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ORIGINAL ARTICLE

Emergent Laparoscopic Colectomy Is an Effective Alternative to Open Resection for Benign and Malignant Diseases: a Meta-Analysis

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Abstract The aim of this study is to compare the perioperative outcomes between laparoscopic and open resections performed for colonic emergencies. A systematic search of the literature identified previously published comparative studies regarding emergent laparoscopic colectomy (ELC) and emergent open colectomy (EOC). Meta-analysis was performed utilizing a pooled odds ratio (OR) for dichotomous variables and a weighted mean difference (WMD) for continuous variables with 95 % confidence intervals (CIs). Eleven studies involving 752 patients were identified. Although operation time was noted to be significantly shorter for EOC, patients post-ELC had significantly lower overall morbidity (OR 0.44; 95 % CI 0.30, 0.66; $P < 0.0001$). Meanwhile, recovery time for post-ELC patients was significantly shorter, as was the length of hospital stay (WMD −2.78 days; 95 % CI −3.17, −2.38; $P < 0.00001$), the time to regular dietary habits (WMD −1.32 days; 95 % CI −2.51, −0.13; $P = 0.03$), and the time to recover bowel movement (WMD −0.55 days; 95 % CI −0.89, −0.22; $P = 0.001$). Reoperation rate and mortality were found to be comparable between ELC and EOC. The R0 resection rate and the number of lymph nodes harvested were also comparable between ELC and EOC for malignant diseases. Whether for benign or malignant disease, ELC is a safe and feasible procedure for colonic emergencies compared with EOC, despite being relatively time-consuming.

Keywords Laparoscopic colectomy · Minimally invasive surgical procedures · Colectomy · Emergencies · Meta-analysis

Introduction

The introduction of abdominal laparoscopic surgery revolutionized the field of general surgery over the past decades, with the former's advantages over open surgery well established, particularly for elective patients with benign or malignant pathology. As well-trained minimally invasive specialty surgeons increased in number, laparoscopic surgery became a feasible and effective alternative to laparotomy for several diseases in the emergency setting as well. The best indications for laparoscopy in case of an emergency include acute appendicitis, calculous cholecystitis, and a perforated peptic ulcer [1].

Due to the shorter length of hospital stay (LOS), quicker recovery, and lower postoperative morbidity, laparoscopic colorectal resection was commonly preferred to open procedures in elective conditions [2]. Thus, the technical demand of laparoscopy for emergent colectomy became a matter of course. Although over one third of urgent surgical admissions were for colorectal pathology [3], the role of laparoscopic colectomy (LC) in the emergency setting remains controversial. The major drawback of emergent laparoscopic colectomy (ELC) was lack of encouraging highly reliable evidence, with a particular weakness in prospective randomized control trials (RCTs). Additionally, most of the aforementioned studies were performed in single-center settings and were retrospective in design. Furthermore, some research even produced

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negative conclusions: a recent study indicated that the emergent laparoscopic Hartmann procedure for complicated diverticulitis could decrease neither the postoperative morbidity nor the mortality when compared with emergent open colectomy (EOC) [4].

This analysis was conducted in order to break a deadlock set in place due to recent conflicts of evidence. Both randomized and nonrandomized studies were considered, since the reliability of high-quality nonrandomized comparative studies was proven to be as powerful as RCTs when adopted for a meta-analysis [5]. We established no restrictions concerning pathological diagnoses since urgent resection of colorectal malignancies is also becoming a major part of routine emergency department work.

Materials and Methods

Search Strategy

An electronic bibliographic search was carried out using the following databases: MEDLINE (PubMed), Embase, and The Cochrane Library. The following search headings were utilized to identify all studies published up to July 2015 in English: "emergency," "laparoscopic," and "colectomy." Related articles additionally broadened results, and all abstracts, studies, and citations scanned were reviewed.

Inclusion Criteria

Included studies satisfied all of the following criteria: (1) the publication must have described a comparative study; (2) the study had to compare the characteristics and perioperative outcomes of adult patients undergoing laparoscopic and open colectomy (OC); (3) all operations had to be performed in an emergency setting; and (4) the disease had to be comparable between ELC and EOC.

