Laparoscopic surgery versus open surgery for colon cancer: short-term outcomes of a randomised trial

*The COlon cancer Laparoscopic or Open Resection Study Group**

Summary

Background The safety and short-term benefits of laparoscopic colectomy for cancer remain debatable. The multicentre COLOR (COlon cancer Laparoscopic or Open Resection) trial was done to assess the safety and benefit of laparoscopic resection compared with open resection for curative treatment of patients with cancer of the right or left colon.

Methods 627 patients were randomly assigned to laparoscopic surgery and 621 patients to open surgery. The primary endpoint was cancer-free survival 3 years after surgery. Secondary outcomes were short-term morbidity and mortality, number of positive resection margins, local recurrence, port-site or wound-site recurrence, metastasis, overall survival, and blood loss during surgery. Analysis was by intention to treat. Here, clinical characteristics, operative findings, and postoperative outcome are reported.

Findings Patients assigned laparoscopic resection had less blood loss compared with those assigned open resection (median 100 mL [range 0–2700] *vs* 175 mL [0–2000], $p<0·0001$), although laparoscopic surgery lasted 30 min longer than did open surgery ($p<0·0001$). Conversion to open surgery was needed for 91 (17%) patients undergoing the laparoscopic procedure. Radicality of resection as assessed by number of removed lymph nodes and length of resected oral and aboral bowel did not differ between groups. Laparoscopic colectomy was associated with earlier recovery of bowel function ($p<0.0001$), need for fewer analgesics, and with a shorter hospital stay ($p<0·0001$) compared with open colectomy. Morbidity and mortality 28 days after colectomy did not differ between groups.

Interpretation Laparoscopic surgery can be used for safe and radical resection of cancer in the right, left, and sigmoid colon.

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Introduction

Minimally invasive surgery reduces surgical trauma. Laparoscopic surgery restricts the extent of abdominal incisions, avoids manual traction and manipulation of abdominal tissue, and prevents undue blood loss, thus diminishing immune activation and catabolism as a response to surgery.[1,2] 15 years after Muehe first did laparoscopic cholecystectomy, minimally invasive surgery has become the preferred approach for treatment of symptomatic cholecystolithiasis, gastro-oesophageal reflux, and morbid obesity.[3–6] Although Jacobs and Verdeja[7] reported a case series on laparoscopic segmental colectomy in patients with sigmoid cancer in 1991, laparoscopic colectomy for cancer has not been readily accepted: the safety of the procedure has been questioned because of early reports of port-site metastases. Despite reduced morbidity and improved convalescence after laparoscopic operations for benign disorders such as gallbladder stones and reflux oesophagitis, surgeons have been sceptical about similar advantages of laparoscopic colectomy for cancer.

The European, multicentre COLOR (COlon cancer Laparoscopic or Open Resection) trial aimed to assess laparoscopic surgery as curative treatment for colon cancer by analysis of short-term outcome and of cancer-free survival 3 years after laparoscopic surgery or open surgery for colon cancer. Data for cancer-free survival will be reported later. Here, the short-term results of clinical characteristics, operative findings, and post-operative outcome are reported.

Methods

Patients

Between March 7, 1997, and March 6, 2003, all patients with colon cancer who presented to the 29 participating hospitals were screened for inclusion into the trial. Patients with one adenocarcinoma, localised in the caecum, ascending colon, descending colon, or sigmoid colon above the peritoneal deflection who were aged 18 years or older and who gave written informed consent were eligible. The number of eligible patients who were not randomised was not recorded. Exclusion criteria were: body-mass index (BMI) of more than 30 kg/m^2; adenocarcinoma of the transverse colon or splenic flexure; metastases in the liver or lungs; acute intestinal obstruction, multiple primary tumours of the colon; scheduled need for synchronous intra-abdominal surgery; preoperative evidence of invasion of adjacent structures, as assessed by CT, MRI, or ultrasonography; previous ipsilateral colon surgery; previous malignant disease (except those who had had curative treatment for basocellular carcinoma of the skin or in-situ carcinoma of the cervix); absolute contraindications to general anaesthesia; and a long-term pneumoperitoneum.

