Systematic Review and Meta-Analysis

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Procedural and post-operative complications associated with laparoscopic versus open abdominal surgery for right-sided colonic cancer resection

A systematic review and meta-analysis

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Abstract

Background: In this analysis, we aimed to systematically compare the procedural and post-operative complications (POC) associated with laparoscopic versus open abdominal surgery for right-sided colonic cancer resection.

Methods: We searched MEDLINE, http://www.ClinicalTrials.gov, EMBASE, Web of Science, Cochrane Central, and Google scholar for English studies comparing the POC in patients who underwent laparoscopic versus open surgery (OS) for right colonic cancer. Data were assessed by the Cochrane-based RevMan 5.4 software (The Cochrane Community, London, UK). Mean difference (MD) with 95% confidence intervals (CIs) were used to represent the results for continuous variables, whereas risk ratios (RR) with 95% CIs were used for dichotomous data.

Results: Twenty-six studies involving a total number of 3410 participants with right colonic carcinoma were included in this analysis. One thousand five hundred and fifteen participants were assigned to undergo invasive laparoscopic surgery whereas 1895 participants were assigned to the open abdominal surgery. Our results showed that the open resection was associated with a shorter length of surgery (MD: 48.63, 95% CI: 30.15–67.12; $P=.00001$) whereas laparoscopic intervention was associated with a shorter hospital stay [MD (–3.09), 95% CI [–5.82 to (–0.37)]; $P=.03$]. In addition, POC such as anastomotic leak (RR: 0.96, 95% CI: 0.60–1.55; $P=.88$), abdominal abscess (RR: 1.13, 95% CI: 0.52–2.49; $P=.75$), pulmonary embolism (RR: 0.40, 95% CI: 0.09–1.69; $P=.21$) and deep vein thrombosis (RR: 0.94, 95% CI: 0.39–2.28; $P=.89$) were not significantly different. Paralytic ileus (RR: 0.87, 95% CI: 0.67–1.11; $P=.26$), intra-abdominal infection (RR: 0.82, 95% CI: 0.15–4.48; $P=.82$), pulmonary complications (RR: 0.83, 95% CI: 0.57–1.20; $P=.32$), cardiac complications (RR: 0.73, 95% CI: 0.42–1.27; $P=.27$) and urological complications (RR: 0.83, 95% CI: 0.52–1.33; $P=.44$) were also similarly manifested. Our analysis also showed 30-day re-admission and re-operation, and mortality to be similar between laparoscopic versus OS for right colonic carcinoma resection. However, surgical wound infection (RR: 0.65, 95% CI: 0.50–0.86; $P=.002$) was significantly higher with the OS.

Conclusions: In conclusion, laparoscopic surgery was almost comparable to OS in terms of post-operative outcomes for right-sided colonic cancer resection and was not associated with higher unwanted outcomes. Therefore, laparoscopic intervention should be considered as safe as the open abdominal surgery for right-sided colonic cancer resection, with a decreased hospital stay.

Abbreviations: CI = confidence intervals, LS = laparoscopic surgery, MD = mean difference, OS = open surgery, POC = post-operative complications, RR = risk ratios.

Keywords: anastomotic leak, colon cancer, hospital stay, ileus, laparoscopic surgery, open surgery, post-operative complications, risk ratios

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YSL and FCM contributed equally to this work and are the co-first authors.

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The datasets generated during and/or analyzed during the current study are publicly available.

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1. Introduction

Colon cancer is among the most common cancers occurring in both men and women and resection is the only way to cure this condition.[1] Previously, large abdominal incisions were carried out to remove colon cancers. However, advance in medical technology has made laparoscopic resection possible. Laparoscopic colectomy was first introduced in the year 1991[2] and soon after, it became a better option for patients with colon cancers who required surgical intervention.

Even though laparoscopic colon resection has well been accepted for the treatment of left and transverse colon cancer, this was not the case with right colon cancer. In fact, due to the complexity of right colon laparoscopic anatomy and variable vascular peduncles that might require a greater laparoscopic experience than left colon and rectum surgery, many surgeons considered laparoscopic approach to right colon a useless and a complete waste of time.[3] However, fortunately different laparoscopic hybrid procedures including total laparoscopic right colectomy,[4] single incision laparoscopic surgery (LS) for right colon,[5] laparoscopic assisted right colectomy,[6] hand-assisted right colectomy with laparoscopic mobilization of colon by hand to the right side,[7] which have been developed to facilitate the intervention for right colonic cancers.

An editorial proved that laparoscopic right hemicolectomy for colon cancer is technically feasible and safe to be carried out in terms of oncological outcomes.[8] However, because the study included outcomes of a single surgery, the author stated that further studies with a larger sample size might be able to better prove the significance of laparoscopic right hemicolectomy.

In this analysis, we aimed to systematically compare the procedural and post-operative complications (POC) associated with laparoscopic versus open abdominal surgery for right-sided colonic cancer resection.

2. Methods

2.1. Search databases and search strategies

We searched MEDLINE, http://www.ClinicalTrials.gov, EMBASE, Web of Science, Cochrane Central, and Google scholar for English studies comparing the POC in patients who underwent laparoscopic versus open abdominal surgery for right colonic cancer.

We used the following searched terms and phrases during this database searched process:

- laparoscopic versus open surgery (OS) for colon cancer;
- laparoscopic versus OS for right colon cancer;
- laparoscopic versus OS for right colonic carcinoma;
- laparoscopic versus open AND right colon cancer;
- invasive versus open abdominal surgery for colon cancer.

Table 1

Complications which were reported in the previous studies.

Studies	Post-operative complications reported
Abdel 2010[12]	Chest infection, DVT, PE, ACS, hemorrhage, Anastomotic leak, wound infection, 30-d re-operation, 30-d re-admission, mortality
Guida 2015[13]	Anastomotic leak, occlusion, abdominal abscess, surgical site/wound infection, mortality
Habib 2016[14]	In-hospital mortality
Khan 2011[15]	Mortality, 30-d re-operation, 30-d re-admission
Li 2012[16]	Anastomotic leakage, abdominal abscess, chest infection, respiratory failure, congestive heart failure, arrhythmia, transient ischemic attack, confusion, renal failure, urinary tract infection, urinary retention, prolong fever, paralytic ileus, deep vein thrombosis, wound infection, re-operation, mortality
Quyn 2013[17]	Wound infection, pneumonia, ileus, urinary infection, cardiac event, anastomotic leak, re-operation, mortality
Tong 2007[18]	Cardiac complication, pulmonary complication, urological complication, DVT, wound complications, anastomotic leakage, ileus, intra-abdominal sepsis
Wang 2018[19]	Ileus, re-admission, 30-d mortality
Zhao 2014[20]	Wound infection, ileus, anastomotic leak, anastomotic stenosis, intra-abdominal hemorrhage, abdominal infection, PE, mortality
Zheng 2005[21]	Massive hemorrhage, anastomotic leak, pulmonary infection, urinary tract infection, wound infection, ileus
Daniel 2007[18]	Wound complication, anastomotic leakage, ileus, intra-abdominal sepsis
Kahokehr 2010[22]	UTI, wound infection, ileus, urinary retention, anastomotic leak, DVT, cardiopulmonary
Baker 2004[23]	Anastomotic leak, UTI, pneumonia, hemorrhage, ileus, wound infection
Leung 1999[24]	Anastomotic leak, pneumonia, DVT, heart failure, wound infection, UTI, death
Nakamura 2009[25]	Wound infection, ileus, postoperative bleeding
Odermatt 2013[26]	Wound infection, anastomotic leak, abscess, bleeding
Alkhamesi 2011[27]	Wound infection, ileus, anastomotic leak
Stulberg 2009[28]	Wound infection, abscess, DVT, UTI, pneumonia, PE, mortality, re-admission, re-operation
Koh 2013[29]	Ileus, wound complication, pulmonary complication, UTI, re-operation
Han 2014[30]	Death, wound infection, pulmonary infection, UTI, urine retention, ileus, anastomotic leak
Tanis 2012[31]	Re-operation, re-admission
Li 2015[32]	Wound infection, pulmonary infection, UTI, urine retention, anastomotic leak, mortality
Ng 2008[33]	Pulmonary embolism, wound infection, MI, chest infection, UTI, urinary retention, ileus, mortality
Lezoche 2002[34]	Anastomotic leak, ileus, mortality
Bokey 1996[35]	Wound infection, UTI, pneumonia, cardiac, DVT, PE
Tan 2009[36]	Wound infection, intra-abdominal abscess, cardiac complication, respiratory complication

ACS = acute coronary syndrome, DVT = deep vein thrombosis, MI = myocardial infarction, PE = pulmonary embolism, UTI = urinary tract infection.

2.2. Inclusion and exclusion criteria

Inclusion criteria consisted of studies that:

- compared laparoscopic versus open abdominal surgery for right colonic carcinoma;
- reported POC following surgical interventions;
- were published in English language.

