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Randomized Clinical Trial

Complications after open and laparoscopic right-sided colectomy with central lymphadenectomy for colon cancer: randomized controlled trial

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Abstract

Background: A central lymphadenectomy in right-sided colon cancer involves dissection along the superior mesenteric axis, but the extent is debated due to a lack of consensus and the fear of major complications. This randomized controlled trial compared the rate of postoperative morbidity in patients undergoing laparoscopic *versus* open right-sided colectomy with central lymphadenectomy.

Methods: This open, prospective, randomized controlled trial compared patients operated on with open and laparoscopic right-sided colectomy (cStages I–III) with a central lymphadenectomy at two Norwegian institutions between October 2016 and December 2021. Dissections were conducted along the superior mesenteric vein in the laparoscopic group, and along the left anterior border of the superior mesenteric artery in the open group, both according to complete mesocolic excision principles. Surgery was standardized and performed by three experienced surgeons for each study group. The primary outcome of interest was to measure postoperative 30-day complications (Clavien–Dindo ≥ grade II).

Results: Of 273 eligible patients, 135 were randomized and 128 analysed (63 operated on with open and 65 using laparoscopic procedures). Postoperative complications occurred in 42.8 per cent of the patients treated with open and 38.4 per cent of the patients treated using laparoscopic surgery, $P = 0.372$. The incidence of Clavien–Dindo grade IIIb complications was 7.9 per cent in the open *versus* 4.6 per cent in the laparoscopic group, $P = 0.341$. There were no grade IV or V complications, and no re-operations due to anastomotic leakages. There was no significant difference in the mean(s.e.m.) number of removed lymph nodes (open *versus* laparoscopic respectively: 31.9(1.8) *versus* 29.3(1.3); $P = 0.235$).

Conclusion: There was no significant difference in complications between the two groups. Standardized oncologic right-sided colectomy with central lymphadenectomy along the mesenterial root was performed safely, both open and laparoscopic, with incidence of major complications ranging between 4.6 and 7.9 per cent and no re-operations for anastomotic leakage. Radicality in terms of lymphadenectomy was comparable between the two groups.

Registration number: NCT03776591 (http://www.clinicaltrials.gov).

Introduction

The incidence of colon cancer in Norway is currently rising and remains the second most common cause of cancer-related deaths[1]. Upfront surgery is still the primary treatment and should follow the principles of surgical oncology, including radicality. Parallel to the development of minimally invasive surgery, there has been increasing focus on more radical surgical techniques in colon cancer, especially the extent of a central lymphadenectomy. Tumours of the right colon differ in morphological characteristics and mutation profiles, and evolve from a different embryological origin than the left colon. The complex anatomical relationship between the ileocolic- and middle-colic artery with the superior mesenteric vein (SMV) makes a central lymphadenectomy in right-sided colon cancer (RCC) demanding[2,3], with the potential for surgical complications such as bleeding. The anatomical and embryological differences between the right and left colon make them non-comparable in terms of cancer surgery. The right colon evolves from the embryological mid-gut with blood supply from the superior mesenteric artery, which is more anatomically complex than the hindgut's (left colon) blood supply from the inferior mesenteric artery, branching directly from the aorta. The rotation of the mid-gut in the late embryologic stage adds complexity by variations in the relation between the mesenteric artery and veins. Lymph node dissection and division of tumour feeding arteries are more demanding in the mid-gut-derived bowel due to the common blood supply from the superior

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mesenteric artery for both the colon and small bowel. Two sets of terms are used to describe radical colon cancer surgery with adequate lymph node harvest and dissection along embryological planes. D3 refers to the dissection of central lymph node stations[4]. In complete mesocolic excision (CME), the corresponding terminology is central vascular ligation (*Fig. S1*). The main CME components are dissection between the mesenteric plane and the parietal fascia[5,6], central vascular tie, and the removal of an adequate length of bowel[7,8]. However, the exact extent of a central lymphadenectomy is ambiguously defined and the medial border of the right mesocolon remains debated. There is evidence that time to recurrence and survival improves with the number of lymph nodes harvested at surgery[5,9–13].

Past studies have shown that stage III RCC has lower survival outcomes after curative resection, higher recurrence rates, and frequently, multiple metastatic sites in the first recurrence[14,15].

The level of vessel ligation varies, and significant remaining arterial stumps have been demonstrated after resection for RCC[16]. This leaves reason to believe that a certain number of central lymph nodes remain after surgery[17]. Evidence of superiority of an extended lymphadenectomy in right-sided colectomy is scarce[18,19] and not accepted as standard care due to a lack of documentation on applicability and safety. Intraoperative injury to other organs such as the superior mesenteric vein and intraoperative bleeding are complications associated with a central lymphadenectomy[20].