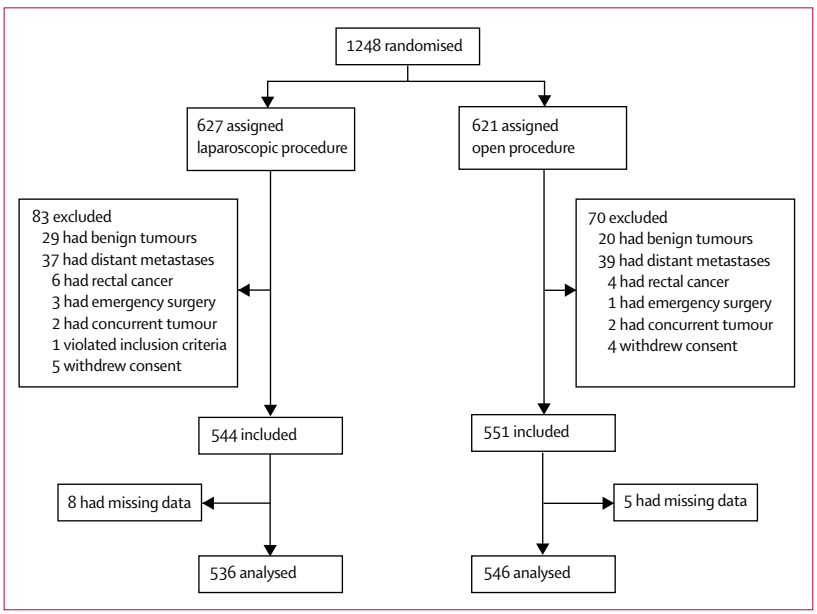

Figure 1: **Trial profile**

627 patients were randomly assigned to laparoscopic resection and 621 to open resection by use of computer-generated random numbers; randomisation was stratified according to participating centre and type of resection (ie, right hemicolectomy, left hemicolectomy, or sigmoidectomy). Patients were randomised by the trial coordinator (RV, who was succeeded by EK) at Erasmus University Medical Center, Rotterdam, Netherlands, and allocation was done by telephone or fax. Patients were not blinded to the procedure they were allocated because covering all possible open and laparoscopic incisions was thought too cumbersome.

	Laparoscopic colectomy (n=627)	Open colectomy (n=621)
Age (years)		
Median (range)	71 (27–92)	71 (31–95)
Sex		
Men	326 (52%)	336 (54%)
American Society of Anesthesiologists group		
I	164 (26%)	166 (27%)
II	353 (56%)	318 (51%)
III	92 (15%)	112 (18%)
IV	4 (1%)	5 (1%)
Missing data	14 (2%)	20 (3%)
Body-mass index (kg/m²)		
Median (range)	24·5 (12·1–37·1)	24·9 (14·5–40·5)
Previous abdominal surgery*		
No	386 (62%)	384 (62%)
Once	167 (27%)	163 (26%)
Twice	41 (7%)	49 (8%)
Three or more times	13 (2%)	9 (1%)
Missing data	20 (3%)	16 (3%)

*Does not total 100% because of rounding.

Table 1: **Baseline characteristics**

Patients were excluded after randomisation only if metastasis was detected during surgery, microscopic examination of the resected sample showed no signs of malignant disease, other primary malignant disease was discovered before or during surgery, patients needed emergency surgery, or if patients withdrew consent. The trial coordinator supervised data gathering and provided progress data to the protocol committee and the monitoring committee. The ethics committees of every participating centre gave ethics approval for the trial.

Diagnosis of colon cancer was confirmed by barium-enema radiography or colonoscopy. Biopsy samples were taken for polyps, but not for macroscopically evident carcinomas. All patients underwent radiographic imaging of the liver and chest to exclude distant metastases. In patients with rectosigmoid carcinoma, lateral barium-enema radiography was done to determine the exact location of the tumour. Bowel preparation, prophylaxis with antibiotics, and prophylactic treatment for thrombosis were done in accordance with standards at the participating institution.

Open surgery and laparoscopic surgery had similar protocols; extent of resection was much the same for both procedures. Right hemicolectomy involved resection of the caecum, ascending colon, and hepatic flexure with preservation of the main and left branches of the middle colic artery. Left hemicolectomy involved resection of at least 5 cm above and 5 cm below the lesion. For sigmoidectomy, resection of the sigmoid 5 cm above and 5 cm below the lesion was done. During laparoscopic surgery, either the tumour and adjacent tissue or the extraction site was protected during removal of the affected bowel. For laparoscopy, all surgical teams had done at least 20 laparoscopically assisted colectomies. An unedited videotape of a laparoscopic colectomy was submitted before a centre participated in the trial to assess safe and thorough techniques. All open colectomies were done by surgical teams who had at least one staff member with credentials in colon surgery. The resected tumour was presented unfixed to a pathologist, who recorded the size of the tumour, involvement of circumferential and longitudinal margins, number of resected lymph nodes, number of positive lymph nodes, and TNM classification in accordance with standardised techniques;[8] pathologists were not informed of the mode of resection.