Exclusion criteria consisted of studies that:

- did not compare laparoscopic versus open abdominal surgery for right colonic carcinoma;
- involved other colon carcinoma apart from right colonic cancers;
- did not report any POC;
- were published in a different language apart from English;
- consisted only of an abstract; the full-text article was not available;
- were repeated studies which were obtained from different search databases.

2.3. Endpoints to be assessed in this analysis

Table 1 lists the post-operative outcomes which were reported in the original studies.

The endpoints which were assessed in this analysis included:

(a) Duration time period of surgical intervention;
(b) length of hospital stay;
(c) anastomotic leak;
(d) surgical wound infection;
(e) abdominal abscess;
(f) pulmonary embolism;
(g) deep vein thrombosis;
(h) paralytic ileus;
(i) intra-abdominal infection;
(j) pulmonary complications involving complications related to the lungs such as pulmonary embolism, chest infection, respiratory failure;
(k) cardiac complications involving complications related to the heart such as acute coronary syndrome, arrhythmia, heart failure;

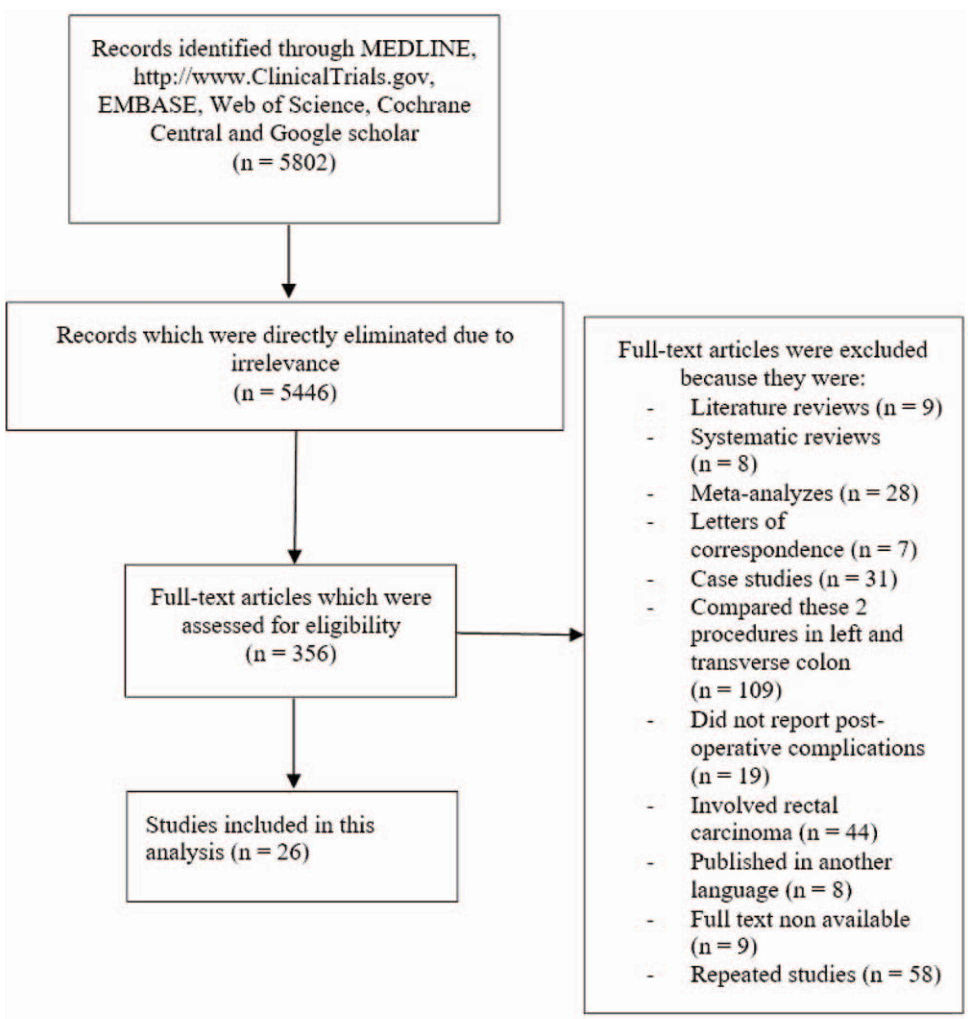


Figure 1. Flow diagram showing the study selection.

Table 2

General features of the studies.

Studies	Type of study	Participants' enrollment time period (yr)	No of participants assigned to laparoscopic group (n)	No of participants assigned to open surgery group (n)	Bias risk grade
Abdel 2010[12]	OS	2003–2007	22	34	B
Guida 2015[13]	OS	2007–2012	17	24	B
Habib 2016[14]	OS	2012–2015	48	17	B
Khan 2011[15]	OS	2006–2007	89	75	B
Li 2012[16]	RCT	1996–2005	71	74	B
Quyn 2013[17]	OS	2006–2011	81	125	B
Tong 2007[18]	OS	2000–2004	77	105	B
Wang 2018[19]	OS	2013–2017	86	90	B
Zhao 2014[20]	OS	2000–2009	119	101	B
Zheng 2005[21]	OS	2000–2003	30	34	B
Daniel 2007[18]	OS	2000–2004	77	105	B
Kahokehr 2010[22]	OS	2005–2008	39	74	B
Baker 2004[23]	OS	1993–2000	33	66	B
Leung 1999[24]	OS	1993–1997	28	56	B
Nakamura 2009[25]	OS	1996–1999	100	100	B
Odermatt 2013[26]	OS	2006–2011	36	72	B
Alkhamesi 2011[27]	OS	2005–2010	148	322	B
Stulberg 2009[28]	OS	2005–2008	40	25	B
Koh 2013[29]	OS	2006–2011	23	23	B
Han 2014[30]	OS	2003–2010	177	147	B
Tanis 2012[31]	OS	2006–2009	30	55	B
Li 2015[32]	OS	2013	10	25	B
Ng 2008[33]	OS	2003–2006	14	29	B
Lezoche 2002[34]	OS	1992–2000	55	44	B
Bokey 1996[35]	OS	1992–1994	28	33	B
Tan 2009[36]	OS	2005–2007	37	40	B
Total No of participants (n)			1515	1895	

OS = observational study, RCT = randomized controlled trial.

Table 3

Baseline features of the participants.

Studies	Age (yr) Lap/Open	Males (%) Lap/Open	Hospital stay Lap/Open	BMI (kg/m^2) Lap/Open
Abdel 2010[12]	77.5/76.0	22.7/64.7	6.0/10.0 d	26.9/26.0
Guida 2015[13]			7.0/8.5 d	
Habib 2016[14]	69.1/70.0	60.0/68.0	6.0/7.8 d	
Khan 2011[15]	76.0/74.0	42.0/55.0	4.0/8.0 d	26.0/26.0
Li 2012[16]	68.0/68.0	46.5/43.2	7.8/10 d	
Quyn 2013[17]	78.0/79.0	54.3/49.6	9.6/11.2 d	
Tong 2007[18]	71.3/71.6	41.5/49.5	6.0/7.0 d	
Wang 2018[19]	63.5/64.2	60.5/62.2	5.5/6.8 d	22.3/21.9
Zhao 2014[20]	61.3/64.5	55.5/56.4	11.4/12.8 d	22.3/22.6
Zheng 2005[21]	60.2/60.0	53.3/58.8	13.9/18.2 d	
Daniel 2007[18]	71.2/71.6	41.5/49.5	6.00/7.00 d	
Kahokehr 2010[22]	73.0/72.0	48.0/32.0	7.00/6.00 d	26.0/26.9
Baker 2004[23]	69.7/69.7		9.90/12.8 d	
Leung 1999[24]	69.6/65.0	53.6/53.6		
Nakamura 2009[25]	64.0/65.0	65.0/65.0		22.0/22.0
Odermatt 2013[26]	74.0/74.0	41.7/53.6		24.0/25.0
Alkhamesi 2011[27]	64.9/67.6	54.1/41.6		
Stulberg 2009[28]	61.5/60.1	42.0/44.0	7.90/11.3 d	27.5/26.0
Koh 2013[29]	60.0/58.0	56.5/56.5		
Han 2014[30]	67.0/65.0	46.9/54.4	10.4/16.9 d	
Tanis 2012[31]	75.0/73.5	40.0/42.0	6.00/7.50 d	25.0/24.5
Li 2015[32]	64.5/62.3	60.0/52.0	7.00/9.00 d	22.2/22.3
Ng 2008[33]	68.5/71.0	42.9/48.3	7.00/9.00 d	21.1/20.7
Lezoche 2002[34]	66.6/66.8	51.0/50.0	9.20/13.2 d	
Bokey 1996[35]				
Tan 2009[36]	68.0/67.0	51.0/55.0	–	23.5/22.9

BMI = body mass index, Lap = laparoscopic surgery, Open = open abdominal surgery.

