Improved Oncologic Outcomes Following Laparoscopic Surgery for Small T4 Colon Cancer: A Multi-center Comparative Study

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Research

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Abstract

**Background:** Laparoscopic surgery for T4 colon cancer may be safe in selected patients. Based on the theory that small tumor size might preoperatively predict a good laparoscopic surgery outcome, we herein compare the clinicopathologic and oncologic outcomes of open and laparoscopic surgery in small T4 colon cancer.

**Methods:** In a retrospective multicenter study, we reviewed the data of 449 patients, including 117 patients with tumors ≤4 cm, who underwent T4 colon cancer surgery between January 2014 and December 2017. We compared the clinicopathologic and 3-year oncologic outcomes between the laparoscopic and open surgery groups.

**Results:** Blood loss, length of hospital stay, and postoperative morbidity were lower in the laparoscopic group than in the open group (86 mL vs. 278 mL, \( p < 0.001 \); 10.0 days vs. 12.5 days, \( p = 0.003 \); and 18.0% vs. 29.5%, \( p = 0.005 \), respectively). There were no intergroup differences in overall survival (OS) and 3-year disease-free survival (DFS; 87.8% vs. 83.2%, \( p = 0.117 \); 69.5% vs. 68.1%, \( p = 0.408 \), respectively). Among patients with tumors of size ≤4 cm, blood loss was lower in the laparoscopic surgery group than in the open group (80 mL vs. 208 mL, \( p = 0.001 \)); despite no statistical difference observed in the 3-year OS (84.4% vs 78.7%, \( p = 0.442 \)), the laparoscopic group had a better 3-year DFS (73.8% vs. 46.0%, \( p = 0.004 \)).

**Conclusions:** Laparoscopic surgery showed similar outcomes to open surgery in T4 colon cancer patients, and may have favorable short-term oncologic outcomes in patients with small T4 tumors.

Background

Approximately 10–20% of patients with colon cancer are diagnosed with T4 colon cancer [1–3]. R0 resection is essential for curative surgery in T4 colon cancer, although R0 resection is not easily achieved in case of tumor invasion into the adjacent organs or structures. Several meta-analyses and randomized controlled trials have reported that laparoscopic surgery is non-inferior to open surgery for colon cancer [4–7]. However, in T4 colon cancer, the feasibility of laparoscopic surgery with regard to the oncologic outcome remains debatable. In addition, treatment guidelines recommend an open approach for pT4 colon cancer.

Several recent studies have reported that laparoscopic surgery for T4 colon cancer showed better short-term outcomes, such as less intraoperative blood loss and shorter hospital stay, than open surgery as well as non-inferiority in oncologic outcomes [8–10]. However, the exact clinical conditions wherein laparoscopic surgery for T4 colon cancer is feasible or harmful, with regard to the oncologic outcomes, need to be ascertained. Studies have reported that a technical difficulty during laparoscopic surgery could threaten oncological safety, while tumor size is a factor that is known to influence the technical difficulty associated with tumor resection [11, 12].
In T4 colon cancer, a laparoscopic approach seems to be superior in regard to clinical outcomes in cases where the tumor is easy to access or handle, such as with a small invasive tumor. However, large-sized tumors are more difficult to resect laparoscopically, which may increase the risk of tumor spillage. However, there is scant evidence of the comparative outcomes of open and laparoscopic surgery with respect to the tumor size in T4 colon cancer.

In this study, we investigated the hypothesis that small tumors may influence the preoperative prediction of a good outcome following a laparoscopic approach, and evaluated the clinicopathologic and oncologic outcomes of open and laparoscopic surgery in small T4 colon cancer patients.

Methods

Patient characteristics

A retrospective chart review and analysis of multicenter data were undertaken, including data of patients diagnosed with pathologic T4 colon cancer who underwent curative surgery at three institutions between January 2014 and December 2017. Rectal cancer was defined as cancer in which the lower margin of the tumor was located within 15 cm above the anal verge, and patients with rectal cancer were excluded from this study. Moreover, patients with stage T1–3 colon cancer, histological diagnosis indicating cancer other than adenocarcinoma, palliative surgery, inflammatory bowel disease, and hereditary colon cancer were excluded.

