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The impact of conversion on the risk of major complication following laparoscopic colonic surgery: an international, multicentre prospective audit

The 2017 and 2015 European Society of Coloproctology (ESCP) collaborating groups

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Abstract

Background Laparoscopy has now been implemented as a standard of care for elective colonic resection around the world. During the adoption period, studies showed that conversion may be detrimental to patients, with poorer outcomes than both laparoscopic completed or planned open surgery. The primary aim of this study was to determine whether laparoscopic conversion was associated with a higher major complication rate than planned open surgery in contemporary, international practice.

Methods Combined analysis of the European Society of Coloproctology 2017 and 2015 audits. Patients were included if they underwent elective resection of a colonic segment from the caecum to the rectosigmoid junction with primary anastomosis. The primary outcome measure was the 30-day major complication rate, defined as Clavien-Dindo grade III-V.

Results Of 3980 patients, 64% (2561/3980) underwent laparoscopic surgery and a laparoscopic conversion rate of 14% (359/2561). The major complication rate was highest after open surgery (laparoscopic 7.4%, converted 9.7%, open 11.6%, $P < 0.001$). After case mix adjustment in a multilevel model, only planned open (and not laparoscopic converted) surgery was associated with increased major complications in comparison to laparoscopic surgery (OR 1.64, 1.27–2.11, $P < 0.001$).

Conclusions Appropriate laparoscopic conversion should not be considered a treatment failure in modern practice. Conversion does not appear to place patients at increased risk of complications *vs* planned open surgery, supporting broadening of selection criteria for attempted laparoscopy in elective colonic resection.

Keywords Colon cancer, rectal cancer, gastrointestinal surgery, laparoscopic surgery, surgery

What does this paper add to the literature?

In modern international practice, 64% of elective colonic resections are started laparoscopically and 14.7% are converted to open. Laparoscopic conversion does not place patients at increased risk of complications when compared to planned open surgery, suggesting colorectal surgeons select patients appropriately for laparoscopic surgery and can convert appropriately. This supports laparoscopy as the primary approach for colonic resection in modern post-implementation practice.

Introduction

Minimally invasive approaches for colonic resection are now incorporated into clinical practice in many settings [1]. A number of major international randomised trials (COST, CLASSICC, COLOR I, ALCCaS) have described the safety, feasibility and benefits of laparoscopic segmental resection including reduced intraoperative blood loss, faster return of bowel function and reduced length of stay, without compromise to oncological outcomes [2–7].

Published studies in the initial period of adoption of laparoscopy suggested that patients who undergo conversion from laparoscopic to open surgery had more short-term infections complications (although oncologically equitable resections) than procedures completed laparoscopically, or those who had planned open surgery [5,8–10]. Since many units have now overcome unit-level learning curves, performance may have changed in terms of indications for conversion, rate of conversion and outcomes when conversion occurs. Following the IDEAL framework for surgical

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innovation, up-to-date, multicentre 'surveillance' is required to assess the safety and penetrance of laparoscopic colonic resection in contemporary practice (IDEAL stage 4), and to support further roll-out of laparoscopic surgery for novel indications and into new settings.

The primary aim of this study was to determine whether laparoscopic conversion was associated with a higher major complication rate than planned open surgery. Our hypothesis was that after adjusted for case-mix, laparoscopic conversion may have a favourable complication profile to primary open surgery within modern post-implementation practice.

Methods

Protocol and centres

This study combines patients from the 2015 ESCP right hemicolectomy audit and the 2017 ESCP left-sided colorectal resection audit, conducted according to pre-specified protocols (http://www.escp.eu.com/research/cohort-studies). Any unit performing elective gastrointestinal surgery was eligible to register to enter patients into the study. No minimum case volume, or centre-specific limitations were specified. Study protocols were disseminated to registered members of the European Society of Coloproctology (ESCP), and through national surgical and colorectal societies, including the European Crohn's and Colitis Organisation.

Patient eligibility

Patients included in this pre-planned analysis were adults (≥ 16 years) undergoing elective segmental colectomy from the caecum to the rectosigmoid colon with a single, primary anastomosis. Open, laparoscopic, and laparoscopic-converted procedures were all included. Patients having robotic or robotic-converted procedures were excluded. Operations with multiple (> 1) anastomoses were excluded, as were resections including the rectum, those with formation of end colostomy without restoration of gastrointestinal continuity (e.g. Hartmann's procedure) or multivisceral resections. Patients undergoing more extensive resection such as subtotal colectomy or panproctocolectomy were excluded. Both operations for malignant and benign indications were eligible.

Data capture

For right-sided colonic resections, patients were captured over a 6-week period between 15 January 2015 and 15 April 2015. For left-sided colonic resections, patients were included over an 8 week period between 1 February 2017 and 10 May 2017. Teams of up to five surgeons and surgical trainees worked collaboratively to collect prospective data on all consecutive eligible patients at each centre. All teams included at least one consultant or attending-level surgeon to quality assure data collection. Data was entered contemporaneously on to a secure, user-encrypted online platform (NetSolving and REDCap for 2015 and 2017 audits respectively) without using patient identifiable information. Centres were asked to validate that all eligible patients during the study period had been entered, and to attain > 95% completeness of data field entry prior to final submission. Laparoscopic conversion was described as unplanned extension of the primary laparotomy incision, or a secondary laparotomy incision, created intraoperatively for any purpose other than specimen extraction or exteriorization (i.e. to form an anastomosis).

