REVIEW

Meta-analysis of medial-to-lateral versus lateral-to-medial colorectal mobilisation during laparoscopic colorectal surgery

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Abstract

Objectives To evaluate comparative outcomes of medial-to-lateral and lateral-to-medial colorectal mobilisation in patients undergoing laparoscopic colorectal surgery.

Methods We conducted a systematic search of electronic databases and bibliographic reference lists. Perioperative mortality and morbidity, procedure time, length of hospital stay, rate of conversion to open procedure, and number of harvested lymph nodes were the outcome parameters. Combined overall effect sizes were calculated using fixed-effects or random-effects models.

Results We identified eight comparative studies reporting a total of 1477 patients evaluating outcomes of medial-to-lateral ($n = 626$) and lateral-to-medial ($n = 851$) approaches in laparoscopic colorectal resection. The medial-to-lateral approach was associated with significantly lower rate of conversion to open (odds ratio (OR) 0.43, $P = 0.001$), shorter procedure time (mean difference (MD) − 32.25, $P = 0.003$) and length of hospital stay (MD − 1.54, $P = 0.02$) compared to the lateral-to-medial approach. However, there was no significant difference in mortality (risk difference (RD) 0.00, $P = 0.96$), overall complications (OR 0.78, $P = 0.11$), wound infection (OR 0.84, $P = 0.60$), anastomotic leak (OR 0.70, $P = 0.26$), bleeding (OR 0.60, $P = 0.50$), and number of harvested lymph nodes (MD − 1.54, $P = 0.02$) between two groups. Sub-group analysis demonstrated that the lateral-to-medial approach may harvest more lymph nodes in left-sided colectomy (MD − 1.29, $P = 0.0009$). The sensitivity analysis showed that overall complications were lower in the medial-to-lateral group (OR 0.72, $P = 0.49$).

Conclusions Our meta-analysis (level 2 evidence) showed that medial-to-lateral approach during laparoscopic colorectal resection may reduce procedure time, length of hospital stay and conversion to open procedure rate. Moreover, it may probably reduce overall perioperative morbidity. However, both approaches carry similar risk of mortality, and have comparable ability to harvest lymph nodes. Future high-quality randomised trials are required.

Keywords Lateral-to-medial · Medial-to-lateral · Laparoscopic colorectal surgery · Colorectal mobilisation

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Introduction

Laparoscopic colorectal surgery has rapidly evolved since its introduction in 1991 [1]. In comparison with the open approach, laparoscopic colorectal resection has been demonstrated to be associated with improved short-term outcomes and similar long-term outcomes and oncological clearance [2–4].

Although the laparoscopic approach for colorectal resection has several advantages, it is technically challenging, has a steep learning curve and is associated with longer procedure time compared to the traditional open approach [5–7]. It involves laparoscopic mobilisation of the colon, division of the mesenteric vessels, bowel exteriorisation, resection and anastomosis [6].

There are two approaches for laparoscopic colorectal mobilisation: the medial-to-lateral or lateral-to-medial. The former involves exploration, identification and proximal division of mesenteric vessels followed by division of the lateral peritoneal attachments while the latter involves sequence of division used in open procedures with division of the lateral peritoneal attachments followed by exploration of the medial mesentery and division of the identified blood vessels proximally [8–11]. The European Association of Endoscopic Surgeons (EAES) consensus statement in 2004 recommended that a medial-to-lateral approach is the preferred choice for mesocolonic dissection [12]. However, the recommendation was based on poor level of evidence.

We aimed to conduct a comprehensive systematic review and meta-analysis to evaluate comparative outcomes of medial-to-lateral and lateral-to-medial colorectal mobilisation in patients undergoing laparoscopic colorectal surgery.

Methods

Design

We highlighted our eligibility criteria, methods, and evaluated outcomes in a review protocol. Our study was conducted in line with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement standards [13].

Study selection criteria

- Randomised controlled trials (RCTs) and comparative observational studies
- Including patients aged > 18 years old of any gender
- Including patients with benign or malignant colorectal pathologies
- Including patients undergoing laparoscopic colorectal resection
- Comparing laparoscopic medial-to-lateral and lateral-to-medial colorectal mobilisation

Types of interventions

The intervention of interest was medial-to-lateral colorectal mobilisation which was defined as exploration, identification and proximal division of mesenteric vessels followed by division of the lateral peritoneal attachments. The primary intervention was compared with the lateral-to-medial colorectal mobilisation which was defined as division of the lateral peritoneal attachments followed by exploration of the medial mesentery and division of the identified blood vessels proximally. We considered laparoscopic right hemicolectomy, left hemicolectomy, sigmoid colectomy, transverse colectomy,

sub-total colectomy, high or low anterior resection, or abdomino-perineal resection.

Outcomes

Primary outcome measures were defined as perioperative (in hospital or 30-day) mortality and morbidity, anastomotic leak, wound infection and bleeding. Procedure time, length of hospital stay, rate of conversion to open procedure and number of harvested lymph nodes were the secondary outcome parameters.

Literature search strategy

Two authors independently searched the following electronic databases: MEDLINE, EMBASE, CINAHL, and the Cochrane Central Register of Controlled Trials (CENTRAL). The literature search was conducted on 18 November 2018. Our search strategy was adapted according to thesaurus headings, search operators and limits in the aforementioned databases (Appendix 1). Furthermore, we searched World Health Organisation International Clinical Trials Registry http://apps.who.int/trialsearch/, ClinicalTrials.gov http://clinicaltrials.gov/, and ISRCTN Register http://www.isrctn.com/ to identify ongoing and unpublished studies. Moreover, the bibliographic lists of relevant articles and reviews were screened for further potentially eligible trials. Finally, we hand-searched the leading journals in general surgery and colorectal surgery.

Selection of studies

The title and abstract of identified articles were evaluated by two independent authors. Subsequently, if relevant, the full texts of identified articles were retrieved and evaluated against the eligibility criteria of our study. Those studies that met our eligibility criteria were included. Discrepancies in this process were resolved by discussion between the authors. However, if the disagreement still existed, an independent author was consulted.