This trial was designed to compare two surgical approaches in patients with non-metastatic RCC with emphasis on, and standardization of, the central lymphadenectomy and dissection in avascular planes.

Methods

Design

This is an open, prospective, randomized, multi-centre clinical trial conducted at two Norwegian institutions from September 2016 to December 2021.

Haraldsplass Deaconess Hospital (HDH) and Haukeland University Hospital (HUH) are neighbouring hospitals cooperating in the treatment of colon cancer with common multidisciplinary team meetings, and pathology and oncology services. The hospitals have a close professional relationship and patients are distributed between them based on capacity. Historically, there have been no differences in total 100-day survival and relative 5-year survival[21]. Since 2007, HDH has focused on laparoscopic CME[22]. From 2011, HUH has participated in a project focusing on open right-sided colectomy with central lymph node dissection[23,24]. Both hospitals are skilled in oncologic right-sided colectomy with central lymphadenectomy, have experienced ward staff, and routine implementation of enhanced recovery principles (*supplementary material*). The perioperative care is equivalent at the two institutions. Both hospitals have performed the resection as described in this protocol since 2012. In each hospital, three high-volume oncologic colorectal surgeons were the main or assistant surgeon during surgery. At the two hospitals, 110 (HUH) patients and 52 (HDH) patients were operated on with the lymphadenectomy described in this protocol prior to project start. HDH operated on patients allocated to the laparoscopic group and HUH operated on patients allocated to the open group.

The study was approved by the Regional Committee of Ethics (REK 2015/2396) and is in accordance with the 'WMA Declaration of Helsinki—Ethical Principles for Medical Research Involving Human Subjects'[25]. Patients were informed about the study, in writing and orally, before they agreed to participate.

Patient selection

Patients aged between 18 and 85 years at the two recruiting hospitals with positive computed tomography, colonoscopy, or histopathologically verified adenocarcinoma of the right colon without metastases were relevant for inclusion (cStages I–III), and were considered eligible for the study. Patients with previous colorectal cancer or ongoing treatment for other cancer were excluded (*supplementary material*).

Endpoints

The aim of this study was to compare complications between open D3 and laparoscopic CME for RCC. The primary endpoint was surgical complications using Clavien–Dindo classification ≥II[26–28] and the primary alternative hypothesis was that laparoscopic surgery reduced postoperative complications, which were registered within 30 days. Secondary endpoints were perioperative blood loss, duration of hospital stay, and number of lymph nodes removed. The duration of operation, Clavien–Dindo <II complications, blood transfusion/infusion of intravenous (i.v.) iron and postoperative ileus, re-operations, anastomotic leak, re-admission, and 90-day mortality were also explored (*supplementary material*).

Resection

Both groups aimed for a central lymphadenectomy with ligation of tumour feeding arteries at their origin. The approach was medial to lateral in both groups. The central dissection was performed from distal to the caudal ileal vein and cranially along the superior mesenteric axis. Open D3 resection was performed with dissection along the lateral left border of the superior mesenteric artery, and laparoscopic resection with denudation anterior to the SMV. Both groups were operated on following the CME principles with dissection between the mesenteric plane and the parietal fascia and the resection of an adequate length of bowel (*Fig. 1*). The gastrocolic trunk of Henle was not routinely divided but was exposed. Branches from the colon were divided selectively when necessary. The right gastroepiploic vein was not routinely divided. Patients with tumour location from the hepatic flexure and distally underwent extended right colectomy where the middle colic artery was divided centrally. In the laparoscopic group, the extended right-sided colectomy included resection of the mesogastrium (gastrocolic ligament divided close to the greater curvature of the stomach) and prepyloric lymph nodes including division of the right gastroepiploic vein. Anastomoses in the open group were open hand-sewn end-to-end, and in the laparoscopic group isoperistaltic, stapled side-to-side. All anastomoses in the laparoscopic group except one were intracorporeal.

Specimen

Specimens were fixed in Tarlym (GEWF: glacial acetic acid, ethanol, distilled water, and formaldehyde)[29,30] and evaluated using the current TNM grading system during the study period (Editions 7 and 8)[31,32]. Evaluation did not differ from standard practice in Norway. All specimens were analysed using the same pathology service. The pathologists were not blinded to operative methods.

Data collection

Data was collected by the project leader from objective information in the electronic patient chart.

