Rate of conversion to an open procedure is reduced in patients undergoing robotic colorectal surgery: A single-institution experience

Leah Ellis Wells¹, Betsy Smith¹, Michael Drew Honaker²

¹Department of Internal Medicine, Mercer University School of Medicine, Navicent Health, Macon, Georgia, ²Department of Surgical Oncology and Colorectal Surgery, Mercer University School of Medicine, Navicent Health, Macon, Georgia

Abstract

Background: Robotic-assisted surgery is becoming increasingly used in colorectal operations. It has many advantages over laparoscopic surgery including three-dimensional viewing, motion scaling, improved dexterity and ergonomics as well as increased precision. However, there are also disadvantages to robotic surgery such as lack of tactile feedback, cost as well as limitations on multi-quadrant surgeries. The purpose of this study was to compare the rate of conversion to an open surgery in patients undergoing robotic-assisted colorectal surgery and traditional laparoscopic surgery.

Methods: Patients undergoing minimally invasive colorectal surgery for neoplastic and dysplastic disease from 2009 to 2016 were identified and examined retrospectively. The statistical software SAS, manufactured by SAS Institute, Cary, North Carolina. Continuous variables were analysed using analysis of variance test. Chi-square test was used to analyse categorical variables. P <0.05 was considered statistically significant.

Results: Two hundred and thirty-five patients were identified that underwent minimally invasive colorectal surgery. One hundred and sixty-four underwent laparoscopic resection and 71 underwent robotic-assisted resection. There was no statistical difference in gender or race between the two groups (both P >0.05). Patients that underwent robotic-assisted resection were slightly younger than patients that underwent laparoscopic resection (61.6 years vs. 65.6 years; P = 0.02). When examining conversion to an open procedure, patients that underwent robotic-assisted resection had a significantly lower chance of conversion than did the patients undergoing a laparoscopic approach (11.27% vs. 29.78%; P = 0.0018).

Conclusion: Conversion rates from a minimally invasive procedure to an open procedure appear to be lower with robotic-assisted surgery compared to laparoscopic surgery.

Keywords: Conversion rates, dysplasia, neoplasia, robotic surgery

Access this article online

Quick Response Code:
Website: www.journalofmas.com
DOI: 10.4103/jmas.JMAS_318_18

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Wells LE, Smith B, Honaker MD. Rate of conversion to an open procedure is reduced in patients undergoing robotic colorectal surgery: A single-institution experience. J Min Access Surg 2020;16:229-34.
INTRODUCTION

Minimally invasive techniques have been associated with multiple benefits including decreased blood loss, earlier return of bowel function, decreased narcotic use, decreased hernia rates, decreased post-operative bowel obstructions, decreased infectious complications and shorter length of stay.\[1-6\]

Robotic-assisted surgery is becoming increasingly used in colorectal operations. Advantages include three-dimensional viewing, increased range of motion of the instruments, improved dexterity and motion scaling. However, disadvantages include lack of tactile feedback, cost and limitations in multi-quadrant surgeries.\[7\]

In rectal cancer operations, studies have shown advantages such as decreased rates of conversion to an open procedure when the robotic platform is utilised.\[8-11\] Suda et al. suggested the more complicated operations are best performed robotically with lower rates of complications and improved short-term outcomes.\[12\] With the benefits of minimally invasive approaches and the increasing use of robotic surgery, we set out to compare rates of conversion to an open procedure between robotic-assisted surgery and traditional laparoscopic surgery.

METHODS

Study design and population
A retrospective cohort study was conducted using data from the Medical Center of Central Georgia, Navicent Health. All patients undergoing procedures for dysplastic or neoplastic disease from 2009 to 2017 were identified and evaluated for inclusion in the study. Demographic data collected and evaluated included age, race, sex, body mass index (BMI) and Charlson Comorbidity Index. Surgery outcome information collected and evaluated included whether a patient was converted from a minimally invasive approach to an open approach or not, number of previous laparoscopic and open surgeries, number of lymph nodes harvested, number of positive lymph nodes harvested, site of cancer, grade of cancer and pathologic stage of cancer. Approval of the study was obtained by the Hospital's Institutional Review Board. There were 261 patients identified who underwent laparoscopic or robotic procedures during this time period. Patients were excluded from the analysis if they underwent multiple procedures or if they were operated on for reasons other than dysplastic or neoplastic disease. After exclusions, 235 patients were identified to be evaluated.

