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REVIEW ARTICLE

Short-term and three-year long-term outcomes of laparoscopic surgery versus open surgery for obstructive colorectal cancer following self-expandable metallic stent placement: a meta-analysis

Shintaro Kanaka[1] · **Takeshi Yamada**[1] · **Akihisa Matsuda**[1] · **Kay Uehara**[1] · **Seiichi Shinji**[1] · **Yasuyuki Yokoyama**[1] · **Goro Takahashi**[1] · **Takuma Iwai**[1] · **Kohki Takeda**[1] · **Sho Kuriyama**[1] · **Toshimitsu Miyasaka**[1] · **Hiroshi Yoshida**[1]

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Abstract

Background A bridge to surgery (BTS) after self-expandable metallic stent (SEMS) placement is a widely recognized treatment strategy for obstructive colorectal cancer. However, there is still a lack of evidence for the efficacy and safety of laparoscopic surgery following SEMS placement. The aim of this systematic review and meta-analysis was to compare the short-term and long-term outcomes of laparoscopic surgery with those of open surgery following SEMS placement in patients with obstructive colorectal cancer.

Methods An electronic literature search through to December 2022 was performed to identify studies comparing short-term and long-term outcomes between laparoscopic and open surgery following SEMS placement for obstructive colorectal cancer. The main outcome measures were postoperative complication rates and mortality. Secondary outcome measures were the 3-year recurrence-free survival (RFS) and 3-year overall survival (OS) rates. The meta-analysis was performed using fixed-effect or random-effects methods to calculate odds ratios (ORs) with 95% confidence intervals (95% CIs).

Results The meta-analysis included 15 studies and 883 patients, of whom 467 (52.9%) underwent laparoscopic surgery and 416 (47.1%) underwent open surgery following SEMS placement. The postoperative complication rate was significantly lower in the laparoscopic surgery group than in the open surgery group (OR 0.47, 95% CI 0.32–0.67, $P<0.001$). There was no significant difference in the 3-year RFS rate or 3-year OS rate between the laparoscopic and open surgery groups (3-year RFS, OR 0.78, 95% CI 0.50–1.24, $P=0.30$; 3-year OS, OR 0.68, 95% CI 0.41–1.12, $P=0.13$).

Conclusion This meta-analysis found that the short-term outcome was better in patients who underwent laparoscopic surgery following SEMS placement than in those who underwent open surgery. Furthermore, there was no significant difference in long-term outcomes between the two groups. Laparoscopic surgery following SEMS placement may be a safe and effective treatment option for obstructive colorectal cancer.

Keywords Colon · Cancer · Obstruction · Self-expandable metallic stent · Laparoscopic · Surgery

Approximately 8–34% of patients with colorectal cancer have obstructive symptoms [1–3]. Obstructive colorectal cancer (OCRC) is considered a life-threatening condition that requires immediate intervention. However, emergency one-stage resection for OCRC is associated with significantly higher mortality and morbidity rates than elective surgery [4, 5]. In the last two decades, elective surgery following self-expandable metallic stent (SEMS) placement, known as a bridge to surgery (BTS), has been introduced and is widely accepted as an alternative treatment strategy to emergency surgery [6–13]. BTS for OCRC is now recommended in the 2020 European Society of Gastrointestinal Endoscopy guidelines [14]. Although the usefulness and safety of laparoscopic surgery is well established in patients with colorectal cancer [15–18], there have been no comprehensive studies in OCRC. Recent retrospective cohort studies have demonstrated better results for laparoscopic surgery than for open surgery following SEMS placement [7, 19–32]. However, it is quite difficult to perform randomized

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✉ Shintaro Kanaka
ks32814@nms.ac.jp

[1] Department of Gastrointestinal and Hepato-Biliary-Pancreatic Surgery, Nippon Medical School, 1-1-5 Sendagi, Bunkyo-Ku, Tokyo 113-8603, Japan

controlled trials (RCTs) with large enough sample sizes to reach a conclusion, partly because of the rarity of OCRC. Therefore, we performed this systematic review and meta-analysis of the relevant published studies, which included a total of 883 patients, to determine the efficacy and safety of laparoscopic surgery following SEMS placement for OCRC.

Methods

The meta-analysis was performed in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [33].

Literature retrieval and study selection

The literature in the MEDLINE (PubMed), Google Scholar, and Cochrane Library databases was systematically searched through to December 2022 to identify relevant studies (Fig. 1). The search was limited to human studies published in English or Japanese. The search terms used were ("colon cancer" OR "colonic obstruction" OR "malignant obstruction") AND ("laparoscopic surgery" OR "minimally invasive surgery" OR "open surgery" OR "laparotomy") AND ("stent" OR "endoscopic decompression"). The related articles function was used to broaden the search. The reference lists of all relevant publications were searched manually for additional studies that may have been initially overlooked using our search strategy. The quality of the included studies was assessed using the Newcastle–Ottawa scale (NOS) for observational studies [34]. Studies were considered to be of high quality if they had an NOS score of ≥ 7. The MINORS (Methodological Index for Non-Randomized Studies) tool was used to assess the risk of bias for individual studies [35]. GRADE (Grading of Recommendations Assessment, Development and Evaluation) methodology was used to assess the quality of evidence and reported in the results with the help of GRADE Pro software (McMaster University and Evidence Prime Inc., Ontario, CA; https://www.gradepro.org/) [36].

Inclusion and exclusion criteria

The inclusion and exclusion criteria were defined a priori. Studies were included if they compared postoperative complications between patients with acute OCRC who underwent laparoscopic surgery and those who underwent open surgery following SEMS placement. Surgery was defined as primary tumor resection with or without primary anastomosis. Duplicated study reports and studies for which predefined outcomes were not reported or it was impossible to extract the number of outcome events were excluded.