The patient characteristics and perioperative outcomes were analyzed, including age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) score, preoperative carcinoembryonic antigen (CEA) level, location, operative time, blood loss, intraoperative transfusion, length of hospital stay, and postoperative morbidity. The pathologic features that were analyzed included tumor size, T stage, nodal status, angio-lymphatic invasion, venous invasion, perineural invasion, adjacent organ resection, and R0 resection. The oncologic outcome included the 3-year disease-free survival (DFS) and overall survival (OS) as the primary outcomes. The tumor size was measured on the basis of the long diameter of the tumor in the pathologic specimen. Patients with ASA scores 1 or 2 and 3 or 4 were included in the same group for analysis. The tumor location was divided into the right (from cecum to transverse colon) and left (from splenic flexure to sigmoid colon) sides. The nodal status was classified as the absence (N0) or presence (N+) of metastatic regional lymph node(s).

All study procedures were conducted in accordance with the principles of the Declaration of Helsinki of 1964 and its later amendments. This study was approved by the institutional review board of the National Cancer Center, Korea (NCC2020-0166), and the need for informed consent was waived due to the retrospective study design.

Outcomes
The primary outcome of this study was the comparison of oncologic outcomes, including 3-year OS and 3-year DFS, between the laparoscopic and open surgery groups for small T4 colon cancer. The secondary outcome was the R0 resection rate. The OS was defined as the time from surgery to death, and the DFS was defined as the time from surgery to any recurrence, a second cancer, or death. R0 resection was defined as the absence of cancer cells, when evaluated microscopically, at the primary tumor site after resection.

**Statistical analysis**

Data are reported as mean and standard deviation (SD) for continuous variables, and as frequency (%) for categorical variables. The comparison of the variables between the open and laparoscopic groups was performed by using the independent *t*-test and chi-square test or Fisher's exact test. Survival curves were analyzed by using the Kaplan–Meier method, and the intergroup differences were compared using the log-rank test. A *p*-value < 0.05 was considered to indicate a significant difference.

**Results**

**Patient characteristics**

A total of 449 patients were included and classified according to tumor size; 117 and 332 patients had tumors of ≤4 and >4 cm, respectively. In the ≤4-cm group, 29 and 88 patients underwent open and laparoscopic surgery, respectively. In the >4-cm group, 138 and 194 patients underwent open and laparoscopic surgery, respectively (Fig. 1). Moreover, 21 patients who converted from laparoscopic surgery to open surgery were included in the laparoscopic group.

Patients in the laparoscopy group had higher BMI (22.0 kg/m² vs. 23.7 kg/m², *p* < 0.001) and a lower proportion of patients in this group had an ASA score greater than 2 (14.1% vs. 4%, *p* < 0.001) than in the open group. The proportions of blood loss (278 mL vs. 86 mL, *p* < 0.001) and postoperative transfusion (12.8% vs. 0.7%, *p* < 0.001) were lower in the laparoscopy group. Moreover, patients in the laparoscopy group had a shorter hospital stay (12.5 days vs. 10.0 days, *p* = 0.003) and a lower postoperative morbidity (29.5% vs. 18%, *p* = 0.005) (Table 1).
Table 1
Patient characteristics and perioperative outcomes