Statistics

This trial was preregistered (clinicaltrials.gov ID: NCT03776591) before all data analysis, but after inclusion started. Improvement

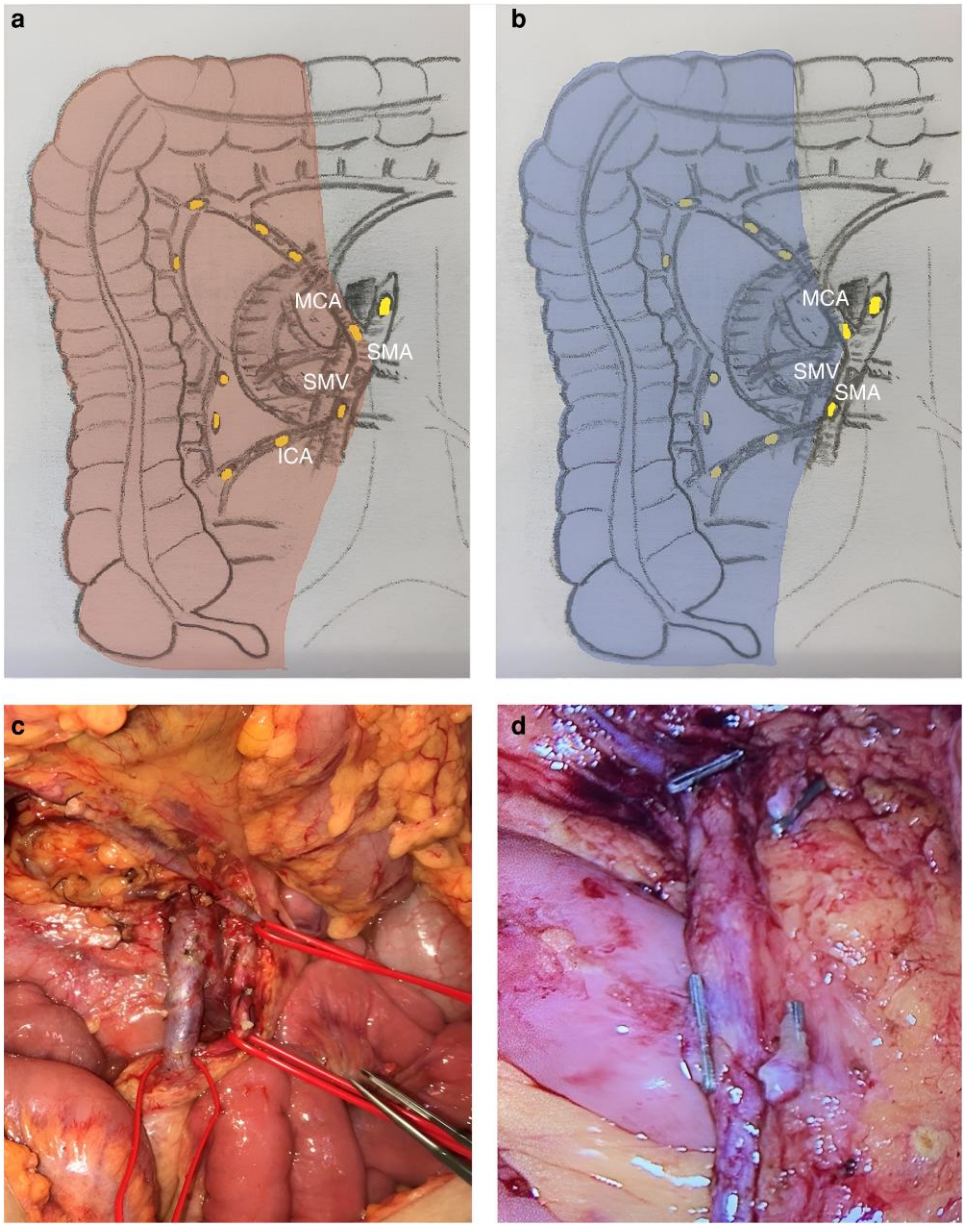

Fig. 1 Upper: schematic overview of the resection area a Open. b Laparoscopic. Lower: photo of the resection site after completed resection with central lymphadenectomy and vascular tie. c Open. d Laparoscopic.
ICA, ileocolic artery; MCA, middle colic artery; SMA, superior mesenteric artery; SMV, superior mesenteric vein.

from 40 per cent Clavien–Dindo grade II–V complications to 20 per cent in the laparoscopic group was considered clinically significant. The primary sample size was revised in February 2020 due to slow recruitment and was reduced from $n = 218$ with 109 patients in each treatment arm (90 per cent power, two-sided chi-squared test with 5 per cent significance) to $n = 126$ with 63 patients in each treatment arm (80 per cent power, one-sided chi-squared test with 5 per cent significance).

Informed written consent was obtained after oral and written information was provided, and patients were randomized. Included patients were assigned a sequential participant number and then referred to open D3 at HUH or laparoscopic CME at HDH. Computer-generated block randomization (block size 6) was used as described in a confidential protocol addendum (*supplementary material*).

