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Laparoscopic Versus Open Colorectal Surgery in the Emergency Setting

A Systematic Review and Meta-analysis

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Objective: This systematic review and meta-analysis aimed to compare published outcomes of patients undergoing laparoscopic versus open emergency colorectal surgery, with mortality as primary outcome.
Background: In contrast to the elective setting, the value of laparoscopic emergency colorectal surgery remains unclear.
Methods: PubMed, Embase, the Cochrane Library, and CINAHL were searched until January 6, 2021. Only comparative studies were included. Meta-analyses were performed using a random-effect model. The Cochrane Risk of Bias Tool and the Newcastle-Ottawa Scale were used for quality assessment.
Results: Overall, 28 observational studies and 1 randomized controlled trial were included, comprising 7865 laparoscopy patients and 55,862 open surgery patients. Quality assessment revealed 'good quality' in 16 of 28 observational studies, and low to intermediate risk of bias for the randomized trial. Laparoscopy was associated with significantly lower postoperative mortality compared to open surgery (odds ratio [OR] 0.44; 95% confidence interval [CI], 0.35–0.54). Laparoscopy resulted in significantly less postoperative overall morbidity (OR, 0.53; 95% CI, 0.43–0.65), wound infection (OR, 0.63; 95% CI, 0.45–0.88), wound dehiscence (OR, 0.37; 95% CI, 0.18–0.77), ileus (OR, 0.68; 95% CI 0.51–0.91), pulmonary (OR, 0.43; 95% CI, 0.24–0.78) and cardiac complications (OR, 0.56; 95% CI, 0.35–0.90), and shorter length of stay. No meta-analyses were performed for long-term outcomes due to scarcity of data.
Conclusions: The systematic review and meta-analysis suggest a benefit of laparoscopy for emergency colorectal surgery, with a lower risk of postoperative mortality and morbidity. However, the almost exclusive use of retrospective observational study designs with inherent biases should be taken into account.

INTRODUCTION

During the past decades, there has been a shift towards laparoscopy in elective colorectal surgery for both benign and malignant colorectal disease. Multiple large randomized studies showed many benefits of laparoscopy compared to open colorectal surgery such as equal safety, reduced pain, less postoperative morbidity, less intensive care unit (ICU) admissions, shorter length of stay (LOS), and lowered costs, as well as increased quality of life.[1–6] Although the use of laparoscopy in the acute setting has also been proven safe and feasible, there is a relatively low uptake of the use of laparoscopy in emergency colorectal procedures. This is probably due to the increased complexity of patients' presentation, advanced or complicated disease, as well as the experience of the surgeon on call during evening and night-time hours.

Emergency surgery is generally associated with increased morbidity and mortality when compared to the elective setting.[7,8] It is hypothesized that the well-established benefits of laparoscopy in the elective setting could also be applicable to the emergency setting. One might even suggest that reducing surgical trauma and stress response, as well as preservation of the abdominal wall integrity, is particularly beneficial for these patients at the highest operative risk. Therefore, laparoscopy might have an impact on one of the most relevant endpoints after colorectal surgery, namely postoperative mortality.

There is a need to elucidate the role of laparoscopy in emergency colorectal surgery, thereby shifting from traditional endpoints in the elective setting such as length of hospital stay to endpoints with the highest clinical impact including postoperative mortality. Prior reviews of the available literature did not perform meta-analyses, and mortality was not included as the main outcome parameter.[9,10] Additionally, published reviews are restricted to literature before 2016. Ever since, more relevant studies have been published, including a randomized controlled trial (RCT), and implementation of laparoscopy progressed over time with broadening of the indications.

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The aim of this study was to provide an up-to-date systematic review of the current literature on patients with acute colorectal disease who underwent emergency surgery by a laparoscopic versus open approach with meta-analyses of postoperative outcomes, including mortality and morbidity, as reported by comparative studies. In addition, the intention was to assess long-term outcomes.

METHODS

The study protocol was prospectively registered at PROSPERO (registration number: CRD42020189955), and the Preferred Reporting Items for Systematic Reviews and Meta-analysis guidance was followed throughout the process.[11] Study selection, data extraction, and quality assessment were independently performed by two reviewers (A.K.W. and E.S.Z.). Any disagreements were resolved through discussion until consensus was reached or discussed with a third and fourth reviewer (E.J.d.G. and P.J.T.).

Search

A clinical librarian was consulted for assembling the search strategy for multiple databases, including PubMed, EMBASE, the Cochrane Library, and CINAHL. The search strategy included (Medical Subject Headings) terms and free text related to or describing colorectal disease, emergency setting, laparoscopic, and open surgery. The complete search strategy is presented in Supplementary Table 1, http://links.lww.com/AOSO/A65. The search was performed on June 4, 2020 and updated on January 6, 2021. In addition, reference lists and bibliographies of included studies were hand searched for relevant studies and trial and study registries were searched for relevant ongoing studies (Netherlands Trial Register[12] and trails.gov[13]).

Study Selection

Both randomized and nonrandomized studies comparing outcomes of patients that underwent laparoscopic versus open colorectal surgery for benign or malignant indications in the emergency setting were included. Emergency setting was defined as any nonelective procedure, ranging from acute semielective procedures to urgent emergency procedures. The used definitions are reported in Supplementary Table 2, http://links.lww.com/AOSO/A65. Study designs other than comparative (ie, case series) or studies including noncolorectal procedures (ie, appendectomy, small bowel surgery, or gastro-duodenal procedures) were excluded. Studies reporting on multiple indications for emergency surgery, but providing separate data for the colorectal subgroup were included. Similarly, studies primarily reporting on the elective setting were also included if providing subanalyses of emergency patients. Studies on peritoneal lavage alone or diagnostic laparoscopies were excluded as well as review articles, studies with no full text available, and studies with less than 10 patients. There were no language restrictions, all non-English studies were translated. Excluded studies were listed with the reason for the omission, and references are reported in Supplementary File 1, http://links.lww.com/AOSO/A65.

