior resection	381 / 728
Carlson et al. (2014) [27]	Retrospective cohort	National ACS-NSQIP database	Anterior resection; SFM versus no SFM	3,890 / 7,222
Fujii et al. (2018) [28]	RCT	Single-center	Rectal cancer; anterior resection; high versus low IMA ligation	164 / 160
Rutegård et al. (2012) [29]	Retrospective cohort	Multicenter	Rectal cancer; anterior resection; high versus low IMA ligation	818 / 1,101
Matsuda et al. (2017) [30]	RCT	Single-center	Rectal cancer; anterior resection; high versus low IMA ligation	51 / 49
You et al. (2020) [31]	Retrospective cohort	Single-center	Rectal cancer; laparoscopic radical resection	174 / 148
Lee et al. (2024) [32]	Retrospective cohort	Single-center	Rectal cancer; anterior resection with apical dissection	244 / 301
Yasuda et al. (2016) [33]	Retrospective cohort	Single-center	Sigmoid and rectal cancer; mixed resections	42 / 147
Yu et al. (2023) [34]	Retrospective cohort	Single-center	Rectal cancer; laparoscopic low anterior resection	134 / 86
Zedan et al. (2015; linked report EJSO 2016) [35,36]	Retrospective cohort	Single-center	Rectal cancer; curative-intent surgery	38 / 76
Huang et al. (2016) [37]	Retrospective cohort	Single-center (as reported)	Rectal cancer; laparoscopic resection	87 / 29

Park et al. (2020) [38]	Retrospective cohort	Single-center	Distal sigmoid or rectal cancer; resection	613 / 163
Luo et al. (2021) [39]	Retrospective cohort	Single-center	Rectal cancer; laparoscopic anterior resection	378 / 236
Zhang et al. (2020) [40]	Retrospective cohort	Single-center	Rectal cancer; anterior resection	126 / 79
AlSuhaimi et al. (2019) [41]	Retrospective cohort	Single-hospital cohort	Rectal cancer; anterior resection	835 / 378

Abbreviations: ACS-NSQIP, American College of Surgeons National Surgical Quality Improvement Program; IMA, inferior mesenteric artery; LAR, low anterior resection; RCT, randomized controlled trial; SFM, splenic flexure mobilization; TME, total mesorectal excision.

Table 2 Study-level risk-of-bias assessment

Study	Design	Tool	Overall judgment	Main reason for judgment
Polovinkin and Pryn (2022)	RCT	RoB 2	Some concerns	Sequence generation and concealment, and selective outcome reporting, were insufficiently described.
Chernikovsky et al. (2017)	Retrospective cohort	ROBINS-I	Serious	Confounding related to surgeon selection and incomplete adjustment.
Ouaissi et al. (2013)	Retrospective cohort	ROBINS-I	Serious	Nonrandom allocation and limited control of clinical complexity.
Mann et al. (2023)	Retrospective cohort	ROBINS-I	Serious	Small single-center cohort and confounding related to the indication.
Ferrara et al. (2018)	Retrospective cohort	ROBINS-I	Serious	Selection of SFM according to operative circumstances.
Syed et al. (2024)	Retrospective cohort	ROBINS-I	Serious	Retrospective selection and residual baseline imbalance.
Meyer et al. (2023)	Prospective cohort	ROBINS-I	Serious	Selective robotic SFM and incomplete control of the indication.
Dilday et al. (2020)	Retrospective cohort; ACS-NSQIP	ROBINS-I	Moderate	Large adjusted database, but anatomical and technical confounding was unmeasured.
Mouw et al. (2019)	Retrospective cohort; multiple cohorts	ROBINS-I	Moderate	Adjusted quality outcomes; cohort structure and residual confounding require auditing.
Tulina et al. (2018)	Retrospective cohort	ROBINS-I	Serious	Small cohort and selective mobilization.
Gezen et al. (2012)	Retrospective cohort	ROBINS-I	Serious	Complete versus partial SFM; different comparator and nonrandom allocation.
Marsden et al. (2011)	Retrospective cohort	ROBINS-I	Serious	Selective SFM with incomplete adjustment for operative difficulty.
Katory et al. (2007)	Retrospective cohort	ROBINS-I	Serious	Historical cohort and possible selection according to procedural complexity.
Brennan et al. (2007)	Retrospective cohort	ROBINS-I	Serious	Small single-center cohort; conversion of hospitalization data requires verification.
Rutegård et al. (2023)	Multicenter retrospective cohort	ROBINS-I	Moderate	Large multicenter cohort; residual confounding and converted medians/IQRs.
Carlson et al. (2014)	Retrospective cohort; ACS-NSQIP	ROBINS-I	Moderate	Large national cohort; possible overlap with Dilday for time outcomes.
Fujii et al. (2018)	RCT	RoB 2	Some concerns	Low risk for randomization and outcome measurement; some concerns about selective reporting.
Rutegård et al. (2012)	Retrospective cohort	ROBINS-I	Moderate	Large adjusted cohort; residual confounding remains possible.
Matsuda et al. (2017)	RCT follow-up	RoB 2	Some concerns	Randomized main cohort; follow-up and secondary oncological reporting require caution.
You et al. (2020)	Retrospective cohort	ROBINS-I	Serious	Retrospective imbalance and ambiguous reported dispersion for lymph-node yield.
Lee et al. (2024)	Retrospective cohort	ROBINS-I	Moderate	Adjusted single-center cohort; possible temporal overlap with Park.
Yasuda et al. (2016)	Retrospective cohort	ROBINS-I	Serious	Unadjusted or limited baseline control and incomplete reporting of dispersion.
Yu et al. (2023)	Retrospective cohort	ROBINS-I	Serious	Retrospective selection and unclear definition of reported dispersion.