| Variable                      | Open (N = 149) | Laparoscopy (N = 300) | p value   |
|-------------------------------|----------------|-----------------------|-----------|
| Age (years)                   | 64.9 ± 12.8    | 63.6 ± 12.6           | 0.298**   |
| Male/female                   | 82/67          | 172/128               | 0.643*    |
| BMI (kg/m²)                   | 22.0 ± 3.3     | 23.7 ± 3.5            | < 0.001** |
| ASA score(12/34)              | 128/21         | 288/12                | < 0.001*  |
| Preoperative CEA (ng/ml)      | 18.5 ± 47.8    | 14.5 ± 39.7           | 0.399**   |
| Location(Rt./Lt.)             | 64/85          | 142/158               | 0.380*    |
| Operative time (min)          | 174 ± 116      | 175 ± 63              | 0.964**   |
| Blood loss (ml)               | 278 ± 457      | 86 ± 97               | < 0.001** |
| Transfusion                   | 19 (12.8%)     | 2 (0.7%)              | < 0.001*  |
| Hospital stay (days)          | 12.5 ± 8.1     | 10.0 ± 9.8            | 0.003**   |
| Postoperative morbidity (%)   | 44 (29.5%)     | 54 (18.0%)            | 0.005*    |

Values are expressed as mean or number (%).

*p-value calculated by the chi-square test. **p-value calculated by the independent t-test. BMI, body mass index; CEA, carcinoembryonic antigen

Pathologic and oncologic outcomes

Patients in the laparoscopy group had a smaller tumor (6.8 cm vs. 5.4 cm, p < 0.001) and a lower T4b rate (43.0% vs 17.3%, p < 0.001). Angio-lymphatic, venous, and perineural invasion were more common in the laparoscopy group (43.0% vs 74%, p < 0.001; 34.9% vs 50%, p = 0.002; 62.4% vs 78%, p < 0.001, respectively) than in the open surgery group. Similarly, the adjacent organ-resection rate was lower in the laparoscopy group (28.2% vs 6%, p < 0.001) than in the open surgery group.

The R0 resection rate did not differ significantly between the two groups (94.0% vs. 97.3%, p = 0.078; Table 2). The median follow-up period was 34 months. There were no significant intergroup differences with regard to the 3-year OS and DFS (83.2% vs. 87.8%, p = 0.117; 68.1% vs. 69.5%, p = 0.408, respectively; Fig. 2).
Table 2
Pathologic features and oncologic outcomes

| Variable                        | Open (N= 149) | Laparoscopy (N= 300) | p value   |
|---------------------------------|---------------|----------------------|-----------|
| Tumor size (cm)                 | 6.8 ± 3.5     | 5.4 ± 2.2            | < 0.001** |
| Node state (N0/N+)              | 53/96         | 85/215               | 0.118*    |
| T4a/T4b                         | 85/64         | 248/52               | < 0.001*  |
| Angiolymphatic invasion (%)     | 64 (43.0%)    | 222 (74.0%)          | < 0.001*  |
| Venous invasion (%)             | 52 (34.9%)    | 150 (50%)            | 0.002*    |
| Perineural invasion (%)         | 93 (62.4%)    | 234 (78.0%)          | < 0.001*  |
| Combined resection (%)          | 42(28.2%)     | 18(6.0%)             | < 0.001*  |
| R0 resection rate (%)           | 140(94.0%)    | 292(97.3%)           | 0.078*    |

Values are expressed as mean or number (%).

*p-value calculated by the chi-square test. **p-value calculated by the independent t-test.

Outcomes of small T4 colon cancer

Table 3 shows the clinical characteristics and perioperative outcomes of patients with tumor size ≤ 4 cm. The laparoscopy group had higher BMI (22.3 kg/m² vs. 23.9 kg/m², p = 0.026) and less blood loss (208 mL vs. 80 mL, p = 0.03). Other variables did not differ significantly between the two study groups. Table 4 presents the pathologic features and oncologic outcomes of patients with tumor size ≤ 4 cm. Patients in the laparoscopy group were more likely to have angiolymphatic invasion (37.9% vs. 77.3%, p < 0.001).
Table 3
Patient characteristics and perioperative outcomes in the group of patients with tumor size ≤ 4 cm