Exclusion Criteria

Studies were excluded from the analysis when the outcomes and parameters of patients were not reported or deemed impossible to calculate for both groups. Single-port laparoscopic and robot-assisted laparoscopic operations were not included in the analysis. Studies were also excluded when the two groups dealt with different diseases or the diagnosis of disease was not reported. If cases were duplicately published, only the most informative and recent study was included.

Data Extraction and Quality Assessment

Two reviewers independently extracted the following parameters from each study: first author(s), year of publication, population characteristics, study design, numbers of subjects undergoing each procedure, and perioperative outcomes. Disagreements were resolved by discussion.

The Newcastle Ottawa scale (NOS) was adopted to assess the quality of nonrandomized studies. Three parameters of studies were evaluated to determine adequate quality: representation of the patient population, comparability of two patient groups, and reliability of outcomes. A study, at most, had nine stars as a full score. Studies with a score equal to or higher than seven were considered methodologically sound.

Outcomes of Interest

The following relevant data were extracted from the studies: population characteristics, intraoperative outcomes (operative time and intraoperative blood loss), postoperative recovery (LOS and time to resumption of normal diet), postoperative complications (overall morbidity, intra-abdominal abscess, intra-abdominal bleeding, and prolonged ileus), reoperation rate, postoperative mortality, and oncological outcomes (R0 resection rate and lymph nodes harvested).

Subgroup Analyses

To further analyze the effects of pathology on postoperative outcomes, subgroup analyses were carried out according to pathologic diagnosis.

Statistical Analysis

This meta-analysis was conducted according to guidelines of Meta-analysis of Observational Studies in Epidemiology (MOOSE) [6]. We analyzed dichotomous variables using estimation of odds ratio (OR) and continuous variables using weighted mean difference (WMD) with a 95 % confidence interval (CI). If the study provided medians and ranges instead of means and standard deviations (SD), we estimated the means and SDs as described by Hozo et al. [7]. $P < 0.05$ indicated a statistically significant difference between the two groups. Before performing meta-analysis, homogeneity of effect sizes was assessed by χ^2 and I^2. We considered heterogeneity to be present if the I^2 statistic was >50 %. A fixed-effect (Mantel–Haenszel) statistical model was used in the absence of significant heterogeneity; otherwise, a random effects (DerSimonian and Laird) model was utilized. Publication bias was examined by the symmetry of funnel plot. Statistical analyses were performed using Review Manager (RevMan) version 5.1.0.

Results

Results of Study Search and Quality Assessment

The bibliographic search identified 389 potentially relevant studies, and subsequent title and abstract screening eliminated 371 studies that obviously did not fit our inclusion criteria. Out of the remaining 18 studies, 11 studies [4, 8–17] were finally included in our meta-analysis after a full-text review (Fig. 1).

There was no RCT component in this analysis. All 11 studies included were retrospective and nonrandomized in design, 5 studies were cohort, and 6 were case-matched studies. Results of quality assessment were satisfactory; three studies got seven stars, six studies got eight stars, and the remaining two got nine stars. No included study was evaluated as being low quality. All dates of surgery mentioned in studies were after 2000, except for those reported by Dunker et al. [9] and Marcello et al. [14]. The sample size of these studies ranged from 18 to 134. Every study recorded at least two of three baseline parameters, containing age, gender, and body mass index. All studies were comparable with age and gender, except for two studies [11, 17]. The basic characteristics and baseline data of included studies are listed in Table 1.

Intraoperative Outcomes

Eight studies [4, 8, 10–14, 17] reported operative time. Pooled data of these eight studies indicated that an open procedure was more time-efficient (random effects model; WMD 36.47 min; 95 % CI 12.07, 60.87; $P = 0.003$). Six studies [11–15, 17] reported the volume of intraoperative blood loss.

Pooled data of the six studies revealed that patients under ELC lost comparable blood as whom under EOC (random effects model; WMD −54.00 ml; 95 % CI −129.66, 21.65; $P = 0.16$).