Statistical analyses
Means and standard deviations or medians and interquartile ranges were reported for continuous variables. Frequencies and percentages were reported for categorical variables. The main analysis consisted of comparing factors between the robotic group and laparoscopic group with bivariate analyses. The Chi-square test and Fisher’s exact test were used to make comparisons for categorical variables. The unpaired t-test and the Mann–Whitney U-test were used to make comparisons for continuous variables. For patients undergoing robotic-assisted surgery, operative time was compared by year with the analysis of variance test. A secondary analysis was conducted to assess the magnitude of the association between converting to an open procedure and surgery type and to identify any factors that confound the association. The analysis consisted of comparing factors between patients who converted to an open approach and patients who did not with bivariate analyses and logistic regression. A two-tailed test was used for all bivariate analyses. Statistical significance was set at $P < 0.05$, and SAS version 9.4 (SAS Institute, Cary, North Carolina) was used for all analyses (SAS Institute, Cary, NC, USA).

RESULTS

Among the 235 patients, 164 underwent a laparoscopic procedure and 71 underwent a robotic procedure. Demographic comparisons between the two surgery groups are reported in Table 1. There were no significant differences between the two groups in regard to race, sex or BMI. There was a significant difference between the two groups for age ($P = 0.030$). The mean age was lower for the robotic group compared to the laparoscopic group ($61.76 \pm 12.08$ vs. $65.59 \pm 12.67$). There was also a significant difference in the Charlson Comorbidity Index between the two groups ($P = 0.0082$). The median score was lower for the robotic group compared to the laparoscopic group ($4.00$ vs. $5.00$), indicating that the robotic group experienced less comorbidities than the laparoscopic group. Scores ranged from 0 to 8 for the robotic group and 2 to 12 for the laparoscopic group.

Surgery outcome comparisons are reported in Table 2. A significantly greater percentage of patients undergoing laparoscopic surgery converted to an open procedure compared to patients undergoing robotic surgery ($29.27\%$ vs. $9.86\%, P = 0.0013$). There were no significant differences between the two groups regarding the number of previous open surgeries experienced, but there was a significant difference between the two groups in the number of previous laparoscopic surgeries experienced ($P = 0.0018$). A greater percentage of patients who underwent laparoscopic surgery compared to patients who underwent robotic surgery experienced...
zero (68.90% vs. 60.56%) or one previous laparoscopic surgery (26.83% vs. 21.13%) while a greater percentage of patients who underwent robotic surgery experienced two or three previous laparoscopic surgeries compared to patients who underwent laparoscopic surgery (18.31% vs. 4.27%). There was a non-significant tendency for the patients in the laparoscopic group to have a higher median number of lymph nodes harvested compared to the patients in the robotic group (P = 0.066); however, there was no significant difference in the number of positive lymph nodes between the two surgery groups. The median number of positive nodes was zero for both groups, with 70% of patients in each group not having any positive nodes.