Patients allocated laparoscopic surgery were converted to open surgery before the first incision when the laparoscopic equipment malfunctioned or when the laparoscopic surgical team was absent. Analysis was by intention to treat—ie, patients who had preoperative conversion remained in the laparoscopic group for analysis. Case-record forms were collected by the coordinating centre in Rotterdam, Netherlands. Short-term morbidity and mortality was defined as 28-day or in-hospital morbidity and mortality.

Interim analyses were done by the data monitoring committee after the report of every 50th recurrence in the whole study population. The trial was to be stopped if there was a convincing difference ($p<0·001$) in recurrence between groups.

Postoperative care, including use of narcotics for the first 3 days after surgery, was done in accordance with standard practice of the surgeons at the participating centre. Adjuvant therapy before and after surgery was allowed at the physician's discretion.

Primary and secondary outcomes

The primary outcome of the trial was cancer-free survival 3 years after surgery, and will be reported elsewhere. Secondary outcomes were short-term morbidity and mortality, number of positive resection margins, local recurrence, port-site and wound-site recurrence, metastasis, overall survival, and blood loss during surgery. Blood loss, operating time, conversions, radicality of resections, morbidity, mortality, and hospital stay are the outcomes reported here. Cost analyses[9] and quality-of-life assessments (not yet reported) have been done separately for every country because health-care costs and measurement of quality of life vary widely among European countries.

Statistical analysis

At the design of the trial, power calculations were done to exclude a difference of 7·4% or more in 3-year disease-free survival with 95% confidence. Thus, 1200 patients were needed to obtain 80% power.

Percentage differences between groups were compared with the χ^2 test or Fisher's exact test; comparison of continuous data was done by use of the Mann-Whitney test. Assessment of the effects of centre on operation time, blood loss, hospital stay, and number of lymph nodes was done with ANOVA after logarithmic transformation of these outcomes to obtain approximate normal distributions, and interaction terms were used to assess whether treatment effect differed between centres. Treatment effects are therefore expressed as ratios of geometric means. Centres with fewer than 30 patients were grouped. Further exploratory analyses, allowing for random centre effects, were done to investigate whether the number of patients per centre affected outcomes; only centres that accrued at least ten patients were included in this analysis. The effects of procedure and study centre on the odds of positive against negative resection margins were analysed by use of exact logistic regression. Statistical analyses were done with SPSS version 5.11. $p=0·05$ (two-sided) was the limit of significance in all analyses.

Role of the funding source

The sponsor of the trial had no role in the study design; collection, analysis, or interpretation of data; or the writing of the report. The corresponding author had full access to all data in the study and had final responsibility to submit the paper for publication.

	Laparoscopic colectomy (n=536)	Open colectomy (n=546)	p
Intervention			
Right hemicolectomy	259 (48%)	253 (46%)	0·87
Left hemicolectomy	57 (11%)	56 (10%)	
Sigmoid resection	199 (37%)	212 (39%)	
Other	21 (4%)	25 (5%)	
Time in theatre (min)*			
Median (range)	202 (50–540)	170 (45–580)	<0·0001
Duration of surgery (skin to skin, min)†			
Median (range)	145 (45–420)	115 (40–355)	<0·0001
Blood loss (mL)‡			
Median (range)	100 (0–2700)	175 (0–2000)	<0·0001

*Data missing for 99 patients. †Time from first incision to skin closure: data missing for 68 patients. ‡Data missing for 69 patients.

Table 2: **Operative data**

Results

Figure 1 shows the trial profile. The trial was not stopped early. 11 patients allocated laparoscopic surgery underwent open surgery because of malfunctioning laparoscopic equipment (eight patients) or absence of a skilled laparoscopic surgeon (three patients). Table 1 shows baseline characteristics of participants.