Outcomes of Morbidity and Mortality

Eight studies [4, 8, 10–13, 15, 17] respectively indicated that the morbidity in the ELC group was lower than that in the EOC group. Pooled data of these ten studies confirmed that patients after ELC were significantly more likely to avoid postoperative complications than whom after EOC (fixed effects model; OR 0.44; 95 % CI 0.30, 0.66; $P < 0.0001$) (Fig. 2a). However, the incidences of surgical complications, including wound infection (random effects model; OR 0.63; 95 % CI 0.23, 1.70; $P = 0.36$), intra-abdominal bleeding (fixed effects model; OR 1.20; 95 % CI 0.30, 4.75; $P = 0.79$), abdominal abscess (fixed effects model; OR 0.72; 95 % CI 0.28, 1.84; $P = 0.49$) and prolonged ileus (fixed effects model; OR 0.62; 95 % CI 0.34, 1.13; $P = 0.12$) were not significantly different between the ELC and EOC groups. Meanwhile, the incidence of reoperation was comparable between ELC and EOC (fixed effects model; OR 0.95; 95 % CI 0.44, 2.04; $P = 0.89$). Nine studies [4, 8, 10–13, 15–17] reported postoperative mortality. Pooled data of these studies revealed that the incidence of postoperative death was comparable between ELC and EOC (fixed effects model; OR 0.54; 95 % CI 0.23, 1.28; $P = 0.16$).

Recovery Outcomes

Nine studies [9–17] reported the results of LOS. Pooled data showed that the LOS was significantly shorter for ELC than

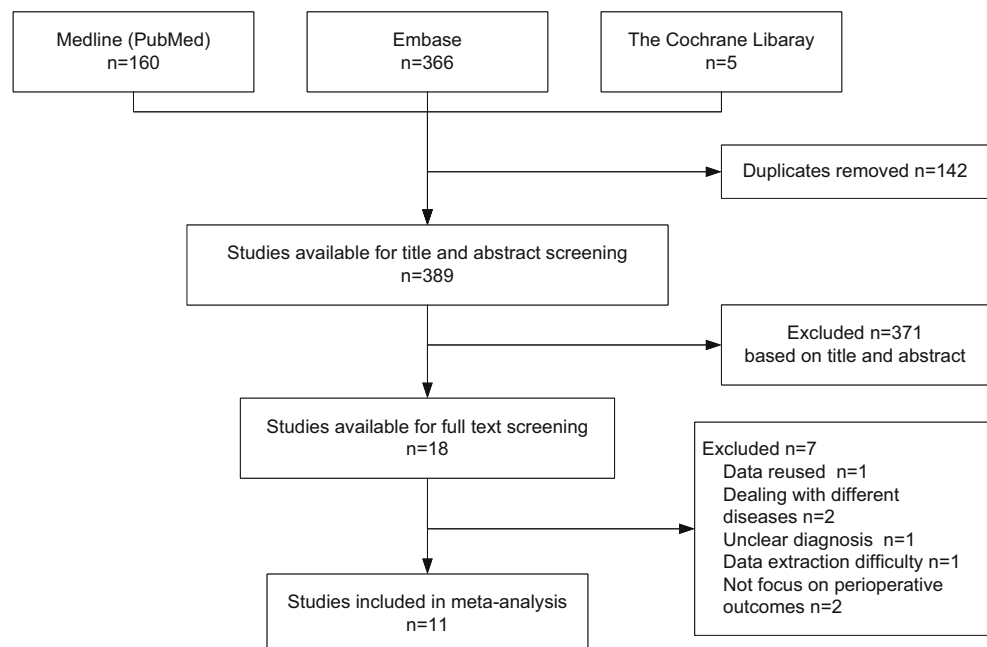Fig. 1 Flowchart of studies retrieved from literature search