Although the study was open, the randomization list was concealed from the hospital representative at the first consultation. Further treatment and control were at the institution the patient was randomized to. Patients who declined to participate in the study were assigned to standard treatment described in the Norwegian National Guidelines from the health authorities[33].

Baseline and tumour characteristics were summarized using descriptive statistics. The primary clinical endpoint examined was Clavien–Dindo grade II–V complications. As planned, a one-sided exact chi-squared test was used to compare this between the two randomized groups. Secondary endpoints were evaluated using the two-sided exact chi-squared test. Gosset's unpaired *t* test[34] was used to compare the duration of operation and lymph nodes, whereas the Wilcoxon–Mann–Whitney test[35,36] was performed for duration of hospital stay and intraoperative bleeding. Risk factors for complications were explored using logistic regression[37]. Results were reported as odds ratios (ORs)

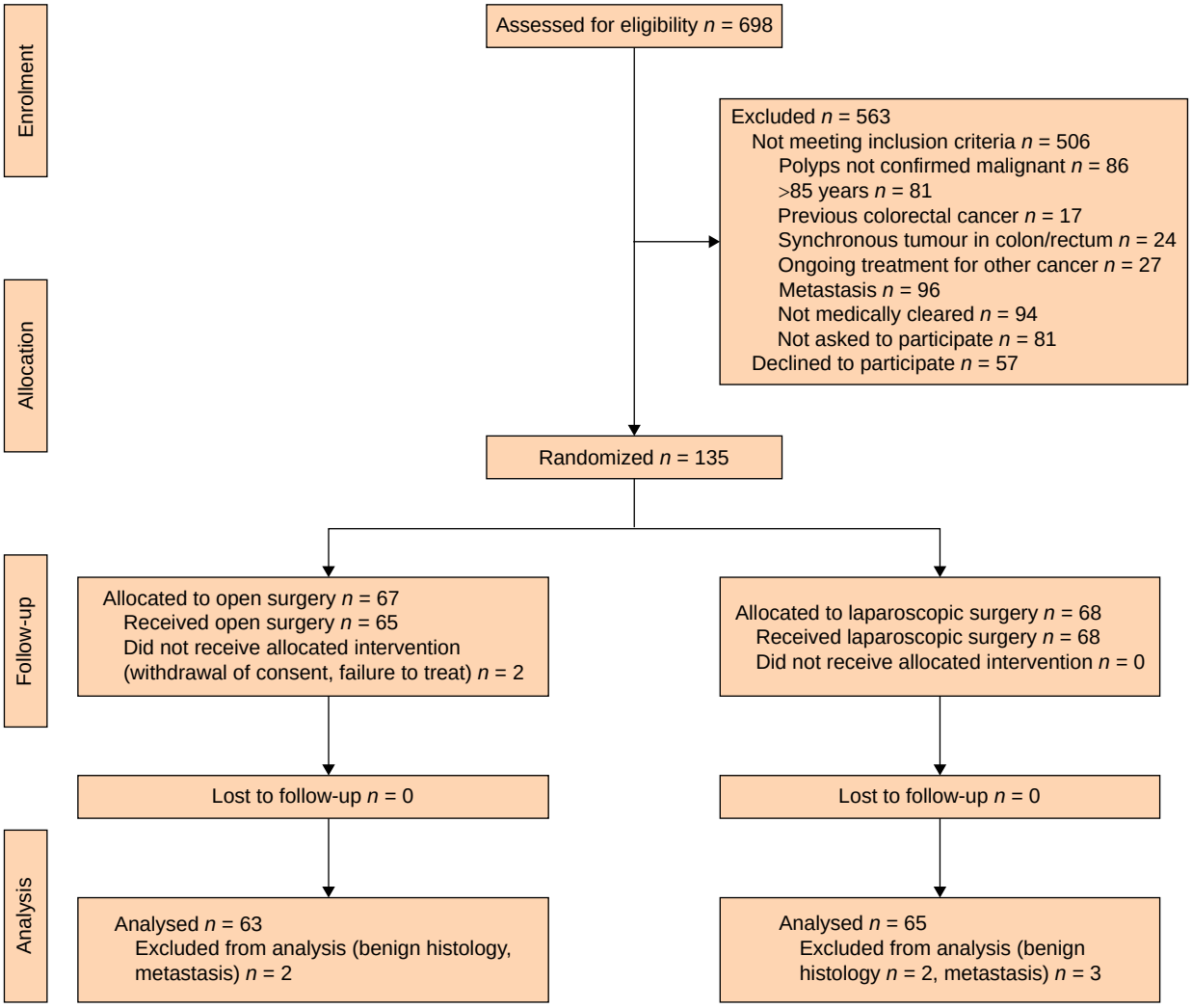

Fig. 2 Inclusion and randomization of patients[38,39].

and adjusted ORs (aORs) with 95 per cent c.i. and likelihood ratio P values (LR-p). ORs were adjusted based on potential predictor variables and confounding factors for complications such as age, sex, BMI, smoking status, co-morbidity, ASA, duration of operation, and operating method. Statistical analyses were performed using SPSS version 26.0.0.1.