Zedan et al. (2015; linked report EJSO 2016)	Retrospective cohort	ROBINS-I	Serious	Small cohort and range data without verified SDs.
Huang et al. (2016)	Retrospective cohort	ROBINS-I	Serious	Limited reporting of prognostic adjustment and outcome data.
Park et al. (2020)	Retrospective cohort	ROBINS-I	Moderate	Large single-center cohort; median/range node data and possible overlap with Lee.
Luo et al. (2021)	Retrospective cohort	ROBINS-I	Moderate	Single-center cohort; the dispersion statistic requires confirmation.
Zhang et al. (2020)	Retrospective cohort	ROBINS-I	Moderate	Reported means/SDs; residual confounding from treatment selection.
AlSuhaimi et al. (2019)	Retrospective cohort	ROBINS-I	Moderate	Large single-hospital cohort; not a national multicenter database.

Note: Among the 26 nonrandomized studies, 10 were judged to have moderate overall risk of bias and 16 serious risk. The three RCTs had some concerns according to RoB 2. No study was judged to have low or critical overall risk. Confounding by indication was the most frequent concern.

SFM and oncological outcomes

R0 resection was reported in seven studies. There was no significant difference with SFM (RR 1.02; 95% CI 0.95–1.10; I^2=52.4%; prediction interval 0.88–1.19).

Lymph-node yield was reported in 10 studies. SFM was associated with an MD of 0.67 nodes (95% CI 0.05–1.29; I^2=0%; prediction interval −0.07–1.42). The absolute difference was less than one node, and pooled means exceeded 12 nodes in both groups. Included reports did not consistently provide the proportion of patients with at least 12 nodes, additional positive nodes, stage migration, or treatment changes. The corresponding forest plots are shown in Fig. 2a and b (lymph-node yield and R0 resection, respectively).

IMA ligation and oncological outcomes

All 13 IMA ligation studies reported lymph-node yield. High ligation was associated with an MD of 1.26 nodes (95% CI 0.61–1.91; I^2=71.4%; prediction interval −0.77–3.29). The difference was statistically significant but small relative to pooled means exceeding 12 nodes, and no consistent improvement in adequate nodal staging, stage migration, or survival was demonstrated. The forest plot for this comparison is shown in Fig. 2c.