Data extraction and management

We created an electronic data extraction spreadsheet according to the Cochrane's recommendations for intervention reviews. The data extraction spreadsheet was pilot-tested in randomly selected articles and adjusted accordingly. The following information were extracted from the included studies by two independent authors:

- Study-related data (first author, publication year, country of origin of the corresponding author, journal in which the study was published, study design and study size)

- Baseline demographic and clinical information of the study populations (age, gender, body mass index (BMI), stage and distribution of colorectal cancer, type of procedure, number of involved surgeons and their grade of expertise)
- Primary and secondary outcome data

Disagreements during data extraction and management were resolved following consultation with a third independent author.

Assessment of risk of bias

The methodological quality and risk of bias assessment were carried out by two authors using the Cochrane's tool [14] and the Newcastle-Ottawa scale (NOS) [15] for RCTs and observational studies, respectively. The Cochrane's tool classifies studies into low, unclear and high risk of bias following evaluating and determining the risk of selection bias, performance bias, detection bias, attrition bias, reporting bias and other sources of bias. The NOS is a star-based scoring system (maximum score 9) which enables review authors to evaluate an observational study in the following aspects: the selection of the study groups, the comparability of the groups and the ascertainment of outcome of interest. Studies with score of nine stars were deemed to be at low risk of bias, studies with score of seven or eight stars were deemed to be at medium risk of bias, and those that scored six or less were judged to be at high risk of bias. We resolved discrepancies in risk of bias assessment by discussion between the assessing authors. Nevertheless, if no agreement could be reached, a third reviewer was involved as an adjudicator.

Summary measures and synthesis

For dichotomous outcome variables (mortality, overall complications, anastomotic leak, wound infection, bleeding and conversion to open), we calculated the odds ratio (OR) or risk difference (RD) (when more than three studies had zero events in both medial-to-lateral and lateral-to-medial groups) as the summary measures. The OR is the odds of an adverse event in the medial-to-lateral group compared to the lateral-to-medial group. The RD is the difference in risk of an adverse event in the medial-to-lateral group compared to the lateral-to-medial group. An OR of less than one would favour the medial-to-lateral approach. For continuous parameters (procedure time, length of hospital stay, and mean number of harvested lymph nodes), we calculated the mean difference (MD) between the two groups.

The individual patient was used as the unit of analysis in this study. Information with regard to dropouts, withdrawals and any other missing data were recorded. We planned to contact authors of the included studies where information about our outcome of
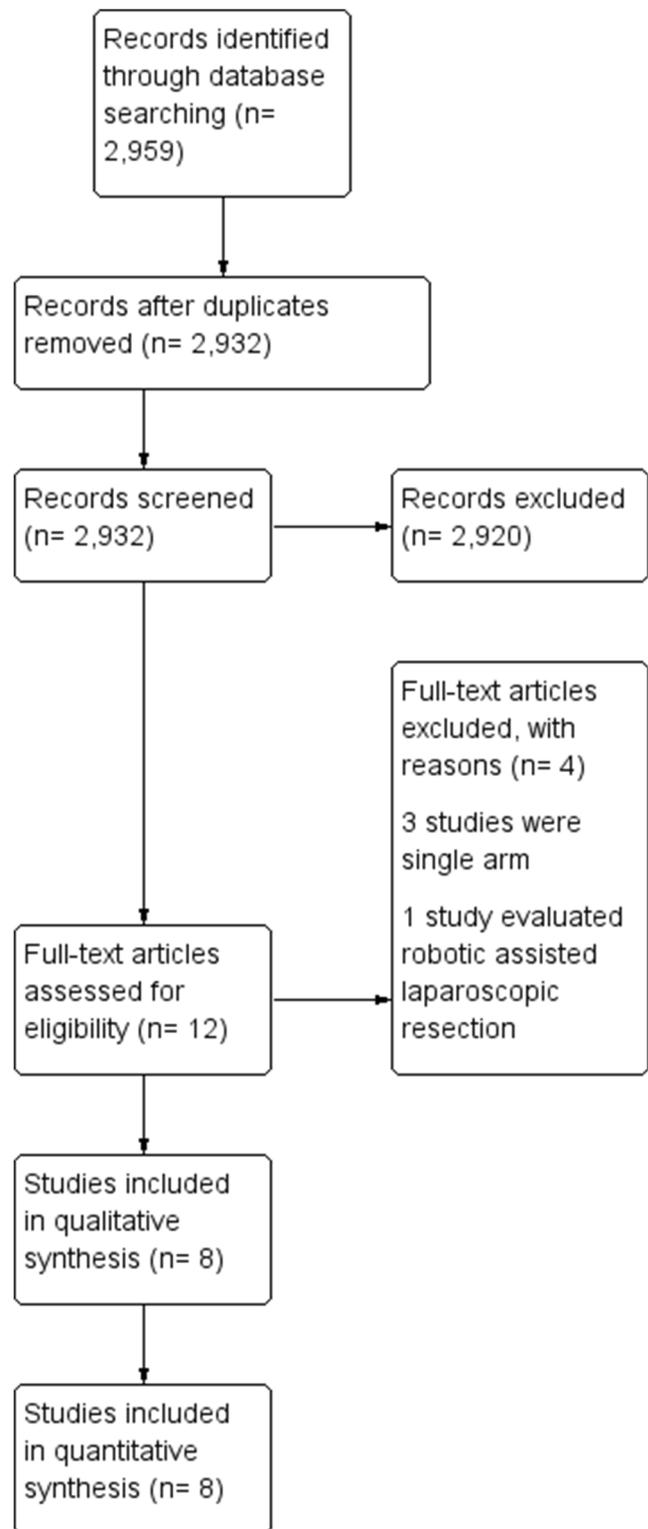

Fig. 1 Study flow diagram

interest were not reported. Our final analysis respected the intention-to-treat concept.