(l) urological complications including conditions such as urinary tract infections, and urinary retention;
(m) 30-day re-admission;
(n) 30-day re-operation;
(o) mortality.

2.4. Data extraction and quality assessment

Data including the duration time period of the surgical intervention, the length of hospital stay, the number of events reported for POC, the type of study, the participants' enrollment time period, the total number of participants who were assigned to the laparoscopic and open abdominal surgical interventions respectively, the baseline characteristics including the median age, the percentage of male participants, the body mass index value, and features describing the methodological quality of the studies were carefully extracted by 3 independent authors.

Any disagreement was referred to the corresponding author for further consideration. It was the responsibility of the corresponding author to take the final decision.

The Newcastle Ottawa Scale[9] and the Cochrane collaboration[10] were the tools used to assess the methodological quality of the studies for observational cohorts and randomized trials respectively. Grades (A, B, or C) representing low, moderate and high risk of bias was then allotted to the respective studies.

2.5. Statistical analysis

Throughout the analysis, the Cochrane-based RevMan 5.4 software (The Cochrane Community, London, UK) was used to assess the data.

Since continuous data (mean and standard deviation) were used to report for the duration time period of surgery and the mean length of hospital stay, mean difference (MD) with 95% confidence intervals (CIs) were used to represent the results.

Dichotomous data were used to report the POC. Therefore, risk ratios (RR) with 95% CIs were used to represent the results.

Heterogeneity was assessed by the Q statistic test. Results representing a P value equals to or less than .05 were considered statistically significant. The I^2 statistic test was also used to assess for heterogeneity. The larger the I^2 value, the larger the heterogeneity. In addition, based on this heterogeneity value, either a fixed or a random statistic model was applied respectively.

Sensitivity analysis was carried out by excluding each of the studies, 1 at a time and a new analysis was carried out each time and was compared with the main results of this study. Also, publication bias was estimated through a visual assessment of the funnel plots.

2.6. Ethical approval

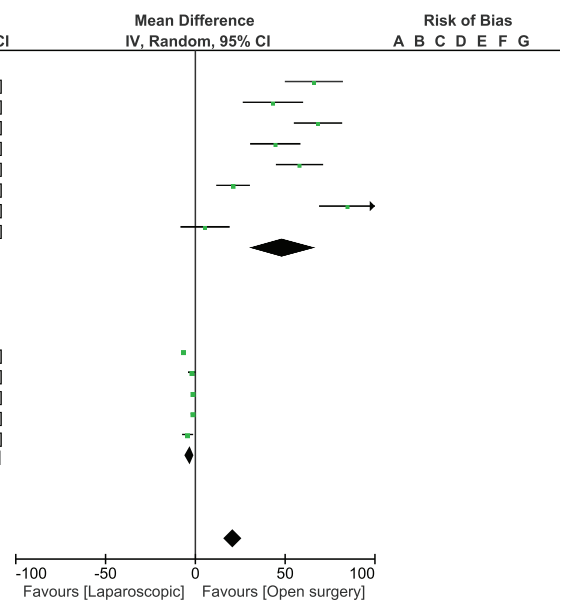
Ethical approval or compliance with ethical guidelines was not required for systematic reviews and meta-analyses.

3. Results

3.1. Search database outcomes

Our search resulted with over 5500 articles (5802 more precisely). The PRISMA reporting guideline was used.[11] The 3 authors carefully assessed the titles to see if they matched with the scope of this research paper. If title of the publications were irrelevant, they were directly eliminated (4128). The authors also carefully assessed the abstracts of the remaining articles (1674).

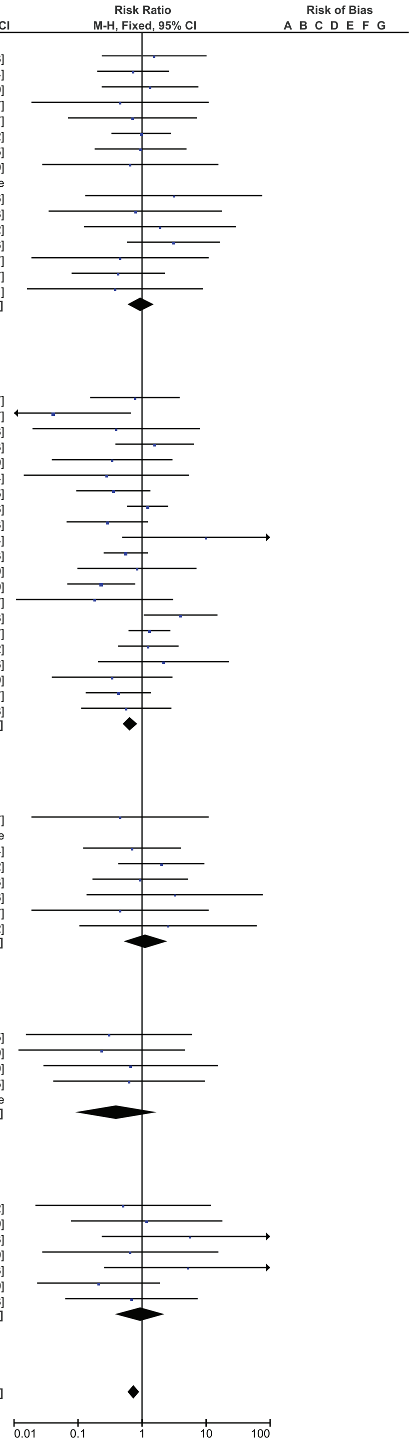
	Laparoscopic			Open surgery				Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
2.1.1 Duration of surgical intervention								
Kahokehr2010	161	44	39	95	37	74	5.2%	66.00 [49.82, 82.18]
Leung1999	191.8	34.5	28	148.6	41.7	56	5.0%	43.20 [26.39, 60.01]
Li2012	198	48	71	129.7	33	74	6.2%	68.30 [54.84, 81.76]
Li2015	186.5	18.4	10	142	20.8	25	6.0%	44.50 [30.48, 58.52]
Quyn2013	197	53	81	139	36	125	6.3%	58.00 [44.85, 71.15]
Wang2018	159	35	86	138	28	90	7.9%	21.00 [11.61, 30.39]
Zhao2014	257.8	67.6	119	173.1	52	101	5.3%	84.70 [68.88, 100.52]
Zheng2005	152.65	28.29	30	147.25	27.5	34	6.1%	5.40 [-8.31, 19.11]
Subtotal (95% CI)			**464**			**579**	**48.0%**	**48.63 [30.15, 67.12]**
Heterogeneity: Tau² = 659.14; Chi² = 102.90, df = 7 (P < 0.00001); I² = 93%								
Test for overall effect: Z = 5.16 (P < 0.00001)								
2.1.2 Duration of Hospital stay								
Han2014	10.4	2.7	177	16.9	4.3	147	10.5%	-6.50 [-7.30, -5.70]
Li2015	7	2.5	10	9	3.6	25	10.4%	-2.00 [-4.10, 0.10]
Wang2018	5.5	3.7	86	6.8	4.3	90	10.5%	-1.30 [-2.48, -0.12]
Zhao2014	11.4	4.7	119	12.8	5.6	101	10.5%	-1.40 [-2.78, -0.02]
Zheng2005	13.94	6.53	30	18.25	5.96	34	10.2%	-4.31 [-7.39, -1.23]
Subtotal (95% CI)			**422**			**397**	**52.0%**	**-3.09 [-5.82, -0.37]**
Heterogeneity: Tau² = 8.81; Chi² = 74.55, df = 4 (P < 0.00001); I² = 95%								
Test for overall effect: Z = 2.22 (P = 0.03)								
Total (95% CI)			**886**			**976**	**100.0%**	**21.06 [15.85, 26.27]**
Heterogeneity: Tau² = 67.08; Chi² = 564.10, df = 12 (P < 0.00001); I² = 98%								
Test for overall effect: Z = 7.92 (P < 0.00001)								
Test for subgroup differences: Chi² = 29.44, df = 1 (P < 0.00001), I² = 96.6%								



Risk of bias legend
(**A**) Random sequence generation (selection bias)
(**B**) Allocation concealment (selection bias)
(**C**) Blinding of participants and personnel (performance bias)
(**D**) Blinding of outcome assessment (detection bias)
(**E**) Incomplete outcome data (attrition bias)
(**F**) Selective reporting (reporting bias)
(**G**) Other bias

Figure 2. Length duration of surgical intervention and hospital stay between laparoscopic and open abdominal surgery for right colon cancer.