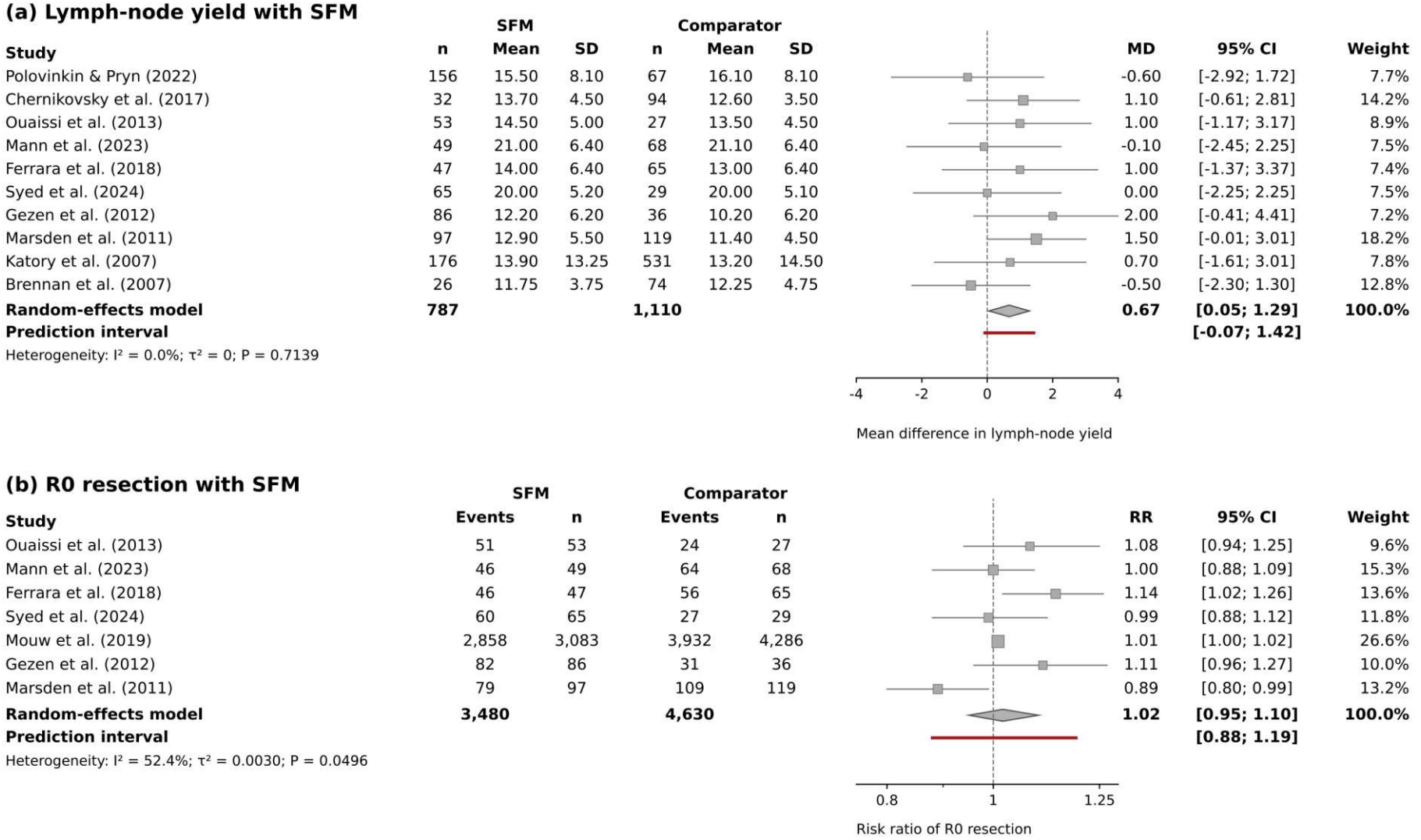


Fig. 2 Oncological outcome panels. (a) Lymph-node yield with SFM. (b) R0 resection with SFM. (c) Lymph-node yield with high versus low IMA ligation. The forest plots show individual study estimates, the pooled random-effects estimate, heterogeneity, and the prediction interval

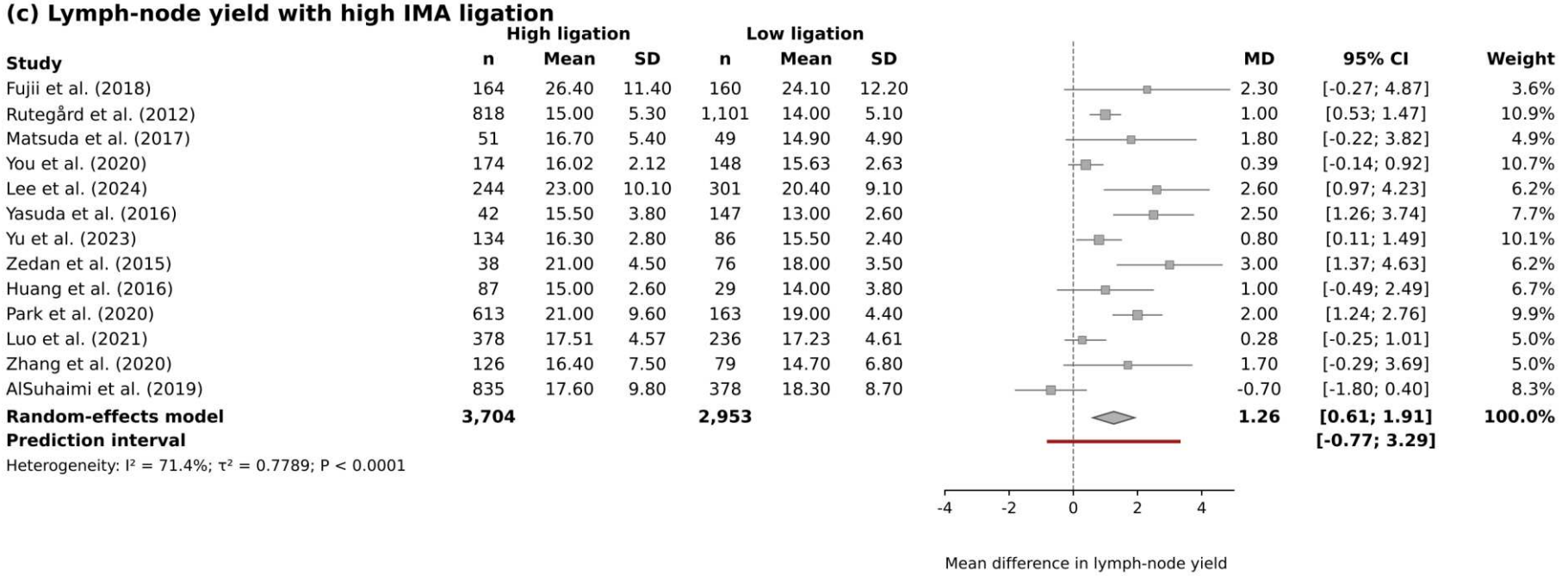


Fig. 2 Continued. (c) Lymph-node yield with high versus low IMA ligation

SFM and surgical outcomes

Anastomotic leakage of any reported grade was evaluated in 13 studies. SFM was associated with an RR of 1.13 (95% CI 1.00–1.27; I^2=23.0%; prediction interval 1.00–1.28). This is an unadjusted pooled estimate and should not be interpreted as a causal iatrogenic effect. SFM was often selected for low or ultralow anastomoses, a short mesocolon, a narrow pelvis, or anticipated tension, factors that may independently increase leakage risk. (Fig. 3a)

Blood loss was reported in five studies. The pooled MD was 43.60 mL (95% CI −85.33–172.52; I^2=95.4%; prediction interval −256.69–343.88). Length of hospital stay was reported in eight studies, with an MD of −3.01 days (95% CI −10.04–4.02; I^2=85.0%; prediction interval −21.61–15.59). Operative time was reported in 12 studies and was longer with SFM (MD 35.36 minutes; 95% CI 19.69–51.03; I^2=89.2%; prediction interval −17.83–88.55). The corresponding forest plots are shown in Fig. 3b–d.