Malignant disease was confirmed preoperatively by a biopsy sample in 827 (76%) of 1082 patients. To diagnose the tumour, 876 (81%) of 1082 patients had colonoscopy and 432 (40%) had barium-enema radiography. Imaging of the primary tumour with CT was done for 48 (4%) of

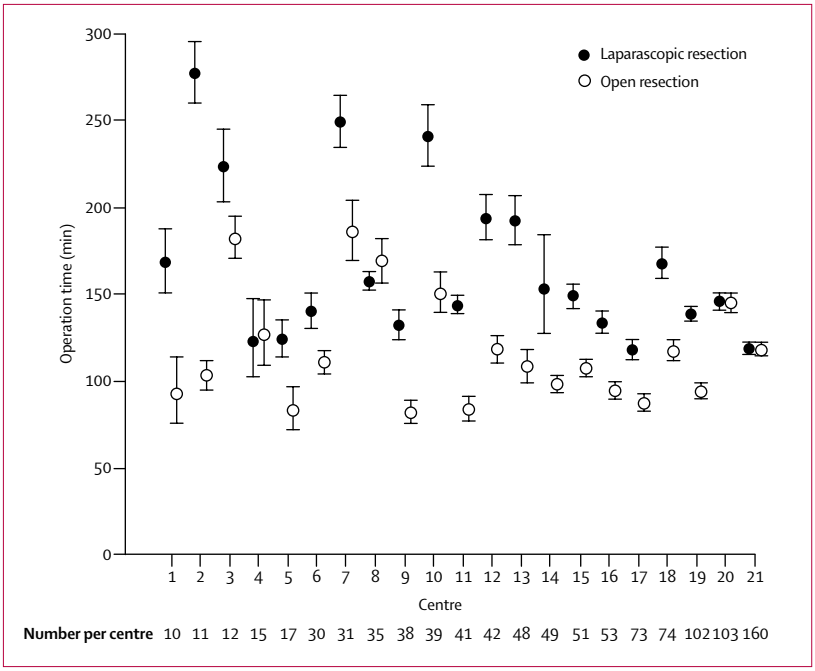

Figure 2: **Mean operation time by centre**
The 21 centres with at least ten patients are ranked according to number per centre. Vertical bars are SE.

Colonoscopic tattooing
Injection of India ink by use of a catheter, which is passed down a working channel in the colonscope, in the bowel wall surrounding the lesion. Blue ink is visualised on the serosal side of the bowel, allowing localisation of small lesions that are not readily visible.

1082 patients, and **colonoscopic tattooing** of the tumour for 37 (3%). In the laparoscopic group 21 tumours were tattooed: 15 in stage I disease, three in stage II, and three in stage III, of which four were in the right colon, five in the descending colon, and 12 in the sigmoid colon. In the open-surgery group, 16 tumours were tattooed: eight in stage I disease, six in stage II, and two in stage III, of which four were in the right colon, three in the descending colon, and nine in the sigmoid colon.

Screening for liver metastases before surgery was done by use of ultrasonography in 869 (80%) of 1082 patients, CT in 75 (7%), ultrasonography and CT in 123 (11%), and MRI combined with ultrasonography or with CT in four patients; 11 (<1%) patients did not have any such procedure and were assumed to have no liver metastases. Screening for pulmonary metastases before surgery was done with plain radiography of the chest in 1046 (97%) of 1082 patients, radiography and CT of the chest in 12 (1%), and chest CT in nine (1%); 15 (1%) patients had no procedure and were assumed to have no pulmonary metastasis. Use of imaging techniques did not differ between groups. The median time between randomisation and surgery was longer in the laparoscopic group than in the open-surgery group (6 days [range 1–85] *vs* 5 days [1–63]; p=0·02).

	Laparoscopic colectomy (n=536)	Open colectomy (n=546)	p
Tumour size (cm)*			
Median (range)	4·0 (0·4–17)	4·5 (0·8–17)	0·09
Resection margins†			
Positive	10 of 526 (2%)	10 of 538 (2%)	1·0
Aboral	1	1	
Oral	0	1	
Circumferential	9	8	
Negative	516 of 526 (98%)	528 of 538 (98%)	
Clinical T stage‡			
T1	41 of 528 (8%)	39 of 537 (7%)	0·95
T2	107 of 528 (20%)	105 of 537 (20%)	
T3	350 of 528 (66%)	359 of 537 (67%)	
T4	30 of 528 (6%)	34 of 537 (6%)	
Clinical N stage§¶			
N0	347 of 528 (66%)	364 of 539 (68%)	0·44
N1	125 of 528 (24%)	122 of 539 (23%)	
N2	45 of 528 (9%)	48 of 539 (9%)	
N3	11 of 528 (2%)	5 of 539 (1%)	
Tumour stage§¶			
I	129 of 528 (24%)	125 of 539 (23%)	0·60
II	218 of 528 (41%)	239 of 539 (44%)	
III	181 of 528 (34%)	175 of 539 (32%)	
Histology§¶			
Well differentiated	90 of 529 (17%)	86 of 538 (16%)	0·89
Well to moderately differentiated	28 of 529 (5%)	32 of 538 (6%)	
Moderately differentiated	321 of 529 (61%)	315 of 538 (59%)	
Moderately to poorly differentiated	13 of 529 (2%)	15 of 538 (3%)	
Poorly differentiated or undifferentiated	46 of 529 (9%)	55 of 538 (10%)	
Not specified	31 of 529 (6%)	35 of 538 (7%)	
Number of positive lymph nodes in resected sample‖			
Median (range)	10 (0–41)	10 (0–42)	0·35