Results

Inclusion and randomization

From 8 August 2016 to 26 November 2021, 698 patients were referred to the two recruiting hospitals with suspected right-sided colon cancer. The six selected surgeons differed in gender (two women, four men) and age at project start. All surgeons were men aged 43–59 years at HUS; the surgeons were aged 39–49 years at HDS.

Two hundred and seventy-three patients were eligible for inclusion, and 192 patients were informed about the trial and asked to participate. Patients eligible for inclusion but not recruited were not informed of this study due to logistics, such as absence of dedicated project staff to assess eligibility or allocation of date for surgery before trial information. One hundred and thirty-five patients consented, were included and randomized. Seven of the included patients were excluded from registration and further analysis because of undetected metastasis observed during surgery (2), polyps without development of cancer in the pathology report (3), withdrawal of consent before surgery (1), and failure of treatment (1). This patient was randomized to open surgery but was treated with robotic-assisted surgery due to miscommunication. The flow chart for inclusion is presented in *Fig. 2*. Inclusion and randomization continued until both hospitals reached a minimum of 63 participants.

The study population included 62 women and 66 men with a mean (range) age of 69.6 (38 to 85) years. Mean (s.d., range) BMI was 25.7 (4.1, 17.8 to 38.7) kg/m^2. Patients were mainly classified as ASA II (68.0 per cent). The main pathologic tumour stage was T3 (50 per cent) and T4 (34.4 per cent). Patient characteristics are presented in *Table 1*, whereas characteristics of those who were not included due to a lack of consent are detailed in *Table S1*. An extended right colectomy was performed in 18 patients in the laparoscopic group.

Postoperative complications

There was no difference in postoperative Clavien–Dindo II–V complications in the two groups (*Table 2*). Five patients in the open group were re-operated for wound dehiscence, and two

Table 1 Basic characteristics of patients included and operated on

Characteristic category	Open D3 $n = 63$	Lap CME $n = 65$
Age (years), mean(s.d.)	70.4(8.0)	68.9(10.0)
Sex ($n = 50$)		
Female	27 (42.9)	35 (53.8)
Male	36 (57.1)	30 (46.2)
BMI, mean(s.d.)	25.6(3.9)	25.8(4.2)
Smoking ($n = 50$)	8 (12.7)	6 (9.2)
ASA ($n = 50$)		
I	3 (4.8)	5 (7.7)
II	47 (74.6)	40 (61.5)
III	13 (20.6)	19 (29.2)
IV	0 (0.0)	1 (1.5)
Co-morbidity ($n = 50$)		
None	4 (6.3)	10 (15.4)
Cardiac	8 (12.7)	17 (26.2)
Pulmonary	11 (17.5)	7 (10.8)
Diabetes	5 (7.9)	7 (10.8)
Hypertension	27 (42.9)	28 (43.1)
Anaemia*	42 (66.7)	39 (60.0)
Steroid use	2 (3.2)	0 (0.0)
Previous abdominal surgery	15 (23.8)	13 (20.0)
Previous treatment for other cancer	3 (4.8)	3 (4.6)
Tumour location ($n = 50$)		
Caecum	26 (41.2)	29 (44.6)
Ascending colon	28 (44.4)	24 (36.9)
Hepatic flexure	5 (7.9)	11 (9.2)
Transverse colon	4 (6.3)	11 (9.2)
pTumour stage ($n = 50$)		
T1	2 (3.2)	3 (4.6)
T2	9 (14.3)	6 (9.2)
T3	33 (52.4)	31 (47.7)
T4	19 (30.2)	25 (38.5)
pNode stage, *n* (%)		
N0	45 (71.4)	39 (60.0)
N1	12 (19.0)	16 (24.6)
N2	6 (9.5)	10 (15.4)
Total no. of lymph nodes, mean(s.e.m.)	31.9(1.8)	29.3(1.3)

D3, dissection of lymph node station 3; CME, complete mesocolic excision; Lap, laparoscopic; Hgb, haemoglobin; p, pathologic. *Anaemia was defined as Hgb below reference value for age and sex (female ≥18 years: Hgb <11.7 g/dl, male ≥18 years: Hgb <13.4 g/dl).