Study or Subgroup	Laparoscopic surgery Events	Laparoscopic surgery Total	Open surgery Events	Open surgery Total	Weight	Risk Ratio M-H, Fixed, 95% CI
1.1.1 Anastomotic leak						
Abdel2010	2	22	2	34	0.9%	1.55 [0.23, 10.18]
Alkhamesi2011	3	148	9	322	3.1%	0.73 [0.20, 2.64]
Baker2004	2	33	3	66	1.1%	1.33 [0.23, 7.59]
Daniel2007	0	77	1	105	0.7%	0.45 [0.02, 10.97]
Guida2015	1	17	2	24	0.9%	0.71 [0.07, 7.17]
Han2014	7	177	6	147	3.6%	0.97 [0.33, 2.82]
Kahokehr2010	2	39	4	74	1.5%	0.95 [0.18, 4.95]
Leung1999	0	28	1	56	0.6%	0.66 [0.03, 15.59]
Lezoche2002	0	55	0	44		Not estimable
Li2012	1	71	0	74	0.3%	3.13 [0.13, 75.46]
Li2015	0	10	1	25	0.5%	0.79 [0.03, 17.88]
Odermatt2013	1	30	1	57	0.4%	1.90 [0.12, 29.32]
Quyn2013	4	81	2	125	0.9%	3.09 [0.58, 16.46]
Tong2007	0	77	1	105	0.7%	0.45 [0.02, 10.97]
Zhao2014	2	119	4	101	2.4%	0.42 [0.08, 2.27]
Zheng2005	0	30	1	34	0.8%	0.38 [0.02, 8.91]
Subtotal (95% CI)		**1014**		**1393**	**18.3%**	**0.96 [0.60, 1.55]**
Total events	25		38			
Heterogeneity: Chi² = 5.01, df = 14 (P = 0.99); I² = 0%						
Test for overall effect: Z = 0.15 (P = 0.88)						
1.1.2 Surgical wound infection						
Abdel2010	2	22	4	34	1.7%	0.77 [0.15, 3.87]
Alkhamesi2011	0	148	26	322	9.2%	0.04 [0.00, 0.67]
Baker2004	0	33	2	66	0.9%	0.39 [0.02, 7.98]
Bokey1996	4	28	3	33	1.5%	1.57 [0.38, 6.43]
Daniel2007	1	77	4	105	1.9%	0.34 [0.04, 2.99]
Guida2015	0	17	2	24	1.2%	0.28 [0.01, 5.44]
Han2014	3	177	7	147	4.2%	0.36 [0.09, 1.35]
Kahokehr2010	9	39	14	74	5.3%	1.22 [0.58, 2.56]
Koh2013	2	23	7	23	3.9%	0.29 [0.07, 1.23]
Leung1999	2	28	0	56	0.2%	9.83 [0.49, 198.04]
Li2012	8	71	15	74	8.1%	0.56 [0.25, 1.23]
Li2015	1	10	3	25	0.9%	0.83 [0.10, 7.09]
Nakamura2009	3	100	13	100	7.2%	0.23 [0.07, 0.79]
Ng2008	0	14	5	29	2.0%	0.18 [0.01, 3.07]
Odermatt2013	6	36	3	72	1.1%	4.00 [1.06, 15.08]
Quyn2013	11	81	13	125	5.6%	1.31 [0.62, 2.77]
Stulberg2009	8	40	4	25	2.7%	1.25 [0.42, 3.72]
Tan2009	2	37	1	40	0.5%	2.16 [0.20, 22.86]
Tong2007	1	77	4	105	1.9%	0.34 [0.04, 2.99]
Zhao2014	4	119	8	101	4.8%	0.42 [0.13, 1.37]
Zheng2005	2	30	4	34	2.1%	0.57 [0.11, 2.88]
Subtotal (95% CI)		**1207**		**1614**	**66.9%**	**0.65 [0.50, 0.86]**
Total events	69		142			
Heterogeneity: Chi² = 31.36, df = 20 (P = 0.05); I² = 36%						
Test for overall effect: Z = 3.06 (P = 0.002)						
1.1.3 Abdominal abscess						
Daniel2007	0	77	1	105	0.7%	0.45 [0.02, 10.97]
Guida2015	0	17	0	24		Not estimable
Li2012	2	71	3	74	1.6%	0.69 [0.12, 4.04]
Odermatt2013	3	36	3	72	1.1%	2.00 [0.42, 9.42]
Stulberg2009	3	40	2	25	1.4%	0.94 [0.17, 5.23]
Tan2009	1	37	0	40	0.3%	3.24 [0.14, 77.06]
Tong2007	0	77	1	105	0.7%	0.45 [0.02, 10.97]
Zhao2014	1	119	0	101	0.3%	2.55 [0.11, 61.92]
Subtotal (95% CI)		**474**		**546**	**6.0%**	**1.13 [0.52, 2.49]**
Total events	10		10			
Heterogeneity: Chi² = 2.17, df = 6 (P = 0.90); I² = 0%						
Test for overall effect: Z = 0.31 (P = 0.75)						
1.1.4 Pulmonary embolism						
Abdel2010	0	22	2	34	1.1%	0.30 [0.02, 6.05]
Bokey1996	0	28	2	33	1.3%	0.23 [0.01, 4.69]
Ng2008	0	14	1	29	0.6%	0.67 [0.03, 15.40]
Stulberg2009	1	40	1	25	0.7%	0.63 [0.04, 9.55]
Zhao2014	0	119	0	101		Not estimable
Subtotal (95% CI)		**223**		**222**	**3.6%**	**0.40 [0.09, 1.69]**
Total events	1		6			
Heterogeneity: Chi² = 0.36, df = 3 (P = 0.95); I² = 0%						
Test for overall effect: Z = 1.25 (P = 0.21)						
1.1.5 Deep Vein Thrombosis						
Abdel2010	0	22	1	34	0.7%	0.51 [0.02, 11.92]
Bokey1996	1	28	1	33	0.5%	1.18 [0.08, 17.99]
Kahokehr2010	1	39	0	74	0.2%	5.63 [0.23, 134.93]
Leung1999	0	28	1	56	0.6%	0.66 [0.03, 15.59]
Li2012	2	71	0	74	0.3%	5.21 [0.25, 106.63]
Stulberg2009	1	40	3	25	2.0%	0.21 [0.02, 1.89]
Tong2007	1	77	2	105	0.9%	0.68 [0.06, 7.38]
Subtotal (95% CI)		**305**		**401**	**5.2%**	**0.94 [0.39, 2.28]**
Total events	6		8			
Heterogeneity: Chi² = 4.54, df = 6 (P = 0.60); I² = 0%						
Test for overall effect: Z = 0.14 (P = 0.89)						
Total (95% CI)		**3223**		**4176**	**100.0%**	**0.75 [0.60, 0.92]**
Total events	111		204			
Heterogeneity: Chi² = 45.02, df = 53 (P = 0.77); I² = 0%						
Test for overall effect: Z = 2.68 (P = 0.007)						
Test for subgroup differences: Chi² = 4.08, df = 4 (P = 0.40), I² = 1.9%						



Risk of bias legend
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(**F**) Selective reporting (reporting bias)
(**G**) Other bias

Figure 3. Post-operative outcomes between laparoscopic versus open surgery for right colon cancer (part I).