IMA ligation and surgical outcomes

Anastomotic leakage of any reported grade was evaluated in 11 studies. There was no statistically significant difference between high and low ligation (RR 1.15; 95% CI 0.97–1.36; I^2=0%; prediction interval 0.95–1.39). The estimate for this comparison is shown in Fig. 3e.

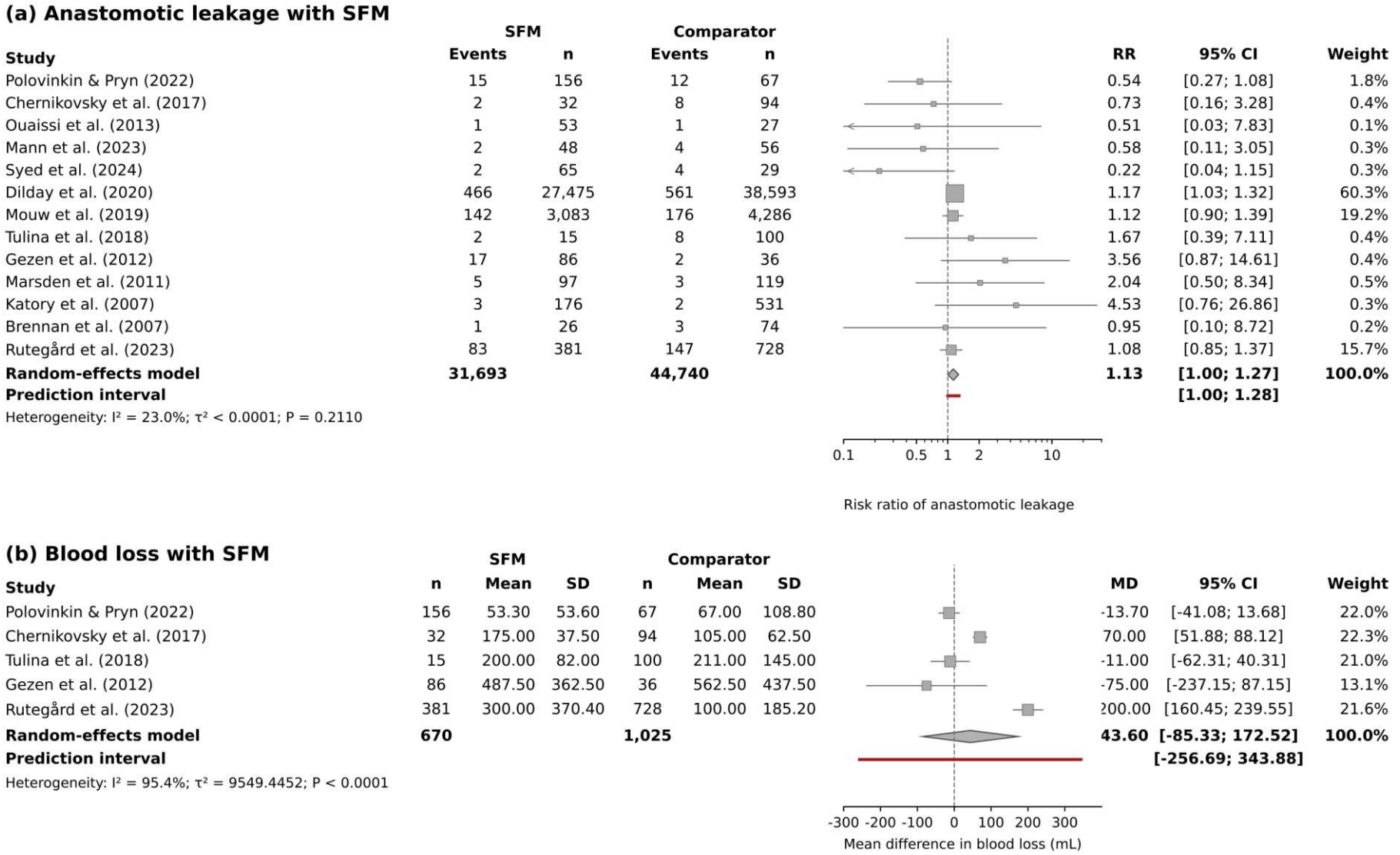
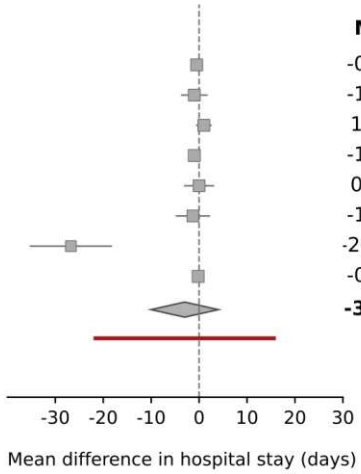


Fig. 3 Surgical outcome panels. (a) Anastomotic leakage with SFM. (b) Blood loss with SFM. (c) Length of hospital stay with SFM. (d) Operative time with SFM. (e) Anastomotic leakage with high versus low IMA ligation. Leakage combines reported grades because grade-specific ISREC counts were not uniformly available