Quality Assessment

Two reviewers (A.K.W. and E.S.Z.) independently assessed the quality of the included studies. The Cochrane Collaboration Tool for Risk of Bias for randomized studies and the Newcastle-Ottawa scale (NOS) for nonrandomized studies were used.[14] The follow-up was scored with one star when the duration was at least 30 days. If follow-up time was not explicitly mentioned, the outcome domain was scored with zero stars. The quality level was then converted to the Agency for Healthcare Research and Quality (AHRQ) standard of "good," "fair," and "poor" quality. Thresholds for converting the NOSs to AHRQ standards (good, fair, and poor)[15] were conducted as described by several previous systematic reviews.[16–18]

No funnel plots were assessed for publication bias since dichotomous outcomes with intervention effects expressed as odds ratio (OR), the standard error of the log OR is mathematically linked to the size of the OR, even in the absence of small-study effects causes unreliable funnel plots.[19,20]

Outcomes and Definitions

The primary outcome was postoperative mortality, which was defined as any deaths reported in the postoperative course regardless of follow-up time. The secondary outcome was overall postoperative morbidity, which was defined as the total complication rate. Other secondary outcomes were ICU admission, reinterventions, wound infection, wound dehiscence, postoperative ileus, anastomotic leakage, intra-abdominal infection or abscess, pulmonary complications, cardiac complications, LOS, readmissions, and long-term outcomes. Furthermore, conversion to open surgery in the laparoscopic group was reported. The precise definitions of the outcomes as reported in the original studies are presented in Supplementary Table 5, http://links.lww.com/AOSO/A65. Long-term outcomes included incisional hernias and oncological outcomes such as survival or recurrence rates.

Data Extraction

A predefined data extraction table was used for data collection and included general study characteristics, patients' characteristics, indications for surgery and procedural characteristics, predefined outcomes, used definitions, and quality assessment. Data were extracted from the included studies if the authors reported our predefined outcome measures or any exact synonyms. Postoperative overall morbidity rates were not calculated if not reported by the authors to prevent overlapping complications within patients. Pulmonary and cardiac complications were composite endpoints, thereby including all reported pulmonary (ie, pneumonia and pulmonary insufficiency) and cardiac complications (ie, arrhythmias and myocardial infarction). If there were data from propensity score analyses or intention-to-treat analyses, the results from these analyses were used rather than the original data.

Data Synthesis and Statistical Analysis

The primary outcome and secondary outcomes were quantitatively summarized. Review Manager version 5.4.0 (The Cochrane Collaboration, London, United Kingdom, 2020) was used for performing meta-analyses. For dichotomous variables, the pooled effect was analyzed using a Mantel-Heanzel test and a random effect model. The pooled effect was reported as OR with corresponding 95% confidence intervals (CIs). Continuous data were analyzed by an inverse-variance method static with a random effect model and expressed as the standardized mean differences (SMDs) with corresponding 95% CI. To calculate the SMD, only studies that reported the mean and SD could be included in the meta-analysis. Therefore, studies reporting medians and interquartile ranges (IQRs) or medians and ranges (minimum and maximum) were converted to estimated means and estimated SDs using the method described by Wan et al[21] Subgroup analyses for morbidity stratified by indication for surgery (eg, colorectal cancer, diverticulitis and inflammatory bowel disease [IBD]) were performed. Heterogeneity between studies was perceived as considerable when $I^2 > 75\%$. A P value of <0.05 was considered statistically significant. If there were zero events of the outcome measured in both arms of the study population, the study was excluded from the meta-analysis.[22] A sensitivity analysis was performed for the primary outcome by evaluating the change in pooled OR when using a fixed-effect model instead of a random effect model, when including solely observational or RCTs, and when including only those studies in the meta-analysis that scored "good" quality on the NOS. There were no deviations from the proposed protocol during study selection, data extraction, statistical analysis, or quality assessment.

RESULTS

Included Studies

The initial literature search identified a total of 2841 studies. One additional study was found by hand-searching reference lists. After the removal of duplicates, 1773 studies remained for title and abstract screening. Eventually, 61 studies were assessed for eligibility based on full text, of which 29 studies were eligible, including 1 feasibility RCT and 28 retrospective cohort studies, including several large population-based studies (Fig. 1). One study was funded by a company that financially supported the author,[23] five studies received financial support or grants from the government, healthcare improvement programs, or foundations but declared no (financial) conflicts of interest,[24–28] and seven studies provided no information on conflicts of interests or financial support.[29–36] Characteristics of the included studies are presented in Table 1.

Quality Assessment

The individual scores of the 28 retrospective cohort studies varied from 4 to 8 out of 9 on the NOS (Table 1). When converting the NOS rating to the AHRQ, standards, 16 of the 28 retrospective cohort studies showed to be of "good" quality, whereas one study was scored to have "fair" quality and 11 studies where scored as "poor" quality. The feasibility RCT by Harji et al[24] showed to have a low to moderate risk of bias according to the Cochrane Risk of Bias Tool.

Study Population

In total, 7865 patients underwent emergency laparoscopy and 55,862 patients laparotomy. The main indications for emergency colorectal surgery were perforated or obstructive