Study or Subgroup	Laparoscopic surgery Events	Laparoscopic surgery Total	Open surgery Events	Open surgery Total	Weight	Risk Ratio M-H, Fixed, 95% CI
1.1.1 Paralytic Ileus						
Alkhamesi2011	17	148	31	322	8.3%	1.19 [0.68, 2.09]
Baker2004	0	33	3	66	1.0%	0.28 [0.01, 5.29]
Daniel2007	5	77	2	105	0.7%	3.41 [0.68, 17.11]
Han2014	3	177	5	147	2.3%	0.50 [0.12, 2.05]
Kahokehr2010	2	39	3	74	0.9%	1.26 [0.22, 7.26]
Koh2013	4	23	7	23	3.0%	0.57 [0.19, 1.69]
Lezoche2002	1	55	0	44	0.2%	2.41 [0.10, 57.77]
Li2012	2	71	3	74	1.3%	0.69 [0.12, 4.04]
Nakamura2009	7	100	20	100	8.5%	0.35 [0.15, 0.79]
Ng2008	3	14	1	29	0.3%	6.21 [0.71, 54.50]
Quyn2013	6	81	5	125	1.7%	1.85 [0.58, 5.87]
Tong2007	5	77	2	105	0.7%	3.41 [0.68, 17.11]
Wang2018	22	86	37	90	15.4%	0.62 [0.40, 0.96]
Zhao2014	4	119	4	101	1.8%	0.85 [0.22, 3.31]
Zheng2005	1	30	0	34	0.2%	3.39 [0.14, 80.15]
Subtotal (95% CI)		**1130**		**1439**	**46.5%**	**0.87 [0.67, 1.11]**
Total events	82		123			
Heterogeneity: Chi² = 21.66, df = 14 (P = 0.09); I² = 35%						
Test for overall effect: Z = 1.12 (P = 0.26)						
1.1.2 Intra-abdominal infection						
Daniel2007	0	77	1	105	0.5%	0.45 [0.02, 10.97]
Tong2007	0	77	1	105	0.5%	0.45 [0.02, 10.97]
Zhao2014	1	119	0	101	0.2%	2.55 [0.11, 61.92]
Subtotal (95% CI)		**273**		**311**	**1.3%**	**0.82 [0.15, 4.48]**
Total events	1		2			
Heterogeneity: Chi² = 0.75, df = 2 (P = 0.69); I² = 0%						
Test for overall effect: Z = 0.23 (P = 0.82)						
1.1.3 Pulmonary complications						
Abdel2010	2	22	5	34	1.7%	0.62 [0.13, 2.91]
Alkhamesi2011	7	148	13	322	3.5%	1.17 [0.48, 2.88]
Baker2004	1	33	3	66	0.9%	0.67 [0.07, 6.16]
Bokey1996	6	28	5	33	2.0%	1.41 [0.48, 4.14]
Han2014	2	177	11	147	5.1%	0.15 [0.03, 0.67]
Koh2013	4	23	1	23	0.4%	4.00 [0.48, 33.12]
Leung1999	1	28	2	56	0.6%	1.00 [0.09, 10.56]
Li2012	0	71	3	74	1.5%	0.15 [0.01, 2.83]
Li2015	1	10	2	25	0.5%	1.25 [0.13, 12.29]
Ng2008	0	14	5	29	1.6%	0.18 [0.01, 3.07]
Quyn2013	9	81	8	125	2.7%	1.74 [0.70, 4.31]
Stulberg2009	2	40	3	25	1.6%	0.42 [0.07, 2.32]
Tan2009	1	37	0	40	0.2%	3.24 [0.14, 77.06]
Tong2007	2	77	4	105	1.4%	0.68 [0.13, 3.63]
Zheng2005	2	30	3	34	1.2%	0.76 [0.14, 4.22]
Subtotal (95% CI)		**819**		**1138**	**24.7%**	**0.83 [0.57, 1.20]**
Total events	40		68			
Heterogeneity: Chi² = 15.32, df = 14 (P = 0.36); I² = 9%						
Test for overall effect: Z = 1.00 (P = 0.32)						
1.1.4 Cardiac complications						
Abdel2010	0	22	2	34	0.8%	0.30 [0.02, 6.05]
Bokey1996	7	28	7	33	2.7%	1.18 [0.47, 2.95]
Kahokehr2010	1	39	4	74	1.2%	0.47 [0.05, 4.10]
Leung1999	1	26	0	56	0.1%	6.33 [0.27, 150.43]
Li2012	0	71	5	74	2.3%	0.09 [0.01, 1.68]
Ng2008	1	14	4	29	1.1%	0.52 [0.06, 4.21]
Quyn2013	3	81	4	125	1.3%	1.16 [0.27, 5.04]
Tan2009	1	37	1	40	0.4%	1.08 [0.07, 16.67]
Tong2007	2	77	5	105	1.8%	0.55 [0.11, 2.74]
Subtotal (95% CI)		**395**		**570**	**11.9%**	**0.73 [0.42, 1.27]**
Total events	16		32			
Heterogeneity: Chi² = 5.93, df = 8 (P = 0.66); I² = 0%						
Test for overall effect: Z = 1.11 (P = 0.27)						
1.1.5 Urological complications						
Baker2004	2	33	1	66	0.3%	4.00 [0.38, 42.53]
Bokey1996	2	28	4	33	1.6%	0.59 [0.12, 2.98]
Daniel2007	0	77	2	105	0.9%	0.27 [0.01, 5.58]
Han2014	4	177	3	147	1.4%	1.11 [0.25, 4.87]
Kahokehr2010	5	39	7	74	2.1%	1.36 [0.46, 3.99]
Koh2013	1	23	1	23	0.4%	1.00 [0.07, 15.04]
Leung1999	0	26	1	56	0.4%	0.70 [0.03, 16.71]
Li2012	5	71	9	74	3.8%	0.58 [0.20, 1.64]
Li2015	0	10	3	25	0.9%	0.34 [0.02, 6.00]
Ng2008	0	14	6	29	1.8%	0.15 [0.01, 2.55]
Quyn2013	3	81	3	125	1.0%	1.54 [0.32, 7.46]
Stulberg2009	4	40	2	25	1.1%	1.25 [0.25, 6.33]
Zheng2005	0	30	0	34		Not estimable
Subtotal (95% CI)		**649**		**816**	**15.6%**	**0.83 [0.52, 1.33]**
Total events	26		42			
Heterogeneity: Chi² = 6.41, df = 11 (P = 0.84); I² = 0%						
Test for overall effect: Z = 0.77 (P = 0.44)						
Total (95% CI)		**3266**		**4274**	**100.0%**	**0.84 [0.70, 1.00]**
Total events	165		267			
Heterogeneity: Chi² = 49.72, df = 53 (P = 0.60); I² = 0%						
Test for overall effect: Z = 1.98 (P = 0.05)						
Test for subgroup differences: Chi² = 0.31, df = 4 (P = 0.99), I² = 0%						

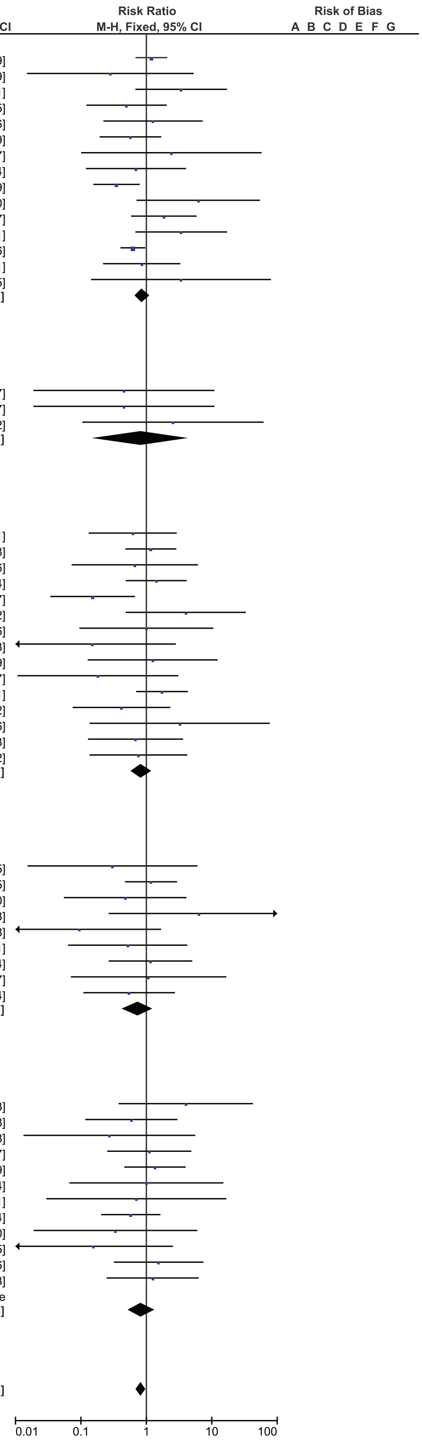

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Figure 4. Post-operative outcomes between laparoscopic versus open surgery for right colon cancer (part II).

The abstracts were checked for relevant data and outcomes. Any abstract that did not report the relevant data or outcomes were eliminated (1318).

Only, 356 full text articles were assessed for eligibility. Further eliminations were carried out based on the inclusion and exclusion criteria:

Literature review (9), systematic reviews (8), meta-analyses (28), letters of correspondence (7), case studies (31), compared laparoscopic versus open abdominal surgery of left or transverse colon (109), did not report the POC (19), involved rectal carcinoma (44), published in another language (8), full-text was not available (9), repeated studies (58).