| Variable                      | Open (N= 29) | Laparoscopy (N= 88) | p value |
|-------------------------------|--------------|----------------------|---------|
| Age (years)                   | 62.2 ± 12.0  | 65.1 ± 12.8          | 0.287** |
| Male/female                   | 14/15        | 46/42                | 0.709*  |
| BMI (kg/m²)                   | 22.3 ± 3.2   | 23.9 ± 3.2           | 0.026** |
| ASA score(12/34)              | 28/1         | 87/1                 | 0.436*  |
| Preoperative CEA (ng/ml)      | 6.2 ± 11.6   | 9.2 ± 18.2           | 0.438** |
| Location(Rt./Lt.)             | 12/17        | 40/48                | 0.702*  |
| Operative time (min)          | 119 ± 99     | 157 ± 56             | 0.060** |
| Blood loss (ml)               | 208 ± 292    | 80 ± 89              | 0.030** |
| Transfusion                   | 2 (6.9%)     | 0                    | 0.060*  |
| Hospital stay (days)          | 10.4 ± 7.2   | 9.5 ± 4.4            | 0.400** |
| Postoperative morbidity (%)   | 6 (20.7%)    | 18 (20.5%)           | 0.978*  |

Values are expressed as mean or number (%).

*p-value calculated by the chi-square test. **p-value calculated by the independent t-test.

BMI, body mass index; CEA, carcinoembryonic antigen
Table 4
Pathologic features and oncologic outcomes in patients with tumor size ≤ 4 cm

| Variable                | Open (N= 29) | Laparoscopy (N= 88) | p value |
|-------------------------|--------------|---------------------|---------|
| Tumor size (cm)         | 3.4 ± 0.6    | 3.1 ± 0.8           | 0.069** |
| Node state (N0/N+)      | 7/22         | 22/66               | 0.926   |
| T4a/T4b                 | 26/3         | 85/3                | 0.161*  |
| Angiolymphatic invasion (%) | 11 (37.9%)  | 68 (77.3%)          | < 0.001*|
| Venous invasion (%)     | 10 (34.5%)   | 38 (43.2%)          | 0.409*  |
| Perineural invasion (%) | 22 (75.9%)   | 77 (87.5%)          | 0.146*  |
| Combined resection (%)  | 2(6.9%)      | 2(2.3%)             | 0.256*  |
| R0 resection rate (%)   | 29(100.0%)   | 88(100%)            | n.c*    |

Values are expressed as mean or number (%).

*p-value calculated by the chi-square test or Fisher’s exact test. **p-value calculated by the independent t-test.

R0 resection was performed in all patients in both groups. In patients with tumor size ≤ 4 cm, the 3-year OS did not differ significantly between the two groups (78.7% vs. 84.4%, p = 0.442). However, the 3-year DFS was higher in the laparoscopy group (46.0% vs. 73.8%, p = 0.004; Fig. 3).

Discussion

Although the safety of laparoscopic surgery for colon cancer had been demonstrated in several studies [4–7], the safety of this surgical approach is controversial in T4 colon cancer. Several studies have suggested that a laparoscopic approach in T4 colon cancer may be feasible in some patients. Few studies have provided useful indications for laparoscopic surgery in T4 colon cancer. Klaver et al. [2] reported that laparoscopic surgery for T4a tumors might be safe. However, the pathologic features would not be helpful in determining the indication of laparoscopic surgery preoperatively. Park et al. [13] found the laparoscopic approach to be feasible for left-sided T4 colon cancer. Nevertheless, a useful predictor is still necessary to preoperatively determine the safety of laparoscopic surgery for T4 cancer.

In this study, the clinicopathologic and oncologic outcomes of laparoscopic surgery for T4 colon cancer were generally comparable to those of open surgery. The laparoscopic approach, especially for small T4 tumors, showed better 3-year DFS than did open surgery.