Outcome measure

The primary outcome measure was the postoperative major complication rate, defined as Clavien-Dindo classification grade 3–5 (reoperation, reintervention, unplanned admission to critical care, organ support requirement or death). The secondary outcome measures were (1) overall anastomotic leak, pre-defined as either (i) gross anastomotic leakage proven radiologically or clinically, or (ii) the presence of an intraperitoneal (abdominal or pelvic) fluid collection on postoperative imaging.

Statistical analysis

This report has been prepared in accordance to guidelines set by the STROBE (strengthening the reporting of observational studies in epidemiology) [11] statement for observational studies. Patient, disease and operative characteristics were compared using Student's *t*-test for normal, continuous data, Mann-Whitney *U* test for non-normal continuous data or Chi-squared test for categorical data. To test the association between the major complications and the main explanatory variables of interest (laparoscopic completed, laparoscopic converted, and open surgery), a mixed-effects logistic regression model was fitted. Clinically plausible patient, disease and operation-specific factors were entered into the model for risk-adjustment, treated as fixed effects. These were defined *a priori* within the study protocol and included irrespective of their significance on univariate analysis. The treating hospital were entered into the model as a random-effect, to adjust for hospital-level variation in outcome. Similar models were created to assess associations with the secondary outcome measures (anastomotic leak and laparoscopic conversion). Effect estimates are presented as odds ratios (OR) with 95% confidence intervals (95% CI) and two-tailed *P*-values. An alpha level of 0.05 was used throughout. Data analysis was undertaken using R STUDIO V3.1.1 (R Foundation, Boston, Massachusetts, USA).

Ethical approval

All participating centres were responsible for compliance to local approval requirements for ethics approval or indemnity as required. In the UK, the National Research Ethics Service tool recommended that this project was not classified as research, and the protocol was registered as clinical audit in all participating centres.

Results

Patients and centres

In this study, 3980 patients, from 566 centres across 48 countries underwent an elective colonic resection (Fig. 1). 1419 (36%) received planned open surgery and 2561 (64%) had their procedures started laparoscopically. Of these laparoscopic operations, 359 required conversion to open surgery, resulting in a conversion rate of 14.7% (Fig. 2).

Compared to those who underwent a planned open resection, laparoscopic converted patients were older (converted *vs* open; 35.9% *vs* 29.7% aged 70–80 years), more likely to be male (60.7% *vs* 51.1%), have a low ASA grade (65.2% *vs* 56.0%), be obese (26.5% *vs* 20.2%) and were less likely to have a history of ischaemic heart disease/cerebrovascular accident (15.9% *vs* 21.7%).