Table 2 Complications by Clavien–Dindo (C–D) in patients included in the trial

Complications	Open D3 $n = 63$	Lap CME $n = 65$	P*
Complications by C–D, *n* (50)			0.372†
No complications	31 (49.2)	35 (53.8)	
Grade I	5 (7.9)	5 (7.7)	
Grade II	22 (34.9)	21 (32.3)	
Grade IIIa	0 (0.0)	1 (1.5)	
Grade IIIb	5 (7.9)	3 (4.6)	
Cardiac arrhythmia ($n = 50$)	3 (4.8)	3 (4.6)	0.969
Pulmonary embolism ($n = 50$)	0 (0.0)	1 (1.5)	0.323
Pneumonia ($n = 50$)	6 (9.5)	0 (0.0)	0.011
Urinary infection ($n = 50$)	3 (4.8)	1 (1.5)	0.295
Dehydration ($n = 50$)	5 (7.9)	0 (0.0)	0.021
Ileus ($n = 50$)	10 (15.9)	12 (18.5)	0.698
Blood transfusion/i.v. iron ($n = 50$)	14 (22.2)	10 (15.4)	0.322
Wound infection ($n = 50$)	3 (4.8)	1 (1.5)	0.295
Fascia rupture ($n = 50$)	5 (7.9)	0 (0.0)	0.021
Anastomotic leakage ($n = 50$)	0 (0.0)	0 (0.0)	
Bleeding (ml), mean(s.e.m.)	109.1(17.5)	77.0(11.4)	0.013‡
Operating time (min), mean(s.e.m.)	142.1(3.8)	227.2(6.4)	< 0.001§
Re-operation ($n = 50$)	6 (9.5)	4 (6.2)	0.478
Re-admission ($n = 50$)	4 (6.3)	4 (6.2)	0.964

Lap, laparoscopic; CME, complete mesocolic excision. *Pearson chi-squared two-sided test, except bleeding and operating time. †One-sided test for C–D: 0–I *versus* II–V: $P = 0.516$. ‡Wilcoxon–Mann–Whitney test. §Gosset's unpaired *t* test.

patients were re-operated twice. Two patients in the laparoscopic group were operated on for mechanical ileus and one for bleeding in the abdominal wall. One patient in each group was operated on for suspected complications without findings with an uneventful recovery. They were not registered as a Clavien–Dindo grade IIIb complication[28]. There were no anastomotic leakages in this trial and no grade IV or V complications. The duration of operation was shorter in the open group by a mean of 85 min.

Other complications and outcomes

More than 50 per cent of the patients had an uneventful recovery. There was no difference in the occurrence of postoperative ileus (POI). There was an increased incidence of wound dehiscence ($n = 5$) and postoperative pneumonia ($n = 6$) in the open group but none of either in the laparoscopic group (*Table 2*). The conversion rate was 1.5 per cent ($n = 1$) in the laparoscopic group.

Mean(s.e.m.) intraoperative blood loss was low in both groups, but higher in the open group at 109.13 (17.5) ml than in the laparoscopic group at 77.00 (11.4) ml, ($P = 0.013$) (*Fig. S2*), with no difference in the rate of peri- and postoperative transfusion (*Table 2*). Ten patients (15.9 per cent) in the open group and seven patients (10.8 per cent) in the laparoscopic group received blood transfusion/i.v. iron as their only postoperative complication. Eighty-five per cent of the patients in the study population had intraoperative bleeding ≤100 ml and only 7 per cent >200 ml. Seven of fifteen patients with bleeding ≥200 ml had bleeding from central mesenteric vessels (6 in the open group and 1 in the laparascopic group).

The median total duration of hospital stay was 5 days in the open group (ranging from 3 to 22 days) and 4 days in the laparoscopic group (ranging from 2 to 28 days), $P < 0.001$. The median total duration of hospital stay for patients without complications was shorter in the laparoscopic group (4 days open (ranging from 3 to 6 days) *versus* 3 days laparoscopic (ranging from 2 to 5), $P < 0.001$). The 90-day mortality was 0 per cent.

Lymph nodes

The mean number of examined lymph nodes in the two groups did not differ (*Table 2*). The mean(s.e.m.) number of positive lymph nodes was the same (1.02(0.32) open *versus* 1.28(0.28) laparoscopic, $P = 0.54$).

Risk factors for complications

The risk of Clavien–Dindo grade II–V complications was explored with logistic regression. The operating method was not found to be a risk factor for complications. Low preoperative haemoglobin (Hgb) and long operating time were associated with increased risk of complications (*Table 3*).