A previous study has reported that malignant cells are intraoperatively exfoliated from the tumor during resection and spread to the peritoneal surface and portal vein system. This can be prevented by minimizing tumor manipulation, e.g., through a laparoscopic approach [14]. As did our study, Lacy et al. showed better cancer-related survival with laparoscopic colectomy than open surgery for non-metastatic
colon cancer in a randomized clinical trial [15]. When laparoscopic surgery is conducted by a well-
experienced surgeon, tumor spillage and spread may be prevented in some patients.

As the tumor size increases, some technical challenges arise with regard to laparoscopic surgery, because it reduces the working space, narrows the operative visual field, increases bleeding, and makes the tumor difficult to remove. Moreover, larger tumors increase the risk of tumor spillage, thereby increasing peritoneal seeding or trocar-site recurrence. Our data shows that the 3-year OS and DFS rates in patients with tumor size > 4 cm were not significantly different between the two groups (84.4% vs. 89.2%, \( p = 0.17 \); 73.8% vs. 68.0%, \( p = 0.625 \), respectively). This suggests that the laparoscopic approach is more feasible in patients with small tumor than in those with larger tumors.

Laparoscopic surgery is better than open surgery in regard to the perioperative outcome. In previous studies comparing laparoscopic and open surgery in T4 colon cancer, laparoscopic surgery was associated with less intraoperative blood loss [1, 16, 17], which has been proven to be a predictor of long-term survival [18, 19]. Some studies have shown that hospital stays are shorter in patients who undergo laparoscopic surgery [20, 21]. In this study, the laparoscopic group patients had less intraoperative blood loss and shorter hospital stays than the open surgery group patients.

In previous studies of T4 colon cancer, the conversion rate from laparoscopic to open surgery was reported to be in the range of 7.1–28.2% [3]. Converted patients have high postoperative morbidity and adverse effects on long-term oncologic outcomes [22]. In the present study, the overall conversion rate was 7%, and the conversion rate for patients with tumor size ≤ 4 cm was 2.3%. The low conversion rate might be responsible for the better oncologic outcomes of laparoscopic surgery.

In this study, the 3-year DFS for the open surgery group with tumor size ≤ 4 cm was 46.0%, which was much lower than the 68.1% for the entire open surgery group. This result is similar to that of the study by Huang et al., which reported that a smaller tumor size was associated with a decreased survival in the T4b subset of colon cancer patients [23]. Huang et al. suggested that small tumors in T4b patients may reflect a more biologically aggressive phenotype. Another plausible explanation is that surgeons may have conducted more aggressive surgery for large tumors. In the present study, the rate of multi-visceral resection was 28.2% in the entire open surgery group, but only 6.9% in the small tumor group. This surgeon-related factor may contribute to worse 3-year DFS in small tumor patients.

The limitations of this study are as follows. As this was a retrospective study, the choice of surgical approach may have been influenced by the patient's condition or tumor progression. First, this study was conducted on the basis of the pathologic T4 instead of the clinical T4, although the former cannot be used to determine the surgical approach preoperatively. Engelmann et al. reported that the CT accuracy of T4 staging in colon cancer was only 70–77% [24], but further studies are needed in patients with clinical T4 colon cancer. Second, more patients had higher ASA scores in the open surgery group. This may have affected the OS or DFS. However, in patients with tumors of ≤ 4 cm, there was no intergroup difference in the ASA scores. Third, the T4b rate and number of adjacent organ resections were higher in the open surgical group. Thus, it is apparent that open surgery was chosen for patients with more advanced
tumors. However, there were no intergroup differences in the T4b rate and adjacent other organ resections in patients with a small tumor.

**Conclusions**

Although laparoscopic surgery showed similar outcomes in T4 colon cancer to open surgery, the former appears to have favorable short-term oncologic outcomes in patients with a small tumor. Prospective large-scale studies are needed to identify improved oncologic outcomes of laparoscopic surgery for small T4 colon cancers.