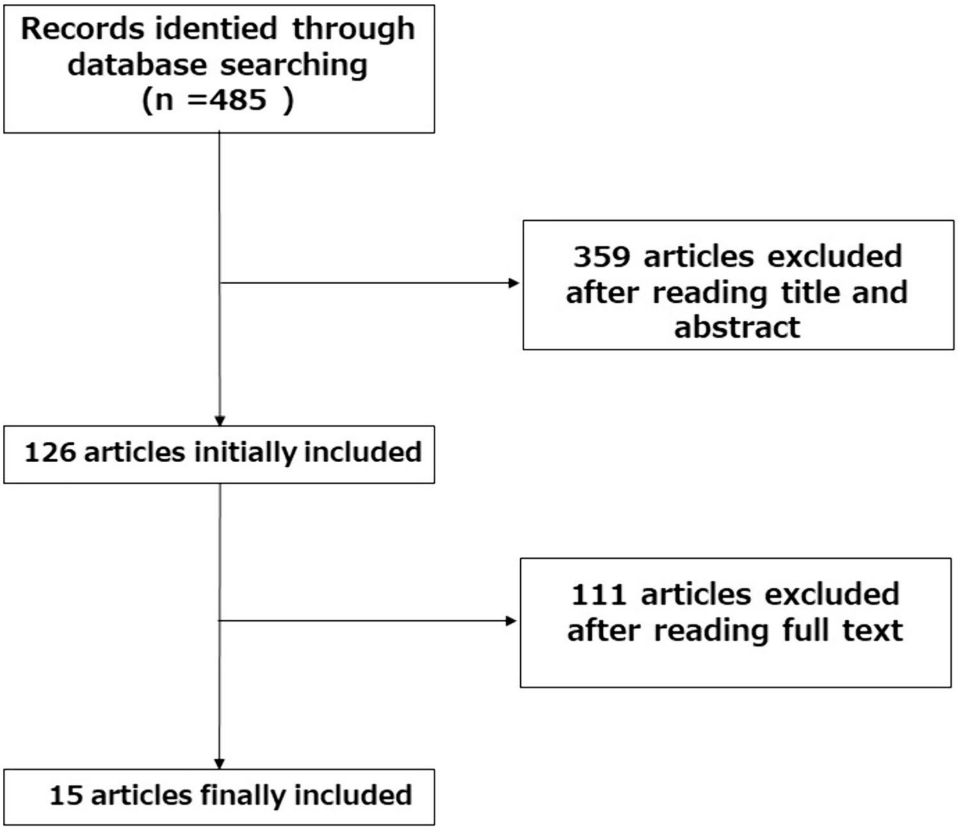


Fig. 1 Flowchart showing the study selection process according to the PRISMA guidelines

Extraction of data

The full-text version of each eligible study was evaluated by two investigators (S.K., A.M.) working independently. The following data were extracted: name of the primary author, year of publication, country in which the study was performed, number of participating institutions, design and duration of the study, number of study participants and their characteristics, including age, sex, and tumor-related variables, interval between SEMS placement and surgery, and all available information on short-term and long-term outcomes.

Data synthesis and statistical analysis

Short-term outcomes (primary anastomosis, stoma construction, overall morbidity, surgical site infection, anastomotic leakage, and postoperative ileus) and long-term outcomes (3-year recurrence-free survival [RFS] and 3-year overall survival [OS]) were compared between patients who underwent laparoscopic surgery (the LS group) and those who underwent open surgery (the OpS group). Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. An OR of < 1 favored the BTS group, and the point estimate of the OR was considered statistically significant at $P < 0.05$ if the 95% CI did not include the value 1. The pooled OR was calculated using a Mantel–Haenszel fixed-effect model or a DerSimonian–Laird random-effects model to combine ORs for outcomes of interest. The meta-analysis was performed using Review Manager (Version 5.1) for Windows (Nordic Cochrane Center, Cochrane Collaboration, Copenhagen, Denmark; http://www.cc-ims.net/RevMan). The Cochran's chi-square-based Q statistic test was used to assess between-study heterogeneity. The I^2 value was used to test for heterogeneity among the included studies. Study heterogeneity was measured using the χ^2 and I^2 statistics, with a χ^2 P value of < 0.05 and an I^2 value of $\geq 50\%$ indicating heterogeneity [37]. A fixed-effect model was used to estimate the overall effect if the OR was homogeneous; if the OR was not homogeneous, a random-effects model was used [38]. Publication bias was assessed by visual examination and statistical analysis of a funnel plot, with asymmetry formally assessed by use of Egger's linear regression test and the rank correlation (Begg's) test using WINPEPI software (available at http://www.brixtonhealth.com/pepi4windows.html) [39, 40].

Results

Literature review and included studies

In total, 485 potentially relevant citations were identified during the initial screening. After reviewing the titles and abstracts, 359 studies were excluded. One hundred and eleven further studies were excluded after full-text evaluation, leaving 15 studies published between 2004 and 2022 [7, 19–32] for inclusion in the meta-analysis (Fig. 1). The background characteristics of the included studies are shown in Table 1. Three studies [19–21] originated from Europe and 12 [7, 22–32] from Asia. All the studies had a retrospective observational design. In total, 467 (52.9%) of the 883 patients included in the meta-analysis underwent laparoscopic surgery and 416 (47.1%) underwent open surgery. The risk of bias was assessed independently using the NOS score (Table 2). The NOS score was ≤ 6 in three studies [19, 20, 24] and ≥ 7 in 12 [7, 21–23, 25–32]. The included studies had a mean MINORS score (± standard deviation) of 12.93 ± 4.15, indicating that the quality of evidence for non-randomized studies was fair. The MINORS results for the included studies are shown in Table 3**.** According to the GRADE criteria, the overall quality of evidence was very low for ileus, stoma construction, and primary anastomosis, low for mortality, anastomotic leak, wound infection, and 3-year OS and RFS, and moderate for postoperative complications (Table 4).