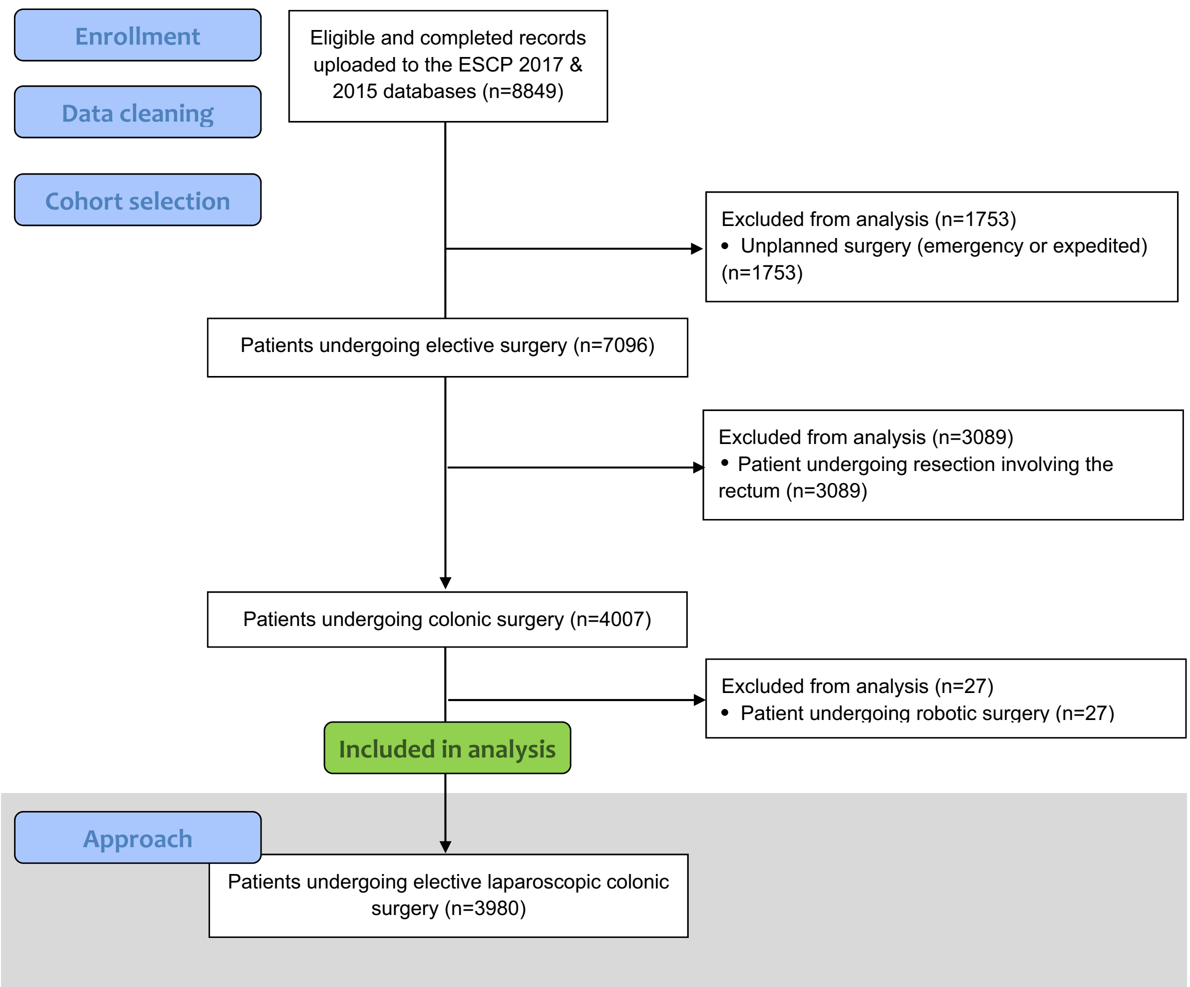

Figure 1 Flowchart for patients included in the analysis of elective, laparoscopic colonic surgery.

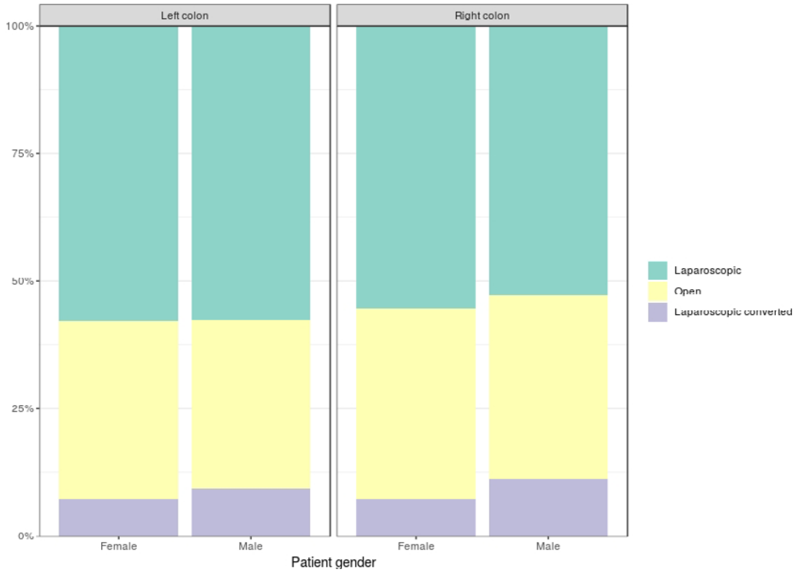

Figure 2 Selection of operative approach by patient gender and location of resection.

Compared to those who underwent a completed laparoscopic resection, patients that required a laparoscopic conversion were older (converted *vs* laparoscopic; 16.7% *vs* 14.2% aged > 80 years), more likely to be male (60.7% *vs* 51.5%), have a high ASA grade (ASA 3 to 5; 34.5% *vs* 27.3%) and be obese (26.5% *vs* 21.3%; Table 1).

Table 1 Patient and disease characteristics of patients undergoing segmental colonic resection by approach.

Factor	Levels	Open	Laparoscopic converted	*P* -value	Laparoscopic	Laparoscopic converted	*P* -value
Age	< 55	227 (16.0)	60 (16.7)	0.032	450 (88.2)	60 (11.8)	0.001
	55–70	497 (35.0)	109 (30.4)		807 (88.1)	109 (11.9)	
	70–80	421 (29.7)	129 (35.9)		633 (83.1)	129 (16.9)	
	> 80	274 (19.3)	60 (16.7)		312 (83.9)	60 (16.1)	
Gender	Female	694 (48.9)	141 (39.3)	0.001	1067 (88.3)	141 (11.7)	0.001
	Male	725 (51.1)	218 (60.7)		1135 (83.9)	218 (16.1)	
ASA class	Low risk (ASA 1–2)	794 (56.0)	234 (65.2)	0.006	1596 (87.2)	234 (12.8)	0.017
	High risk (ASA 3–5)	622 (43.8)	124 (34.5)		602 (82.9)	124 (17.1)	
BMI	Normal weight	511 (36.0)	104 (29.0)	0.047	745 (87.8)	104 (12.2)	0.032
	Underweight	59 (4.2)	13 (3.6)		44 (77.2)	13 (22.8)	
	Overweight	498 (35.1)	131 (36.5)		820 (86.2)	131 (13.8)	
	Obese	287 (20.2)	95 (26.5)		468 (83.1)	95 (16.9)	
History of IHD/CVA	No	1111 (78.3)	302 (84.1)	0.015	1835 (85.9)	302 (14.1)	0.709
	Yes	308 (21.7)	57 (15.9)		367 (86.6)	57 (13.4)	
History of diabetes mellitus	No	1183 (83.4)	301 (83.8)	0.345	1871 (86.1)	301 (13.9)	0.748
	Diet or tablet controlled	115 (8.1)	36 (10.0)		184 (83.6)	36 (16.4)	
	Insulin controlled	37 (2.6)	7 (1.9)		44 (86.3)	7 (13.7)	
	Diabetes: any control	84 (5.9)	15 (4.2)		103 (87.3)	15 (12.7)	
Smoking history	Non-smoker	1187 (83.7)	291 (81.1)	0.392	1822 (86.2)	291 (13.8)	0.413
	Current	183 (12.9)	51 (14.2)		261 (83.7)	51 (16.3)	
Indication	Benign	250 (17.6)	68 (18.9)	0.559	472 (87.4)	68 (12.6)	0.283
	Malignant	1169 (82.4)	291 (81.1)		1730 (85.6)	291 (14.4)	
Resection location	Left colon	465 (32.8)	116 (32.3)	0.869	790 (87.2)	116 (12.8)	0.19
	Right colon	954 (67.2)	243 (67.7)		1412 (85.3)	243 (14.7)	