One independent review author entered the extracted data into Review Manager 5.3 software for data synthesis [14]. The entered data were subsequently checked by a second

Table 1 Included studies related data

Author	Year	Country	Journal	Study design	M-t-L	L-t-M
Liang [16]	2003	Taiwan	World Journal of Surgery	Randomised controlled trial	36	31
Rotholtz [17]	2009	Argentina	Surgical Laparoscopy Endoscopy and Percutaneous Techniques	Retrospective observational study	76	126
Poon [18]	2009	Hong Kong	World Journal of Surgery	Retrospective observational study	224	196
Day [19]	2010	Hong Kong	World Journal of Surgery	Retrospective observational study	56	88
Yan [20]	2010	China	Chinese Journal of Gastrointestinal Surgery	Randomised controlled trial	24	24
Kim [21]	2012	China	Colorectal Disease	Retrospective observational study	73	164
Honaker [22]	2016	USA	International Journal of Colorectal Disease	Retrospective observational study	79	154
Hussain [23]	2018	UK	Annals of Medicine and Surgery	Retrospective observational study	58	68

M-t-L medial-to-lateral, *L-t-M* lateral-to-medial

independent review author. Random-effects or fixed-effects modelling were used, as appropriate, for analysis. Only when significant between-study heterogeneity existed, random-effects models were applied. This has previously been defined by Higgins et al. [14] We reported the results of our analysis for each outcome parameter in a forest plot with 95% confidence intervals (CIs).

Heterogeneity among the studies was assessed using the Cochran Q test (χ [2]). We quantified inconsistency by calculating I^2 and interpreted it using the following guide [14]: 0 to 25% might not be important; 25 to 75% may represent moderate heterogeneity; 75 to 100% may represent substantial heterogeneity. Moreover, where more than ten studies were available in analysis of an outcome parameter, funnel plots were planned to be constructed in order to assess their symmetry to visually evaluate publication bias.

We conducted sub-group analysis with respect to right or left-sided resection. We conducted sensitivity analyses to explore potential sources of heterogeneity and assess the robustness of our results. For each outcome parameter, we repeated the primary analysis using random-effects or fixed-effects models. Moreover, for each of our defined dichotomous variable, we calculated the pooled OR, risk ratio (RR) or RD. Finally, we evaluated the effect of each study on the overall effect size and heterogeneity by repeating the analysis following excluding one study at a time.

Results

Our literature search through the aforementioned databases identified 2959 articles. After further evaluation of the identified articles, eight articles [16–23] were deemed appropriate for inclusion (Fig. 1). The included studies consisted of two RCTs and six retrospective observational studies reporting a total of 1477 patients of whom 626 underwent laparoscopic colorectal resection using the medial-to-lateral approach and the remaining 851 had laparoscopic colorectal resection using the lateral-to-medial approach**.**

Table 1 presents the date of publication and country of origin, journal and study design of the included studies. Baseline demographic and clinical characteristics of the study populations are presented in Table 2. Patients in the medial-to-lateral and lateral-to-medial groups were of comparable age in all of the included studies and comparable gender in most of the included studies (the number of male patients were higher in the medial-to-lateral group in two of the included studies). Five studies included patients with colorectal cancer whereas three studies included patients with either malignant or benign colorectal pathologies. Reporting of the TNM staging was variable, with little difference between the groups. Only four studies reported the BMI of their included patients. The mean BMI in the medial-to-lateral and lateral-to-medial groups were 23.4 ± 0.43 and 23.6 ± 1.59, respectively. There was no significant different in BMI between two groups ($P = 0.56$). The details of performed surgical procedures in each study are outlined in Table 2.

Methodological appraisal

The methodological appraisal of the six observational studies is presented in Table 3. The risk of bias was judged as low in three studies and moderate in two studies, and high in one. Moreover, Fig. 2 presents the risk of bias assessment of the included RCTs.

Data synthesis

Outcomes are summarised in Fig. 3.

Mortality Seven studies reported perioperative mortality as an outcome. Only two patients died in perioperative period, one (0.2%) in the medial-to-lateral group and one (0.1%) in the lateral to medial group. The pooled analysis of 1410 patients demonstrated that there was no significant difference in mortality between two groups (RD 0.00; 95% CI, − 0.01–0.01, $P = 0.96$). Between-study heterogeneity was low (I^2 0%, $P = 1.00$).

Table 2 Baseline demographic and clinical characteristics of included studies

Author	Age*	Male*	BMI*	Colorectal cancer	TNM stage	Procedure	Number of surgeons involved	Surgeon's expertise
Liang [16]	64.0 ± 10.2 vs 62.2 ± 9.8, $P=$ NS	55.6% vs 61.3%, $P=$ NS	22.9 ± 2.4 vs 21.3 ± 2.9	100%	II–III	Laparoscopic resection of recto-sigmoid cancer ($n=67$)	1	Consultant
Rotholtz [17]	67.2 vs 60.5, $P=$ NS	71.1% vs 58.8%, P: NR	26.2 vs 24.4	43%	NR	Laparoscopic right colectomy ($n=53$) Laparoscopic left colectomy ($n=149$)	NR	Consultant
Poon [18]	70 vs 70, $P=$ NS	50.2% vs 54.9%, $P=$ NS	NR	86%	III–IV	Laparoscopic right colectomy ($n=102$) Laparoscopic left colectomy ($n=30$) Laparoscopic sigmoid colectomy ($n=24$) Laparoscopic low anterior/anterior resection ($n=247$) Other ($n=17$)	1 M-to-L 2 L-to-M	Consultant
Day [19]	71.88 vs 67.13, $P=$ NS	67.9% vs 65.9%, $P=$ NS	NR	100%	NR	Laparoscopic colectomy ($n=144$)	NR	Consultant
Yan [20]	55.3 ± 8.3 vs 55.5 ± 7.8, $P=$ NS	66.7% vs 54.1%, $P=$ NS	23.6 ± 2.4 vs 24.4 ± 2.7	100%	I–III	Laparoscopic right hemicolectomy ($n=48$)	NR	Consultant
Kim [21]	65.3 ± 11.1 vs 65.6 ± 10.7, $P=$ NS	58.9% vs 68.9%, $P=$ NS	23.7 ± 3.0 vs 23.5 ± 3.1	100%	I–IV	Laparoscopic low anterior resection ($n=237$)	1	Consultant
Honaker [22]	66.8 ± 14.2 vs 67.2 ± 13.3, $P=$ NS	78% vs 56%, $P=0.0015$	NR	70%	II–III	Laparoscopic right colectomy ($n=233$)	5 M-to-L 3 L-to-M	Consultant
Hussain [23]	NR	46.1% vs 53.9%, $P=$ NS	NR	100%	NR	Laparoscopic right hemicolectomy ($n=33$) Laparoscopic left hemicolectomy ($n=12$) Laparoscopic sigmoid colectomy ($n=9$) Laparoscopic transverse colectomy ($n=1$) Laparoscopic sub-total colectomy ($n=1$) Laparoscopic anterior resection ($n=54$) Laparoscopic abdomino-perineal resection ($n=16$)	NR	Consultant