Preoperative anaemia was associated with risk of transfusion in the logistic regression model, but intraoperative blood loss volume and operating methods were not (*Table 4*). The risk of complications was further explored for haemoglobin < reference value. The risk of transfusion only ($n = 17$) and risk of complications (Clavien–Dindo I–V) except transfusion only ($n = 45$) *versus* no complications ($n = 66$) were analysed ($P = 0.032$). Haemoglobin < reference value was confirmed to be associated with an increased risk of transfusion only (OR = 5.88, 95 per cent

Table 3 Logistic regression models of potential risk factors for Clavien–Dindo complications grade II–V in 128 patients operated on

Potential risk factor	Unadjusted models			Adjusted model		
	OR	95% c.i.	P	aOR	95% c.i.	P
Age (years)	1.04	(1.00, 1.08)	0.082	1.04	(0.96, 1.09)	0.160
Sex (female *versus* male)	0.86	(0.42, 1.74)	0.669	1.29	(0.55, 3.05)	0.555
BMI (kg/m^2)	0.98	(0.90, 1.07)	0.720	1.00	(0.90, 1.11)	0.945
Smoking (current)	0.79	(0.25, 2.51)	0.692	1.10	(0.28, 5.93)	0.889
ASA	1.30	(0.68, 2.47)	0.425	1.33	(0.52, 3.42)	0.556
Cardiac disease	1.45	(0.60, 3.50)	0.403	1.45	(0.46, 4.61)	0.529
Pulmonary disease	1.20	(0.44, 3.28)	0.722	0.77	(0.22, 2.72)	0.689
Diabetes	1.05	(0.31, 3.50)	0.938	0.85	(0.22, 3.25)	0.808
Hypertension	0.84	(0.41, 1.71)	0.625	0.57	(0.25, 1.33)	0.192
Anaemia*	2.08	(0.97, 4.47)	0.057†	2.47	(1.03, 5.93)	0.038†
Albumin < reference‡	0.51	(0.11, 3.05)	0.504	0.33	(0.05, 2.27)	0.242
Elevated creatinine	1.20	(0.44, 3.28)	0.722	0.89	(0.28, 2.84)	0.849
Steroids	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other cancer	0.72	(0.13, 4.08)	0.710	0.35	(0.05, 2.47)	0.281
Previous abdominal surgery	0.63	(0.26, 1.52)	0.301	0.67	(0.24, 1.84)	0.431
Surgery (lap *versus* open)	0.83	(0.41, 1.69)	0.613	0.32	(0.10, 1.07)	0.059
Operating time (min)	1.00	(1.00, 1.01)	0.502	1.01	(1.00, 1.02)	0.042

OR, odds ratio; aOR, adjusted odds ratio; c.i., confidence interval; P value, from likelihood ratio test; n.a., not analysed as there were only two patients in the open group; lap, laparoscopic. *Haemoglobin below reference value for age and sex (female ≥18 years: Hgb < 11.7 g/dl, male ≥18 years: Hgb < 13.4 g/dl). †Risk of complications was further explored for haemoglobin < reference value (*Table S2*). ‡Reference value for age (≤69 years: albumin < 39 g/l, ≥ 70 years: albumin < 36 g/l).

Table 4 Logistic regression analysis of potential risk factors for blood transfusion/i.v. iron in 128 patients operated on

Potential risk factor	Unadjusted model			Adjusted model		
	OR	95% c.i.	P	aOR	95% c.i.	P
Preoperative anaemia*	8.39	(1.88, 37.55)	<0.001	7.57	(1.68, 34.23)	0.001
Peroperative bleeding (ml)	1.00	(1.00, 1.01)	0.038	1.00	(1.00, 1.01)	0.156
Operating method (lap *versus* open)	0.64	(0.26, 1.56)	0.322	1.03	(0.24, 4.37)	0.963
Operating time (min)	1.00	(0.99, 1.01)	0.481	1.00	(0.98, 1.01)	0.555

OR, odds ratio; aOR, adjusted odds ratio; c.i., confidence interval; lap, laparoscopic. *Haemoglobin (Hgb) below reference value for age and sex (female ≥18 years: Hgb < 11.7 g/dl, male ≥18 years: Hgb < 13.4 g/dl).

c.i. (1.24, 27.79) and aOR = 8.72, 95 per cent c.i. (1.54, 49.45)). Risk of complications except transfusion only was not increased (OR = 1.42, 95 per cent c.i. (0.65, 3.10) and aOR = 1.41, 95 per cent c.i. (0.59, 3.37)) (*Table S2*).

Discussion

In this trial, there was no difference in Clavien–Dindo grade II–V postoperative complications between patients operated on by skilled surgeons with open or laparoscopic oncologic right-sided colectomy with central lymphadenectomy.

Clavien–Dindo grade II–V complications were selected as the endpoint and the expected reduction in the laparoscopic group compared with open surgery was based on historical data. Complications were primarily grade II. The incidence of major complications (Clavien–Dindo grade ≥IIIb) was lower in this trial compared with other studies[20,40,41]. It is remarkable that there were no Clavien–Dindo grade IV complications, no perioperative mortality, and no anastomotic leakages. This indicates that surgery with dedicated, skilled surgeons results in good outcomes. The results were in accordance with previous studies evaluating volume and quality[42] and can possibly influence long-term survival.