P -value derived from χ^2 test for categorical variables. % shown by row.
SD, Standard deviation; IQR, Interquartile range; IHD, Ischemic heart disease; CVA, Cerebrovascular accident; N/A, Not applicable.

Unadjusted postoperative outcomes

Completed laparoscopic surgery was associated with low rates of major postoperative complications, anastomotic leaks and re-operation (Table 2). When comparing the unadjusted postoperative outcomes between laparoscopic converted and open surgeries, there were no significant differences in major postoperative complications (9.7% *vs* 11.6%), re-operation (8.1% *vs* 6.8%), or anastomotic leak (9.5% *vs* 8.4%) rates between the groups.

Adjusted postoperative outcomes

The major complication rate was highest after open surgery (laparoscopic 7.4%, converted 9.7%, open 11.6%, $P < 0.001$). After adjustment for confounding factors, in comparison to completed laparoscopic surgery, open surgery was associated with increased major postoperative complications (OR 1.64, 1.27–2.11, $P < 0.001$) but laparoscopic converted surgery was not (OR 1.24, 0.83–1.87, $P = 0.30$; Table 3). The anastomotic leak rate was highest after converted surgery (5.4%, 9.5%, 8.4% respectively, $P < 0.001$). In the multilevel model, laparoscopic converted surgery (OR 2.07, 1.34–3.21, $P = 0.001$) and open surgery (OR 1.87, 1.37–2.56, $P < 0.001$) had similar higher risks of leak compared to completed laparoscopic surgery (Table 4).

Predicting laparoscopic conversion to open surgery

In the multivariable analysis, independent predictors of laparoscopic conversion were (Table 5):

1. Age ≥ 70 years (age 71–80, OR 1.55, 1.03–2.32, $P = 0.04$; age > 80, OR 1.62, 1.00–2.61, $P = 0.05$)
2. Male gender (OR 1.50, 1.17–1.93, $P = 0.001$)
3. ASA grade 3–5 (OR 1.43, 1.07–1.92, $P = 0.02$)
4. Low BMI (Underweight, OR 2.37, 1.18–4.75, $P = 0.02$)

Patients with a history of ischaemic heart disease or cerebrovascular accident were less likely to have a conversion (OR 0.65, 0.45–0.93, $P = 0.02$).

Discussion

This study showed that laparoscopic converted colonic resection was not associated with increased major complications compared to laparoscopic completed surgery, or with increased anastomotic leaks compared to open surgery. This supports laparoscopic resection as the primary approach when colonic resection is indicated. It suggests that following widespread implementation of laparoscopic surgery over the last two decades, as surgical experience has increased colorectal surgeons are now able to better select patients for both a complete laparoscopic operation, and judge intraoperatively to convert to an open procedure (Fig. 3).

In this multicentre international study, two thirds of patients underwent a planned laparoscopic operation. This is one of the highest rates described worldwide showing the high implementation of laparoscopic approach in contemporary practice [12]. This study did not collect data on previous surgery or size or stage of lesion resection, which may have indicated that an open operation in the first instance was entirely appropriate. We also have not included robotic surgical approaches in this analysis which may underestimate the overall minimally invasive surgery rate. However, our data provides scope to increase the laparoscopic rate in units or areas where it has not yet been implemented (including those in low and middle-income settings).

Table 2 Outcomes of patients undergoing segmental colonic resection by approach.

Factor	Levels	Open	Laparoscopic converted	*P* -value	Laparoscopic	Laparoscopic converted	*P* -value
Post-operative complication	No major complication	1220 (86.0)	318 (88.6)	0.408	2009 (91.2)	318 (88.6)	0.261
	Major complication	165 (11.6)	35 (9.7)		162 (7.4)	35 (9.7)	
	Missing	34 (2.4)	6 (1.7)		31 (1.4)	6 (1.7)	
Leak	No leak	1221 (86.0)	312 (86.9)	0.285	2047 (93.0)	312 (86.9)	< 0.001
	Leak	119 (8.4)	34 (9.5)		118 (5.4)	34 (9.5)	
Re-operation	No	1323 (93.2)	330 (91.9)	0.385	2079 (94.4)	330 (91.9)	0.064
	Yes	96 (6.8)	29 (8.1)		123 (5.6)	29 (8.1)	
Length of stay	Mean (SD)	10.2 (6.1)	8.8 (5.8)	< 0.001	7.1 (5)	8.8 (5.8)	< 0.001

Major postoperative complications were pre-defined as Clavien-Dindo grade complications 3 to 5 (re-operation, re-intervention, admission to critical care or death *P* -values derived from χ^2 test for categorical variables and Student's *T*-test for parametric continuous variables, % shown by column.