Short-term outcomes

Postoperative complications

All 15 studies reported postoperative complications. Only four studies [7, 19, 31, 32] reported the severity of these complications and eight [7, 19, 23, 25, 29–32] reported postoperative complications occurring within 30 days after surgery. Therefore, postoperative complications were defined as the overall morbidities listed in the included studies [7, 19–32]. The postoperative complication rate was 13.3% (62/467) in the LS group and 23.8% (99/416) in the OpS group. The heterogeneity test indicated a χ^2 value of 19.06 and an I^2 value of 27%, demonstrating homogeneity. Therefore, a fixed-effect model was adopted (OR 0.47, 95% CI 0.32–0.67, $P < 0.001$) (Fig. 2). This meta-analysis demonstrated that laparoscopic surgery contributed to a significant reduction in postoperative complications compared to open surgery. We found no significant publication bias by visual inspection of the funnel plot (Supplementary Fig. 1) or on Egger's test ($P = 0.772$) or Begg's test ($P = 0.255$).

Mortality

Mortality was reported in eleven studies. The postoperative mortality rates in the LS and OpS groups were 0.5% (2/408) and 0.3% (1/329), respectively. The heterogeneity test indicated a χ^2 value of 0.63 and an I^2 value of 0%, indicating homogeneity. Therefore, the fixed-effect model was adopted (OR 1.01, 95% CI 0.18–5.55, $P = 0.99$) (Fig. 3).

Table 1 Basic characteristics of the fifteen included studies

							LS				OpS			
References	Year	Country	Institution	Study design	Study period	Total cases (LS/OpS)	Age (years, mean)	Male/ Female	Time to surgery (days, mean)	Pathological staging (I/II/III/IV)	Age (years, mean)	Male/ Female	Time to surgery (days, mean)	Pathological staging (I/II/ III/IV)
Balague et al. [19]	2004	Spain	Single center	RS	1997–2004	6 (4/2)	56.5	2/2	7	-	76	1/1	11	-
Olmi et al. [20]	2007	Italy	Single center	RS	2001–2006	23 (19/4)	-	-	-	0/10/9/0	-	-	-	0/1/2/1
Stipa et al. [21]	2008	Italy	Single center	RS	2002–2005	21 (6/15)	65.8	5/1	14.8	0/2/2/2	71.2	7/8	10.7	1/6/7/1
Chung et al. [22]	2008	Korea	Single center	RS	2002–2007	25 (17/8)	69	8/9	7	I,II,III 12/ IV 5	61	3/5	5	I,II,III 6/IV 2
Zhou et al. [23]	2013	China	Single center	RS	2008–2012	72 (14/58)	57.7	10/4	13.9	0/6/5/3	60.2	36/22	10.6	1/24/21/12
Watanabe et al. [24]	2014	Japan	Single center	RS	2012–2014	20 (7/13)	-	-	-	-	-	-	-	-
Tanaka et al. [25]	2014	Japan	Single center	RS	-2013	19 (9/10)	73.2	8/1	-	I,II,III 4/ IV 5	77.6	4/6	-	I,II,III 6/IV 4
Shimada et al. [26]	2015	Japan	Single center	RS	2010–2014	48 (34/14)	67.5	21/13	-	0/15/9/10	71.3	5/9	-	-
Enomoto et al. [27]	2016	Japan	Single center	RS	2005–2013	58 (26/32)	65	15/11	9	0/12/8/6	75	21/11	10	0/12/8/12
Matsushima et al. [28]	2017	Japan	Single center	RS	2014–2016	18 (7/11)	-	-	-	-	-	-	-	-
Chinswang-watanakul et al. [29]	2017	Thailand	Single center	RS	2007–2012	43 (24/19)	66	15/9	-	2/5/13/4	65	12/7	-	2/5/11/1
Yang et al. [7]	2019	Korea	Single center	RS	2006–2015	182 (105/77)	66.5	59/46	8	0/50/55/0	63.4	48/29	8	0/36/41/0
Bae et al. [30]	2019	Korea	Multi center	RS	2005–2013	94 (44/50)	69	36/8	11	I,II,III 44/ IV 0	66	26/24	12	I,II,III 50/ IV 0
Tajima et al. [31]	2020	Japan	Single center	RS	2013–2018	75 (54/21)	63.5	33/21	-	1/18/20/14	68	15/6	-	0/8/5/8
Kim et al. [32]	2022	Korea	Multi center	RS	2002–2011	179 (97/82)	63.4	52/45	7	0/39/58/0	64.1	54/28	10	0/35/47/0

LS laparoscopic surgery, *OpS* open surgery, *RS* retrospective study

Table 2 NOS score of included studies

References	Selection				Comparability	Exposure			NOS Scores
	Adequate definition of cases	Representativeness of the cases	Selection of controls	Definition of controls	Control for important factor	Ascertainment of exposure	Same method of ascertainment for cases and controls	Non-response rate	
Balague et al. [19]	*	*	/	*	*	*	/	*	6
Olmi et al. [20]	*	*	/	*	*	*	*	/	6
Stipa et al. [21]	*	*	/	*	*	*	*	*	7
Chung et al. [22]	*	*	*	*	**	*	*	*	9
Zhou et al. [23]	*	*	/	*	**	*	*	*	8
Watanabe et al. [24]	*	*	/	/	*	*	*	/	5
Tanaka et al. [25]	*	/	*	*	**	*	*	*	8
Shimada et al. [26]	*	*	*	*	**	*	*	*	9
Enomoto et al. [27]	*	*	/	*	**	*	*	/	7
Matsushima et al. [28]	*	*	*	*	*	*	*	/	7
Chinswangwatanakul et al. [29]	*	*	*	*	**	*	*	*	9
Yang et al. [7]	*	*	*	*	**	*	*	*	9
Bae et al. [30]	*	*	/	*	**	*	*	/	7
Tajima et al. [31]	*	*	/	*	**	*	*	/	7
Kim et al. [32]	*	*	*	*	**	*	*	*	9

NOS Newcastle–Ottawa scale

There was no significant difference in mortality between the two groups. We found no significant publication bias during visual inspection of the funnel plot (Supplementary Fig. 2) or on Egger's test ($P = 0.975$) or Begg's test ($P = 0.602$).