*Data missing for 11 patients. †Data missing for 18 patients. ‡Data missing for 17 patients. §Data missing for 15 patients. ¶Might not add to 100% because of rounding. ‖Data missing for 36 patients.

Table 3: **Details of pathology report**

Table 2 shows operative findings. Duration of surgery was longer for patients assigned laparoscopic resection than for those assigned open resection. ANOVA showed that the centre-adjusted ratio (laparoscopic/open) of geometric mean duration of surgery was 1·39 (95% CI 1·32–1·49), but this effect differed significantly between centres. Random-effects regression analysis showed that the difference in duration of surgery between groups decreased with increasing numbers of patients per centre, an effect that was significant for the laparoscopic group (p=0·027) but not for the open-resection group (figure 2). Furthermore, time spent in the operating theatre was shorter for patients assigned open surgery than for those assigned laparoscopic surgery (table 2). By use of ANOVA, the centre-adjusted ratio (laparoscopic/open) of geometric mean time spent in theatre was 1·27 (1·22–1·32, p<0·001), which differed significantly between centres (data not shown). Random-effects regression analysis showed that mean time spent in theatre for patients assigned laparoscopic resection dropped with increased number of patients per centre (p=0·032), whereas no such association was noted for those assigned open colectomy.

Blood loss during laparoscopic colectomy was significantly less than that during open colectomy (table 2). ANOVA showed a centre-adjusted ratio (open/laparoscopic) of geometric mean blood loss of 1·66 (1·37–2·00)—a treatment effect that did not differ significantly between centres (data not shown).

During laparoscopic colectomy, adhesions were more frequently classified as problematic than during open colectomy (26 patients [5%] *vs* 11 patients [2%], p=0·02). During surgery, 91 (17%) patients who were undergoing laparoscopic colectomy were converted to open surgery because of: fixation to, or invasion of, adjacent structures by the tumour (n=31); size of the tumour (n=8); extensive adhesions (n=10); inability to localise the tumour (n=8); bleeding (n=7); tumour in transverse colon or below promontory (n=5); bad vision (n=5); length of procedure (n=3); anatomical difficulties (n=3); macroscopic suspicious lymph nodes needing extensive resection (n=3); ischaemia of the distal colon (n=1); intra-abdominal abscess (n=1); urethral injury (n=1); two synchronous tumours (n=1); gaseous distention of the bowls after colonoscopy during surgery (n=1); resection of leiomyoma of the adnex (n=1); and unknown reasons (n=2).

Postoperative microscopic examination showed no differences between laparoscopically resected and openly resected samples. Stage distribution, size of the tumour, and histological type were much the same for both groups (table 3). Furthermore, groups did not differ in the number of positive resection margins (table 3), and centre did not modify this effect (data not shown). The common odds ratio for positive against negative resection margins was 1·01 (0·36–2·68, p=1·0). In patients assigned laparoscopic resection, positive

margins were recorded in four patients with T3 tumours and in six patients with T4 tumours. In patients assigned open resection, four patients with positive margins had T3 tumours and six had T4 tumours. Groups did not differ in the number of lymph nodes harvested during surgery (table 3). ANOVA showed a centre-adjusted ratio (open/laparoscopic) of geometric mean number of lymph nodes of 1·08 (0·98–1·17, p=0·106), which did not differ significantly between centres (data not shown).