Table 3 Univariable and multilevel models for major postoperative complications following colonic surgery.

Factor	Levels	No major complication	Major complication	OR (univariable)	OR (multilevel)
Approach	Laparoscopic	1827 (56.1)	145 (44.2)	– *(Reference)*	– *(Reference)*
	Open	1134 (34.8)	151 (46.0)	1.68 (1.32–2.13, $P < 0.001$)	1.64 (1.27–2.11, $P < 0.001$)
	Laparoscopic converted	293 (9.0)	32 (9.8)	1.38 (0.91–2.03, $P = 0.120$)	1.24 (0.83–1.87, $P = 0.297$)
Age	< 55	619 (19.0)	49 (14.9)	–	–
	55–70	1179 (36.2)	108 (32.9)	1.16 (0.82–1.66, $P = 0.415$)	1.00 (0.68–1.48, $P = 0.995$)
	70–80	960 (29.5)	101 (30.8)	1.33 (0.94–1.91, $P = 0.117$)	1.09 (0.72–1.65, $P = 0.676$)
	> 80	496 (15.2)	70 (21.3)	1.78 (1.22–2.63, $P = 0.003$)	1.34 (0.85–2.12, $P = 0.211$)
Gender	Female	1593 (49.0)	130 (39.6)	–	–
	Male	1661 (51.0)	198 (60.4)	1.46 (1.16–1.84, $P = 0.001$)	1.38 (1.09–1.76, $P = 0.008$)
ASA class	Low risk (ASA 1–2)	2208 (67.9)	179 (54.6)	–	–
	High risk (ASA 3–5)	1046 (32.1)	149 (45.4)	1.76 (1.40–2.21, $P < 0.001$)	1.46 (1.12–1.92, $P = 0.005$)
BMI	Normal weight	1177 (36.2)	115 (35.1)	–	–
	Underweight	99 (3.0)	10 (3.0)	1.03 (0.49–1.94, $P = 0.923$)	1.05 (0.53–2.10, $P = 0.884$)
	Overweight	1255 (38.6)	120 (36.6)	0.98 (0.75–1.28, $P = 0.874$)	0.92 (0.70–1.22, $P = 0.576$)
	Obese	723 (22.2)	83 (25.3)	1.17 (0.87–1.58, $P = 0.288$)	1.06 (0.78–1.46, $P = 0.704$)
History of IHD/CVA	No	2690 (82.7)	245 (74.7)	–	–
	Yes	564 (17.3)	83 (25.3)	1.62 (1.23–2.10, $P < 0.001$)	1.29 (0.95–1.75, $P = 0.097$)
History of diabetes mellitus	No	2755 (84.7)	265 (80.8)	–	–
	Diet or tablet controlled	270 (8.3)	30 (9.1)	1.16 (0.76–1.69, $P = 0.477$)	1.00 (0.66–1.53, $P = 0.991$)
	Insulin controlled	62 (1.9)	11 (3.4)	1.84 (0.91–3.41, $P = 0.066$)	1.34 (0.68–2.64, $P = 0.403$)
	Diabetes: any control	167 (5.1)	22 (6.7)	1.37 (0.84–2.13, $P = 0.182$)	1.02 (0.61–1.69, $P = 0.946$)
Anticoagulant or antiplatelet use	No	997 (30.6)	99 (30.2)	–	–
	Yes	185 (5.7)	25 (7.6)	1.36 (0.84–2.14, $P = 0.195$)	0.98 (0.60–1.61, $P = 0.934$)
	Not collected	2072 (63.7)	204 (62.2)	0.99 (0.77–1.28, $P = 0.947$)	0.87 (0.65–1.17, $P = 0.357$)
Smoking history	Non-smoker	2842 (87.3)	274 (83.5)	–	–
	Current	412 (12.7)	54 (16.5)	1.36 (0.99–1.84, $P = 0.052$)	1.41 (1.02–1.94, $P = 0.039$)
Indication	Benign	660 (20.3)	60 (18.3)	–	–
	Malignant	2594 (79.7)	268 (81.7)	1.14 (0.85–1.54, $P = 0.392$)	0.97 (0.69–1.36, $P = 0.839$)
Resection location	Left colon	1182 (36.3)	124 (37.8)	–	–
	Right colon	2072 (63.7)	204 (62.2)	0.94 (0.74–1.19, $P = 0.596$)	–

Major postoperative complications were pre-defined as Clavien-Dindo grade complications 3 to 5 (re-operation, re-intervention, admission to critical care or death. Odds ratio (OR) presented with 95% confidence intervals. % shown by column.
SD, Standard deviation; IQR, Interquartile range; IHD, Ischemic heart disease; CVA, Cerebrovascular accident; N/A, Not applicable.