(c) Length of hospital stay with SFM

Study	SFM n	SFM Mean	SFM SD	Comparator n	Comparator Mean	Comparator SD	MD	95% CI	Weight
Chernikovsky et al. (2017)	32	10.00	2.00	94	10.50	2.75	-0.50	[-1.39; 0.39]	13.1%
Ouaissi et al. (2013)	53	11.00	5.00	27	12.00	6.00	-1.00	[-3.63; 1.63]	12.7%
Ferrara et al. (2018)	47	11.00	4.00	65	10.00	4.00	1.00	[-0.50; 2.50]	13.1%
Syed et al. (2024)	65	7.00	1.50	29	8.00	1.50	-1.00	[-1.66; -0.34]	13.1%
Tulina et al. (2018)	15	10.55	5.30	100	10.55	6.60	0.00	[-2.98; 2.98]	12.6%
Gezen et al. (2012)	86	8.60	7.10	36	9.90	9.40	-1.30	[-4.72; 2.12]	12.5%
Brennan et al. (2007)	26	18.00	7.50	74	44.75	34.75	-26.75	[-35.18; -18.32]	9.8%
Carlson et al. (2014)	3,890	6.90	5.60	7,222	7.10	6.70	-0.20	[-0.43; 0.03]	13.1%
Random-effects model	**4,214**			**7,647**			**-3.01**	**[-10.04; 4.02]**	**100.0%**
Prediction interval								**[-21.61; 15.59]**	

Heterogeneity: $I^2 = 85.0\%$; $\tau^2 = 54.6665$; $P < 0.0001$



(d) Operative time with SFM

Study	SFM n	SFM Mean	SFM SD	Comparator n	Comparator Mean	Comparator SD	MD	95% CI	Weight
Polovinkin & Pryn (2022)	156	253.20	72.80	67	252.00	78.00	1.20	[-20.69; 23.09]	7.9%
Chernikovsky et al. (2017)	32	188.00	37.50	94	167.00	67.00	21.00	[2.16; 39.84]	8.3%
Ouaissi et al. (2013)	53	150.00	75.00	27	120.00	50.00	30.00	[-9.50; 69.50]	5.5%
Ferrara et al. (2018)	47	255.00	25.00	65	190.00	60.50	65.00	[48.65; 81.35]	8.6%
Syed et al. (2024)	65	264.00	21.00	29	225.00	18.00	39.00	[30.69; 47.31]	9.5%
Meyer et al. (2023)	121	233.50	45.90	315	211.70	51.10	21.80	[11.86; 31.74]	9.5%
Dilday et al. (2020)	27,475	219.80	97.80	38,593	184.30	90.30	35.50	[34.03; 36.97]	9.8%
Tulina et al. (2018)	15	286.70	84.20	100	253.50	76.60	33.20	[-11.98; 78.38]	4.9%
Gezen et al. (2012)	86	225.65	55.20	36	224.20	50.00	1.40	[-19.31; 22.11]	8.1%
Brennan et al. (2007)	26	167.00	17.50	74	120.00	21.25	47.00	[38.71; 55.29]	9.5%
Rutegård et al. (2023)	381	313.00	129.60	728	225.00	101.50	88.00	[73.04; 102.96]	8.8%
Carlson et al. (2014)	3,890	204.00	86.70	7,222	172.20	81.90	31.80	[28.48; 35.12]	9.7%
Random-effects model	**32,347**			**47,350**			**35.36**	**[19.69; 51.03]**	**100.0%**
Prediction interval								**[-17.83; 88.55]**	

Heterogeneity: $I^2 = 89.2\%$; $\tau^2 = 531.9920$; $P < 0.0001$

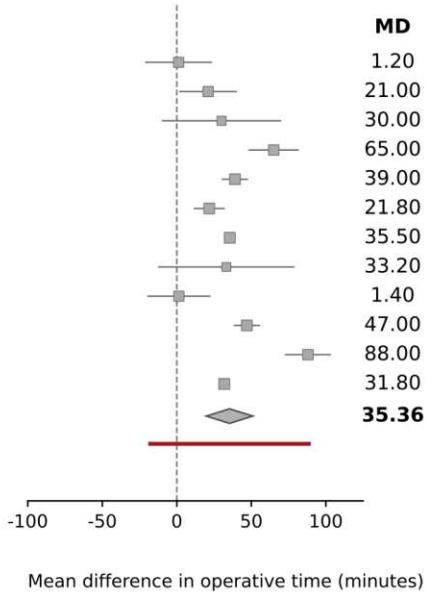


Fig. 3 Continued. (c) Length of hospital stay with SFM. (d) Operative time with SFM

