INTRODUCTION

Obesity is a well-known and increasingly common problem in the Western world. In the United States, the number of overweight (body mass index [BMI] ≥ 25 kg/m²) and obese (BMI ≥ 30 kg/m²) individuals has continued to increase at alarming rates; according to the National Institutes of Health in 2010, 68% of adult Americans were categorized as overweight and 33.8% of these were obese [1]. Obesity is correlated with various diseases and is considered to be a risk factor for postoperative morbidity after abdominal surgery. Increasing BMI is significant risk factor for the occurrence of colon cancer. In the past, obesity was considered to be a relative contraindication to laparoscopy, as the condition had been associated with technical difficulties during the procedure [2-9]. Most studies have compared the outcomes for obese (BMI ≥ 30 kg/m²) and non-obese (BMI < 30 kg/m²) patients. However, the
distribution of BMI has been found to differ among ethnic groups and in Asian populations, obese (BMI ≥ 30 kg/m²) patients are rare. In general, the average BMI of Asian populations is lower than that of non-Asian communities [10].

Because Asians have a greater tendency towards abdominal obesity than non-Asians, the application of the current World Health Organization (WHO) obesity BMI cutoff of 30 kg/m² would underestimate obesity-related risks in Asian populations. Based on risk factors and morbidities, the International Obesity Task Force (IOTF) has recommended a BMI cutoff of 25.0 kg/m² obesity in Asians [11].

To date, little is known about the surgical outcomes of laparoscopic colon surgery in obese Asians patients. The goal of this study was to evaluate the feasibility and safety of laparoscopic surgery in Asian patients with colon cancer, as a function of BMI.

METHODS

Patients

Between January 2008 and December 2010, 1,740 consecutive patients who underwent curative resection for colon cancer at the Samsung Medical Center were analyzed retrospectively. Patients with stage IV disease (n = 90); rectal cancer or benign disease (n = 47), insufficient or no follow-up data (n = 152), with rectosigmoid colon cancer who underwent lower abdominal resection (n = 160) were excluded. Cases involving robotic surgery or reduced port laparoscopic surgery (n = 99) were also excluded. Finally, 1,192 patients were enrolled in this study and were divided into right and left colon group. The right colon group was defined as patients with involvement of the colon from the appendix to the transverse colon; and the left colon group was defined as patients with involvement of the colon from the splenic flexure to the rectosigmoid junction [12].

Methods

For this study, patient data were collected from the Samsung Medical Center Colon Cancer Surgery Database. Insufficient data were re-evaluated using electronic medical charts. The preoperative clinical evaluation included a physical examination, colonoscopy, abdominopelvic computed tomography (CT), chest radiography or CT, complete blood cell count, liver function test, and carcinoembryonic antigen (CEA) level. Depending on the extent of the disease, rectal or liver magnetic resonance imaging and CT combined with positron emission tomography were also performed. The preoperative physical status of the patients was categorized according to ASA classifications.

All the patients underwent surgery performed by five colon surgeons in a single center. This study was reviewed and approved by the appropriate institutional review board.

In the conventional laparoscopic surgery procedure, the initial trocar for the laparoscope was placed in the umbilical region after creation of the pneumoperitoneum with a standard Veress needle technique. Four additional trocars were then inserted in each of the four quadrants of the abdomen under laparoscopic visualization. After initial exploration, similar standard techniques were used in both procedures [13-16]. The postoperative management and discharge criteria were similar among surgeons because they shared a common clinical protocol (CP) at the institution. Patients who underwent surgery were usually permitted to drink water at postoperative day 1 or 2. They were allowed to eat a soft diet the day after they started to drink water. They were discharged after the wound was completely healed, unless it interfered with daily life after postoperative days 6 to 7.

The patients visited the outpatient clinic every 3 months for the first 2 years, every 6 months for the subsequent 3 years, and annually thereafter. Regular laboratory tests and a physical examination were performed. Chest and abdominopelvic CT scans were obtained every 6 months or every year to detect recurrence during the follow-up period. Local recurrence or systemic metastasis was determined on clinical and radiologic examinations or by using histologic confirmation. The survival analyses were evaluated with the 5-year overall survival rate and 5-year disease-free survival between 2008 and 2013.