Other outcomes

The surgical outcomes are shown in Table 5 and in Supplementary Figs. 3, 4, and 5. The operation time was shorter in the OpS group than in the LS group, and the postoperative hospital stay was shorter in the LS group than in the OpS group. The between-group differences in both outcomes were statistically significant ($P < 0.01$).

The other short-term outcomes are shown in Table 6 and in Supplementary Figs. 6, 7, 8, 9, and 10. The primary anastomosis rate was favored the LS group over OpS group (97.9% [190/194] vs. 91.2% [145/159]) and as was the stoma construction rate (5.5% [10/182] vs. 15.1% [24/159]). The between-group differences for both these outcomes were statistically significant (OR 0.23, 95% CI 0.08–0.66, $P = 0.006$ for primary anastomosis; OR 0.28, 95% CI 0.13–0.62, $P = 0.002$ for stoma construction) and without between-study heterogeneity ($\chi^2 = 1.86$, $I^2 = 0\%$, $P = 0.87$ and $\chi^2 = 2.90$, $I^2 = 0\%$, $P = 0.41$, respectively).

Postoperative anastomotic leakage, wound infection, and ileus were analyzed. The meta-analyses of wound infection demonstrated significantly favorable results in the LS group over OpS group (OR 0.42, 95% CI 0.21–0.84, $P = 0.02$) without between-study heterogeneity ($\chi^2 = 3.51$, $I^2 = 0\%$, $P = 0.94$, respectively). There was no significant between-group difference in the anastomotic leak rate (OR 0.67, 95% CI 0.31–1.45, $P = 0.31$) or in the frequency of ileus (OR 0.64, 95% CI 0.34–1.21, $P = 0.17$ for ileus). There was no between-study heterogeneity ($\chi^2 = 2.18$, $I^2 = 0\%$, $P = 0.98$, and $\chi^2 = 7.26$, $I^2 = 0\%$, $P = 0.61$, respectively).

Table 3 MINORS assessment of included studies

References	A clearly stated aim	Inclusion of consecutive patients	Prospective collection of data	End points appropriate to the aims of the study	Unbiased assessment of the study endpoint	Follow-up periods appropriate to the aim of the study	Loss to follow-up less than 5%	Prospective calculation of the study size	An adequate control group	Contemporary groups	Baseline equivalence of groups	Adequate statistical analyses	Total
Balague et al. [19]	2	2	0	1	0	0	0	0	2	2	0	0	9
Olmi et al. [20]	2	2	0	1	0	2	2	0	0	2	0	0	11
Stipa et al. [21]	2	2	0	1	0	0	0	0	1	2	0	0	8
Chung et al. [22]	2	2	0	1	0	0	0	0	2	2	2	1	12
Zhou et al. [23]	2	2	0	1	0	1	2	0	2	2	2	2	16
Watanabe et al. [24]	2	1	0	1	0	0	0	0	0	2	0	1	7
Tanaka et al. [25]	2	2	0	1	0	1	2	0	2	2	2	2	16
Shimada et al. [26]	2	2	0	1	0	1	0	0	0	2	2	2	12
Enomoto et al. [27]	2	1	0	1	0	0	0	0	2	2	2	2	12
Matsushima et al. [28]	2	2	0	1	0	0	0	0	0	2	0	0	7
Chinswangwatanakul et al. [29]	2	2	0	2	0	2	2	0	2	2	2	2	18
Yang et al. [7]	2	2	1	2	0	2	2	0	2	2	2	2	19
Bae et al. [30]	2	2	0	1	0	2	2	0	2	2	2	2	17
Tajima et al. [31]	2	1	0	1	0	0	0	0	2	2	2	2	12
Kim et al. [32]	2	2	0	2	0	2	2	0	2	2	2	2	18