Similar to other trials, a significantly longer operating time was found in the laparoscopic group[4], and an increased risk of complications was confirmed with increasing duration of the operation[40,43]. The significant longer duration of operation in the laparoscopic group may contribute to the lack of difference in complications between the groups. Meticulous dissection along the vessels is particularly time-consuming and technically demanding with a minimal invasive approach, but does not lead to increased intraoperative bleeding, or risk of bleeding from central mesenteric vessels.

As expected, the total duration of hospital stay was shorter in the laparoscopic group. Ninety-day mortality was 0 per cent although the patient population was heterogenous and old (72.7 per cent over 65 years).

Although differences in the approach to and dissection of the superior mesenteric vessels should be acknowledged, dissection along the left arterial border instead of SMV did not lead to higher lymph node yield, and the number of lymph nodes did not differ significantly.

The most frequent complications were blood transfusion/i.v. iron and postoperative paralytic ileus, both Clavien–Dindo grade II. Transfusion of allogene erythrocytes or administration of i.v. iron is, by definition in the Clavien–Dindo system, a postoperative complication. Incidence of blood transfusion/i.v. iron was not related to intraoperative blood loss but to preoperative anaemia. Sixty-three per cent of the patients had preoperative anaemia and the rate of transfusion reflects this rather than being an actual postoperative complication. Due to a lack of logistics and routines for capturing anaemic patients early, preoperative administration of i.v. iron or transfusion was not routinely implemented in this trial. Better preoperative care with the treatment of anaemia can reduce Clavien–Dindo postoperative complications.

Impairment of bowel function after colon surgery is a normal process which usually resolves spontaneously in 2–3 days.

Although it is part of the normal postoperative course, POI is considered one of the most common complications after intra-abdominal surgery (12–18 per cent) and an important cause of prolonged hospitalizations and re-admission[43–45]. The exact incidence of POI is difficult to estimate as definitions vary[44,46]. It is unknown whether the high incidence of POI after right-sided colectomy is due to the ileocolic anastomosis, dissection over the duodenum, or other factors[47,48].

Seventy per cent of informed patients accepted inclusion. Fifty-seven patients declined to participate; the main reason being preference for either hospital or surgical access. The other common reason for decline was inability to consider the concept of randomization because they were overwhelmed by their diagnosis and upcoming treatment. Patients were most likely to agree to participation when asked by dedicated project staff. An unexpected high number of patients eligible for inclusion were not informed about the study (81 patients (29.7 per cent of eligible patients)). There is a risk of selection bias due to the large number of eligible, unincluded patients; however, their basic characteristics did not differ significantly from the included patients.

The mean age for diagnosis of colon cancer was lower in this study (70 years) than in Norway in general (73 years)[49]. Although the upper age limit in this study was 85 years, 35.9 per cent ($n = 46$) of the patients were ≥75 years, and amongst them 8.6 per cent ($n = 11$) ≥80 years at inclusion. During the recruiting period, only 11.6 per cent of the total patient population (81 of 698) were above the upper age limit for this study. Despite an upper age limit, the study population largely reflects the actual disease population. Another large group of excluded patients are the 13.5 per cent ($n = 94$) evaluated as not medically cleared, since the oldest patients and patients with severe medical conditions were not considered eligible.

Despite a year-long recruiting process, the study population was relatively small. The largest difference between this trial and other similar trials was that all patients were diagnosed with proximal colon cancer and underwent the same surgical procedure with right-sided colectomy. The comparison of complications to other trials is challenging due to patient selection, different definitions, and classifications of postoperative complications[20,50,51].

Long-term complications are beyond the scope of this paper, where only re-operations during 30 days after surgery are registered. The rate of hernioplasties and other re-operations such as for bowel obstruction will be accounted for when 5 years of surveillance is completed. Long-term results including oncologic outcome and quality of life must be taken into consideration, when agreeing upon recommendations for future procedures. The lymphadenectomy was equivalent in the two groups. The significantly longer operating time in the laparoscopic group tends to favour the open approach, but shorter duration of hospital stay and no wound dehiscence in the laparoscopic group favours this approach.

In summary, in this study there was no difference in Clavien–Dindo grade II–V complications in patients operated on with open and laparoscopic oncologic right-sided colectomy with central lymphadenectomy by high volume oncologic surgeons, with no anastomotic leakages in this trial.

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Disclosure

The authors declare no conflict of interest.

Supplementary material

Supplementary material is available at *BJS Open* online.

Data availability

The authors confirm that the data supporting the findings of this study are available from the corresponding author upon reasonable request.

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