Patients were classified according to the categories proposed by the IOTF as Non-obese (BMI < 25.0 kg/m²), Obese I (BMI 25.0–29.9 kg/m²), and Obese II (BMI ≥ 30 kg/m²) [11,17,18]. Surgical outcomes, including open conversion, total operative time, and postoperative hospital stay, were compared in Non-obese, Obese I, and Obese II patients. The laparoscopic group was defined as patients who had their entire surgery performed laparoscopically, and the conversion group was defined as patients who required conversion to open surgery.

Statistical analysis

Statistical evaluation was carried out using the statistical package SPSS for Windows (ver. 22.0; IBM, Armonk, NY, USA). Differences between groups were analyzed using the Chi-square tests, Fisher exact tests, and Student’s t-tests as appropriate. Groups were compared using the one-way analysis of variance with post hoc comparisons (Tukey’s test), depending on the nature of the data. Data are presented as the number of patients and percentage or as the mean with standard deviation. Survival rates were calculated using the Kaplan–Meier method, and prognostic factors and survival curves were compared using the log-rank test. Only variables with
a statistical P-value of < 0.05 in the univariate analysis were entered into the Cox regression model for multivariate analysis. A P-value of < 0.05 was considered statistically significant, and confidence intervals (CI) were set at the 95% level.

RESULTS

Of the 1,192 patients, 812 (68.1%), 360 (30.2%), and 20 (1.7%), were classified as Non-obese, Obese I, and Obese II, respectively (Table 1). The sex, underlying disease, and previous operative history were significantly different among the three groups (P < 0.001, P < 0.001, P = 0.005, respectively). However, the other characteristics were not significantly different.

Tumors were likely to be located in the left colon, although this was not statistical different (P = 0.927) (Table 2). The Obese II group had higher conversion rates (10.0% vs. 3.6% and 1.6%, P = 0.008) and longer operative times (180.35 vs. 162.54 and 147.84 minutes, P < 0.001) than the Obese I and Non-obese groups. However, the rates of cancer obstruction and perforation (P = 0.291, 0.877), postoperative hospital stay (P = 0.975), and post-

Table 1. Basic characteristics among the three groups

| Characteristic                  | Non-obese (< 25 kg/m²) (n = 812) | Obese I (25.0–29.9 kg/m²) (n = 360) | Obese II (> 30 kg/m²) (n = 20) | P-value |
|--------------------------------|----------------------------------|------------------------------------|-------------------------------|---------|
| Age (yr)                       | 57.58 (± 11.69)                  | 58.56 (± 10.65)                    | 61.10 (± 9.05)                | 0.178   |
| Weight (kg)                    | 58.94 (± 8.05)                   | 71.65 (± 7.84)                     | 81.24 (± 10.41)               | < 0.001 |
| Height (cm)                    | 162.17 (± 8.42)                  | 163.71 (± 8.52)                    | 159.66 (± 9.10)               | 0.005   |
| Body mass index (kg/m²)        | 22.33 (± 1.78)                   | 26.67 (± 1.19)                     | 31.77 (± 1.99)                | < 0.001 |
| Sex                            |                                  |                                    |                               | < 0.001 |
| Male                           | 441 (54.3)                       | 243 (67.5)                         | 6 (30.0)                      |         |
| Female                         | 371 (45.7)                       | 117 (32.5)                         | 14 (70.0)                     |         |
| Smoking                        | 180 (22.2)                       | 89 (24.7)                          | 3 (15.0)                      | 0.443   |
| Alcohol intake                 | 307 (37.8)                       | 154 (42.8)                         | 5 (25.0)                      | 0.117   |
| Underlying disease             | 401 (49.4)                       | 219 (60.8)                         | 16 (80.0)                     | < 0.001 |
| Previous operative history     | 226 (27.8)                       | 78 (21.7)                          | 10 (50.0)                     | 0.005   |

Values are presented as mean ± standard deviation or number (%).