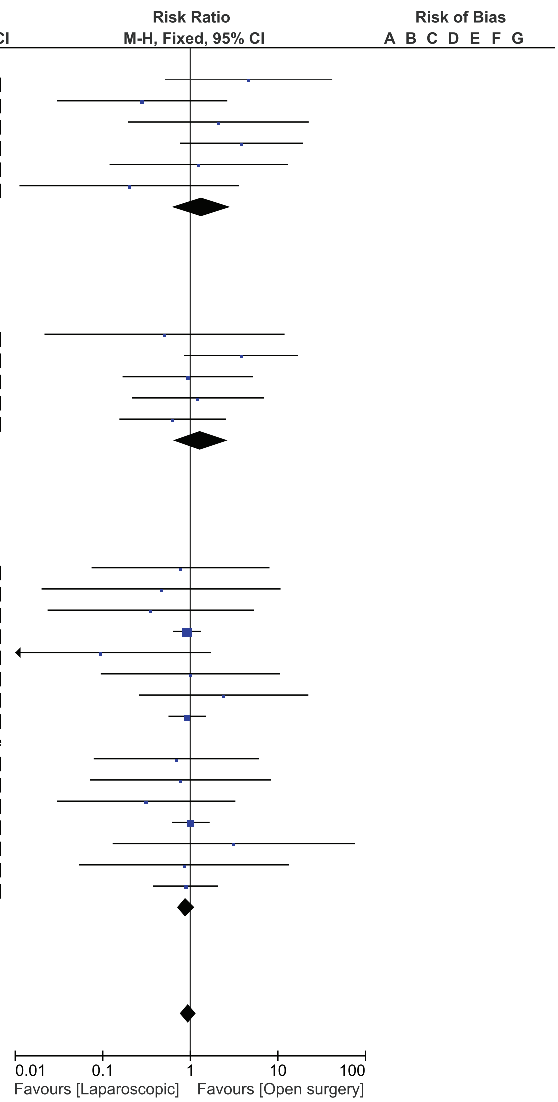
Finally only 26 studies[12–36] were included in this meta-analysis. The flow diagram for the study selection has been shown in Figure 1.

3.2. Characteristics of the studies and participants

Twenty-six studies involving a total number of 3410 participants with right colonic cancer were included in this analysis. One thousand five hundred and fifteen participants were assigned to undergo invasive LS whereas 1895 participants were assigned to the open abdominal surgery as shown in Table 2. The participants were enrolled between the years 1992 to 2017. Most of the studies were observational cohorts.

The studies were allotted a bias grade B denoting moderate risk following a methodological assessment.

Study or Subgroup	Laparoscopic surgery Events	Laparoscopic surgery Total	Open surgery Events	Open surgery Total	Weight	Risk Ratio M-H, Fixed, 95% CI
1.1.1 30-day re-operation						
Abdel2010	3	22	1	34	0.6%	4.64 [0.51, 41.79]
Khan2011	1	89	3	75	2.3%	0.28 [0.03, 2.64]
Li2012	2	71	1	74	0.7%	2.08 [0.19, 22.48]
Quyn2013	5	81	2	125	1.1%	3.86 [0.77, 19.41]
Stulberg2009	2	40	1	25	0.9%	1.25 [0.12, 13.08]
Tanis2012	0	30	4	55	2.3%	0.20 [0.01, 3.61]
Subtotal (95% CI)		**333**		**388**	**7.9%**	**1.35 [0.63, 2.86]**
Total events	13		12			
Heterogeneity: Chi² = 6.52, df = 5 (P = 0.26); I² = 23%						
Test for overall effect: Z = 0.77 (P = 0.44)						
1.1.2 30-day re-admission						
Abdel2010	0	22	1	34	0.9%	0.51 [0.02, 11.92]
Khan2011	9	89	2	75	1.6%	3.79 [0.85, 17.01]
Stulberg2009	3	40	2	25	1.8%	0.94 [0.17, 5.23]
Tanis2012	2	30	3	55	1.5%	1.22 [0.22, 6.91]
Wang2018	3	86	5	90	3.5%	0.63 [0.15, 2.55]
Subtotal (95% CI)		**267**		**279**	**9.2%**	**1.31 [0.64, 2.68]**
Total events	17		13			
Heterogeneity: Chi² = 3.48, df = 4 (P = 0.48); I² = 0%						
Test for overall effect: Z = 0.74 (P = 0.46)						
1.1.3 Mortality						
Abdel2010	1	22	2	34	1.1%	0.77 [0.07, 8.02]
Guida2015	0	17	1	24	0.9%	0.46 [0.02, 10.73]
Habib2016	1	48	1	17	1.1%	0.35 [0.02, 5.36]
Han2014	44	177	40	147	31.3%	0.91 [0.63, 1.32]
Khan2011	0	89	4	75	3.5%	0.09 [0.01, 1.72]
Leung1999	1	28	2	56	1.0%	1.00 [0.09, 10.56]
Lezoche2002	3	55	1	44	0.8%	2.40 [0.26, 22.28]
Li2012	19	59	23	66	15.5%	0.92 [0.56, 1.52]
Li2015	0	10	0	25		Not estimable
Ng2008	1	14	3	29	1.4%	0.69 [0.08, 6.06]
Quyn2013	1	81	2	125	1.1%	0.77 [0.07, 8.37]
Stulberg2009	1	40	2	25	1.8%	0.31 [0.03, 3.27]
Tong2007	20	77	27	105	16.3%	1.01 [0.61, 1.66]
Wang2018	1	86	0	90	0.3%	3.14 [0.13, 75.99]
Zhao2014	1	119	1	101	0.8%	0.85 [0.05, 13.40]
Zheng2005	7	30	9	34	6.0%	0.88 [0.37, 2.08]
Subtotal (95% CI)		**952**		**997**	**82.9%**	**0.89 [0.71, 1.12]**
Total events	101		118			
Heterogeneity: Chi² = 5.42, df = 14 (P = 0.98); I² = 0%						
Test for overall effect: Z = 1.00 (P = 0.32)						
Total (95% CI)		**1552**		**1664**	**100.0%**	**0.96 [0.78, 1.19]**
Total events	131		143			
Heterogeneity: Chi² = 16.93, df = 25 (P = 0.88); I² = 0%						
Test for overall effect: Z = 0.34 (P = 0.73)						
Test for subgroup differences: Chi² = 1.91, df = 2 (P = 0.38), I² = 0%						



Risk of bias legend
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(**G**) Other bias

Figure 5. Post-operative outcomes between laparoscopic versus open surgery for right colon cancer (part III).

Table 4

Main results of this analysis.

Post-operative complications	RR with 95% CI	*P* values	I^2 (%)
Anastomotic leak	0.96 [0.60–1.55]	.88	0
Surgical wound infection	0.65 [0.50–0.86]	.002	36
Abdominal abscess	1.13 [0.52–2.49]	.75	0
Pulmonary embolism	0.40 [0.09–1.69]	.21	0
Deep vein thrombosis	0.94 [0.39–2.28]	.89	0
Paralytic ileus	0.87 [0.67–1.11]	.26	35
Intra-abdominal infection	0.82 [0.15–4.48]	.82	0
Pulmonary complications	0.83 [0.57–1.20]	.32	9
Cardiac complications	0.73 [0.42–1.27]	.27	0
Urological complications	0.83 [0.52–1.33]	.44	0
30-d re-admission	1.31 [0.64–2.68]	.46	0
30-d re-operation	1.35 [0.63–2.86]	.44	23
Mortality	0.89 [0.71–1.12]	.32	0
Other endpoints	**MD with 95% CI**	***P* values**	**I^2 (%)**
Duration of surgical intervention	48.63 [30.15–67.12]	.00001	93
Length of hospital stay	–3.09 [-5.82 to (–0.37)]	.03	95

CI = confidence intervals, MD = mean difference, RR = risk ratios.

Table 3 lists the baseline features as well as the number of days of hospital stay.

3.3. Analysis of the procedural length and POC associated with laparoscopic versus OS for right-sided colon carcinoma

Our results showed that the OS for right-sided colonic cancer was associated with a shorter length of surgery (MD: 48.63, 95% CI: 30.15–67.12; $P=.00001$) as shown in Figure 2. However, laparoscopic intervention was associated with a shorter hospital stay [MD (–3.09), 95% CI [–5.82 to (–0.37)]; $P=.03$] as shown in Figure 2.

When the POC were compared between laparoscopic versus OS for right colonic cancer resection, anastomotic leak (RR: 0.96, 95% CI: 0.60–1.55; $P=.88$), abdominal abscess (RR: 1.13, 95% CI: 0.52–2.49; $P=.75$), pulmonary embolism (RR: 0.40, 95% CI: 0.09–1.69; $P=.21$) and deep vein thrombosis (RR: 0.94, 95% CI: 0.39–2.28; $P=.89$) were not significantly different as shown in Figure 3. However, surgical wound infection (RR: 0.65, 95% CI: 0.50–0.86; $P=.002$) was significantly higher with the OS.

Paralytic ileus (RR: 0.87, 95% CI: 0.67–1.11; $P=.26$), intra-abdominal infection (RR: 0.82, 95% CI: 0.15–4.48; $P=.82$), pulmonary complications (RR: 0.83, 95% CI: 0.57–1.20; $P=.32$), cardiac complications (RR: 0.73, 95% CI: 0.42–1.27; $P=.27$) and urological complications (RR: 0.83, 95% CI: 0.52–1.33; $P=.44$) were similarly manifested as shown in Figure 4.