After laparoscopic colectomy, patients tolerated an oral fluid intake of more than 1 L 1 day earlier than did patients assigned open surgery, and time to first bowel movement was shorter after laparoscopic surgery than after open surgery (table 4). Moreover, laparoscopic colectomy was associated with a lower need for opioid analgesics on days 2 and 3 after surgery, and for non-opioids on the first day after surgery than was open resection. Epidural analgesics were used less frequently in the laparoscopic group compared with the open-resection group for the first 3 days after surgery (table 4).

Overall morbidity was much the same after laparoscopic surgery and open surgery (table 4). Groups did not differ in the occurrence of pulmonary or cardiac events, anastomotic failure, wound or urinary-tract infections, bowel obstruction for more than 3 days after surgery, or postoperative bleeding. The number of deaths were similar after surgery for both groups (table 4).

Groups did not differ in the numbers of reinterventions done 28 days after surgery (table 4). In the laparoscopic group, 18 reinterventions were needed for anastomotic leakage and abdominal sepsis, five for wound infections and dehiscence, four for bowel obstruction lasting more than 3 days, five for bleeding, one for a ruptured inflammatory aneurysm, two for a perforated gastric ulcer, one for explorative laparotomy, and one for removal of a rectal adenoma. In the open-resection group, eight reinterventions were needed for anastomotic leakage, nine for wound infections and dehiscence, four for bowel obstruction lasting more than 3 days, three for bleeding, and one for an ischaemic bowel.

Postoperative hospital stay was 1 day shorter in the laparoscopic group than in the open-resection group (table 4). By use of ANOVA, the centre-adjusted ratio (open/laparoscopic) of geometric mean hospital stay was 1·16 (1·08–1·23), and this treatment effect did not differ significantly between centres.

	Laparoscopic colectomy (n=536)	Open colectomy (n=546)	Mean difference between groups (95% CI)	p
Fluid intake >1 L (days)*				
Mean (SD)	2·9 (1·9)	3·8 (3·4)	0·9 (0·6 to 1·2)	<0·0001
First bowel movement (days)†				
Mean (SD)	3·6 (1·7)	4·6 (3·0)	1·0 (0·7 to 1·3)	<0·0001
Hospital stay (days)‡				
Mean (SD)	8·2 (6·6)	9·3 (7·3)	1·1 (0·2 to 1·9)	<0·0001
Analgesic use				
Day 1				
Opiates	292 of 516 (57%)	313 of 526 (60%)	3 (−3 to 9)	0·37
Non-opiates	366 of 517 (71%)	335 of 526 (64%)	−7 (−13 to −1)	0·02
Epidural	111 of 517 (22%)	190 of 526 (36%)	14 (9 to 20)	<0·0001
Day 2				
Opiates	208 of 514 (41%)	256 of 524 (49%)	8 (2 to 14)	0·008
Non-opiates	421 of 514 (82%)	443 of 524 (85%)	3 (−2 to 7)	0·29
Epidural	95 of 514 (18%)	164 of 523 (31%)	13 (8 to 18)	<0·0001
Day 3				
Opiates	132 of 513 (26%)	191 of 524 (37%)	11 (5 to 16)	0·0003
Non-opiates	343 of 513 (67%)	368 of 526 (70%)	3 (−2 to 9)	0·27
Epidural	42 of 513 (8%)	83 of 524 (16%)	8 (4 to 12)	0·0002
Complications§				
Overall	111 of 535 (21%)	110 of 545 (20%)	−1 (−5 to 4)	0·88
Wound infection	20 of 535 (4%)	16 of 545 (3%)	−1 (−3 to 1)	0·57
Wound dehiscence	2 of 534 (<1%)	7 of 544 (1%)	0·6 (−0·2 to 2)	0·18
Pulmonary	8 of 535 (2%)	13 of 545 (2%)	0·9 (−1 to 3)	0·40
Cardiac	4 of 535 (1%)	9 of 545 (2%)	1 (−0·5 to 2)	0·28
Bleeding	13 of 534 (2%)	8 of 544 (2%)	−0·9 (−3 to 1)	0·36
Urinary-tract infection	12 of 535 (2%)	13 of 545 (2%)	0·2 (−2 to 2)	1·00
Anastomotic failure	15 of 535 (3%)	10 of 545 (2%)	−1 (−3 to 1)	0·39
Bowel obstruction >3 days	10 of 534 (2%)	15 of 544 (3%)	0·9 (−1 to 3)	0·45
Other	45 of 534 (8%)	40 of 544 (7%)	−1 (−4 to 2)	0·59
Reintervention	37 of 535 (7%)	25 of 545 (5%)	−2 (−5 to 0·4)	0·13
Death	6 of 535 (1%)	10 of 545 (2%)	0·7 (−0·7 to 2·2)	0·45

*Data missing for 64 patients. †Data missing for 54 patients. ‡Data missing for 11 patients. §Some patients had more than one complication.