MINORS methodological index for non-randomized studies

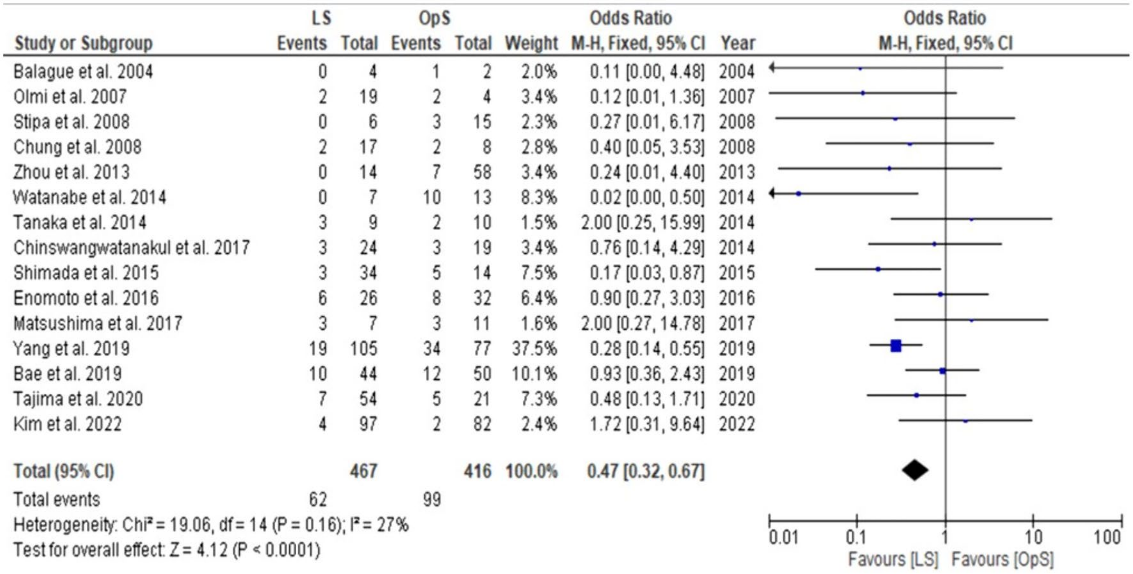
Table 4 GRADE evidence profile

Certainty assessment							Number of patients		Effect		Certainty	Importance
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	LS	OpS	Relative (95% CI)	Absolute (95% CI)		
Postoperative complications												
15	observational studies	not serious	not serious	not serious	not serious	all plausible residual confounding would reduce the demonstrated effect	62/467 (13.3%)	99/416 (23.8%)	OR 0.50 (0.31 to 0.81)	103 fewer per 1000 (from 150 to 36 fewer)	⊕⊕⊕○ Moderate	CRITICAL
Mortality												
11	observational studies	not serious	not serious	not serious	not serious	none	2/408 (0.5%)	1/329 (0.3%)	OR 1.02 (0.16 to 6.62)	0 more per 1000 (from 3 fewer to 17 more)	⊕⊕○○ Low	CRITICAL
Anastomotic leakage												
14	observational studies	not serious	not serious	not serious	not serious	none	12/370 (3.2%)	16/334 (4.8%)	OR 0.69 (0.31 to 1.52)	14 fewer per 1000 (from 33 fewer to 23 more)	⊕⊕○○ Low	IMPORTANT
Wound infection												
14	observational studies	not serious	not serious	not serious	not serious	none	11/370 (3.0%)	23/334 (6.9%)	OR 0.44 (0.21 to 0.90)	37 fewer per 1000 (from 54 to 6 fewer)	⊕⊕○○ Low	IMPORTANT
Ileus												
14	observational studies	serious	serious	not serious	not serious	all plausible residual confounding would reduce the demonstrated effect	16/370 (4.3%)	21/334 (6.3%)	OR 0.55 (0.28 to 1.10)	27 fewer per 1000 (from 45 fewer to 6 more)	⊕○○○ Very low	IMPORTANT
Stoma construction												

Table 4 (continued)

Certainty assessment							Number of patients		Effect		Certainty	Importance
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	LS	OpS	Relative (95% CI)	Absolute (95% CI)		
4	observational studies	very serious	not serious	not serious	not serious	all plausible residual confounding would reduce the demonstrated effect	10/182 (5.5%)	24/159 (15.1%)	OR 0.32 (0.14 to 0.73)	97 fewer per 1000 (from 127 to 36 fewer)	⨁◯◯◯ Very low	IMPORTANT
Primary anastomosis												
7	observational studies	very serious	not serious	not serious	not serious	all plausible residual confounding would reduce the demonstrated effect	190/194 (97.9%)	145/159 (91.2%)	OR 3.79 (1.29 to 11.17)	63 more per 1000 (from 18 to 79 more)	⨁◯◯◯ Very low	IMPORTANT
3y OS												
6	observational studies	not serious	not serious	not serious	not serious	none	191/252 (75.8%)	178/234 (76.1%)	OR 1.46 (0.87 to 2.45)	62 more per 1000 (from 26 fewer to 126 more)	⨁⨁◯◯ Low	CRITICAL
3y RFS												
4	observational studies	not serious	not serious	not serious	not serious	none	138/191 (72.3%)	126/190 (66.3%)	OR 1.28 (0.81 to 2.02)	53 more per 1000 (from 49 fewer to 136 more)	⨁⨁◯◯ Low	CRITICAL

LS laparoscopic surgery, *OpS* open surgery, *CI* confidence interval, *OR* odds ratio, *3y OS* three-year overall survival, *3y RFS* three-year recurrence-free survival