Table 1 The characteristics and baseline parameters of the included studies

Author	Year	Country	Design	Laparoscopic approach	Pathology	No. of patients		Age		Gender (male)		BMI		Quality Score
						ELC	EOC	ELC	EOC	ELC	EOC	ELC	EOC	
Catani M	2011	Italy	Case-match	Lap	Ben, Mal	32	61	50.1 ± 19.15	54.9 ± 16.38	19	29	NR	NR	8
Dunker MS	2000	The Netherlands	Cohort	Lap, HALS	Ben	10	32	33 ± 7.7	37 ± 12.1	3	14	19.7 ± 4.1	20.9 ± 3.5	7
Koh FH	2013	Singapore	Case-match	Lap, HALS	Ben, Mal	23	23	NA	NA	13	13	NR	NR	8
Letarte F	2014	Canada	Cohort	Lap	Ben	39	86	61.6 ± 13.7	60.9 ± 12.0	12*	53*	26.3 ± 4.0	26.7 ± 4.5	8
Li JC	2009	Hong Kong, China	Cohort	Lap	Ben	6	12	47 (30–87)	48.5 (16–68)	4	6	NR	NR	7
Li Z	2015	China	Case-match	HALS	Mal	10	25	64.5 ± 9.7	62.3 ± 10.2	6	14	22.2 ± 3.4	22.3 ± 4.1	9
Marcello PW	2001	USA	Case-match	Lap	Ben	19	29	32 (15–60)	33 (20–58)	10	13	24 (17–34)	24 (16–36)	8
Ng SS	2008	Hong Kong, China	Cohort	Lap	Mal	14	29	68.5 (45–80)	71 (44–94)	6	14	21.1 (18.6–35.5)	20.7 (17.8–26.9)	8
Odermatt M	2013	UK	Case-match	Lap	Mal	36	72	74 (32–93)	77.5 (30–92)	15	36	24 (16–41)	26 (15–38)	8
Turley RS	2013	USA	Case-match	Lap	Ben	67	67	58.5 ± 16.3	59 ± 13.5	41	40	27.6 ± 7.8	26.7 ± 6.5	9
Watanabe K	2009	Japan	Cohort	HALS	Ben	30	30	26.9 (13–64)*	35.7 (19–84)*	17	19	18.6 (11.5–24.2)	18.5 (13.8–22.5)	7

NA not assessable, *NR* not reported, *Lap* laparoscopy, *HALS* hand-assisted laparoscopic surgery, *Ben* benign, *Mal* malignant, *BMI* body mass index

*$P < 0.05$

EOC (fixed effects model; WMD −2.78 days; 95 % CI −3.17, −2.38; $P < 0.00001$) (Fig. 2b). Three studies [9, 12, 17] reported the time to resume normal diet. Patients following ELC were noted to require significantly less time to resume a normal diet (fixed effects model; WMD −1.32 days; 95 % CI −2.51, −0.13; $P = 0.03$) (Fig. 3a). Meanwhile, three studies [12, 14, 15] reported the first day to recover bowel movement. Pooled data showed that patients after ELC recovered bowel movement significantly more quickly than whom after EOC (fixed effects model; WMD −0.55 days; 95 % CI −0.89, −0.22; $P = 0.001$) (Fig. 3b).

Subgroup Analyses

In our included studies, there were six studies [4, 9, 11, 12, 14, 17] dealing with benign diseases. Results of this subgroup analysis kept highly consistent with the results of the aforementioned meta-analysis, including operative duration, intra-operative blood loss, overall postoperative morbidity, wound infection, intra-abdominal bleeding, intra-abdominal abscess, prolonged ileus, reoperation rate, LOS, time to resume diet, and mortality.

Three studies [13, 15, 16] were included into the malignant disease subgroup. Subgroup analyses were performed for three parameters, including wound infection, LOS, and mortality, whose results were also consistent with the results of the aforementioned meta-analysis. The oncological outcomes of malignant disease were also reported by these three studies. Ng et al. [15] did not reported outcomes of R0 resection rate. All patients got R0 resection in Li's study [13]. The R0 resection rate was comparable in Odermatt's study [16], 72.2 % for ELC and 88.9 % for EOC, respectively. The number of lymph nodes harvested was similar between ELC and EOC (fixed effects model; WMD 2.24; 95 % CI −0.45, 4.92; $P = 0.10$) (Fig. 3c).

Outcomes of Heterogeneity

Statistical heterogeneity was observed in three parameters including operative time, wound infection, and blood loss. However, in the relatively more important parameters, there was no statistical heterogeneity, such as LOS, mortality, morbidity, and reopreation rate.

Outcomes of Publication Bias

Funnel plots were constructed for each outcome and showed symmetry, suggesting that publication bias was not large and was unlikely to drive conclusions. The funnel plot of overall morbidity is shown in Fig. 4.