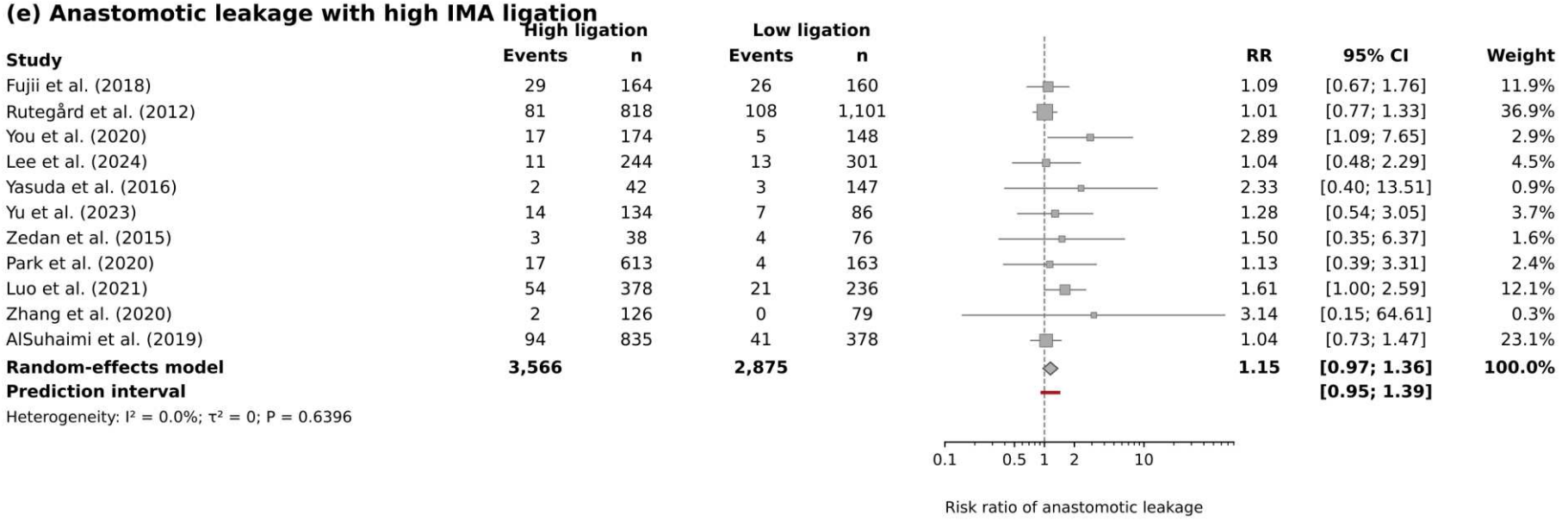


Fig. 3 Continued. (e) Anastomotic leakage with high versus low IMA ligation

Overall survival and five-year survival probabilities

Only Lee et al. and Yasuda et al. provided comparable time-to-event estimates. For high versus low IMA ligation, Lee et al. reported an unadjusted HR of 1.40 (95% CI 0.84–2.33), whereas Yasuda et al. reported an adjusted HR of 0.64 (95% CI 0.20–1.69). These estimates were not pooled because they differed in adjustment status, population, and clinical context. The remaining studies did not provide HRs, O−E/V statistics, or sufficient numbers at risk for a valid Kaplan–Meier reconstruction.

Five-year Kaplan–Meier survival probabilities ranged from 61.46% to 87.70% with high ligation and from 59.51% to 92.60% with low ligation. High ligation was numerically favorable in Luo et al., Yasuda et al., and Zedan et al., whereas low ligation was numerically favorable in the other studies. These are survival probabilities at a fixed time point, and no consistent advantage was established.

Heterogeneity subgroup analyses and small-study effects

High I^2 values for blood loss, length of hospital stay, operative time, and lymph-node yield in IMA ligation studies persisted after the extracted data were reanalyzed.

Surgical approach, tumor location, procedure type, and SFM policy could not be analyzed because outcome data were not uniformly stratified within studies.

Egger's tests showed no statistical evidence of small-study effects for lymph-node yield with SFM (P=0.463), leakage with SFM (P=0.636), operative time with SFM (P=0.871), or lymph-node yield with IMA ligation (P=0.115). Funnel-plot asymmetry was detected for leakage with IMA ligation (Egger intercept 0.98; P=0.037), which may reflect small-study effects, sparse events, clinical differences, or chance. Formal tests were not performed for outcomes with fewer than 10 studies or for survival without a pooled estimate.

Certainty of evidence

According to GRADE, evidence certainty was low for anastomotic leakage of any reported grade in the SFM comparison and very low for lymph-node yield, R0 resection, blood loss, length of hospital stay, and operative time. In the high versus low IMA ligation comparison, certainty was very low for lymph-node yield, anastomotic leakage, and overall survival. Effect estimates, numbers of studies and participants, and the specific reasons supporting each outcome rating are presented in Supplementary Tables S2 and S3.

Discussion

This systematic review found that SFM and high IMA ligation were associated with small increases in lymph-node yield, but the absolute differences were below a threshold likely to change oncological management. SFM was also associated with longer operative time. Neither maneuver showed a consistent improvement in R0 resection, blood loss, length of hospital stay, anastomotic leakage, or survival. Evidence certainty was low or very low, and pooled associations should be interpreted as estimates from heterogeneous observational evidence rather than therapeutic effects established through randomization.

The physiological rationale for SFM is mechanical: mobilization may increase reach and reduce tension in a colorectal or coloanal anastomosis. The rationale for ligation level is vascular and oncological. After IMA ligation, perfusion of the remaining descending or sigmoid colon depends on collateral pathways, including the marginal artery of Drummond and,

variably, the arcade of Riolan through the middle colic circulation. The caliber, continuity, and adequacy of these pathways differ between patients [42–44]. High ligation may facilitate central or D3 lymph-node dissection but may reduce flow through the left colic artery and raise concerns about distal perfusion or autonomic nerve injury [12,45]. Conversely, low ligation with dissection around the IMA root may preserve the left colic artery while addressing apical nodes when oncologically indicated [45,46].

The apparent increase in leakage with SFM should be interpreted in the context of confounding by indication. Surgeons may mobilize the flexure when the anastomosis is lower, the pelvis is more complex, the mesocolon is short, or tension is anticipated. These same characteristics increase baseline leakage risk. Source studies also used different leakage definitions, did not uniformly report ISREC grades, and frequently lacked adjusted estimates. These limitations explain the persistence of high I^2 values and the exploratory nature of subgroup testing.