BMI body mass index, NS not significant, NR not reported

*Medial-to-lateral vs lateral-to-medial

Table 3 Methodological quality of the observational studies assessed with the Newcastle–Ottawa Scale

Author	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of follow up of cohorts	Total score
Rotholtz [17]	*	*	*	*	*	*	*	*	8
Poon [18]	*	*	*	*	**	*	*	*	9
Day [19]	*		*	*		**	*	*	6
Kim [21]	*	*	*	*	**	*	*	*	9
Honaker [22]	*	*	*	*	*	*	*	*	8
Hussain [23]	*	*	*	*	**	*	*	*	9

Overall complications A total of 210 perioperative complications were reported by 8 studies (1244 patients), 81 (14.8%) in the medial-to-lateral group and 125 (17.9%) in the lateral-to-medial group. No significant difference was found in the complication rate between the two groups (OR 0.78; 95% CI, 0.57–1.06, $P = 0.11$). There was moderate between-study heterogeneity (I^2 43%, $P = 0.11$).

Anastomotic leak All included studies (1477 patients) reported anastomotic leak as an outcome. The anastomotic leak rates in the medial-to-lateral and the lateral-to-medial groups were 2.5% and 3.8%, respectively. The pooled analysis did not demonstrate any significant difference in anastomotic leak rate between the two groups (OR 0.70; 95% CI, 0.38–1.30, $P = 0.26$). Heterogeneity among the included studies was low (I^2 0%, $P = 0.54$).

Wound infection Seven studies reported wound infection as an outcome. Wound infection occurred in 15 (2.7%) and 20 (2.8%) patients in the medial-to-lateral and the lateral-to-medial groups, respectively. The pooled analysis of 1244 patients demonstrated that the incidence of wound infection was similar in both groups (OR: 0.84; 95% CI, 0.43–1.63, $P = 0.60$). Low heterogeneity existed among the included studies (I^2 0%, $P = 0.61$).

Bleeding Perioperative bleeding was reported by five studies (680 patients). There was no significant difference in the bleeding rate between the medial-to-lateral (0.3%) and the lateral-to-medial groups (0.9%) (OR 0.60; 95% CI, 0.13–2.68, $P = 0.50$). There was low between-study heterogeneity (I^2 0%, $P = 0.83$).

Conversion to open The pooled analysis included 1477 patients from eight studies. The rate of conversion to open procedure in the medial-to-lateral group was 3.5% while it was 6.5% in the lateral-to-medial group. The medial-to-lateral approach significantly reduced the rate of conversion to open procedure (OR 0.43; 95% CI, 0.26–0.72, $P = 0.001$). Heterogeneity among the included studies was low ($I^2 = 0\%$, $P = 0.45$).

Procedure time Four studies (772 patients) reported their procedure time as an outcome. Our analysis showed that the medial-to-lateral approach was associated with a significantly shorter procedure time than the lateral-to-medial approach (160.4 min vs 193.6 min, MD − 32.25; 95% CI, − 53.16 to − 11.33, $P = 0.003$). Heterogeneity among the studies was substantial ($I^2 = 95\%$, $P < 0.00001$).

Length of hospital stay Five studies reported the length of hospital stay as an outcome. The pooled analysis, which included 898 patients, demonstrated that medial-to-lateral approach was associated with significantly shorter length of

Fig. 2 Risk of bias summary and graph showing authors' judgments about each risk of bias item
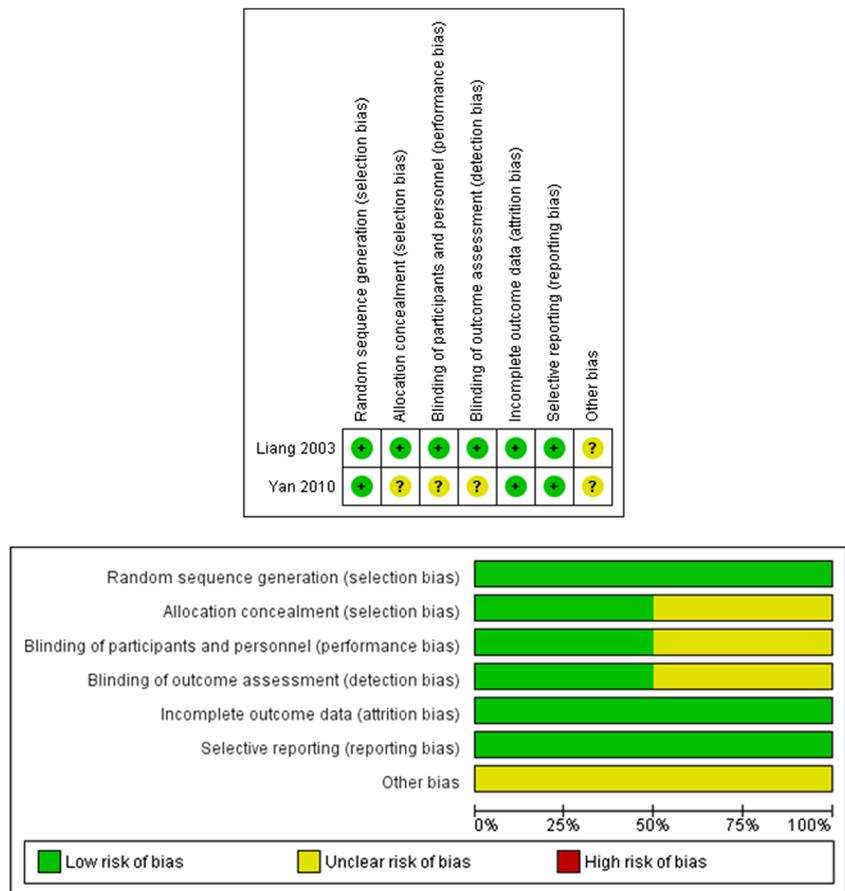
hospital stay compared to the lateral-to-medial approach (9.3 days vs 11.4 days, MD − 1.54; 95% CI, − 2.79 to − 0.29, $P = 0.02$). Significant heterogeneity among the included studies was detected ($I^2 = 85\%$, $P < 0.0001$).