The conversion rate was 14%, consistent with a decreasing trend since the introduction of laparoscopic surgery. In 2005, the CLASICC trial showed a laparoscopic conversion rate of 29.0% [3]. Subsequently, several studies showed conversion rates between 10.4 and 29.0% with detrimental outcome [3,4,13–15]. More recently, a Dutch national review reported a conversion rate of 8.6% for colon cancer [13]. The literature has been divided about whether conversion impacts detrimentally on short-term outcomes. Dutch series have reported higher rates of postoperative complications in patients who had laparoscopic conversion when compared to open resections. These rates were significantly higher in those with late conversion (> 30 min) compared to early conversion (OR 1.34, 1.05–1.72). There was no impact of conversion on mortality in these patients [13]. In contrast, one of the largest series of segmental resections reported, with 207 311 patients operated in the United States, found that conversion had a higher morbidity and mortality than completed laparoscopic procedures, but better outcomes than primary open procedures [16]. Allaix *et al.* showed no significant differences in short-term postoperative morbidity, mortality, or hospital stay between converted and laparoscopic completed group in a cohort of 1114 patients [5]. The present prospective multicentre study

Table 4 Univariable and multilevel models for anastomotic leak amongst patients undergoing colonic surgery with anastomosis only.

Factor	Levels	No leak	Leak	OR (univariable)	OR (multilevel)
Approach	Laparoscopic	1839 (56.8)	98 (43.8)	– *(Reference)*	– *(Reference)*
	Open	1114 (34.4)	96 (42.9)	1.62 (1.21–2.16, $P = 0.001$)	1.87 (1.37–2.56, $P < 0.001$)
	Laparoscopic converted	285 (8.8)	30 (13.4)	1.98 (1.27–2.99, $P = 0.002$)	2.07 (1.34–3.21, $P = 0.001$)
Age	< 55	599 (18.5)	44 (19.6)	–	–
	55–70	1174 (36.3)	84 (37.5)	0.97 (0.67–1.43, $P = 0.892$)	0.94 (0.61–1.43, $P = 0.756$)
	70–80	967 (29.9)	60 (26.8)	0.84 (0.57–1.27, $P = 0.411$)	0.79 (0.49–1.26, $P = 0.313$)
	> 80	498 (15.4)	36 (16.1)	0.98 (0.62–1.55, $P = 0.945$)	0.86 (0.50–1.48, $P = 0.583$)
Gender	Female	1570 (48.5)	90 (40.2)	–	–
	Male	1668 (51.5)	134 (59.8)	1.40 (1.07–1.85, $P = 0.016$)	1.28 (0.96–1.71, $P = 0.089$)
ASA class	Low risk (ASA 1–2)	2183 (67.4)	144 (64.3)	–	–
	High risk (ASA 3–5)	1055 (32.6)	80 (35.7)	1.15 (0.86–1.52, $P = 0.334$)	1.03 (0.74–1.44, $P = 0.844$)
BMI	Normal weight	1164 (35.9)	76 (33.9)	–	–
	Underweight	96 (3.0)	6 (2.7)	0.96 (0.36–2.08, $P = 0.920$)	0.90 (0.38–2.16, $P = 0.819$)
	Overweight	1254 (38.7)	86 (38.4)	1.05 (0.76–1.45, $P = 0.763$)	1.00 (0.72–1.39, $P = 0.994$)
	Obese	724 (22.4)	56 (25.0)	1.18 (0.83–1.69, $P = 0.353$)	1.05 (0.72–1.53, $P = 0.812$)
History of IHD/CVA	No	2660 (82.1)	177 (79.0)	–	–
	Yes	578 (17.9)	47 (21.0)	1.22 (0.87–1.69, $P = 0.239$)	1.14 (0.77–1.67, $P = 0.514$)
History of diabetes mellitus	No	2743 (84.7)	181 (80.8)	–	–
	Diet or tablet controlled	273 (8.4)	22 (9.8)	1.22 (0.75–1.89, $P = 0.394$)	1.33 (0.81–2.19, $P = 0.256$)
	Insulin controlled	64 (2.0)	7 (3.1)	1.66 (0.68–3.43, $P = 0.213$)	1.63 (0.71–3.73, $P = 0.251$)
	Diabetes: any control	158 (4.9)	14 (6.2)	1.34 (0.73–2.29, $P = 0.308$)	0.94 (0.51–1.74, $P = 0.841$)
Anticoagulant or antiplatelet use	No	965 (29.8)	67 (29.9)	–	–
	Yes	175 (5.4)	22 (9.8)	1.81 (1.07–2.96, $P = 0.022$)	1.84 (1.06–3.20, $P = 0.031$)
	Not collected	2098 (64.8)	135 (60.3)	0.93 (0.69–1.26, $P = 0.622$)	1.25 (0.67–2.33, $P = 0.481$)
Smoking history	Non-smoker	2818 (87.0)	187 (83.5)	–	–
	Current	420 (13.0)	37 (16.5)	1.33 (0.91–1.89, $P = 0.131$)	1.22 (0.83–1.78, $P = 0.310$)
Indication	Benign	616 (19.0)	51 (22.8)	–	–
	Malignant	2622 (81.0)	173 (77.2)	0.80 (0.58–1.11, $P = 0.170$)	0.81 (0.55–1.19, $P = 0.288$)
Resection location	Left colon	1140 (35.2)	89 (39.7)	–	–
	Right colon	2098 (64.8)	135 (60.3)	0.82 (0.63–1.09, $P = 0.172$)	–
Anastomotic configuration	End to End	808 (25.0)	68 (30.4)	–	–
	Side to Side	1359 (42.0)	100 (44.6)	0.87 (0.64–1.21, $P = 0.411$)	0.70 (0.38–1.28, $P = 0.249$)
	Side to End	147 (4.5)	7 (3.1)	0.57 (0.23–1.17, $P = 0.162$)	0.43 (0.19–0.97, $P = 0.043$)
	End to Side	134 (4.1)	4 (1.8)	0.35 (0.11–0.87, $P = 0.047$)	0.25 (0.08–0.82, $P = 0.023$)
Defunctioning stoma	Yes	46 (1.4)	5 (2.2)	–	–
	No	3192 (98.6)	219 (97.8)	0.63 (0.27–1.83, $P = 0.334$)	0.80 (0.31–2.10, $P = 0.654$)