Clinically, the data support selective SFM when additional length is required for a safe, tension-free reconstruction, rather than routine mobilization solely to increase lymph-node yield. High IMA ligation should be individualized according to apical nodal disease, vascular anatomy, perfusion assessment, and the need to preserve autonomic nerves. Low ligation combined with appropriate apical or D3 lymphadenectomy is a reasonable alternative when it achieves the oncological objective and preserves the left colic artery. Future prospective multicenter studies should prespecify SFM policy, surgical approach, tumor location, procedure type, perfusion assessment, ISREC grade, and adjusted time-to-event outcomes.

Strengths and limitations

Strengths include the separate analysis of two clinically distinct surgical questions, explicit handling of linked reports, design-specific risk-of-bias tools, GRADE assessment, survival analysis that avoided converting censored five-year percentages into HRs, and formal tests for small-study effects when study numbers permitted. Limitations include the predominance of retrospective studies, residual confounding, heterogeneous definitions and reporting, uncertain estimates of dispersion in several studies, possible cohort overlap, limited RCT evidence, and the inability to perform clinical subgroup analyses using reliable cross-classified data.

Conclusions

SFM was associated with a small increase in lymph-node yield and longer operative time, without evidence of benefit in R0 resection, blood loss, or length of hospital stay. The borderline association with leakage should be interpreted as a marker of complex, higher-risk anastomoses that may require SFM, rather than evidence of a causal iatrogenic effect. High IMA ligation modestly increased lymph-node yield without reducing leakage, and the available HRs did not establish a consistent survival advantage. Small differences in node yield did not demonstrate a clinically significant improvement beyond adequate staging thresholds and do not justify routine use of either maneuver.

Statements and Declarations

Protocol registration: PROSPERO CRD420261392853. Ethics approval: Not required because the study used published aggregate data. Data availability: Extracted aggregate data and the analysis audit are available in the supplementary files. Competing interests: No conflicts of interest were declared.

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Supplementary material

Impact of Splenic Flexure Mobilization and Inferior Mesenteric Artery Ligation Level on Surgical and Oncological Outcomes in Left-Sided Colorectal Cancer: A Systematic Review and Meta-Analysis

Supplementary Table S1 Search strategies and documented retrieval counts

Publication period: January 1, 2006–December 31, 2025. Reported initial search date: May 30, 2026.

Source	Fields and limits	Normalized search equation	Total count
MEDLINE / PubMed	No explicit field tag. Publication date: 2006–2025.	("colorectal cancer" OR "rectal cancer" OR "sigmoid cancer" OR "left-sided colorectal cancer") AND ("splenic flexure mobilisation" OR "splenic flexure mobilization") AND ("anastomotic leak" OR "anastomotic leakage" OR "lymph node yield" OR "operative time" OR "blood loss" OR "hospital stay" OR "oncological outcomes") AND ("2006/01/01": "2025/12/31") ("colorectal cancer" OR "rectal cancer" OR "sigmoid cancer") AND ("inferior mesenteric artery" OR IMA) AND ("high ligation" OR "high tie") AND ("low ligation" OR "low tie" OR "low-tie") AND ("lymph node yield" OR "anastomotic leakage" OR "overall survival" OR "disease-free survival" OR recurrence OR "oncological outcomes") AND ("2006/01/01" : "2025/12/31")	111
Scopus	TITLE-ABS-KEY; PUBYEAR > 2005 and < 2026.	TITLE-ABS-KEY(("colorectal cancer" OR "rectal cancer" OR "sigmoid cancer" OR "left-sided colorectal cancer") AND ("splenic flexure mobilisation" OR "splenic flexure mobilization") AND ("anastomotic leak" OR "anastomotic leakage" OR "lymph node yield" OR "operative time" OR "blood loss" OR "hospital stay" OR "oncological outcomes")) AND PUBYEAR > 2005 AND PUBYEAR < 2026 TITLE-ABS-KEY(("colorectal cancer" OR "rectal cancer" OR "sigmoid cancer") AND ("inferior mesenteric artery" OR IMA) AND ("high ligation" OR "high tie") AND ("low ligation" OR "low tie" OR "low-tie") AND ("lymph node yield" OR "anastomotic leakage" OR "overall survival" OR "disease-free survival" OR recurrence OR "oncological outcomes")) AND PUBYEAR > 2005 AND PUBYEAR < 2026	61
Cochrane Library	Publication interval 2006–2025 in the interface.	(("colorectal cancer" OR "rectal cancer" OR "sigmoid cancer" OR "left-sided colorectal cancer") AND ("splenic flexure mobilisation" OR "splenic flexure mobilization") AND ("anastomotic leak" OR "anastomotic leakage" OR "lymph node yield" OR "operative time" OR "blood loss" OR "hospital stay" OR "oncological outcomes")) (("colorectal cancer" OR "rectal cancer" OR "sigmoid cancer") AND ("inferior mesenteric artery" OR IMA) AND ("high ligation" OR "high tie") AND ("low ligation" OR "low tie" OR "low-tie") AND ("lymph node yield" OR "anastomotic leakage" OR "overall survival" OR "disease-free survival" OR recurrence OR "oncological outcomes"))	21
SciELO	All indexes; Spanish, English, and Portuguese; period 2006–2025.	("cáncer colorrectal" OR "cancer colorectal" OR "colorectal cancer" OR "cáncer rectal" OR "câncer colorretal") AND ("movilización de la flexura esplénica" OR "splenic flexure mobilization" OR "mobilização da flexura esplênica") AND ("fuga anastomótica" OR "anastomotic leakage" OR "rendimiento ganglionar" OR "lymph node yield" OR "tiempo operatorio" OR "operative time") ("cáncer colorrectal" OR "cancer colorectal" OR "colorectal cancer" OR "cáncer rectal" OR "câncer colorretal") AND ("arteria mesentérica inferior" OR "inferior mesenteric artery" OR IMA) AND ("ligadura alta" OR "high ligation" OR "high tie" OR "ligadura baja" OR "low ligation" OR "low tie")	16