Number of harvested lymph nodes Five studies reported the mean number of harvested lymph nodes in their study groups. The pooled analysis of 898 patients found no significant difference in the number of harvested lymph nodes between the two groups (17.2 vs 16.4, MD: 0.57; 95% CI, − 1.48 to 2.61, $P = 0.59$). Significant heterogeneity among the included studies was detected ($I^2 = 92\%$, $P < 0.00001$).

Sub-group analysis

Right colectomy

Mortality There was no significant difference in mortality between two groups (RD 0.00; 95% CI, −0.03–0.03, $P = 1.00$). Between-study heterogeneity was low (I^2 0%, $P = 1.00$).

Overall complications No significant difference was found in the complication rate between the two groups (OR: 0.56; 95%

CI, 0.16–1.93, $P = 0.36$). There was low between-study heterogeneity (I^2 0%, $P = 0.54$).

Anastomotic leak No significant difference in anastomotic leak rate was found between the two groups (OR 0.32; 95% CI, 0.01–8.25, $P = 0.49$). Heterogeneity among the included studies was low (I^2 0%, $P = 0.63$).

**Wound infection** Sub-group analysis was not possible to be conducted.

Bleeding There was no significant difference in the bleeding rate between the medial-to-lateral and the lateral-to-medial groups (OR 0.57; 95% CI, 0.07–4.75, $P = 0.61$). There was low between-study heterogeneity (I^2 0%, $P = 0.61$).

Conversion to open No difference in conversion rate was found between the two groups (OR 0.48; 95% CI, 0.04–5.66, $P = 0.58$). Heterogeneity among the included studies was low ($I^2 = 0\%$, $P = 0.67$).
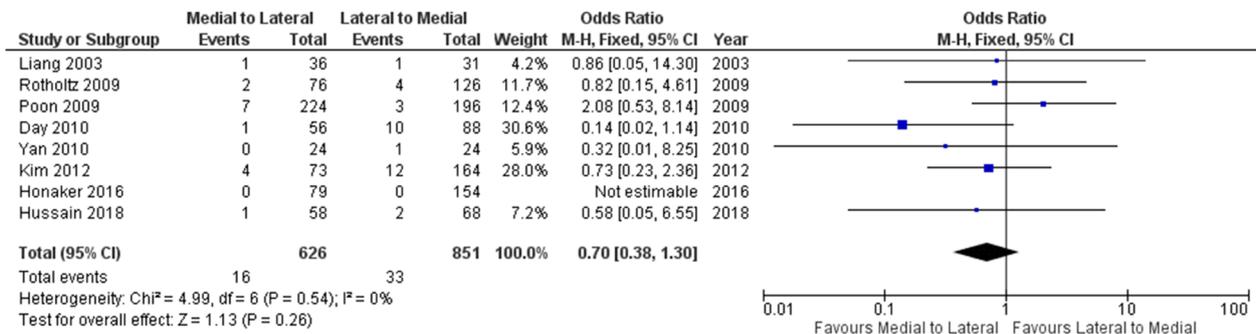
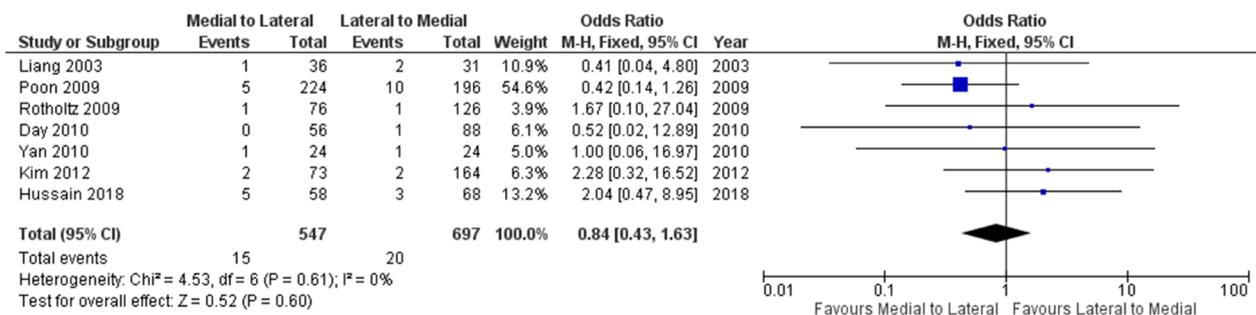**Procedure time** Sub-group analysis was not possible to be conducted.
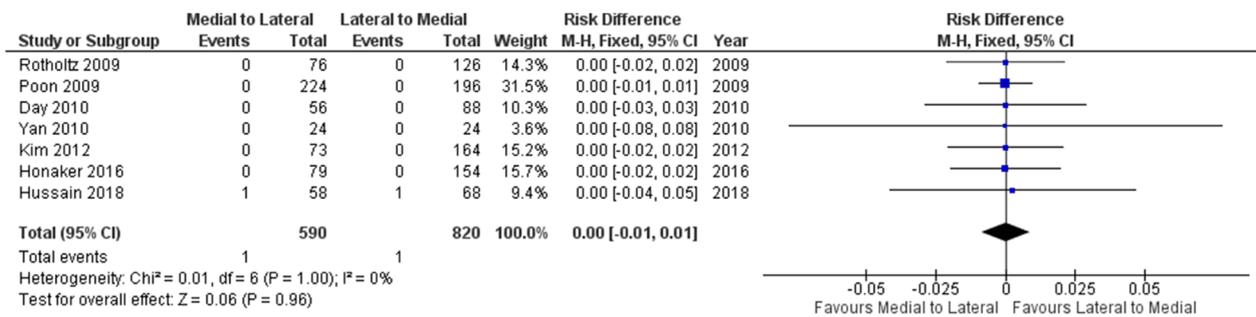
a Mortality
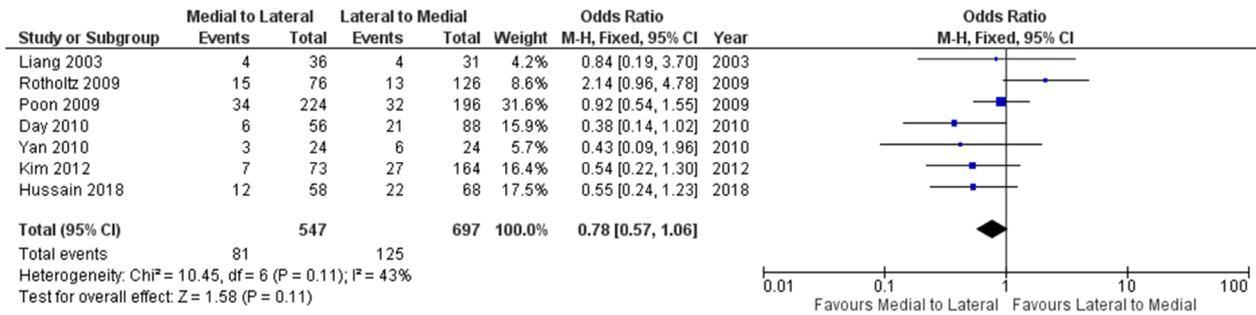
**b** Overall complications