Our analysis also showed 30-day re-admission (RR: 1.31, 95% CI: 0.64–2.68; $P=.46$), 30-day re-operation (RR: 1.35, 95% CI:

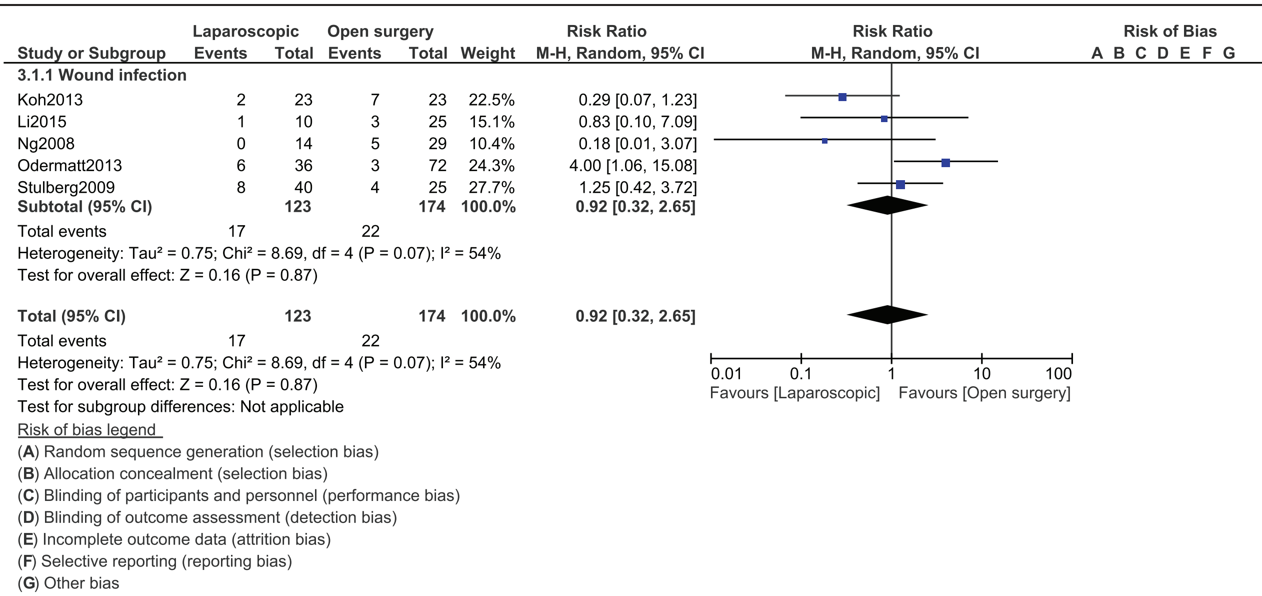


Figure 6. Post-operative outcomes for emergency laparoscopic versus open surgery for right colon cancer (part I).

0.63–2.86; $P=.44$), and mortality (RR: 0.89, 95% CI: 0.71–1.12; $P=.32$) to be similar between laparoscopic versus OS for right colonic cancer resection as shown in Figure 5.

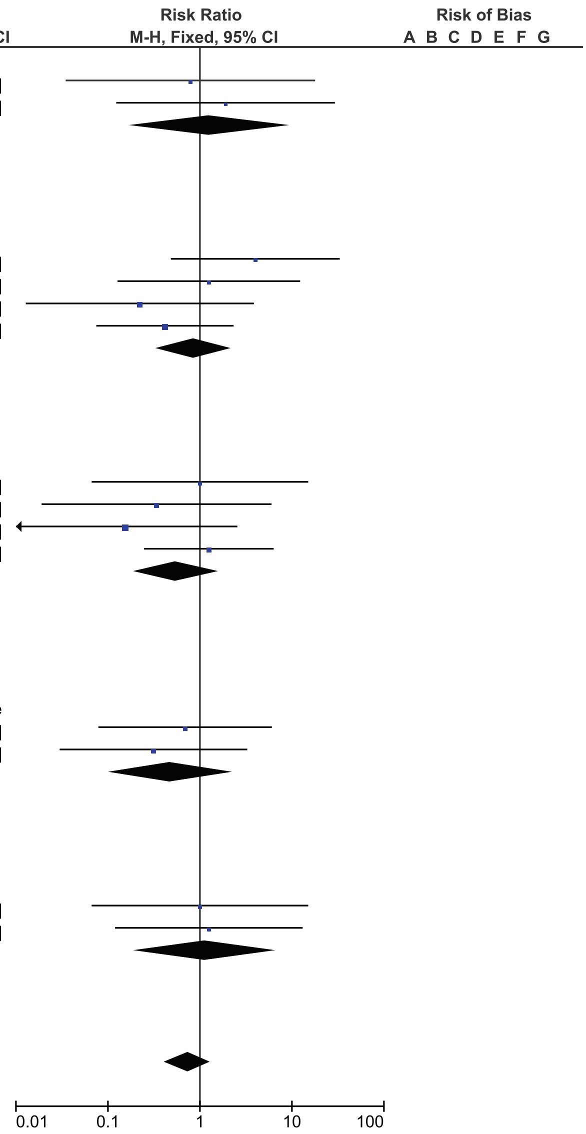
The results were summarized in Table 4.

3.4. A subgroup analysis of participants who underwent emergency surgery for right-sided colonic cancer resection

We also carried out a subgroup analysis showing the POC associated with emergency laparoscopic versus OS for right-sided colon carcinoma. Our results showed that wound infection (RR: 0.92, 95% CI: 0.32–2.65; $P=.87$) was similar in both groups as shown in Figure 6. In addition, anastomotic leak (RR: 1.27, 95% CI: 0.17–9.51; $P=.81$), pulmonary complications (RR: 0.86, 95% CI: 0.34–2.21; $P=.76$), urological complications (RR: 0.55, 95% CI: 0.19–1.62; $P=.28$), mortality (RR: 0.48, 95% CI: 0.10–2.29; $P=.36$) and re-operation (RR: 1.14, 95% CI: 0.19–6.70; $P=.89$) were also similarly manifested as shown in Figure 7.

Consistent results involving procedural duration time, length of hospital stay, and POC were obtained throughout

Study or Subgroup	Laparoscopic Events	Laparoscopic Total	Open surgery Events	Open surgery Total	Weight	Risk Ratio M-H, Fixed, 95% CI
3.1.1 Anastomotic leak						
Li2015	0	10	1	25	3.3%	0.79 [0.03, 17.88]
Odermatt2013	1	30	1	57	2.6%	1.90 [0.12, 29.32]
Subtotal (95% CI)		**40**		**82**	**5.9%**	**1.27 [0.17, 9.51]**
Total events	1		2			
Heterogeneity: Chi² = 0.17, df = 1 (P = 0.68); I² = 0%						
Test for overall effect: Z = 0.24 (P = 0.81)						
3.1.2 Pulmonary complications						
Koh2013	4	23	1	23	3.7%	4.00 [0.48, 33.12]
Li2015	1	10	2	25	4.2%	1.25 [0.13, 12.29]
Ng2008	0	14	4	29	11.1%	0.22 [0.01, 3.86]
Stulberg2009	2	40	3	25	13.7%	0.42 [0.07, 2.32]
Subtotal (95% CI)		**87**		**102**	**32.8%**	**0.86 [0.34, 2.21]**
Total events	7		10			
Heterogeneity: Chi² = 3.68, df = 3 (P = 0.30); I² = 18%						
Test for overall effect: Z = 0.31 (P = 0.76)						
3.1.3 Urological complications						
Koh2013	1	23	1	23	3.7%	1.00 [0.07, 15.04]
Li2015	0	10	3	25	7.7%	0.34 [0.02, 6.00]
Ng2008	0	14	6	29	16.1%	0.15 [0.01, 2.55]
Stulberg2009	4	40	2	25	9.1%	1.25 [0.25, 6.33]
Subtotal (95% CI)		**87**		**102**	**36.7%**	**0.55 [0.19, 1.62]**
Total events	5		12			
Heterogeneity: Chi² = 2.07, df = 3 (P = 0.56); I² = 0%						
Test for overall effect: Z = 1.08 (P = 0.28)						
3.1.4 Mortality						
Li2015	0	10	0	25		Not estimable
Ng2008	1	14	3	29	7.3%	0.69 [0.08, 6.06]
Stulberg2009	1	40	2	25	9.1%	0.31 [0.03, 3.27]
Subtotal (95% CI)		**64**		**79**	**16.4%**	**0.48 [0.10, 2.29]**
Total events	2		5			
Heterogeneity: Chi² = 0.24, df = 1 (P = 0.63); I² = 0%						
Test for overall effect: Z = 0.92 (P = 0.36)						
3.1.5 Re-operation						
Koh2013	1	23	1	23	3.7%	1.00 [0.07, 15.04]
Stulberg2009	2	40	1	25	4.6%	1.25 [0.12, 13.08]
Subtotal (95% CI)		**63**		**48**	**8.3%**	**1.14 [0.19, 6.70]**
Total events	3		2			
Heterogeneity: Chi² = 0.01, df = 1 (P = 0.90); I² = 0%						
Test for overall effect: Z = 0.14 (P = 0.89)						
Total (95% CI)		**341**		**413**	**100.0%**	**0.73 [0.41, 1.30]**
Total events	18		31			
Heterogeneity: Chi² = 6.93, df = 13 (P = 0.91); I² = 0%						
Test for overall effect: Z = 1.06 (P = 0.29)						
Test for subgroup differences: Chi² = 1.19, df = 4 (P = 0.88), I² = 0%						



Risk of bias legend
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Figure 7. Post-operative outcomes for emergency laparoscopic versus open surgery for right colon cancer (part II).