Fig. 2 Forest plots of the meta-analysis of overall postoperative morbidity (**a**) and the length of hospital stay (**b**). *ELC* emergent laparoscopic colectomy, *EOC* emergent open colectomy
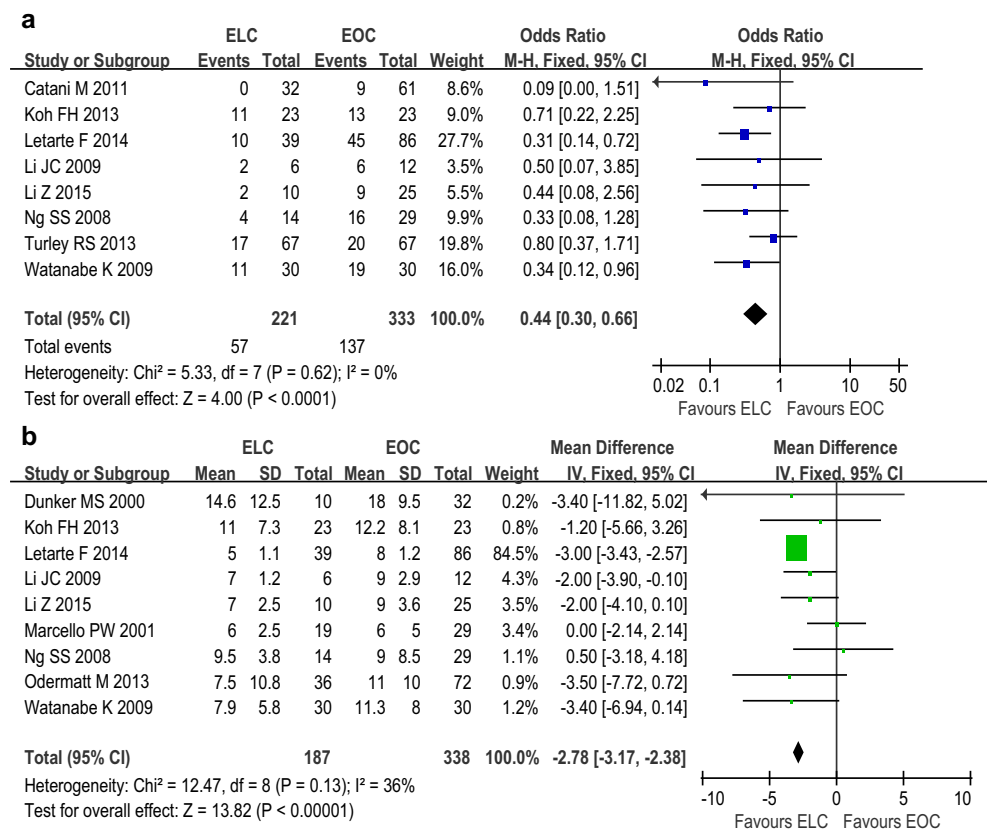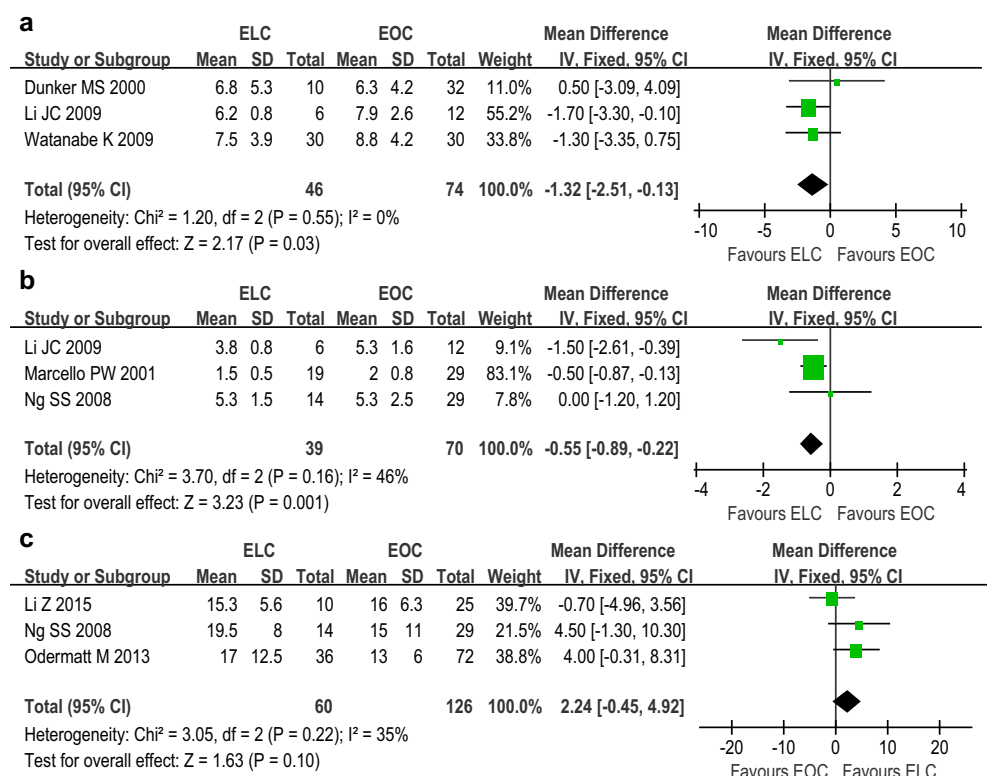