Table 2. Clinicopathological characteristics among the three groups

| Characteristic                  | Non-obese (< 25 kg/m²) (n = 812) | Obese I (25.0–29.9 kg/m²) (n = 360) | Obese II (> 30 kg/m²) (n = 20) | P-value |
|--------------------------------|----------------------------------|------------------------------------|-------------------------------|---------|
| Location                       |                                  |                                    |                               | 0.927   |
| Right colon                    | 275 (33.9)                       | 120 (33.3)                         | 6 (30.0)                      |         |
| Left colon                     | 537 (66.1)                       | 240 (66.7)                         | 14 (70.0)                     |         |
| Diverting stoma                | 2 (0.2)                          | 2 (0.4)                            | 0                             | 0.688   |
| Adhesiolysis                   | 15 (1.8)                         | 7 (1.9)                            | 0                             | 0.821   |
| Polypectomy                    | 75 (10.5)                        | 45 (12.5)                          | 2 (10.0)                      | 0.586   |
| Cancer obstruction             | 94 (11.6)                        | 35 (9.7)                           | 4 (20.0)                      | 0.291   |
| Cancer perforation             | 6 (0.7)                          | 2 (0.6)                            | 0                             | 0.877   |
| Total operation time (min)     | 147.84 (± 46.77)                 | 162.54 (± 46.77)                   | 180.35 (± 69.63)              | < 0.001 |
| Conversion                     | 13 (1.6)                         | 13 (3.6)                           | 2 (10.0)                      | 0.008   |
| Postoperative hospital stay (day)| 9.76 (± 3.43)                   | 9.78 (± 3.19)                      | 9.85 (± 1.53)                 | 0.990   |
| Size (mm)                      | 3.95 (± 2.20)                    | 3.80 (± 2.27)                      | 3.81 (± 1.92)                 | 0.537   |
| T stage                        |                                  |                                    |                               | 0.049   |
| 0, I                           | 237 (29.2)                       | 131 (36.4)                         | 6 (30.0)                      |         |
| II, III                        | 575 (70.8)                       | 229 (63.6)                         | 14 (70.0)                     |         |
| N stage                        |                                  |                                    |                               | 0.778   |
| 0, I                           | 570 (70.2)                       | 260 (72.2)                         | 14 (70.0)                     |         |
| II                             | 242 (29.8)                       | 100 (27.8)                         | 6 (30.0)                      |         |

Values are presented as number (%) or mean ± standard deviation.
operative mortality ($P = 0.787$) were similar in the non-obese and obese patients. Setting the T stage as the two groups showed a higher T stage as BMI increased ($P = 0.049$).

Table 3 shows the difference between the laparoscopic and conversion groups. BMI was significantly different between the two groups with a P-value of 0.049. The size of tumor was also significantly different ($P < 0.001$), along with the T stage and N stage ($P = 0.009$ and $P < 0.001$, respectively). Finally, alcohol intake, rates of cancer obstruction and perforation, timing of adhesiolysis, and previous operative history were also significantly different ($P = 0.033$, $P = 0.001$, $P < 0.001$, $P = 0.005$, $P = 0.002$, respectively).

We performed multivariate logistic regression for the analysis of risk factors for intraoperative conversion with the significant variables found in Table 4. BMI and total operative time were significantly different with P-values of 0.029 and < 0.001, respectively (Table 4).

Table 5 and 6 shows the factors that influence the overall survival and disease-free survival rates. We first evaluated with univariate analysis and then performed multivariate analysis on the factors that were significant in the univariate analysis. On overall survival rate, age, cancer obstruction rate, and N stage were significantly related, and on disease-free survival, cancer obstruction, adhesiolysis, and T stage and N stage were significantly related.