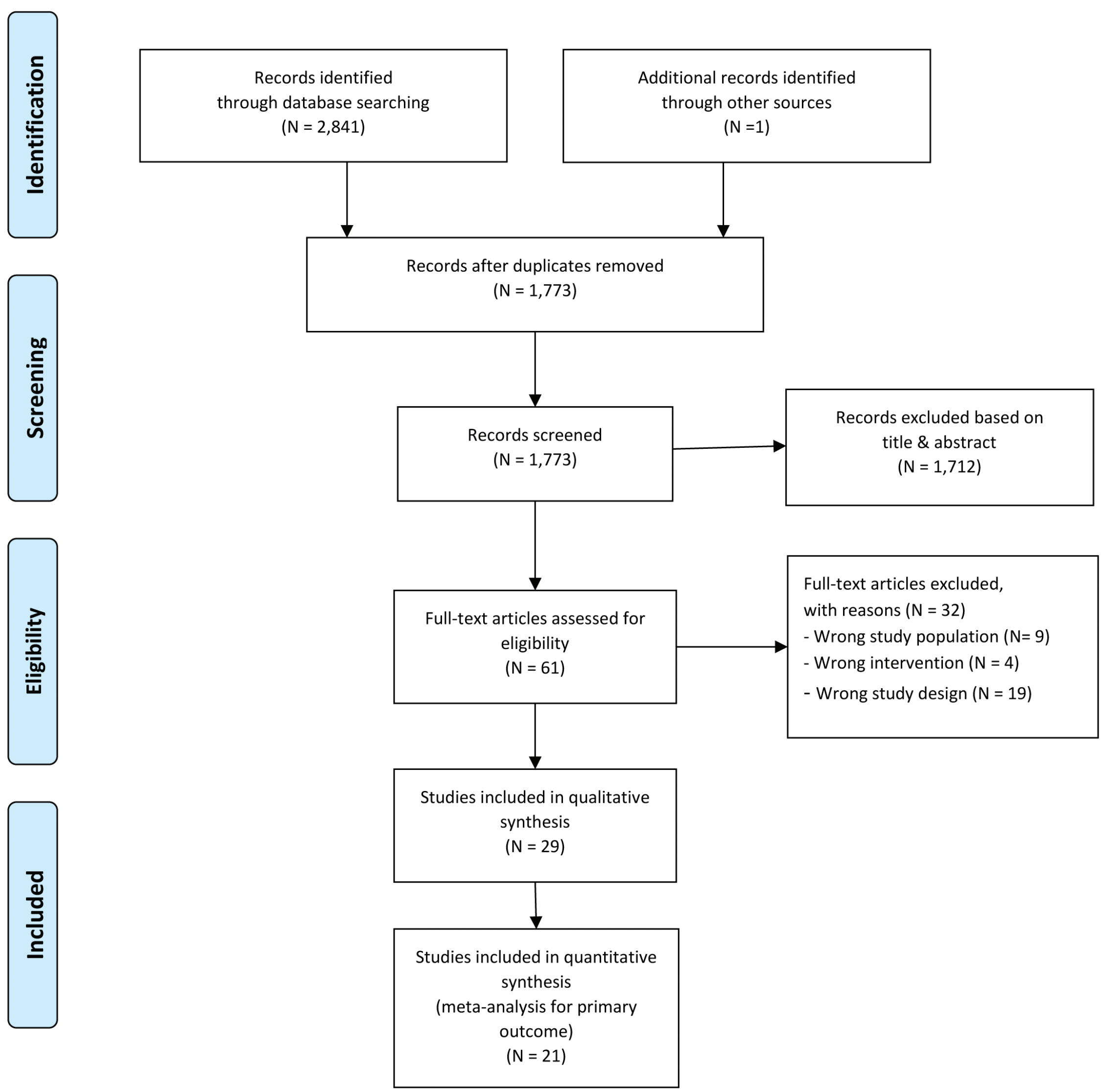


FIGURE 1. PRISMA flowchart of the included studies in this systematic review and meta-analysis of the primary outcome (ie, postoperative mortality; last search January 6, 2021). Reasons for exclusion after full-text reading: wrong study population (nonemergency patients and noncolorectal patients), wrong intervention (intervention other than laparoscopy or open surgery), wrong study design (noncomparative studies, case-series, systematic reviews, and conference abstracts). PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analysis.

colorectal cancer, complicated diverticulitis, and severe, therapy refractory IBD. Patient characteristics and indications for emergency colorectal surgery, as well as procedural characteristics of the included studies, are shown in Supplementary Table 2, http://links.lww.com/AOSO/A65 and Table 2, respectively. Most studies included patients with various indications for emergency surgery. Surgical procedures ranged from segmental colectomies to subtotal colectomies with or without the creation of a stoma. Reported conversion rates ranged from 0% to 38% across the studies.

Primary Outcome Postoperative Mortality

Twenty-six studies reported the primary outcome of postoperative mortality, of which five studies reported zero events in both the laparoscopic and open surgery group (Supplementary Table 3, http://links.lww.com/AOSO/A65). Therefore, 21 studies were included in the meta-analysis (Fig. 2). The short-term postoperative outcomes, stratified by surgical approach, are presented for each study in Table 2. Laparoscopic surgery resulted in a significantly lower likelihood of postoperative mortality in meta-analysis compared to open surgery, with a pooled OR of 0.44 (95% CI, 0.35–0.54, P < 0.001 and I^2 33%, P = 0.07). Sensitivity analyses demonstrated no change in pooled OR for when a fixed effect model was used, if the RCT of Harji et al[24] was excluded, and if only "good" quality studies were included.

Secondary Outcomes

The mean LOS with SD was reported in seven studies, whereas the median and IQR or range were reported in 13 studies. When converting the medians and IQR or ranges to estimated means and SDs, meta-analysis showed an SMD of −0.42 (95% CI −0.55 to −0.29, P < 0.001, with I^2 84%, P < 0.001) (Fig. 3D-i) in favor of laparoscopy. Due to significant heterogeneity, an additional meta-analysis was performed for studies that reported means and SDs, which showed an SMD of −0.25 between laparoscopic and open surgery (95% CI −0.32 to −0.18, with I^2 28%, P = 0.22) (Fig. 3D-ii).

The pooled OR for overall postoperative morbidity showed that there was significantly less morbidity in the laparoscopic group compared to the open surgery group (OR, 0.53; 95% CI, 0.43–0.65, P < 0.001 and I^2 68%, P < 0.001) (Fig. 3A). In subgroup analyses for colorectal cancer, complicated diverticulitis and IBD, comparable results favoring laparoscopic surgery were observed (Supplemental Figures 1A–C, http://links.lww.com/AOSO/A63). In meta-analyses for individual patient complications, laparoscopic surgery revealed significantly lower rates for wound infection (OR, 0.63; 95% CI, 0.45–0.88; P = 0.006, and I^2 43%, P = 0.04) (Fig. 3B), wound dehiscence (OR, 0.37; 95% CI, 0.18–0.77; P = 0.008 and I^2 0%, P = 0.90) (Supplemental Figure 2C, http://links.lww.com/AOSO/A64), postoperative ileus (OR 0.68; 95% CI, 0.51–0.91; P = 0.009 and I^2 49%, P = 0.02) (Fig. 3C), pulmonary complications (OR 0.43; 95% CI, 0.24–0.78; P < 0.001; I^2 86%, P < 0.001) (Supplemental Figure 2D, http://links.lww.com/AOSO/A64) and cardiac complications (OR, 0.56; 95% CI, 0.35–0.90; P = 0.02 and I^2 0%, P = 0.86) (Supplemental Figure 2E, http://links.lww.com/AOSO/A64). There was no significant difference in reinterventions (OR, 0.83; 95% CI, 0.65–1.04; P = 0.11 and I^2 22%, P = 0.21) or ICU admissions (OR, 0.49; 95% CI, 0.21–1.14; P = 0.10 and I^2 51%, P = 0.09) between the two groups. No meta-analyses were performed for anastomotic leakage, intra-abdominal infection or abscess, and readmission, due to inconsistent definitions, overlapping variables and no expected differences in outcomes.

TABLE 1.