Overall anastomotic leak was pre-defined as either i) gross anastomotic leakage proven radiologically or clinically, or ii) the presence of an intraperitoneal (abdominal or pelvic) fluid collection on post-operative imaging. Odds ratio (OR) presented with 95% confidence intervals. % shown by column.

SD, Standard deviation; IQR, Interquartile range; IHD, Ischemic heart disease; CVA, Cerebrovascular accident; N/A, Not applicable.

validates the findings of these retrospective analyses in a modern, real-world cohort, demonstrating that conversion does not place patients at increased risk of major complications, nor does it alter the baseline risk of leak to that of open surgery. This is likely to reflect satisfactory patient selection for both the initial laparoscopic procedure and conversion to open surgery; however, we did not collect specific information on early *vs* later conversions, or the indication for conversion in this study.

Our data demonstrates that male gender, older age, low BMI and higher ASA grade are all associated with a higher risk of laparoscopic conversion. The factors

Table 5 Factors associated with laparoscopic completion amongst patients undergoing attempted laparoscopic colonic surgery.

Factor	Levels	Minimally invasive completion	Conversion	OR (univariable)	OR (multilevel)
Age	< 55	414 (21.0)	56 (17.2)	–	–
	55–70	727 (36.9)	101 (31.1)	1.03 (0.73–1.46, $P = 0.880$)	1.06 (0.72–1.56, $P = 0.773$)
	70–80	561 (28.4)	113 (34.8)	1.49 (1.06–2.11, $P = 0.024$)	1.55 (1.03–2.32, $P = 0.036$)
	> 80	270 (13.7)	55 (16.9)	1.51 (1.01–2.25, $P = 0.046$)	1.62 (1.00–2.61, $P = 0.049$)
Gender	Female	961 (48.7)	129 (39.7)	–	–
	Male	1011 (51.3)	196 (60.3)	1.44 (1.14–1.84, $P = 0.003$)	1.50 (1.17–1.93, $P = 0.001$)
ASA class	Low risk (ASA 1–2)	1450 (73.5)	213 (65.5)	–	–
	High risk (ASA 3–5)	522 (26.5)	112 (34.5)	1.46 (1.14–1.87, $P = 0.003$)	1.43 (1.07–1.92, $P = 0.015$)
BMI	Normal weight	706 (35.8)	98 (30.2)	–	–
	Underweight	41 (2.1)	12 (3.7)	2.11 (1.03–4.03, $P = 0.031$)	2.37 (1.18–4.75, $P = 0.015$)
	Overweight	781 (39.6)	127 (39.1)	1.17 (0.88–1.56, $P = 0.272$)	1.10 (0.82–1.48, $P = 0.529$)
	Obese	444 (22.5)	88 (27.1)	1.43 (1.04–1.95, $P = 0.025$)	1.33 (0.95–1.85, $P = 0.093$)
History of IHD/CVA	No	1649 (83.6)	277 (85.2)	–	–
	Yes	323 (16.4)	48 (14.8)	0.88 (0.63–1.22, $P = 0.465$)	0.65 (0.45–0.93, $P = 0.020$)
History of diabetes mellitus	No	1684 (85.4)	272 (83.7)	–	–
	Diet or tablet controlled	161 (8.2)	32 (9.8)	1.23 (0.81–1.81, $P = 0.310$)	1.00 (0.65–1.54, $P = 0.991$)
	Insulin controlled	33 (1.7)	6 (1.8)	1.13 (0.42–2.53, $P = 0.792$)	0.88 (0.35–2.19, $P = 0.785$)
	Diabetes: any control	94 (4.8)	15 (4.6)	0.99 (0.54–1.68, $P = 0.966$)	0.91 (0.50–1.68, $P = 0.774$)
Anticoagulant or antiplatelet use	No	640 (32.5)	98 (30.2)	–	–
	Yes	110 (5.6)	14 (4.3)	0.83 (0.44–1.46, $P = 0.543$)	0.78 (0.42–1.47, $P = 0.445$)
	Not collected	1222 (62.0)	213 (65.5)	1.14 (0.88–1.48, $P = 0.324$)	1.12 (0.83–1.51, $P = 0.443$)
Smoking history	Non-smoker	1729 (87.7)	275 (84.6)	–	–
	Current	243 (12.3)	50 (15.4)	1.29 (0.92–1.79, $P = 0.126$)	1.35 (0.96–1.90, $P = 0.089$)
Indication	Benign	430 (21.8)	64 (19.7)	–	–
	Malignant	1542 (78.2)	261 (80.3)	1.14 (0.85–1.54, $P = 0.391$)	0.91 (0.64–1.29, $P = 0.588$)
Resection location	Left colon	750 (38.0)	112 (34.5)	–	–
	Right colon	1222 (62.0)	213 (65.5)	1.17 (0.91–1.50, $P = 0.218$)	–