**Abbreviations**

OS, overall survival; BMI, body mass index; ASA, American Society of Anesthesiologists; CEA, carcinoembryonic antigen; DFS, disease-free survival; SD, standard deviation

**Declarations**

**Ethics approval and consent to participate:**

This study was approved by the institutional review board of the National Cancer Center, Korea (NCC2020-0166). The need for informed consent was waived due to the retrospective study design.

**Consent for publication:**

We simply extracted data and did not involve the private information of patients.

**Availability of data and materials:**

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

**Competing interests:**

The authors declare that they have no conflicts of interest.

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References

1. de’Angelis N, Vitali GC, Brunetti F, Wassmer C-H, Gagniere C, Puppa G, Tournigand C, Ris F. Laparoscopic vs. open surgery for T4 colon cancer: a propensity score analysis. Int J Colorectal Dis. 2016;31:1785–97.

2. Klaver CE, Kappen TM, Borstlap WA, Bemelman WA, Tanis PJ. Laparoscopic surgery for T4 colon cancer: a systematic review and meta-analysis. Surgical endoscopy. 2017;31:4902–12.

3. Liu Z-H, Wang N, Wang F-Q, Dong Q, Ding J. Oncological outcomes of laparoscopic versus open surgery in pT4 colon cancers: A systematic review and meta-analysis. Int J Surg. 2018;56:221–33.

4. Buunen M. Colon Cancer Laparoscopic or Open Resection Study Group. Survival after laparoscopic surgery versus open surgery for colon cancer: long-term outcomes of a randomised clinical trial. Lancet Oncol. 2009;10:44–52.

5. Jayne DG, Guillou PJ, Thorpe H, Quirke P, Copeland J, Smith AM, Heath RM, Brown JM. Randomized trial of laparoscopic-assisted resection of colorectal carcinoma: 3-year results of the UK MRC CLASICC Trial Group. J Clin Oncol. 2007;25:3061–8.

6. Kuhry E, Schwenk W, Gaupset R, Romild U, Bonjer J. Long-term outcome of laparoscopic surgery for colorectal cancer: a cochrane systematic review of randomised controlled trials. Cancer treatment reviews. 2008;34:498–504.

7. Ohtani H, Tamamori Y, Azuma T, Mori Y, Nishiguchi Y, Maeda K, Hirakawa K. A meta-analysis of the short-and long-term results of randomized controlled trials that compared laparoscopy-assisted and conventional open surgery for rectal cancer. J Gastrointest Surg. 2011;15:1375–85.
8. Chan D KH, Tan K-K. Laparoscopic surgery should be considered in T4 colon cancer. Int J Colorectal Dis. 2017;32:517–20.

9. Lu J, Dong B, Yang Z, Song Y, Yang Y, Cao J, Li W. Clinical efficacy of laparoscopic surgery for T4 colon cancer compared with open surgery: a single center’s experience. J Laparoendosc Adv Surg Tech. 2019;29:333–9.

10. Yamanashi T, Nakamura T, Sato T, Naito M, Miura H, Tsutsui A, Shimazu M, Watanabe M. Laparoscopic surgery for locally advanced T4 colon cancer: the long-term outcomes and prognostic factors. Surg Today. 2018;48:534–44.

11. Kang S-B, Park J-S, Kim D-W, Lee T-G. Intraoperative technical difficulty during laparoscopy-assisted surgery as a prognostic factor for colorectal cancer. Diseases of the colon rectum. 2010;53:1400–8.

12. Targarona EM, Balague C, Pernas JC, Martinez C, Berindoague R, Gich I, Trias M. Can we predict immediate outcome after laparoscopic rectal surgery? Multivariate analysis of clinical, anatomic, and pathologic features after 3-dimensional reconstruction of the pelvic anatomy. Annals of surgery. 2008;247:642–9.

13. Park JH, Park H-C, Park SC, Sohn DK, Oh JH, Kang S-B, Heo SC, Kim MJ, Park JW, Jeong S-Y. Laparoscopic approach for left-sided T4 colon cancer is a safe and feasible procedure, compared to open surgery. Surgical endoscopy. 2019;33:2843–9.