Study Characteristics and Quality Assessment

Study	Year	Country	Study Design	Period	Centre(s)	N	Quality Assessment*
Ballian et al	2012	USA	RC	2005–2008	MC	3,552	8 out of 9
Cassini et al	2017	Italy	RC	2008–2016	SC	60	7 out of 9
Catani et al	2011	Italy	RC	2007–2009	SC	93	6 out of 9
Cocorullo et al	2016	Italy	RC	2013–2014	SC	159	4 out of 9
Cui et al	2019	China	RC	2013–2018	SC	128	7 out of 9
Dunker et al	2000	NL	RC	1996–1999	MC	42	5 out of 9
Gietelink et al	2016	NL	RC	2010–2013	MC	5,192	7 out of 9
Harji et al	2020	UK	RCT	2016–2017	MC	64	NA
Keller et al	2016	USA	RC	2008–2011	MC	22,719	7 out of 9
Kim et al	2015	Korea	RC	2008–2013	SC	49	7 out of 9
Koh et al	2013	Singapore	RC	2006–2011	SC	46	6 out of 9
Lee et al	2019	USA	RC	2012–2017	MC	3,756	8 out of 9
Letarte et al	2015	Canada	RC	2000–2010	SC	125	5 out of 9
Li et al	2009	China	RC	2001–2006	SC	18	5 out of 9
Li et al	2015	China	RC	2013–2013	SC	35	5 out of 9
Liu et a	2014	China	RC	2007–2012	SC	193	7 out of 9
Marceau et al	2007	France	RC	1999–2006	SC	88	7 out of 9
Marcello et al	2011	USA	RC	1997–1999	MC	48	5 out of 9
Moghadamyeghaneh et al	2020	USA	RC	2012–2017	MC	1,293	8 out of 9
Nash et al	2010	USA	RC	2001–2006	SC	68	6 out of 9
Ng et al	2008	China	RC	2003–2006	SC	43	6 out of 9
Odermatt et al	2013	UK	RC	2006–2011	SC	108	7 out of 9
Schloricke et al	2013	Germany	RC	1997–2009	SC	36	4 out of 9
Stulberg et al	2009	USA	RC	2005–2008	SC	67	8 out of 9
Sujatha-Bhaskar et al	2017	USA	RC	2012–2014	MC	10,018	8 out of 9
Turley et al	2013	USA	RC	2005–2009	MC	134	8 out of 9
Vallance et al	2019	UK	RC	2010–2016	MC	15,516	8 out of 9
Vennix et al	2015	NL	RC	2010–2014	MC	117	7 out of 9
Watanabe et al	2009	Japan	RC	2000–2004	SC	60	5 out of 9

Study characteristics and Newcastle-Ottawa Scale score (NOS score).

MC, multicenter; RC, retrospective cohort; RCT, randomized controlled trial; SC, single center.

TABLE 2.

Indications and Surgical Procedure Characteristics

Study	Indication(s)	Procedure(s)	Laparoscopy, N (%)	Open, N (%)	Conversion, N (%)
Ballian et al	CRC, IBD, CD, other	C	341 (9.6)	3211 (90.4)	–
Cassini et al	CD	S	36 (60.0)	24 (40.0)	4 (11.1)
Catani et al	CRC, IBD, CD, other	LHC, RHC, SC, LAR	32 (33.7)	61 (66.3)	2 (6.3)
Cocorullo et al	NS	C	31 (46.3)	36 (53.7)	–
Cui et al	CRC, NS	NS	65 (50.8)	63 (49.2)	–
Dunker et al	IBD	STC	10 (31.3)	32 (68.7)	0 (0.0)
Gietelink et al	CRC	NS	694 (13.4)	4498 (86.6)	–
Harji et al	CRC, IBD, CD, other	LHC, RHC, SC, STC, SR, other	33 (51.6)	31 (48.4)	0 (0.0)
Keller et al	CRC, CD, IBD, other	LHC, RHC, SR	954 (4.2)	21,774 (95.8)	–
Kim et al	CRC	LHC, RHC, STC, PC, TC, SR, LAR	11 (22.4)	23 (77.6)	0 (0.0)
Koh et al	CRC, CD, other	LHC, RHC, SR	23 (50.0)	23 (50.0)	4 (17.4)
Lee et al	CD	SR	457 (12.2)	3299 (87.8)	175 (38)
Letarte et al	CD	C, SR	39 (31.2)	86 (68.8)	2 (5.1)
Li et al (2009)	CD	RHC	6 (3.3)	12 (66.7)	0 (0.0)
Li et al (2015)	CRC	RHC	10 (28.6)	25 (71.4)	0 (0.0)
Liu et al	CRC	NS	55 (28.4)	138 (71.5)	–
Marceau et al	IBD	STC	40 (45.5)	48 (54.5)	2 (5.0)
Marcello et al	IBD	TC	19 (39.6)	29 (60.4)	0 (0.0)
Moghadamyeghaneh et al	CRC	NS	249 (19.3)	1044 (80.7)	80 (28.5)
Nash et al	CRC, IBD, CD, other	LHC, RHC, TC, STC, SR	36 (52.9)	32 (47.1)	5 (13.9)
Ng et al	CRC	RHC	14 (32.6)	29 (67.4)	0 (0.0)
Odermatt et al	CRC	LHC, RHC, STC	36 (33.3)	72 (66.7)	–
Schloricke et al	IP	NS	24 (66.7)	12 (33.3)	–
Stulberg et al	CRC, IBD, other	LHC, RHC, TC, SR	40 (61.5)	25 (38.5)	4 (9.5)
Sujatha-Bhaskar et al	CRC, CD	C	1039 (10.4)	8979 (89.6)	44 (4.2)
Turley et al	CD	S	67 (50.0)	67 (50.0)	–
Vallance et al	CRC	NS	3435 (22.1)	12,081 (78.9)	–
Vennix et al	CD	SR	39 (33.3)	78 (66.7)	–
Watanabe et al	IBD	STC	30 (50.0)	30 (50.0)	–

Indications and surgical procedure characteristics of the included studies.

C, colectomy; CD, complicated diverticulitis; CRC, colorectal carcinoma; IBD, inflammatory bowel disease; IP, iatrogenic perforation by colonoscopy; LAR, low anterior resection; LHC, left hemicolectomy; NS, not specified acute colonic disease; RHC, right hemicolectomy; SC, segmental colectomy; SR, sigmoid resection; STC, subtotal colectomy; NS, not specified surgical procedure.