Site of cancer differed significantly between the two surgery groups (P < 0.0001). A greater percentage of patients in the laparoscopic group experiencing cancer in the ascending, transverse and sigmoid areas, while a greater percentage of patients in the robotic group experienced cancer in the rectal area [Table 2]. There was no significant difference between the two surgery groups regarding pathologic

### Table 1: Characteristics of patients undergoing laparoscopic and robotic surgeries

| Characteristic                              | Total (n=235), n (%) | Laparoscopic (n=164), n (%) | Robotic (n=71), n (%) | P*         |
|---------------------------------------------|----------------------|-----------------------------|-----------------------|------------|
| Age (years), mean±SD                       | 64.43±12.59          | 65.59±12.67                 | 61.76±12.08          | 0.030      |
| Race                                        |                      |                             |                       |            |
| Caucasian                                  | 141 (60.00)          | 95 (57.93)                  | 46 (64.79)           | 0.48       |
| African American                           | 92 (39.15)           | 67 (40.85)                  | 25 (35.21)           |            |
| Other                                       | 2 (0.85)             | 2 (1.22)                    | 0 (0.00)             |            |
| Sex                                         |                      |                             |                       |            |
| Male                                        | 132 (56.17)          | 92 (56.10)                  | 40 (56.34)           | 1.00       |
| Female                                      | 103 (43.83)          | 72 (43.90)                  | 31 (43.66)           |            |
| BMI (kg/m²)**, median (IQR)                | 28.00 (24.00, 33.00) | 28.00 (24.00, 33.00)        | 28.50 (24.00, 33.00) | 0.94       |
| Charlson Comorbidity Index**, median (IQR)  | 5.00 (3.00, 6.00)    | 5.00 (4.00, 6.00)           | 4.00 (3.00, 5.00)    | 0.0082     |

*Derived from Chi-square or Fisher’s exact test for categorical variables and unpaired t-test or Mann-Whitney U-test for continuous variables, **5 missing BMI; Mann-Whitney U-test produces mean scores: Laparoscopic group mean score= 115.28 and robotic group mean score= 116.00. ***Higher scores represent greater likelihood that the predicted outcome will result in mortality or higher resource use; Mann-Whitney U-test produces mean scores: Laparoscopic group mean score= 125.60 and robotic group mean score= 100.45. SD: Standard deviation, IQR: Interquartile range, BMI: Body mass index

### Table 2: Surgery outcome comparisons between patients undergoing laparoscopic and robotic surgeries

| Characteristic                              | Total (n=235), n (%) | Laparoscopic (n=164), n (%) | Robotic (n=71), n (%) | P*         |
|---------------------------------------------|----------------------|-----------------------------|-----------------------|------------|
| Converted to open                           |                      |                             |                       |            |
| Yes                                         | 55 (23.40)           | 48 (29.27)                  | 7 (9.86)              | 0.0013     |
| No                                          | 180 (76.60)          | 116 (70.73)                 | 64 (90.14)            |            |
| Number of previous laparoscopic surgeries   |                      |                             |                       |            |
| 0                                           | 156 (66.38)          | 113 (68.90)                 | 43 (60.56)            | 0.0018     |
| 1                                           | 59 (25.11)           | 44 (26.83)                  | 15 (21.13)            |            |
| 2-4                                         | 20 (8.51)            | 7 (4.27)                    | 13 (18.31)            |            |
| Number of previous open surgeries           |                      |                             |                       |            |
| 0                                           | 188 (80.34)          | 127 (77.91)                 | 61 (85.92)            | 0.40       |
| 1                                           | 39 (16.67)           | 30 (18.40)                  | 9 (12.68)             |            |
| 2-3                                         | 2 (0.85)             | 6 (3.68)                    | 1 (1.41)              |            |
| Number of lymph nodes harvested, median (IQR) | 17.00 (13.00, 21.00) | 17.00 (13.00, 22.00)        | 15.00 (13.00, 19.00)  | 0.066      |
| Number of positive lymph nodes, median (IQR) | 0.00 (0.00, 1.00)   | 0.00 (0.00, 1.00)           | 0.00 (0.00, 1.00)     | 0.76       |
| Site                                        |                      |                             |                       |            |
| Ascending                                   | 89 (37.87)           | 74 (45.12)                  | 15 (21.13)            | <0.0001    |
| Transverse                                  | 22 (9.36)            | 18 (10.98)                  | 4 (5.63)              |            |
| Descending, left, sigmoid                   | 65 (27.66)           | 47 (28.66)                  | 18 (25.35)            |            |
| Rectal, rectosigmoid                        | 59 (25.11)           | 25 (15.24)                  | 34 (47.89)            |            |
| Grade                                       |                      |                             |                       |            |
| I                                           | 20 (10.05)           | 8 (5.56)                    | 12 (21.82)            | 0.0065     |
| II                                          | 154 (77.39)          | 118 (81.94)                 | 36 (65.45)            |            |
| III                                         | 24 (12.06)           | 17 (11.81)                  | 7 (12.73)             |            |
| IV                                          | 1 (0.50)             | 1 (0.69)                    | 0 (0.00)              |            |
| Pathologic stage                            |                      |                             |                       |            |
| I                                           | 63 (26.47)           | 49 (34.51)                  | 14 (26.92)            | 0.16       |
| II                                          | 56 (28.87)           | 41 (28.87)                  | 15 (28.85)            |            |
| III                                         | 54 (27.84)           | 34 (23.94)                  | 20 (38.46)            |            |
| IV                                          | 21 (10.82)           | 18 (12.68)                  | 3 (5.77)              |            |