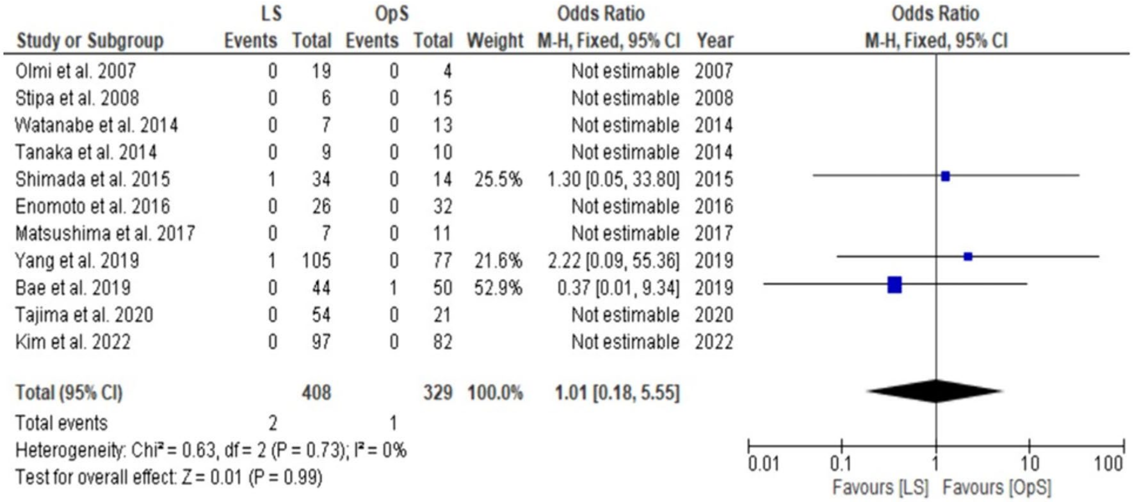


Study or Subgroup	LS Events	LS Total	OpS Events	OpS Total	Weight	Odds Ratio M-H, Fixed, 95% CI	Year
Balague et al. 2004	0	4	1	2	2.0%	0.11 [0.00, 4.48]	2004
Olmi et al. 2007	2	19	2	4	3.4%	0.12 [0.01, 1.36]	2007
Stipa et al. 2008	0	6	3	15	2.3%	0.27 [0.01, 6.17]	2008
Chung et al. 2008	2	17	2	8	2.8%	0.40 [0.05, 3.53]	2008
Zhou et al. 2013	0	14	7	58	3.4%	0.24 [0.01, 4.40]	2013
Watanabe et al. 2014	0	7	10	13	8.3%	0.02 [0.00, 0.50]	2014
Tanaka et al. 2014	3	9	2	10	1.5%	2.00 [0.25, 15.99]	2014
Chinswangwatanakul et al. 2017	3	24	3	19	3.4%	0.76 [0.14, 4.29]	2014
Shimada et al. 2015	3	34	5	14	7.5%	0.17 [0.03, 0.87]	2015
Enomoto et al. 2016	6	26	8	32	6.4%	0.90 [0.27, 3.03]	2016
Matsushima et al. 2017	3	7	3	11	1.6%	2.00 [0.27, 14.78]	2017
Yang et al. 2019	19	105	34	77	37.5%	0.28 [0.14, 0.55]	2019
Bae et al. 2019	10	44	12	50	10.1%	0.93 [0.36, 2.43]	2019
Tajima et al. 2020	7	54	5	21	7.3%	0.48 [0.13, 1.71]	2020
Kim et al. 2022	4	97	2	82	2.4%	1.72 [0.31, 9.64]	2022
Total (95% CI)		**467**		**416**	**100.0%**	**0.47 [0.32, 0.67]**	
Total events	62		99				

Heterogeneity: Chi² = 19.06, df = 14 (P = 0.16); I² = 27%

Test for overall effect: Z = 4.12 (P < 0.0001)

Fig. 2 Meta-analysis of postoperative complication rates using a fixed-effect Mantel–Haenszel model. Odds ratios are shown with 95% CIs. *CI* confidence interval, *LS* laparoscopic surgery, *OpS* open surgery



Study or Subgroup	LS Events	LS Total	OpS Events	OpS Total	Weight	Odds Ratio M-H, Fixed, 95% CI	Year
Olmi et al. 2007	0	19	0	4		Not estimable	2007
Stipa et al. 2008	0	6	0	15		Not estimable	2008
Watanabe et al. 2014	0	7	0	13		Not estimable	2014
Tanaka et al. 2014	0	9	0	10		Not estimable	2014
Shimada et al. 2015	1	34	0	14	25.5%	1.30 [0.05, 33.80]	2015
Enomoto et al. 2016	0	26	0	32		Not estimable	2016
Matsushima et al. 2017	0	7	0	11		Not estimable	2017
Yang et al. 2019	1	105	0	77	21.6%	2.22 [0.09, 55.36]	2019
Bae et al. 2019	0	44	1	50	52.9%	0.37 [0.01, 9.34]	2019
Tajima et al. 2020	0	54	0	21		Not estimable	2020
Kim et al. 2022	0	97	0	82		Not estimable	2022
Total (95% CI)		**408**		**329**	**100.0%**	**1.01 [0.18, 5.55]**	
Total events	2		1				

Heterogeneity: Chi² = 0.63, df = 2 (P = 0.73); I² = 0%

Test for overall effect: Z = 0.01 (P = 0.99)

Fig. 3 Meta-analysis of postoperative mortality rates using a fixed-effect Mantel–Haenszel model. Odds ratios are shown with 95% confidence intervals. *CI* confidence interval, *LS* laparoscopic surgery, *OpS* open surgery

Table 5 Meta-analysis of other short-term outcomes

	No. of studies	Cases	MD§	95% CI¶	*P* value	Heterogeneity χ^2	I^2 (%)	*P* value
		(LS†: OpS‡)						
Operation time	4	51: 103	48.12	42.66–53.59	*< 0.01**	3.71	19	*0.29*
Blood loss	3	47: 101	− 33.00	− 73.84–7.84	*0.11*	1.66	0	*0.44*
Postoperative hospital stay	3	44: 92	− 5.57	− 7.09–4.04	*< 0.01**	30.23	97	*< 0.01**

*Statistically significant ($P < 0.05$)

LS laparoscopic surgery, *OpS* open surgery, *MD* median difference, *CI* confidence interval