Long-term Outcomes

There were only six studies that reported long-term outcomes, as presented in Supplementary Table 4, http://links.lww.com/AOSO/A65. Three studies provided long-term oncological outcomes as 3-year overall survival and 3-year recurrence-free survival, without significant difference between the surgical approaches. However, it was decided not to perform meta-analysis in view of the small patient numbers at risk after 3 years of follow-up and differences in calculating survival rates (crude versus cumulative). The other three studies reported incisional hernias, all reporting an advantage for laparoscopy. Again, due to small patient numbers and inconsistency of length of follow-up, no meta-analysis was performed.

DISCUSSION

This systematic review and meta-analysis comprising 28 comparative cohort studies, including several large population-based studies, and 1 feasibility RCT showed that intentional laparoscopic emergency colorectal surgery is associated with decreased postoperative mortality compared to the open approach. Additionally, laparoscopy demonstrated lower rates of overall morbidity, wound infection, wound dehiscence, postoperative ileus, pulmonary and cardiac complications, and reduced LOS compared to open surgery. Comparable results favoring laparoscopic surgery were found in subgroup analyses for colorectal cancer, complicated diverticulitis, and IBD.

Although older retrospective cohort studies comparing laparoscopic and open colorectal surgery in the emergency setting did not find any significant difference in 30-day mortality individually,[23,25,26,28,33,34,36–42] the pooled OR in this meta-analysis did show reduced postoperative mortality after laparoscopy. This was due to the inclusion of several large population-based studies[43,44] and more recently published studies of superior quality according to their NOS scores.[27,45,46] Besides, effective training programs, broad implementation, and increasing experience with (advanced) laparoscopy might have contributed to better results when compared to open emergency surgery in more recent studies.

The decreased postoperative mortality following laparoscopic surgery might be a direct consequence of reduced postoperative morbidity. A previous meta-analysis of Pucher et al[47] showed that postoperative morbidity after major surgery for various diseases was associated with significantly higher all-cause mortality. Fernandez-Bustamante et al[48] showed that pulmonary complications after noncardiothoracic surgery increased the risk of mortality, ICU admission, and prolonged hospital stay. Gietelink et al[43] showed that laparoscopic colorectal surgery at a population level decreased the risk of 30-day mortality in both the elective and emergency setting, likely related to a reduction of cardiopulmonary complications. Laparoscopy reduces pain, facilitating deep breathing and coughing, and allows for earlier mobilization, all potentially reducing the risk of pulmonary complications. Similarly, less pain and surgical stress by minimally invasive surgery can reduce cardiac complications, translating into lower postoperative mortality.

Improvements in surgical morbidity after laparoscopy, as observed in the present study are likely explained by less surgical trauma. Not only the size of wounds are limited, but also immune activation is reduced with better preservation of the postoperative immunological defense compared to laparotomy.[49,50] This is reflected by the reduced number of postoperative wound infections and wound dehiscence. Also, the observed positive influence on postoperative ileus seems to be directly related to the surgical approach, given the association between the risk of developing small bowel obstruction and the degree of surgical trauma.[51,52] Reducing the risk of postoperative ileus

Study or Subgroup	Laparoscopic surgery Events	Laparoscopic surgery Total	Open surgery Events	Open surgery Total	Weight	Odds Ratio M-H, Random, 95% CI	Year
Ng	1	14	3	29	0.8%	0.67 [0.06, 7.05]	2008
Stulberg	1	40	2	25	0.7%	0.29 [0.03, 3.43]	2009
Watanabe	0	30	1	30	0.4%	0.32 [0.01, 8.24]	2009
Nash	0	36	5	32	0.5%	0.07 [0.00, 1.29]	2010
Catani	0	32	1	61	0.4%	0.62 [0.02, 15.67]	2011
Ballian	18	341	420	3211	10.4%	0.37 [0.23, 0.60]	2012
Schloricke	1	24	1	12	0.5%	0.48 [0.03, 8.38]	2013
Turley	2	67	3	67	1.2%	0.66 [0.11, 4.06]	2013
Odermatt	3	36	9	72	2.1%	0.64 [0.16, 2.51]	2013
Liu	0	55	1	135	0.4%	0.81 [0.03, 20.13]	2014
Letarte	0	39	4	86	0.5%	0.23 [0.01, 4.42]	2015
Vennix	1	39	3	78	0.8%	0.66 [0.07, 6.54]	2015
Cocorullo	1	31	2	36	0.7%	0.57 [0.05, 6.57]	2016
Gietelink	30	694	379	4498	13.3%	0.49 [0.34, 0.72]	2016
Keller	29	954	1442	21774	13.6%	0.44 [0.30, 0.64]	2016
Cassini	6	36	4	24	2.1%	1.00 [0.25, 4.00]	2017
Sujatha-bhaskar	48	1039	1206	8979	16.2%	0.31 [0.23, 0.42]	2017
Lee	10	457	237	3299	7.4%	0.29 [0.15, 0.55]	2019
Vallance	242	3435	1302	12081	21.5%	0.63 [0.54, 0.72]	2019
Harji	0	33	1	31	0.4%	0.30 [0.01, 7.73]	2020
Moghadamyeghaneh	8	249	102	1044	6.1%	0.31 [0.15, 0.64]	2020
Total (95% CI)		**7681**		**55604**	**100.0%**	**0.44 [0.35, 0.54]**	
Total events	401		5128				

Heterogeneity: Tau² = 0.05; Chi² = 30.04, df = 20 (P = 0.07); I² = 33%
Test for overall effect: Z = 7.79 (P < 0.00001)

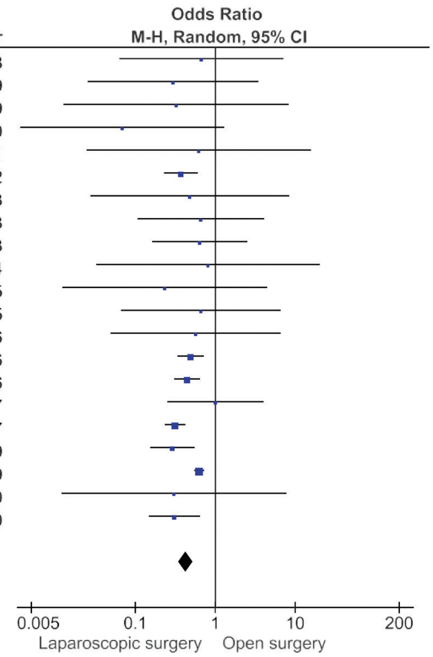


FIGURE 2. Postoperative mortality after laparoscopic vs open emergency colorectal surgery. Forest plot of the primary outcome; postoperative mortality. CI, confidence interval.

is of particular importance in the emergency setting, as some patients will already have a bowel obstruction and others are at risk for paralytic bowel to infectious problems (eg, IBD or diverticulitis). At the moment, there is a lack of studies focusing on long-term adhesion formation after laparoscopy versus open emergency colorectal surgery.