Fig. 1 show the (A) disease-free survival rates and (B) overall survival rates among the three groups. However, they showed no

### Table 3. Basic and clinicopathological characteristics between the laparoscopic and intraoperative conversion groups

| Characteristic                  | Laparoscopic group (n = 1164) | Conversion group (n = 28) | P-value |
|--------------------------------|-------------------------------|--------------------------|---------|
| Age (yr)                        | 57.88 (11.34)                 | 60.46 (12.21)            | 0.233   |
| Weight (cm)                     | 63.15 (10.2)                  | 63.63 (10.04)            | 0.804   |
| Height (kg)                     | 162.67 (8.48)                 | 159.28 (8.67)            | 0.037   |
| Body mass index (kg/m²)         | 23.78 (2.77)                  | 25.01 (2.78)             | 0.020   |
| Sex                             |                               |                          | 0.151   |
| Male                            | 678 (58.25)                   | 12 (42.86)               |         |
| Female                          | 486 (41.75)                   | 16 (57.14)               |         |
| Smoking                         | 267 (22.94)                   | 5 (17.86)                | 0.685   |
| Alcohol intake                  | 461 (39.60)                   | 5 (17.86)                | 0.033   |
| Underlying disease              | 617 (53.01)                   | 19 (67.86)               | 0.172   |
| Previous operative history      | 299 (25.69)                   | 15 (53.57)               | 0.002   |
| Location                        |                               |                          | 0.212   |
| Right colon                     | 388 (33.33)                   | 13 (46.43)               |         |
| Left colon                      | 776 (66.67)                   | 15 (53.57)               |         |
| Polypectomy                     | 130 (11.17)                   | 2 (7.14)                 | 0.714   |
| Cancer obstruction              | 124 (10.65)                   | 9 (32.14)                | 0.001   |
| Cancer perforation              | 5 (0.43)                      | 3 (10.71)                | < 0.001 |
| Adhesiolysis                    | 19 (1.63)                     | 3 (10.71)                | 0.005   |
| Size (mm)                       | 3.88 (2.21)                   | 5.36 (2.13)              | < 0.001 |
| T stage                         |                               |                          | 0.009   |
| 0, I                            | 372 (31.96)                   | 2 (7.14)                 |         |
| II, III                         | 792 (68.04)                   | 26 (92.86)               |         |
| N stage                         |                               |                          | < 0.001 |
| 0, I                            | 834 (71.65)                   | 10 (35.71)               |         |
| II                              | 330 (28.35)                   | 18 (64.29)               |         |

Values are presented as number (%) or mean ± standard deviation.

### Table 4. Analysis of risk factors for intraoperative conversion (multivariate analysis)

| Effects                  | Odds ratio | 95% Confidence interval | P-value |
|--------------------------|------------|-------------------------|---------|
| Height                   | 0.978      | 0.923–1.036             | 0.451   |
| Body mass index          | 1.165      | 1.015–1.337             | 0.029   |
| Size                     | 0.977      | 0.762–1.254             | 0.856   |
| Total operative time     | 1.015      | 1.009–1.021             | < 0.001 |
| Alcohol intake           | 0.325      | 0.092–1.142             | 0.079   |
| Previous operative history | 2.38     | 1.001–5.656             | 0.049   |
| Cancer obstruction       | 1.668      | 0.612–4.494             | 0.320   |
| Cancer perforation       | 75.83      | 9.069–634.045           | < 0.001 |
| Adhesiolysis             | 3.166      | 0.698–14.365            | 0.135   |
| T stage (0, I)           | 7.114      | 0.993–50.946            | 0.051   |
| N stage (II)             | 2.082      | 0.784–5.53             | 0.141   |