Long-term outcomes

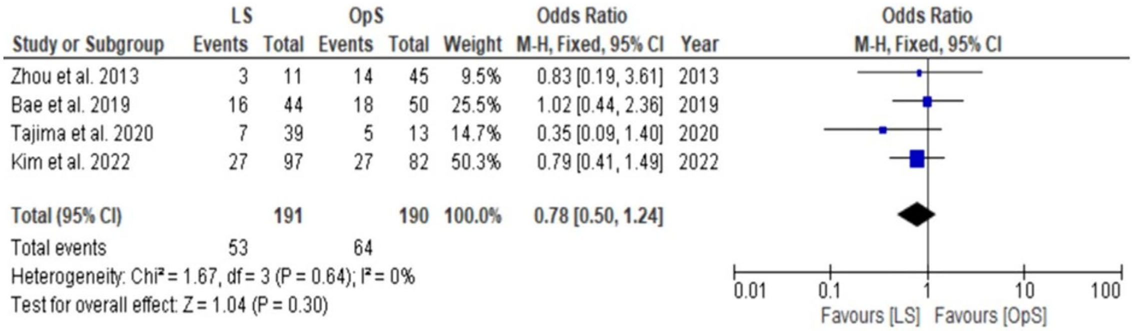
The long-term outcomes are demonstrated in Figs. 4 and 5. Four studies [23, 30–32] reported the 3-year RFS rate and six [20, 23, 29–32] reported the 3-year OS rate. Data on 3-year RFS were available for 381 patients and data on 3-year OS for 486 patients. There was no significant difference in 3-year RFS (OR 0.78, 95% CI 0.50–1.24, $P = 0.30$) or 3-year OS (OR 0.68, 95% CI 0.41–1.12, $P = 0.13$) between the LS and OpS groups or any between-study heterogeneity ($\chi^2 = 1.67$, $I^2 = 0\%$, $P = 0.30$ and $\chi^2 = 1.08$, $I^2 = 0\%$, $P = 0.90$, respectively). We found no significant publication bias in terms of either outcome by visual inspection of the funnel plot (Supplementary Figs. 11 and 12) or on Egger's test ($P = 0.509$) or Begg's test ($P = 1.00$) and Egger's test ($P = 0.299$) or Begg's test ($P = 0.142$).

Table 6 Meta-analysis of other short-term outcomes

	No. of studies	Rates % (LS†: OpS‡)	ORs§	95% CI¶	*P* value	Heterogeneity χ^2	I^2 (%)	*P* value
Primary anastomosis	7	97.9: 91.2	4.27	1.50–12.15	*0.006**	1.86	0	*0.87*
Stoma construction	4	5.5: 15.1	0.28	0.13–0.62	*0.002**	2.9	0	*0.41*
Anastomotic leakage	14	3.2: 4.8	0.67	0.31–1.45	*0.31*	2.18	0	*0.98*
Wound infection	14	3.0: 6.9	0.42	0.21–0.84	*0.02**	3.51	0	*0.94*
Ileus	14	4.3: 6.3	0.63	0.34–1.19	*0.16*	7.35	0	*0.60*

*Statistically significant ($P < 0.05$)

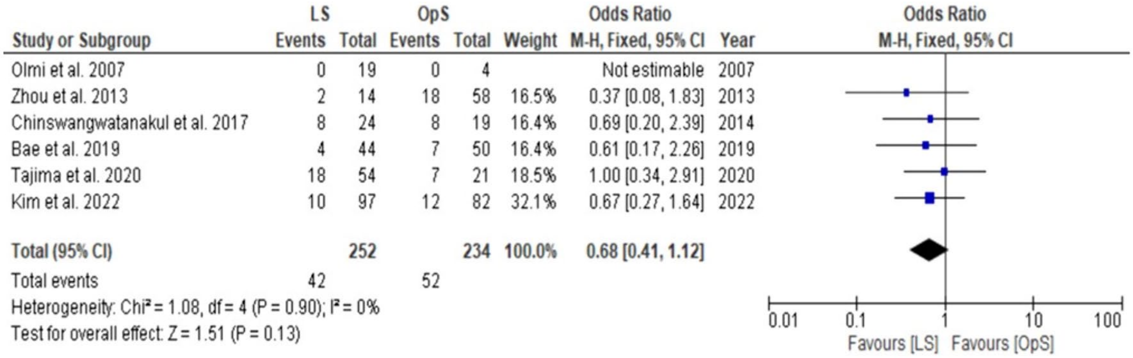
LS laparoscopic surgery, *OpS* open surgery, *OR* odds ratio, *CI* confidence interval



Study or Subgroup	LS Events	LS Total	OpS Events	OpS Total	Weight	Odds Ratio M-H, Fixed, 95% CI	Year
Zhou et al. 2013	3	11	14	45	9.5%	0.83 [0.19, 3.61]	2013
Bae et al. 2019	16	44	18	50	25.5%	1.02 [0.44, 2.36]	2019
Tajima et al. 2020	7	39	5	13	14.7%	0.35 [0.09, 1.40]	2020
Kim et al. 2022	27	97	27	82	50.3%	0.79 [0.41, 1.49]	2022
Total (95% CI)		**191**		**190**	**100.0%**	**0.78 [0.50, 1.24]**	
Total events	53		64				

Heterogeneity: Chi² = 1.67, df = 3 (P = 0.64); I² = 0%
Test for overall effect: Z = 1.04 (P = 0.30)

Fig. 4 Meta-analysis of 3-year recurrence-free survival using a fixed-effect Mantel–Haenszel model. Odds ratios are shown with 95% confidence intervals. *CI* confidence interval, *LS* laparoscopic surgery, *OpS* open surgery



Study or Subgroup	LS Events	LS Total	OpS Events	OpS Total	Weight	Odds Ratio M-H, Fixed, 95% CI	Year
Olmi et al. 2007	0	19	0	4		Not estimable	2007
Zhou et al. 2013	2	14	18	58	16.5%	0.37 [0.08, 1.83]	2013
Chinswangwatanakul et al. 2017	8	24	8	19	16.4%	0.69 [0.20, 2.39]	2014
Bae et al. 2019	4	44	7	50	16.4%	0.61 [0.17, 2.26]	2019
Tajima et al. 2020	18	54	7	21	18.5%	1.00 [0.34, 2.91]	2020
Kim et al. 2022	10	97	12	82	32.1%	0.67 [0.27, 1.64]	2022
Total (95% CI)		**252**		**234**	**100.0%**	**0.68 [0.41, 1.12]**	
Total events	42		52				