**c** Anastomotic leak

d Wound infection

Fig. 3 Forest plots of comparison of **a** mortality, **b** overall complications, **c** anastomotic leak, **d** wound infection, **e** bleeding, **f** conversion to open, **g** procedure time, **h** length of hospital stay and **i** number of harvested lymph nodes. The solid 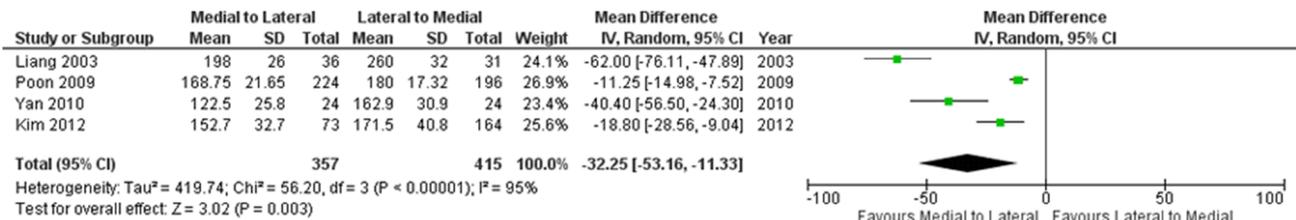squares denote the odds ratios (ORs), risk difference (RD) or mean difference (MD). The horizontal lines represent the 95% confidence intervals (CIs), and the diamond denotes the pooled effect size. M-H Mantel–Haenszel test
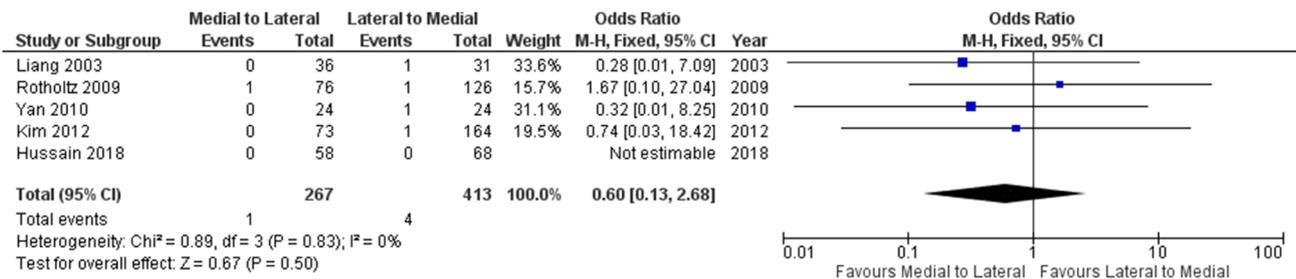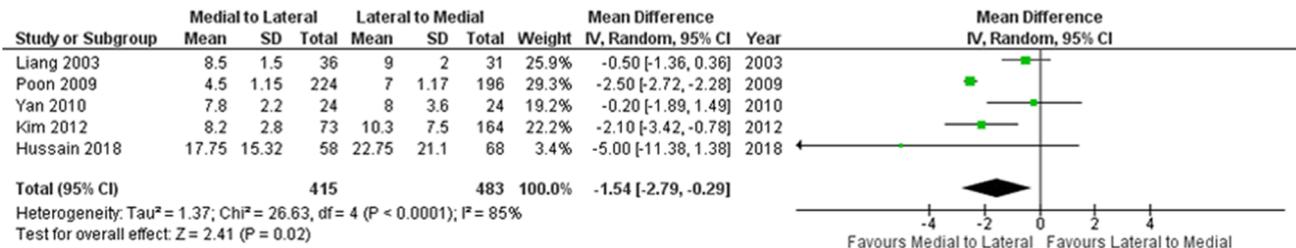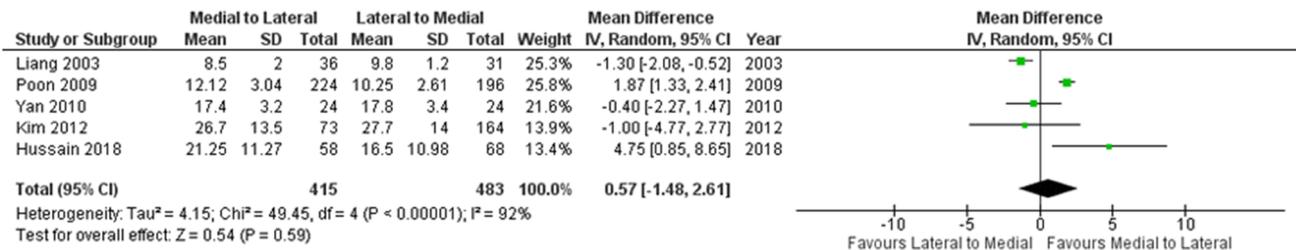
e bleeding
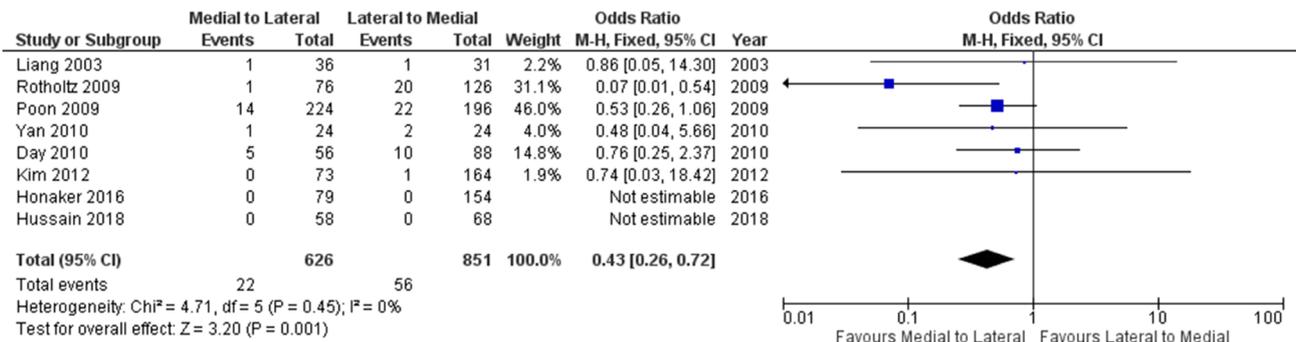
f Conversion to open