Google Scholar	General search; interval 2006–2025.	"colorectal cancer" "splenic flexure mobilization" “colorectal cancer" "inferior mesenteric artery" ("high tie" OR "high ligation") ("low tie" OR "low ligation")	50

Supplementary Table S2 Summary of findings and GRADE certainty for SFM versus no SFM or selective mobilization

Population: Adults undergoing curative-intent resection for left-sided colorectal cancer. Intervention: SFM. Comparator: No SFM or selective mobilization.

Outcome	Studies / participants	Effect (95% CI)	Absolute effect (95% CI)	GRADE certainty	Reasons for judgment
Anastomotic leakage of any reported grade	13 studies 76,433	RR 1.13 (1.00–1.27)	Comparator: 21/1,000. SFM: 24/1,000. 3 more per 1,000 (0 to 6 more).	Low	Confounding by indication; borderline precision.
R0 resection	7 studies 8,110	RR 1.02 (0.95–1.10)	Comparator: 916/1,000. SFM: 934/1,000. 18 more per 1,000 (46 fewer to 84 more).	Very low	Risk of bias; inconsistency and imprecision.
Lymph-node yield	10 studies 1,897	MD +0.67 nodes (+0.05 to +1.29)	0.67 more nodes (0.05 to 1.29 more).	Very low	Predominance of serious risk of bias.
Blood loss	5 studies 1,695	MD +43.60 mL (−85.33 to +172.52)	43.60 mL more (85.33 less to 172.52 more).	Very low	Risk of bias; extreme heterogeneity and imprecision.
Length of hospital stay	8 studies 11,861	MD −3.01 days (−10.04 to +4.02)	3.01 fewer days (10.04 fewer to 4.02 more).	Very low	Risk of bias; high heterogeneity and imprecision.
Operative time	12 studies 79,697	MD +35.36 min (+19.69 to +51.03)	35.36 more minutes (19.69 to 51.03 more).	Very low	Risk of bias and high heterogeneity.

Leakage: 13 studies, 76,433 participants (31,693 with SFM and 44,740 in the comparator group). Corrected Mann counts were used: 2/48 versus 4/56; for Mouw, the ACS-NSQIP cohort was retained: 142/3,083 versus 176/4,286.

Illustrative baseline risks were obtained from 931/44,740 for leakage and 4,243/4,630 for R0 resection, rounded per 1,000. Intervention risk was derived from the RR, and the absolute difference was rounded separately. Sample sizes correspond to the sum for each outcome.

Leakage combines reported grades; uniform data were unavailable for ISREC stratification. The leakage RR is an unadjusted pooled association and does not demonstrate a causal iatrogenic effect. Small increases in lymph-node yield did not demonstrate improved staging or treatment changes.

Supplementary Table S3 Summary of findings and GRADE certainty for high versus low IMA ligation

Population: Adults undergoing curative-intent resection for left-sided colorectal cancer. Intervention: High IMA ligation. Comparator: Low IMA ligation.

Outcome	Studies / participants	Effect (95% CI)	Absolute effect (95% CI)	GRADE certainty	Reasons for judgment
Anastomotic leakage of any reported grade	11 studies 6,441	RR 1.15 (0.97–1.36)	Low ligation: 81/1,000. High ligation: 93/1,000. 12 more per 1,000 (2 fewer to 29 more).	Very low	Risk of bias; imprecision; possible small-study effects (Egger P=0.037).
Lymph-node yield	13 studies 6,657	MD +1.26 nodes (+0.61 to +1.91)	1.26 more nodes (0.61 to 1.91 more).	Very low	Risk of bias and inconsistency (I^2=71.4%).
Overall survival assessed using HRs	2 studies 734	Lee et al.: HR 1.40 (0.84–2.33), unadjusted. Yasuda et al.: HR 0.64 (0.20–1.69), adjusted. No pooled estimate.	Not estimable as a pooled effect.	Very low	Risk of bias; different adjustment; imprecision and discordant estimates.

Overall survival assessed using HRs: Lee et al. (2024), 545 participants, unadjusted HR 1.40 (95% CI 0.84–2.33); Yasuda et al. (2016), 189 participants, adjusted HR 0.64 (95% CI 0.20–1.69). Both HRs express high versus low ligation. They were not pooled because of differences in adjustment and clinical context.

Reports presenting five-year Kaplan–Meier survival probabilities without an extractable HR were described narratively. Censored percentages were not converted into events and were not included as HR studies in this table.

The illustrative baseline leakage risk was obtained from 232/2,875, rounded to 81 per 1,000. Egger's test indicates possible asymmetry, which may have explanations other than publication bias. Heterogeneity in lymph-node yield limits the applicability of the mean increase.

Abbreviations: IMA, inferior mesenteric artery; SFM, splenic flexure mobilization; RR, risk ratio; MD, mean difference; HR, hazard ratio; CI, confidence interval; GRADE, Grading of Recommendations Assessment, Development and Evaluation.