Several studies have demonstrated that laparoscopic colorectal surgery leads to faster patient recovery, and as a consequence to a shorter LOS resulting in lower healthcare costs.[53,54] Our pooled analyses also showed that for the emergency setting, the LOS was significantly shorter for laparoscopically treated patients. The reintervention rate was not significantly different between the laparoscopic group and open surgery group. However, the two largest and most highly weighted studies in the meta-analysis individually did show lower reintervention rates in the laparoscopy group.[35,44] This illustrates the potential impact on healthcare resources if extending the indications for laparoscopy to the emergency setting.

No meta-analyses on long-term outcomes following emergency colorectal surgery could be performed since these were scarcely reported. One might hypothesize that reduction of (infectious) complications by laparoscopy can translate into less cancer recurrence and improved survival.[55–59] An inflammatory environment has several similar signaling molecules (such as IL-1 and IL-6) and infection-based immunologic pathways that also play a role in tumor cell invasion, migration, and dissemination.[60–62] Future studies have to confirm this hypothesis.

Incisional herniation is one of the most common long-term complications after midline laparotomy, with a considerable burden on patients' QOL and emergency surgery as an important risk factor.[63–65] Unfortunately, only three studies provided data on this endpoint; however, all three studies showed lower incisional hernia rates following laparoscopy.[29,33,41] Retaining the abdominal wall integrity might even be one of the most significant advantages of laparoscopy, in the long run, emphasizing the importance of this endpoint in future studies.

Before concluding that laparoscopic emergency colorectal surgery is superior to the open approach, several limitations need to be addressed. Two factors presumably leading to selection bias in the included studies must be taken into account. First of all, there might be confounding by indication because the initial disease for which the emergency procedure was performed might influence the surgical approach and its outcomes, as patients with a malignant indication likely differ from patients with a benign indication with regard to age and condition. We were not able to assess all outcomes in subgroup analyses based on indication, because outcomes were often not provided separately depending on the underlying disease. Nevertheless, we did perform a subgroup meta-analysis for the combined outcome of overall morbidity. Besides, the preoperative level of illness of the patients might have influenced the type of surgical approach. For example, patients that show signs of sepsis or even a septic shock are probably more likely to undergo open surgery due to the preference of the surgeon or anesthesiologist. Interestingly, the included studies that did report level of illness did not find a significant difference between patients in the laparoscopic and open group for the Mannheim peritonitis score,[41] the APACHE score,[39] vital clinical parameters as reported by Marcello et al,[32] or in the Truelove and Witt's criteria.[36] Studies that did find significant differences in baseline clinical illness severity used propensity score matching to assess the outcomes.[26,28,46] Five of these studies were included in the meta-analyses for postoperative mortality, with one of these studies[46] showing a significantly lower risk of mortality following laparoscopy (Fig. 2). Another study that adjusted outcomes for clinical illness severity[28] showed significantly lower postoperative morbidity after laparoscopy (Fig. 3A).

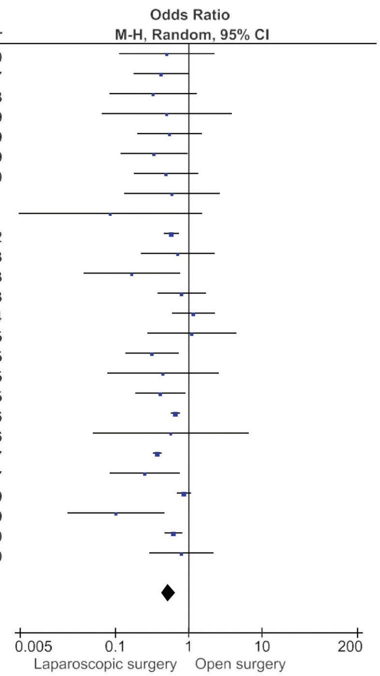
Second, several of the included studies showed that in the emergency setting, laparoscopic procedures are more often performed in high-volume hospitals with dedicated colorectal emergency services and thus specialized colorectal surgeons.[27,66–68] Therefore, these results may not represent the outcomes of the general population since emergency cases also present at night. Surgery during night hours can negatively influence postoperative outcomes, probably because of less experienced surgeons preferably performing traditional laparotomy.[69] However, we were not able to perform subgroup analysis on timing of surgery, as none of the studies reported outcomes of emergency surgery during night time compared to day time.

One of the main strengths of this systematic review and meta-analysis is that data of over 60,000 patients were pooled, which will be difficult to achieve in a prospective setting. Furthermore, included population-based studies increase the external validity and generalizability of the results. Additionally, a recently published feasibility multicenter, single-blind, parallel-group RCT was included, which showed that emergency laparoscopy is feasible and safe.[24] Ideally, larger prospective studies should be conducted; however, it might be difficult to complete such trials with sufficient