g Procedure time

h Length of hospital stay

i Number of harvested lymph nodes

Fig. 3 (continued)

Length of hospital stay Sub-group analysis was not possible to be conducted.

Number of harvested lymph nodes Sub-group analysis was not possible to be conducted.

Left colectomy

Mortality

Sub-group analysis was not possible to be conducted.

Overall complications

No significant difference was found in the complication rate between the two groups (OR 0.60; 95% CI, 0.28–1.27, $P = 0.18$). There was low between-study heterogeneity (I^2 0%, $P = 0.61$).

Anastomotic leak

No significant difference in anastomotic leak rate was found between the two groups (OR 0.75; 95% CI, 0.26–2.20, $P = 0.60$). Heterogeneity among the included studies was low (I^2 0%, $P = 0.92$).

Wound infection

No significant difference in wound infection rate was found between the two groups (OR 1.09; 95% CI, 0.25–4.86, $P = 0.91$). Heterogeneity among the included studies was low (I^2 12%, $P = 0.29$).

Bleeding

There was no significant difference in the bleeding rate between the groups (OR 0.45; 95% CI, 0.05–4.37, $P = 0.49$). There was low between-study heterogeneity (I^2 0%, $P = 0.67$).

Conversion to open

There was marginally significant reduction in the rate of conversion in favour of the medial-to-lateral approach (OR 0.25; 95% CI, 0.06–1.01, $P = 0.05$). Heterogeneity among the included studies was low ($I^2 = 0$%, $P = 0.47$).

Procedure time

The medial-to-lateral approach was associated with a non-significant reduction in procedure time (MD − 40.09; 95% CI, − 82.42 to 2.24, $P = 0.06$). Heterogeneity among the studies was significant ($I^2 = 96$%, $P < 0.00001$).

Length of hospital stay

The medial-to-lateral approach was associated with a non-significant reduction in length of hospital stay (MD − 1.22; 95% CI, − 2.78 to 0.34, $P = 0.13$). Moderate heterogeneity among the included studies was detected ($I^2 = 75$%, $P = 0.05$).

Number of harvested lymph nodes

The lateral-to-medial approach was associated with a significantly higher number of harvested lymph nodes (MD − 1.29; 95% CI, − 2.50 to 0.53, $P = 0.0009$). Low heterogeneity among the included studies was detected ($I^2 = 0$%, $P = 0.88$).

Malignant colorectal disease

Mortality

There was no significant difference in mortality between two groups (RD 0.00; 95% CI, − 0.02 to 0.02, $P = 0.94$). Between-study heterogeneity was low (I^2 0%, $P = 1.00$).

Overall complications

The medial-to-lateral approach significantly reduced overall complications rate (OR 0.51; 95% CI, 0.32–0.81, $P = 0.004$). There was low between-study heterogeneity (I^2 0%, $P = 0.93$).

Anastomotic leak

Although the medial-to-lateral approach reduced the rate of anastomotic leak, the reduction was not statistically significant (OR 0.46; 95% CI, 0.20–1.05, $P = 0.06$). Heterogeneity among the included studies was low (I^2 0%, $P = 0.71$).

Wound infection

No significant difference in wound infection rate was found between the two groups (OR 1.30; 95% CI, 0.52–3.26, $P = 0.57$). Heterogeneity among the included studies was low (I^2 0%, $P = 0.76$).

Bleeding

There was no significant difference in the bleeding rate between the two groups (OR 0.40; 95% CI, 0.06–2.59, $P = 0.61$). There was low between-study heterogeneity (I^2 0%, $P = 0.90$).

Conversion to open

No difference in conversion rate was found between the two groups (OR 0.72; 95% CI, 0.29–1.82, $P = 0.49$).

Heterogeneity among the included studies was low ($I^2 = 0\%$, $P = 0.99$).

Procedure time

The medial-to-lateral approach was associated with a significantly shorter procedure time (MD − 40.02; 95% CI, − 66.91 to − 13.17, $P = 0.003$). Heterogeneity among the studies was significant ($I^2 = 92\%$, $P < 0.00001$).

Length of hospital stay

The medial-to-lateral approach was associated with a non-significant reduction in length of hospital stay (MD − 1.06; 95% CI, − 2.21 to 0.09, $P = 0.07$). Moderate heterogeneity among the included studies was detected ($I^2 = 52\%\%$, $P = 0.10$).

Number of harvested lymph nodes

No significant difference in the number of harvested lymph nodes was found between the two groups (MD − 0.06; 95% CI, − 1.98 to 1.86, $P = 0.95$). Moderate heterogeneity among the included studies was detected ($I^2 = 68\%$, $P = 0.03$).

Sensitivity analysis

Using random-effects or fixed-effects models did not affect the pooled effect size in analysis of any of the reported outcomes. The direction of pooled effect size remained unchanged when OR, RR or RD were calculated for dichotomous variables. In the analysis of overall complications, removal of study of Rotholtz et al. [17] affected the direction of pooled effect size in favour of the medial-to-lateral group (OR 0.65, 95% CI 0.46–0.91, $P = 0.01$) and reduced the overall heterogeneity from 43 to 0%.