Odds ratio (OR) presented with 95% confidence intervals. % shown by column.
SD, Standard deviation; IQR, Interquartile range; IHD, Ischemic heart disease; CVA, Cerebrovascular accident; N/A, Not applicable.

included within this model are not comprehensive; presence of intraabdominal abscess or fistula, previous surgery and surgeon experience were not collected here [17]. Therefore this analysis should be seen as exploratory only. Whilst, this study supports a laparoscopic first approach where feasible, presentation of this data with help tailor informed consent for patients undergoing attempted laparoscopic colonic surgery using simple, easily comprehensible patient factors. Despite equivalent short-term patient outcomes, laparoscopic conversion is not without consequence to patients and health systems. Health economic data from the United States suggests a prolonged length of stay and significant cost implication to laparoscopic conversion (adjusted mean cost: \$20 165) *vs* planned open (\$18 797) or laparoscopic completed surgery (\$16 206) [18]. Better understanding of why and when colorectal surgeons choose to convert remains an important focus for future research.

We have tried to mitigate against some of the limitations of observational studies in our study methods. In this case, firstly the inherent selection bias for laparoscopic and open surgery may have varied between centres and surgeons, subjecting patients to different outcomes masked by a pooled analysis. This bias is lessened by collating an international dataset that was adjusted using mixed-effects modelling for case-mix, was pre-planned and allows local units to

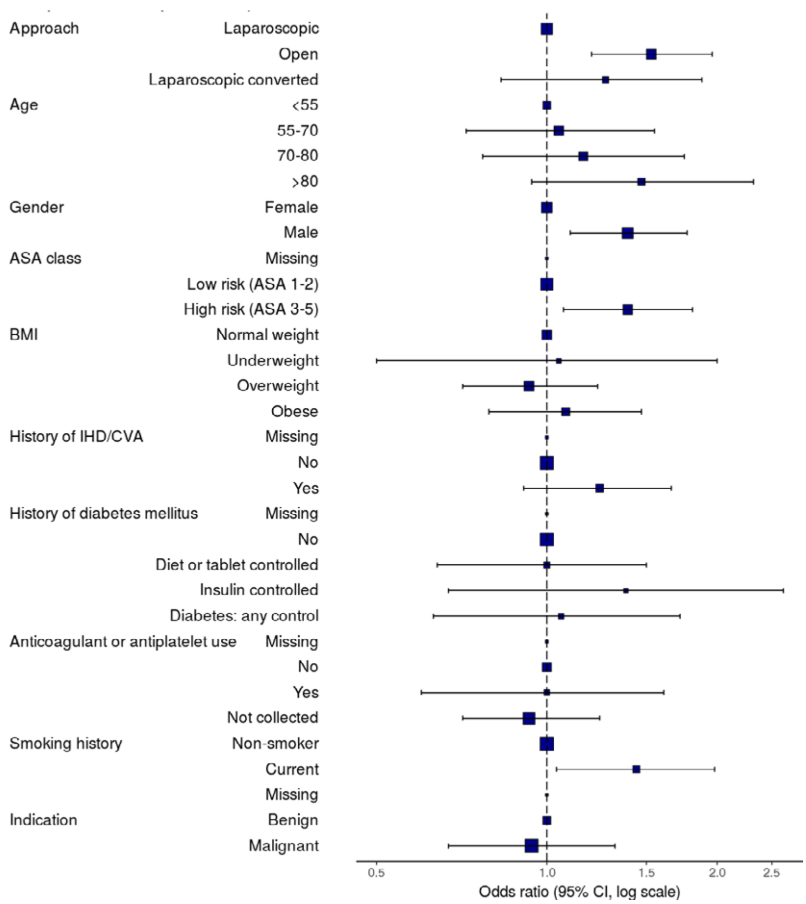

Figure 3 Forest plot demonstrating multilevel model for factors associated with major complications in elective laparoscopic colonic surgery.

benchmark their own performance against. The chance of selection and reporting biases was further reduced by the inclusion of all eligible patients at each centre. Other studies have reported contemporary practice in laparoscopic colonic surgery, including larger patient groups than included here. However, these include data from a single country and are retrospective analyses of registries [16,19]. Prospective data collection, pre-specified analysis plans, and an international cohort from 48 countries increases external validity of our study findings. There was a 2-year interval in data collection between right-sided (2015) and left-sided (2017) resections. Increasing surgeon experience over these 2 years may have led to reduced conversions and improved postoperative outcomes within the left-sided resection group. However, the site of resection was not identified as a significant predictor of conversion, indicating that this short interval did not have a significant impact on this study.

Although we did not analyse by unit or country (as pre-planned in the study protocol), identifying and reaching units that have low laparoscopy rates to safely increase patients' access to technology should be a priority. The introduction of laparoscopic colonic surgery over the past 25 years is a model for dissemination of new surgical techniques and makes this an example of an IDEAL phase 4 study [20].

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Conflicts of interest

None to declare.

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