14. Bessa X, Castells A, Lacy AM, Elizalde JI, Delgado S, Boix L, Piñol V, Pellisé M, García-Valdecasas JC, Piqué JM. Laparoscopic-assisted vs. open colectomy for colorectal cancer: influence on neoplastic cell mobilization. J Gastrointest Surg. 2001;5:66–73.

15. Lacy AM, García-Valdecasas JC, Delgado S, Castells A, Taurá P, Piqué JM, Visa J. Laparoscopy-assisted colectomy versus open colectomy for treatment of non-metastatic colon cancer: a randomised trial. The Lancet. 2002;359:2224–9.

16. Aoki T, Matsuda T, Hasegawa H, Yamashita K, Sumi Y, Ishida R, Yamamoto M, Kanaji S, Oshikiri T, Nakamura T. Outcomes of laparoscopic surgery for pathological T4 colon cancer. Int J Colorectal Dis. 2019;34:1259–65.

17. Kang J, Baik SH, Lee KY, Sohn S-K. Outcomes of laparoscopic surgery in pathologic T4 colon cancers compared to those of open surgery. Int J Colorectal Dis. 2017;32:531–8.

18. Lehnert T, Methner M, Pollok A, Schaible A, Hinz U, Herfarth C. Multivisceral resection for locally advanced primary colon and rectal cancer: an analysis of prognostic factors in 201 patients. Annals of surgery. 2002;235:217.

19. Nakafusa Y, Tanaka T, Tanaka M, Kitajima Y, Sato S, Miyazaki K. Comparison of multivisceral resection and standard operation for locally advanced colorectal cancer: analysis of prognostic factors for short-term and long-term outcome. Diseases of the colon rectum. 2004;47:2055–63.

20. Kim IY, Kim BR, Kim YW. The short-term and oncologic outcomes of laparoscopic versus open surgery for T4 colon cancer. Surgical endoscopy. 2016;30:1508–18.

21. Yang X, Zhong ME, Xiao Y, Zhang G, Xu L, Lu J, Lin G, Qiu H, Wu B. Laparoscopic vs open resection of pT 4 colon cancer: a propensity score analysis of 94 patients. Colorectal Dis. 2018;20:0316–25.
22. Clancy C, O'Leary D, Burke J, Redmond H, Coffey J, Kerin M, Myers E. A meta-analysis to determine the oncological implications of conversion in laparoscopic colorectal cancer surgery. Colorectal Dis. 2015;17:482–90.

23. Huang B, Feng Y, Mo S-B, Cai S-J, Huang L-Y. Smaller tumor size is associated with poor survival in T4b colon cancer. World journal of gastroenterology. 2016;22:6726.

24. Engelmann BE, Loft A, Kjær A, Nielsen HJ, Berthelsen AK, Binderup T, Brinch K, Brünner N, Gerds TA, Høyer-Hansen G. Positron emission tomography/computed tomography for optimized colon cancer staging and follow up. Scand J Gastroenterol. 2014;49:191–201.

Figures

![Flow chart showing patient enrollment.](image)
Figure 2

Kaplan–Meier curve showing survival outcomes between the open and laparoscopic surgery groups: (a) 3-year overall survival (OS) and (b) 3-year disease-free survival (DFS). There were no significant intergroup differences with regard to the 3-year OS and DFS (83.2% vs 87.8%, p = 0.117; 68.1% vs 69.5%, p = 0.408, respectively).

Figure 3

Kaplan–Meier curve showing survival between open vs laparoscopic surgery in tumor size ≤4 cm. (a) 3-year overall survival (OS) and (b) 3-year disease-free survival. In patients with tumor size ≤4 cm, the 3-
year OS did not significantly differ between the two groups (78.7% vs 84.4%, p = 0.442). The 3-year DFS was higher in the laparoscopy group (46.0% vs 73.8%, p = 0.004).