Fig. 3 Forest plots of the meta-analysis of the time to regular dietary habits (**a**), the time to recover bowel movement (**b**), and the number of lymph nodes harvested (**c**). *ELC* emergent laparoscopic colectomy, *EOC* emergent open colectomy
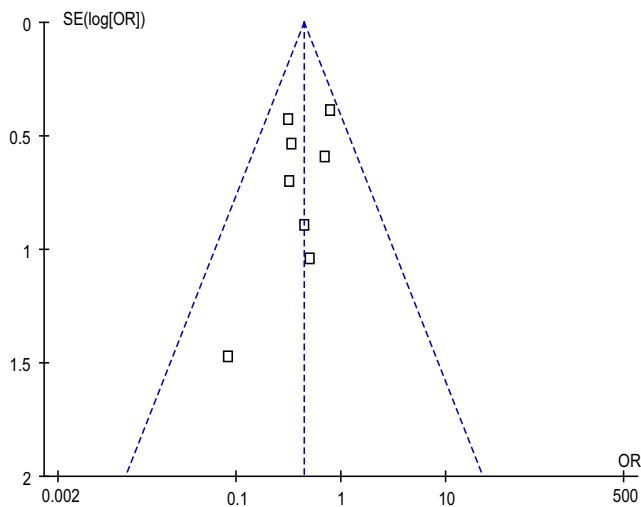
Fig. 4 Funnel plot of overall postoperative morbidity

Discussion

The benefits of elective LC have been widely confirmed, especially for benign disease [18]. Our analysis confirmed that the benefits of laparoscopy still existed under the emergency setting. This analysis also took malignant disease into consideration, because up to 20 % of colorectal cancers presented as surgical emergencies [19]. Furthermore, these patients who received operative intervention in a timely manner after emergency admission had better outcomes: Gunnarsson et al. [20] reported that colonic cancer patients who underwent colectomy within 3 days after emergency admission had a lower postoperative mortality and a higher 5-year survival rate than those who were operated upon after more than 3 days.

Nowadays, laparoscopy is widely adopted in colonic cancer surgery. Data from eight institutions of the National Comprehensive Cancer Center Network indicated that the proportion of laparoscopy-assisted surgery in colonic cancers was over 50 % in 2010 and the number was deemed increasing as the time passed [21]. An obvious superiority of LC over open resection for colon cancer was supported on the basis of lower postoperative mortality and quicker recovery [22]. Moreover, long-term survival for malignant disease was reported to be comparable between LC and OC [23]. However, there were few studies reporting the oncological safety of ELC for colonic malignancies. To our best knowledge, this is the first meta-analysis which revealed the oncological outcomes of malignant diseases (R0 resection rate and lymph nodes harvested) between ELC and EOC.

Most crucially, malignant pathology has not been a technical barrier to the application of laparoscopy for surgical treatment of colonic disease: Vaccaro et al. [24] stated that independent risk factors for conversion of laparoscopic colorectal resections contained lesion location, body size, and gender,

but not disease type, and neither neoplastic or nonneoplasic characteristics. Based on the above realizations, emergent malignant diseases should have been taken into account along with benign surgical diagnoses, which was reinforced by the absence of heterogeneity within major parameters and the stable outcomes of subgroup analyses.