Heterogeneity: Chi² = 1.08, df = 4 (P = 0.90); I² = 0%
Test for overall effect: Z = 1.51 (P = 0.13)

Fig. 5 Meta-analysis of 3-year overall survival using a fixed-effect Mantel–Haenszel model. Odds ratios are shown with 95% confidence intervals. *CI* confidence interval, *LS* laparoscopic surgery, *OpS* open surgery

Discussion

This meta-analysis was performed to obtain an overview of the recent literature on the outcomes of laparoscopic surgery following SEMS placement for OCRC. Although several retrospective studies of laparoscopic surgery following SEMS placement have been published, there have been no RCTs to date, possibly because of the rarity of OCRC, the urgent situation at the time of initial diagnosis, and the oncological safety of BTS itself not having been established [41, 42]. Based on our present findings, an RCT comparing short-term and long-term outcomes between laparoscopic surgery and open surgery following SEMS placement for OCRC would be expected to have a 3-year RFS rate of 30% for open surgery and 20% for laparoscopic surgery. Therefore, a sample size of at least 260 would be required in each group for a statistical power of 80% and a significance level of 0.05 [15, 16]. It would be very difficult to collect such a large number of cases for an RCT. This systematic review and meta-analysis was performed to determine if laparoscopic surgery following SEMS placement is safe and effective for OCRC and drew on as much evidence as possible from previous reports in a sample of adequate size ($n = 883$).

Large-scale RCTs in patients with colon cancer have established that laparoscopic surgery decreases surgical trauma and perioperative complications, allows more rapid recovery, and has a non-inferior oncological prognosis [15–18]. However, in patients with OCRC, laparoscopic surgery following SEMS placement may be contraindicated because of the limited surgical field as a result of the distended bowel and the peculiarities of tumor size and depth. Morino et al. [13] were the first to describe use of the laparoscopic approach following SEMS placement for OCRC and concluded that the colonic segment was bulkier and more technically difficult to resect by laparoscopy. Thirteen of the studies in this meta-analysis [7, 19, 21–27, 29–32] compared baseline characteristics between an LS group and an OpS group. Although only one of the studies reported a significantly higher proportion of men in its LS group [25], there was no significant difference in background characteristics. Twelve studies analyzed data on pathological stage and found no significant between-group difference [7, 20–23, 25–27, 29–32]. However, one study excluded patients with suspected invasion of other organs from its LS group [26] and another study reported a significantly greater number of patients with pathological T4b disease in its OpS group [31]. Therefore, differences in patient characteristics in the individual studies would not be expected to have much statistical impact on our results.

Many large-scale trials have demonstrated the feasibility and safety of laparoscopic colorectal surgery, particularly a reduction in postoperative complications [15–18, 43, 44]. Our present meta-analysis found that the risk of postoperative complications was significantly lower in patients who underwent laparoscopic surgery than in those who underwent open surgery (OR 0.47, 95% CI 0.32–0.67, $P < 0.001$) after BTS for OCRC. Postoperative complications have been widely reported to have a negative oncological impact after digestive cancer surgery [45–48], and the same finding has been reported for colorectal cancer surgery. Several explanations for this finding have been suggested, including local and systemic activation of proinflammatory cytokines and mediators, delayed or canceled adjuvant chemotherapy, and abdominal implantation of intraluminal cancer cells in patients with anastomotic leakage [49–53]. A significant correlation of postoperative complications with a worse prognosis was also reported in a BTS cohort [54]. Therefore, efforts to minimize postoperative complications are important in BTS for OCRC and choice of laparoscopic surgery may be useful.

This study had several limitations. First, as with all systematic reviews, the strength of our conclusions depends on the quality of the primary studies. Unfortunately, the design and quality of the studies included in this review were not high. Furthermore, no relevant RCTs or prospective studies were available for analysis. RCTs investigating the safety and usefulness of the BTS strategy with an adequate sample size are difficult to perform because of (1) lack of evidence for its use (an RCT is currently underway in Japan) and (2) the fact that a proportion of patients with OCRC have metastasis to other organs, which makes laparoscopic surgery difficult and inevitably introduces significant bias stemming from the surgeon's level of skill and judgment. Second, there was heterogeneity between studies because of differences in sample size, pathological staging, study design, and follow-up. There was also heterogeneity in the definitions of morbidity and mortality. Moreover, there was considerable heterogeneity in long-term outcomes in terms of pathological staging and postoperative adjuvant therapy. This heterogeneity had a marked effect on our results.

In conclusion, laparoscopic surgery following placement of a SEMS for OCRC significantly reduces the postoperative complication rate. Furthermore, there were no significant differences in long-term outcomes between the two procedures. Our findings suggest that laparoscopic surgery following SEMS placement is a safe and effective treatment option for OCRC.

Disclosures

Shintaro Kanaka, Takeshi Yamada, Akihisa Matsuda, Kay Uehara, Seiichi Shinji, Yasuyuki Yokoyama, Goro Takahashi, Takuma Iwai, Kohki Takeda, Sho Kuriyama, Toshimitsu Miyasaka, and Hiroshi Yoshida have no conflicts of interest or financial ties to disclose.

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Author contributions Study concept and design: SK, TY, AM, KU, and SS. Literature search and data collection: SK and AM. Statistical analysis and interpretation of data: SK, YY, GT, TI, KT, SK, and TM. Drafting of the manuscript: SK. Revising the manuscript: AM and TY. Study supervision: TY and HY. All authors read and approved the final version of the manuscript.

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