A

Study or Subgroup	Laparoscopic surgery Events	Total	Open surgery Events	Total	Weight	Odds Ratio M-H, Random, 95% CI	Year
Dunker	6	10	24	32	1.6%	0.50 [0.11, 2.23]	2000
Marceau	14	40	27	48	3.7%	0.42 [0.18, 0.99]	2007
Ng	4	14	16	29	1.8%	0.33 [0.08, 1.28]	2008
Li 2009	2	6	6	12	0.9%	0.50 [0.07, 3.85]	2009
Stulberg	18	40	15	25	3.0%	0.55 [0.20, 1.50]	2009
Watanabe	11	30	19	30	2.8%	0.34 [0.12, 0.96]	2009
Nash	20	36	23	32	3.0%	0.49 [0.18, 1.35]	2010
Marcello	3	19	7	29	1.6%	0.59 [0.13, 2.64]	2011
Catani	0	32	9	61	0.5%	0.09 [0.00, 1.51]	2011
Ballian	106	341	1409	3211	9.5%	0.58 [0.45, 0.73]	2012
Koh	11	23	13	23	2.4%	0.71 [0.22, 2.25]	2013
Schloricke	6	24	8	12	1.6%	0.17 [0.04, 0.76]	2013
Turley	17	67	20	67	4.4%	0.80 [0.37, 1.71]	2013
Liu	18	55	40	135	5.0%	1.16 [0.59, 2.27]	2014
Kim	4	11	13	38	1.8%	1.10 [0.27, 4.45]	2015
Letarte	10	39	45	86	3.9%	0.31 [0.14, 0.72]	2015
Li 2015	2	10	9	25	1.2%	0.44 [0.08, 2.56]	2015
Vennix	17	39	51	78	4.2%	0.41 [0.19, 0.90]	2015
Keller	274	954	8286	21774	10.3%	0.66 [0.57, 0.76]	2016
Cocorullo	1	31	2	36	0.7%	0.57 [0.05, 6.57]	2016
Sujatha-bhaskar	368	1039	5356	8979	10.4%	0.37 [0.32, 0.42]	2017
Cassini	12	36	16	24	2.6%	0.25 [0.08, 0.75]	2017
Lee	123	457	993	3299	9.7%	0.86 [0.69, 1.07]	2019
Cui	2	65	15	63	1.5%	0.10 [0.02, 0.47]	2019
Moghadamyeghaneh	124	249	644	1044	9.1%	0.62 [0.47, 0.81]	2020
Harji	12	33	13	31	3.0%	0.79 [0.29, 2.16]	2020
Total (95% CI)		**3700**		**39223**	**100.0%**	**0.53 [0.43, 0.65]**	
Total events	1185		17079				

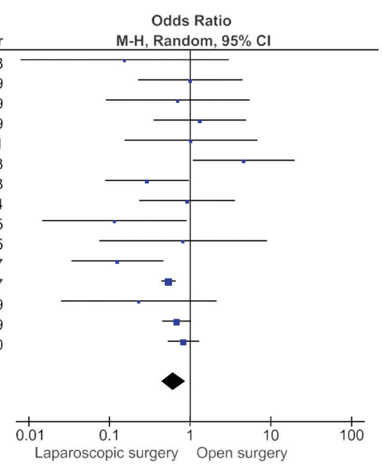
Heterogeneity: Tau² = 0.10; Chi² = 77.23, df = 25 (P < 0.00001); I² = 68%
Test for overall effect: Z = 6.04 (P < 0.00001)



B

Study or Subgroup	Laparoscopic surgery Events	Total	Open surgery Events	Total	Weight	Odds Ratio M-H, Random, 95% CI	Year
Ng	0	14	5	29	1.2%	0.15 [0.01, 2.99]	2008
Watanabe	4	30	4	30	4.2%	1.00 [0.23, 4.43]	2009
Li 2009	2	6	5	12	2.4%	0.70 [0.09, 5.43]	2009
Stulberg	8	40	4	25	5.1%	1.31 [0.35, 4.92]	2009
Marcello	2	19	3	29	2.8%	1.02 [0.15, 6.75]	2011
Odermatt	6	36	3	72	4.3%	4.60 [1.08, 19.62]	2013
Turley	4	67	12	67	6.0%	0.29 [0.09, 0.95]	2013
Liu	3	55	8	135	4.8%	0.92 [0.23, 3.59]	2014
Letarte	1	39	16	86	2.4%	0.12 [0.01, 0.90]	2015
Li 2015	1	10	3	25	1.8%	0.81 [0.07, 8.91]	2015
Cassini	4	36	12	24	5.1%	0.13 [0.03, 0.46]	2017
Sujatha-bhaskar	109	1039	1611	8979	22.7%	0.54 [0.44, 0.66]	2017
Cui	1	65	4	63	2.1%	0.23 [0.03, 2.12]	2019
Lee	27	457	280	3299	18.1%	0.68 [0.45, 1.02]	2019
Moghadamyeghaneh	26	249	130	1044	17.2%	0.82 [0.52, 1.28]	2020
Total (95% CI)		**2162**		**13919**	**100.0%**	**0.63 [0.45, 0.88]**	
Total events	198		2100				

Heterogeneity: Tau² = 0.12; Chi² = 24.45, df = 14 (P = 0.04); I² = 43%
Test for overall effect: Z = 2.74 (P = 0.006)



C

Study or Subgroup	Laparoscopic surgery Events	Total	Open surgery Events	Total	Weight	Odds Ratio M-H, Random, 95% CI	Year
Marceau	3	40	3	48	2.7%	1.22 [0.23, 6.39]	2007
Ng	3	14	1	29	1.4%	7.64 [0.72, 81.54]	2008
Li 2009	0	6	3	12	0.8%	0.21 [0.01, 4.76]	2009
Watanabe	4	30	4	30	3.2%	1.00 [0.23, 4.43]	2009
Marcello	1	19	0	29	0.7%	4.78 [0.18, 123.74]	2011
Schlöricke	1	24	2	12	1.2%	0.22 [0.02, 2.68]	2013
Koh	4	23	7	23	3.6%	0.48 [0.12, 1.95]	2013
Liu	3	55	6	135	3.5%	1.24 [0.30, 5.15]	2014
Kim	1	11	3	38	1.4%	1.17 [0.11, 12.48]	2015
Letarte	5	39	28	86	5.9%	0.30 [0.11, 0.86]	2015
Cassini	2	36	0	24	0.8%	3.55 [0.16, 77.27]	2017
Sujatha-bhaskar	208	1039	2952	8979	27.4%	0.51 [0.44, 0.60]	2017
Lee	139	457	1141	3299	25.7%	0.83 [0.67, 1.02]	2019
Moghadamyeghaneh	58	249	323	1044	21.6%	0.68 [0.49, 0.94]	2020
Total (95% CI)		**2042**		**13788**	**100.0%**	**0.68 [0.51, 0.91]**	
Total events	432		4473				

Heterogeneity: Tau² = 0.07; Chi² = 25.47, df = 13 (P = 0.02); I² = 49%
Test for overall effect: Z = 2.63 (P = 0.009)

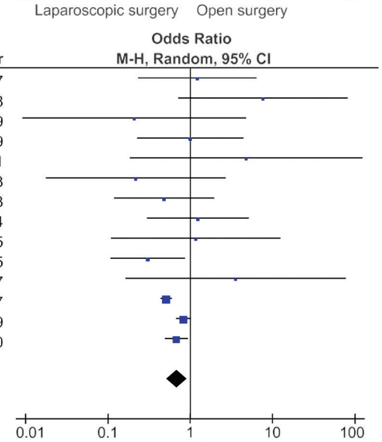
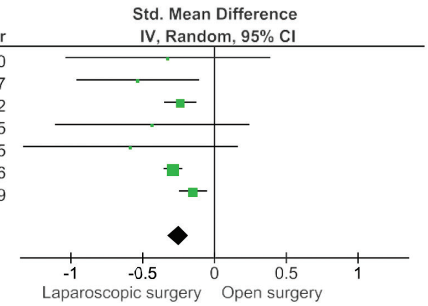


FIGURE 3. (*Continued*).