As for important intraoperative parameters, the operative duration of ELC was noted to be significantly longer than that of EOC, according to pooled data.

Firstly, the additional processing time of laparoscopy was probably due to a steep learning curve. A systematic review [25] of 4852 patients demonstrated that the length of the learning curve for laparoscopic colorectal resection ranged from 87 to 152 cases. Concretely, the accumulation of about 100 cases' worth of experience was required for a stable operative time, and about 150 cases for procedure conversion. Factoring in off-duty surgeries, a lack of sufficient, timely preoperative readiness, and the wide variety of surgical settings surveyed, ELC outcome was undoubtedly influenced by a greater number of unforeseen variables than was elective LC. However, in most of the included studies, the total case quantity was noted to be fewer than 40, and cases were not all from a single surgeon. The heterogeneity of operative duration also reflected a disparity in surgical skills and technical proficiency among surgeons.

Secondly, converted cases were commonly counted into the laparoscopic patient group based on a presumed initial laparoscopic approach. Conversion doubtlessly extended the average operative time by a great deal.

Despite the inferiority regarding time efficiency, ELC was found to conserve as much blood as EOC. Up to 200–250 ml of blood loss was demonstrated to correlate with postoperative complications such as surgical site infection, bowel anastomosis leak, and lowered long-term survival rates [26]. Concurrently, the superiority of LC in regards to morbidity and mortality would disappear when the surgical duration surpassed 3 h [27]. While it is still unknown whether blood conservation or decreased surgery duration alone has a greatest influence on ELC.

Even if each procedure had its own merits and drawbacks among intraoperative outcomes, ELC presented a distinct advantage in overall morbidity. However, meta-analysis revealed ELC to have no clear advantage in events of wound infection, intra-abdominal bleeding, abscess formation, or prolonged ileus, all classified under surgery-related complications. The following reasons may adequately explain such inconsistency: firstly, other surgery-related complications (such as intestinal fistula and anastomotic leakage) resulted in an increased number of operative complications in the EOC group. Previous research [28] demonstrated that 3.6 % of serious complications needing reoperative after colonic resection were intestinal fistula or anastomotic leakage, but only 0.5 % were intra-abdominal bleeding.

Unfortunately, such important parameters could not be extracted from included studies.

Post-ELC patients were released from the hospital much earlier, which owes to quicker recovery from laparoscopy. The time to normal diet resumption was about 1 day shorter in the ELC group than that in the EOC group. The lower post-ELC morbidity was associated with a shorter LOS, because postoperative morbidity is an independent risk factor influencing the LOS [29].

In addition to clinical outcomes, economic worth has been perceived to be a limiting factor in the development and popularization of laparoscopic colonic surgery. Under elective conditions, due to application of disposable instruments, the operative cost of LC was higher than that of OC. However, the total in-hospital charge of LC was comparable with OC, sometimes even lower, as was the community cost, due to the lower postoperative morbidity and the shorter LOS [30]. There are few studies on the cost of ELC, but the technical superiority of ELC is likely to evolve into cost-effectiveness as elective LC has. In fact, one [10] of the included studies reported that an in-hospital charge was comparable between ELC and EOC. We expect more studies on the economic comparisons between ELC and OLC in the future.

Limitation of This Meta-Analysis

None of the included studies was of randomized, prospective design, which made the conclusions almost impossible to avoid a selection bias. However, the availability of appropriate surgeons and instruments would be much more uncertain in emergency settings, as well as conditions of patients. Thus, performance of a RCT concerning an emergency setting would also be much more difficult. Fortunately, all included studies were assessed to be of high reliability in nature.

The sample size of each included study was distributed among a wide range. However, the samples of the 11 included studies were considered to be from a similar statistical population, based on heterogeneity factors. Meanwhile, key clinical outcomes kept stable after subgroup analyses.

Conclusions

Whether for benign or malignant disease, ELC is a safe and feasible procedure for colonic emergencies compared with open surgery, despite being relatively time-consuming.

Compliance with Ethical Standards

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