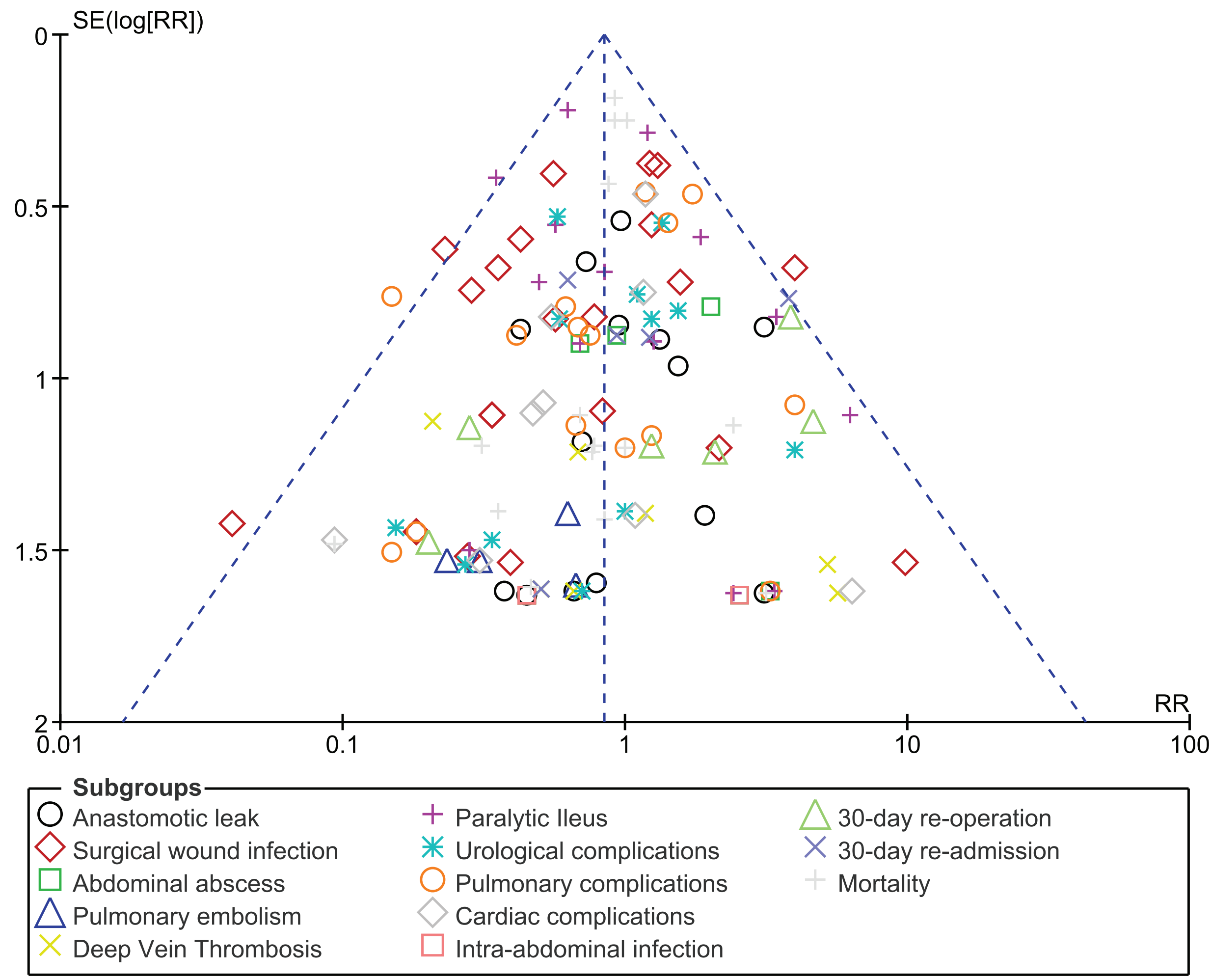

Figure 8. Funnel plot showing publication bias.

following sensitivity analyses. No deviation was observed from the main results. In addition, the funnel plot was symmetrical indicating a low evidence of publication bias among the studies which assessed these POC as shown in Figure 8.

4. Discussion

Based on the results of this analysis, it was observed that laparoscopic intervention for right colon cancer was equally effective and safe compared to the open abdominal surgery and was not associated with higher POC except for surgical wound infection which was significantly higher in the OS group. Anastomotic leak, abdominal abscess, pulmonary embolism, deep vein thrombosis, paralytic ileus, intra-abdominal infection, other pulmonary, cardiac, and urological complications were similarly observed with both interventions. In addition, the length of hospital stay following LS was shorter compared to the open surgical intervention. However, it was more time consuming compared to the open abdominal surgery.

Pulmonary embolism and deep vein thrombosis have often been common POC especially for those patients who require strict bed rest for a longer duration of time post operatively. LS is associated with a short hospital stay which could allow the patient to better mobilize sooner after the surgery, and could be a better advantage to reduce the risk of any pulmonary embolism[37] or deep vein thrombosis.[38] In addition, smaller abdominal incisions are done in laparoscopic surgeries which would allow a rapid healing time, and lesser chances for surgical wound infections[39] when compared to the open abdominal surgeries for right-sided colon carcinoma.

A recent systematic review and meta-analysis showed LS to have similar intraoperative and postoperative recovery parameters compared to the open surgical procedure.[40] The analysis even showed that duration of surgery was longer with the laparoscopic technique. However, advantages included a shorter hospital stay, minimal intraoperative blood loss, and shorter length of incision.

Another systematic review and meta-analysis showed LS to be associated with a similar survival rate compared to the OS again supporting the results of this current analysis.[41] However, the authors stated that OS was associated with more harvest of affected lymph nodes but they are not sure whether this was clinically significant. The authors also stated that surgeons should always be prepared for the conversion of laparoscopic to open abdominal surgery.

Our analysis was based on patients with right colon cancer. A retrospective cohort study[42] using data identified from the Ontario Cancer Registry and physician billing data between January 2010 and December 2014 showed that patients who underwent LS were most likely to be from urban areas, and have undergone planned surgeries, and to have minimal local tumor invasions compared to those undergoing OS. However, there was no significant difference in post discharge symptoms. In addition, other systematic reviews and meta-analyses have also been published.[43,44]

Even though this current analysis showed no significant difference in POC between laparoscopic resection versus OS for right colon cancers, another study,[30] which aimed to investigate the applicability, safety, short term, and long term outcomes of laparoscopic versus open resection for the treatment of right colon cancer with D3 lymphadenectomy, showed that even if both operative techniques were effective and safe, the laparoscopic-assisted right hemicolectomy with D3 lymphadenectomy was also superior in terms of short term outcomes. Also, several developments are continually being done for the management of right-sided colonic disease including robotic right hemicolectomy which apparently could show positive outcomes.[45] However, it would be vital to also consider the costs of these new robotic, laparoscopic and open abdominal surgeries.[46–48]

4.1. Limitations

We have described the limitations as follow: Due to the inclusion of a total number of only 3410 participants, the results might have to be confirmed in larger studies with far more participants. Another limitation could be the fact that the co-morbidities prior to surgery was ignored. Moreover, many endpoints were not reported in all the original studies, and therefore, several subgroups assessing different POC included only a minimum number of studies which could be another limitation of this analysis. Another limitation could be the fact that most of the studies which were included in this analysis were observation cohorts (90%). The original studies were researches carried out in different hospitals from different parts of the world with differences in hospital settings and peri-operative care. This might have had an impact on the outcomes. At last, nowadays there are immense improvements in operative techniques, operative equipment and hospital operative settings when compared to previous years. This variation in previous and recent hospital set ups and improved technologies might also be another limitation of this analysis.

5. Conclusions

In conclusion, LS was almost comparable to OS in terms of post-operative outcomes for right-sided colonic cancer resection and was not associated with higher unwanted outcomes. Therefore, laparoscopic intervention should be considered as safe as the open abdominal surgery for right-sided colonic cancer resection, with a decreased hospital stay.

Author contributions

The authors Yong Sheng Li, Fan Chun Meng and Jun Kai Lin were responsible for the conception and design, acquisition of data, analysis and interpretation of data, drafting the initial manuscript, and revising it critically for important intellectual content. Yong Sheng Li and Fan Chun Meng are the first co-authors and they wrote this manuscript, agreed and approved it as it is.

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