D

Study or Subgroup	Laparoscopic surgery Mean	SD	Total	Open surgery Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI	Year
Dunker	14.6	12.5	10	18	9.5	32	1.0%	-0.33 [-1.04, 0.39]	2000
Marceau	9	3	40	12	7	48	2.7%	-0.54 [-0.96, -0.11]	2007
Ballian	11.2	12.6	341	15	16.2	3211	24.8%	-0.24 [-0.35, -0.13]	2012
Kim	13	4	11	17	10	38	1.1%	-0.43 [-1.11, 0.24]	2015
Li 2015	7	2.5	10	9	3.6	25	0.9%	-0.59 [-1.33, 0.16]	2015
Keller	10.8	8	954	14.8	14	21774	40.7%	-0.29 [-0.35, -0.22]	2016
Lee	11.2	8.2	457	12.7	10.2	3299	28.7%	-0.15 [-0.25, -0.05]	2019
Total (95% CI)			**1823**			**28427**	**100.0%**	**-0.25 [-0.32, -0.18]**	

Heterogeneity: Tau² = 0.00; Chi² = 8.28, df = 6 (P = 0.22); I² = 28%
Test for overall effect: Z = 6.73 (P < 0.00001)



Study or Subgroup	Laparoscopic surgery Mean	SD	Total	Open surgery Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI	Year
Dunker	14.6	12.5	10	18	9.5	32	2.4%	-0.33 [-1.04, 0.39]	2000
Marceau	9	3	40	12	7	48	4.9%	-0.54 [-0.96, -0.11]	2007
Ng	9.5	3.5	14	16	8.4	29	2.7%	-0.88 [-1.55, -0.22]	2008
Watanabe	31.3	13	30	46.3	20.3	30	3.7%	-0.87 [-1.40, -0.34]	2009
Li 2009	7	0.8	6	9	3.1	12	1.4%	-0.73 [-1.75, 0.29]	2009
Stulberg	10.8	7	40	15.5	11.3	25	4.0%	-0.52 [-1.03, -0.01]	2009
Nash	24	15.1	36	40	24.1	32	4.1%	-0.80 [-1.29, -0.30]	2010
Catani	7	1.6	32	22.5	13.8	61	4.3%	-1.37 [-1.84, -0.89]	2011
Marcello	6	2.7	19	10	4.9	29	3.1%	-0.94 [-1.55, -0.33]	2011
Ballian	11.2	12.6	341	15	16.2	3211	10.1%	-0.24 [-0.35, -0.13]	2012
Koh	10.8	6.5	23	12	7.3	23	3.3%	-0.17 [-0.75, 0.41]	2013
Odermatt	15.8	10.2	36	21	12.6	72	5.2%	-0.44 [-0.84, -0.03]	2013
Schloricke	13.5	4.6	24	19.3	8.5	12	2.4%	-0.92 [-1.65, -0.19]	2013
Turley	7.3	4.5	67	8.3	3.8	67	6.1%	-0.24 [-0.58, 0.10]	2013
Kim	13	4	11	17	10	38	2.7%	-0.43 [-1.11, 0.24]	2015
Li 2015	7	2.5	10	9	3.6	25	2.3%	-0.59 [-1.33, 0.16]	2015
Letarte	9.6	5.4	39	7	3	86	5.4%	0.66 [0.27, 1.05]	2015
Keller	10.8	8	954	14.8	14	21774	10.7%	-0.29 [-0.35, -0.22]	2016
Vallance	9.3	7.4	3425	13.7	9.6	12081	10.9%	-0.48 [-0.52, -0.44]	2019
Lee	11.2	8.2	457	12.7	10.2	3299	10.3%	-0.15 [-0.25, -0.05]	2019
Total (95% CI)			**5614**			**40986**	**100.0%**	**-0.42 [-0.55, -0.29]**	

Heterogeneity: Tau² = 0.04; Chi² = 121.02, df = 19 (P < 0.00001); I² = 84%
Test for overall effect: Z = 6.49 (P < 0.00001)

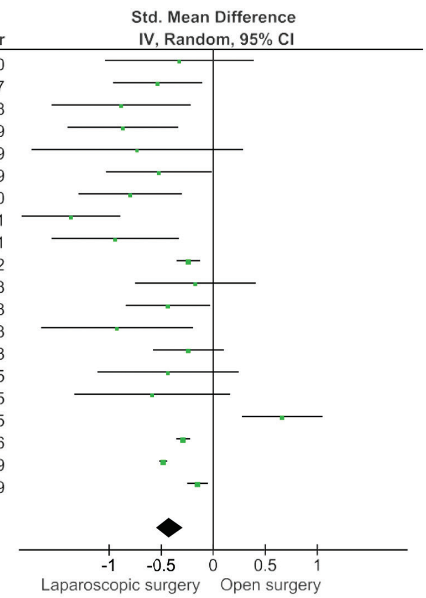


FIGURE 3. Forest plots of the secondary outcomes after emergency colorectal surgery for a laparoscopic and open approach. (A–D) Forest plots of secondary outcomes after laparoscopic vs open emergency colorectal surgery. (A) Forest plot of overall morbidity. Overall morbidity after emergency colorectal surgery: laparoscopic vs open approach. (B) Forest plot of wound infections. (C) Forest plot of ileus. Ileus after emergency colorectal cancer surgery: laparoscopic vs open approach. (D) Forest plot of length of hospital stay (only studies that reported mean and SD are included in this meta-analysis). (D-i) Length of hospital stay after emergency colorectal surgery: laparoscopic vs open approach. (D-ii) Length of hospital stay after emergency colorectal surgery combining mean and median: laparoscopic vs open approach. CI, confidence interval.

sample sizes that allow for proper assessment of rare events such as mortality.

In conclusion, this systematic review and meta-analysis showed that emergency laparoscopic surgery for colorectal diseases has a lower postoperative mortality rate, overall morbidity rate, and a shorter length of hospital stay compared to open surgery. However, the almost exclusive use of retrospective observational study designs with inherent biases should be taken into account.

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