Discussion

The best approach for laparoscopic colorectal resection is controversial. We conducted a comprehensive systematic review and meta-analysis of comparative studies to evaluate comparative outcomes of medial-to-lateral and lateral-to-medial colorectal mobilisation in patients undergoing laparoscopic colorectal resection. Our literature review identified eight comparative studies [16–23] reporting a total of 1477 patients of whom 626 underwent laparoscopic colorectal resection using the medial-to-lateral approach and the remaining 851 had laparoscopic colorectal resection using the lateral-to-medial approach. The meta-analyses of outcomes demonstrated that the medial-to-lateral approach was associated with significantly lower rate of conversion to open, shorter procedure time and length of hospital stay compared to the lateral-to-medial approach. However, there was no significant difference in mortality, overall complications, wound infection, anastomotic leak, bleeding, and number of harvested lymph nodes between two groups. The between-study heterogeneity in the analyses of mortality, anastomotic leak, wound infection, bleeding and conversion to open were low, indicating that our findings about these outcomes may be robust. Moreover, the heterogeneity among the included studies in the analysis of overall complications was moderate. Nevertheless, removal of source of heterogeneity during sensitivity analysis not only made the results in favour of the medial-to lateral group with statistical significance but also reduced the heterogeneity from moderate to low. High between-study heterogeneity in the analyses of procedure time, length of hospital stay, and number of harvested lymph nodes indicates that our findings about these outcomes may be less robust.

We also conducted sub-group analyses with respect to the left- or right-sided colorectal disease and malignant colorectal disease. The sub-group analyses demonstrated that the lateral-to-medial approach was associated with significantly higher number of harvested lymph nodes in left-sided colorectal resection. When only malignant disease was considered, the medial-to-lateral approach was associated with significantly lower rate of overall complications than the lateral-to medial approach. Moreover, although the procedure time and length of hospital stay were shorter in favour of the medial-to-lateral approach in all the analyses, they lost their statistical significance in the analyses of left-sided colectomy. However, it should be taken into account that the number of analysed studies were much lower in the sub-group analyses which, undoubtedly, affected the robustness of our findings in the sub-group analysis.

Our findings with regard to conversion to open procedure, procedure time, wound infection, bleeding and anastomotic leak are consistent with finding of a meta-analysis conducted by Ding et al. [24] in 2013. However, our findings are not in agreement with those of Ding et al. [24] on length of hospital stay and number of harvested lymph nodes. Ding et al. [24] found a significantly higher number of harvested lymph node in favour of the lateral-to-medial approach whereas we did not find any significant difference between two groups although our sub-group analysis found significantly higher number of harvested lymph nodes in left sided colorectal resection in favour of lateral-to-medial approach. The authors included only 115 patients from 2 studies in their pooled analysis whereas our pooled analysis for this outcome included 898 patients from 5 studies. It needs to be taken into account that pooled data from only two studies do not lead to a meaningful

meta-analysis. Similarly, Ding et al. [24] included only two studies in their analysis of length of hospital stay and found no significant difference between two groups. However, our analysis of 898 patients from 5 studies found a significantly reduced length of hospital stay in favour of the medial-to-lateral approach. Moreover, unlike Ding et al. [24], we have conducted sub-group analysis with respect to right or left-sided colectomy and malignant colorectal disease.

The findings of our meta-analysis suggest that both approaches may be similar with regard to short-term clinical outcomes such as perioperative morbidity and mortality. Nevertheless, the medial-to-lateral approach is associated with more superior fragile patient related and surgeon dependent outcomes such as procedure time, conversion rate and length of hospital stay.

The European Association of Endoscopic Surgeons (EAES) consensus statement in 2004 advocated medial-to-lateral mesocolonic dissection during laparoscopic colorectal surgery [12]. However, the recommendation has been criticised for being based on poor level of evidence (level of evidence: 5, recommendation: Grade D) [24]. Our meta-analysis of best available evidence (mainly observational studies, level 2) further confirms the recommendation made by EAES and highlights that the medial-to-lateral approach may be associated with better outcomes than the lateral-to-medial approach. Nevertheless, the available evidence is not convincing enough to discourage surgeons from their preferences.

Our study has some limitations which should be taken into account when interpreting our findings. Only two of our included studies were RCTs, the gold standard study design for comparative studies, to provide high-quality evidence for or against medial-to-lateral or lateral-to-medial colorectal mobilisation. The best available evidence comes mainly from retrospective observational studies which are inevitably subject to selection bias. Considering the data provided by the included studies, we could not report some of our outcomes with respect to right-sided or left-sided colectomy. This might have biased our findings in favour of an intervention. Furthermore, the risk of bias was moderate in two studies which may bias our results in favour of an intervention. Furthermore, three [17, 18, 22] of the included studies included patients with both benign and malignant colorectal diseases. Of these studies, Rotholtz et al. [17] included 57% non-cancer patients. Although we conducted an independent sub-group and sensitivity analyses with exclusion of these studies collectively and individually, respectively, as the medial-to-lateral or lateral-to-medial approach may be beneficial for one pathology but not for another, the findings of our main analysis might have been biased by including heterogeneous pathologies. In those studies that reported the BMI of their patients, there was no patient with obesity which is known to be a negatively influencing risk factor for poor surgical outcome. Therefore, our findings may or may not be applicable to patients with very high BMI. Finally, some of the include studies reported their continuous data as median and interquartile range. We have calculated their mean and standard deviation using the method described by Hozo et al. [25] This might have subjected our findings to some degree of bias.

Conclusions

The medial-to-lateral approach during laparoscopic colorectal resection may reduce procedure time, length of hospital stay and conversion to open procedure rate compared to the lateral-to-medial approach. Moreover, it may probably reduce overall perioperative morbidity. However, both approaches carry similar risk of perioperative mortality and have comparable ability to harvest lymph nodes. The best available evidence, which comes mainly from retrospective observational studies, may not be sufficient to convince surgeons to change their preferred approach. Future high-quality randomised studies may provide stronger evidence in favour of either approach. We encourage future research to evaluate the impact of patient's BMI on the clinical outcomes of each approach.

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