### Table 5. Univariate and multivariate Cox regression of overall survival

| Effects                  | Univariate Hazard ratio | 95% Confidence interval | P-value |
|--------------------------|-------------------------|-------------------------|---------|
| Age                      | 0.018                   | 1.052                   | 1.014–1092 | 0.007 |
| Weight                   | 0.623                   |                         |         |
| Height                   | 0.481                   |                         |         |
| Body mass index          | 0.881                   |                         |         |
| Total operative time     | 0.602                   |                         |         |
| Sex                      | 0.096                   |                         |         |
| Smoking                  | 0.501                   |                         |         |
| Alcohol intake           | 0.576                   |                         |         |
| Underlying disease       | 0.288                   |                         |         |
| Previous operative history | 0.057             |                         |         |
| Location                 | 0.090                   |                         |         |
| Polypectomy              | 0.676                   |                         |         |
| Cancer obstruction       | 0.001                   | 2.785                   | 1.169–7.071 | 0.022 |
| Cancer perforation       | 0.080                   |                         |         |
| Adhesiolysis             | 0.451                   |                         |         |
| T stage                  | 0.264                   |                         |         |
| N stage (II)             | 0.001                   | 4.003                   | 1.634–9.808 | 0.002 |
| Conversion               | 0.078                   |                         |         |
In addition, we performed sex specific analyses because there was a sex specific difference in BMI. However, we did not find any differences between sexes for our results (data not shown).

**DISCUSSION**

Obesity is a well-known and increasingly common problem in the Western world.

Obesity is associated with various diseases and considered to be a risk factor for postoperative morbidity after abdominal surgery. Increasing BMI is a significant risk factor for the occurrence of colon cancer. In the past, obesity had been considered a relative contraindication to laparoscopy, as the condition was associated with technical difficulties during the procedure [2-9].

However, opinions on the specific impact of obesity on the complications after laparoscopic colectomy have differed. While some have reported that the conversion and complication rates in obese patients undergoing laparoscopic colectomy are similar to those in non-obese patients, laparoscopic colectomy in the obese is associated with an increased risk for conversion, which results in greater technical difficulty in the laparoscopic approach.

However, Delaney et al. [7] did not demonstrate any difference in operative times between obese and non-obese patients undergoing laparoscopic colectomy, and Leroy et al. [6] did not find an increased conversion rate or any other significant difference in any of the other parameters. However, early reports from the Cleveland Clinic found that the operative time was significantly longer in obese subjects compared with those with a normal weight [2] and Martin and Stocchi [19] reported that obese patients required longer operations and higher conversion rates. Our study also showed significant differences in the conversion rate between three groups. The Obese II group had a higher conversion rate than the Obese I and Non-obese group (10% vs. 3.6% and 1.6%, re-
respectively). This study showed a longer operative time in the Obese II group than in the Obese I and Non-obese groups, which was significantly different (180.35 vs. 162.54 and 147.84 minutes, \( P < 0.001 \)). This study however, did not show a significant difference in postoperative hospital stay (\( P = 0.975 \)). Our study differs from previously published studies in that our institution has a CP that is followed for all patients who undergo colon surgery. The CP indicates the timing of diet resumption and discharge if the patient does not have any problems

There are several limitations to our study. First, it was not a prospective randomized trial, introducing the possibility of type II error. The patients were not selected in accordance with definitive criteria, but were appointed to each group based on surgeon preference.

Second, because the follow-up period was relatively short, we could not completely exclude long-term oncologic outcomes or the incidence of long-term complications, such as adhesive ileus or incisional hernia. Long-term follow-up for a larger subset of patients is needed to more definitively evaluate the standard oncologic outcomes. Third, the five surgeons were experienced laparoscopic colon surgeons. There was no analysis of the outcomes among the five surgeons. Additional data that includes cases from young surgeons should be evaluated to confirm the advantages of the laparoscopic procedure in obese patients with regard to the shorter learning curve. In our study, there were no differences in oncologic outcomes, but the independent risk factors for conversion were found to be BMI, total operative time, previous operative history, and cancer perforation. Appropriate selection of patients for laparoscopic colectomy is important.

In conclusion, laparoscopic colon cancer surgery is a safe and feasible approach for obese patients with all of the advantages of minimally invasive surgery. The outcomes of laparoscopic colon surgery in obese patients are similar to those in non-obese patients. The management of colon cancer patients with BMI ≥ 30 kg/m² requires meticulous perioperative care, and colon surgeons must be familiar with the obesity-related challenges in such patients, including a higher conversion rate to open surgery. It is therefore very important for surgeons to pay close attention during laparoscopic colon surgery in obese patients, and to carefully explain these risk factors for conversion to patients.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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