Table 4: **Postoperative recovery, morbidity, and mortality**

Discussion

The short-term outcomes of the COLOR trial show that although duration of surgery for laparoscopic colectomy for colon cancer was longer than that of open colectomy, patients who underwent the laparoscopic procedure had less blood loss during surgery. Moreover, tumours resected by laparoscopy or by open surgery did not differ in stage, distribution, size, histology, number of positive resection margins, and number of positive lymph nodes. After surgery, patients allocated laparoscopic colectomy tolerated fluid intake and had a first bowel movement, earlier than did those allocated open colectomy. Patients assigned laparoscopic colectomy had a lower need for analgesics and epidurals in the 3 days after surgery than did those assigned open colectomy.

29 university hospitals and community hospitals in seven European countries participated in this trial, and the outcomes thus give an insight into laparoscopic colon surgery as done in Europe. Importantly, however, this trial started in 1997 when the laparoscopic technique of segmental colectomy was changing. In the past 8 years, new ways of vessel sealing, such as bipolar and ultrasonic forceps, have been introduced. These devices allow faster and more secure haemostasis than do conventional laparoscopic techniques such as clips and unipolar diathermia. Furthermore, a shortcoming of this trial is that patients were not blinded as to the procedure they were allocated, which could have affected subjective outcomes. Missing data for 13 of 1248 patients seems acceptable, given that the trial was multicentre.

In this trial, patients who underwent laparoscopic colectomy spent longer undergoing surgery than did those who had open colectomy, but needed fewer opioids on the second and third postoperative day than did those who had open surgery. By contrast, Joels and colleagues[10] associated use of opioids after open colectomy with operative time as a result of more extensive tissue manipulation and protracted incision of the abdominal wall. The findings reported here suggest that manipulation of tissues is a more important determinant of postoperative pain than is operative time, and are consistent with Weeks and co-workers'[11] trial, which recorded shorter postoperative use of parenteral analgesics after laparoscopic colectomy than after open colectomy ($p<0·001$).

Bowel obstruction after colectomy, as defined by postoperative day of fluid intake of more than 1 L and postoperative day of first bowel movement, was 1 day shorter in patients who had laparoscopic surgery than in those who had open surgery in the COLOR trial. Braga and colleagues[12] noted first bowel movement 1 day earlier after laparoscopic colectomy than after open colectomy, and animal studies[13] have shown that laparoscopic colectomy reduces postoperative atony of the small bowel, as measured by electromyographic activity, compared with open colectomy. Clinical manometric recordings[14] of motility at the splenic flexure of the colon have shown that colonic motility recovers earlier after laparoscopic colectomy than after open colectomy. Rapid rehabilitation protocols involving thoracic epidural local anaesthetic blockade, early mobilisation of the patient, and solid food on the first postoperative day have reduced bowel obstruction to 1–2 days.[15]

Findings reported here show that hospital stay after laparoscopic colectomy was 1 day shorter with laparoscopic colectomy than with open colectomy, and are consistent with the findings of Lacy and colleagues[16] and the Clinical Outcomes of Surgical Therapy (COST) study group.[17] However, Basse and co-workers[18] showed substantial reduction of hospital stay after open colectomy by use of transverse incisions combined with accelerated multimodal rehabilitation programmes. Further assessment of the effect of such rehabilitation programmes on the outcome of laparoscopic and open colectomy are needed.

Conversion of laparoscopic procedures to open surgery was needed in 19% of patients, mainly because of the presence of a large and invasive cancer. Size and infiltration of adjacent tissues by a tumour cannot be assessed accurately by either colonoscopy or barium enema. However, these imaging modalities are regarded as the standard of care in Europe. Only 5% of patients had a CT scan to image the primary tumour, and use of CT or MRI in patients with colon cancer may identify patients with bulky or invasive lesions, or lesions at the flexures or transverse colon, which are less amenable to laparoscopic removal.

Operating time varies with surgical experience, and gaining experience with laparoscopic colectomy can reduce the operating time to that with open colectomy. Although in this trial, laparoscopic colectomies lasted longer than did open procedures, operating time varied substantially between centres. Although total open surgical procedures done per centre was not recorded, the presence of a skilled colorectal surgeon during all open colectomies ensured appropriate and timely procedures. Reluctance to implement laparoscopic colectomy in surgical practice because of restraints on operating time therefore seems unsubstantiated.

Blood loss during laparoscopic colectomy was less than that during open colectomy in this study. Kiran and colleagues[19] assessed use of blood products (ie, packed cell or transfused red cells) in a case-matched study of patients undergoing laparoscopic colectomy or open colectomy, and reported that demand for blood transfusions during and after surgery was less in the laparoscopic group compared with the open-surgery group. Furthermore, the safety and effectiveness of laparoscopic surgery can be measured by the degree of resection and disease-free survival. In the COLOR trial, the extent of resection of the colon and mesocolon was much the same for both groups. These findings are consistent with other prospective trials[20,21] of laparoscopic resection versus open resection for colon cancer, and by a consensus conference.[22] Moreover, a median number of ten lymph nodes were removed during surgery in both groups. It has been suggested[23] that at least 12 lymph nodes should be removed to ensure radical resection. However, the number of removed lymph nodes recorded by the pathologist is a function of the scrutiny of the detection method. In this study, pathologists were not urged to do a more thorough search for lymph nodes than is done in practice. A consensus conference[22] that documented available data for laparoscopic versus open colectomy showed that both procedures commonly yield ten lymph nodes. Assessment of 5-year survival after laparoscopic colectomy for tumours in the left and right colon by Jacob and Salky[24] showed that the mean harvest of ten lymph nodes was much the same as that with open colectomy.

Patients with a BMI of more than 30 kg/m^2 were excluded from the COLOR trial because at the time of trial design obesity was regarded as a technical challenge to laparoscopic colectomy. Delaney and co-workers[25] studied patients with a BMI of more than 30 kg/m^2 who had either laparoscopic colectomy or open colectomy. The researchers found that operating times and morbidity did not differ between groups and that hospital stay was 2 days shorter after laparoscopic surgery than after open surgery. However, the conversion rate from laparoscopic surgery to open surgery was 30%. Leroy and colleagues[26] assessed outcome of laparoscopic colectomy in obese and non-

obese patients who had diverticular disease or colon cancer, and found that groups did not differ in operating times, radicality of resection, and morbidity. Moreover, none of the 23 patients with a BMI of more than 30 kg/m^2 needed conversion to open surgery in Leroy and colleagues' study.[26] Patients who are obese can thus benefit from laparoscopic surgery, and obesity should no longer be regarded as a contraindication to laparoscopic colectomy.

Elderly patients were not been excluded from the COLOR trial. Yamamoto[27] showed that surgical outcome after laparoscopic colectomy for patients 80–90 years old was much the same as for those 60 years or younger. Furthermore, Sklow and co-workers[28] reported faster recovery after laparoscopic colectomy than after open colectomy in patients older than 75 years despite a longer operating time compared with open surgery.

The improved short-term outcome after laparoscopic surgery compared with open surgery may be a consequence of reduced surgical trauma. Serum concentration of interleukin 6 is a commonly used measure of surgical trauma: Ozawa and colleagues[29] recorded lower concentrations of serum interleukin 6 after laparoscopic colectomy than after open colectomy, and Whelan and co-workers[30] showed that open colectomy was associated with significant suppression of the cell-mediated immune response whereas laparoscopic colectomy was not ($p<0·007$).

In conclusion, the outcomes of studies on laparoscopic resection for colon cancer reflect experience of the past decade. During this period, laparoscopic surgical techniques have improved substantially as a result of growing experience and progressing technology that allows better video imaging, and safer and more efficient tissue ablation. Procedure times have dropped and undue tissue manipulation has decreased. The practice of open colectomy is changing too, with the implementation of rapid-recovery protocols. Further studies of the current surgical approaches for colon cancer are warranted to establish the optimum procedure for the individual patient with colon cancer.

Contributors

H J Bonjer was the principal investigator, and developed the protocol and helped write the report. E Haglind, J Jeekel, G Kazemier, and L Påhlman developed the protocol. W C J Hop did statistical analyses and helped write the report. R Veldkamp, E Kuhry, E Haglind, L Påhlman, M A Cuesta, S Msika, M Morino, A Lacy, and J Jeekel helped write the report.

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Conflict of interest

We declare no conflicts of interest.

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