*Derived from Chi-square test, Fisher’s exact test or Mann-Whitney U-test. 1 missing number of previous open surgeries; 5 missing number of positive nodes harvested; 5 missing number of positive nodes; 36 not applicable for grade; 41 not applicable for pathologic stage. Mann-Whitney U-test produces mean scores: Laparoscopic group mean score= 120.67 and robotic group mean score= 102.93 for number of lymph nodes harvested, laparoscopic group mean score= 116.20 and robotic group mean score= 100.45. SD: Standard deviation, IQR: Interquartile range, BMI: Body mass index
stage, but there was a significant difference with grade of cancer \( (P = 0.0065) \) [Table 2]. A greater percentage of patients who underwent robotic surgery compared to patients who underwent laparoscopic surgery presented with Grade I (21.82\% vs. 5.56\%) and Grade III (12.73\% vs. 11.81\%) while a greater percentage of patients undergoing laparoscopic surgery presented with Grade II compared to patients undergoing robotic surgery (81.94\% vs. 65.45\%).

BMI and previous surgeries were compared between the laparoscopic group and robotic group for patients who converted to an open procedure. Due to small numbers, previous laparoscopic and open surgeries were categorised as to whether they occurred or not (yes or no). There were no significant differences between the two groups in regard to BMI or if a previous laparoscopic or open surgery occurred [Table 3]. As prior surgeries could add to an increase in the rates of conversion if different between the two cohorts. The majority of patients in the laparoscopic group had not experienced a previous laparoscopic or open surgery. Among the robotic group, a little over half of the patients had not experienced a previous laparoscopic surgery and none of the patients had experienced an open surgery previously.

Operative time did not significantly differ by year of surgery for the 71 patients who underwent robotic surgery. There was no trend in operative time increasing or decreasing for the robotic procedures between 2009 and 2017. Results from the secondary analyses confirmed the significant association between conversion to an open procedure and surgery type by estimating the magnitude of the association. The odds of converting to an open procedure were decreased for patients who underwent a robotic-assisted surgery compared to patients who underwent a laparoscopic surgery (odds ratio = 0.26, 95\% confidence interval = 0.11 and 0.62). However, none of the additional factors assessed (age, race, sex, BMI, Charlson Comorbidity Index, number of previous laparoscopic surgeries, number of previous open surgeries, grade of cancer, pathological stage, site of cancer, number of lymph nodes harvested and number of positive lymph nodes) significantly remained in the logistic regression models as confounders in the association between converting to an open procedure and surgery type.

**DISCUSSION**

Minimally invasive techniques provide multiple advantages with respect to outcomes in patients undergoing colorectal resections.\[1\]–\[4\] Robotic-assisted surgery is evolving and increasingly being utilised in colorectal operations. We set out to determine if there is a difference in rates of conversion to an open procedure between the two approaches in a cohort of patients with colorectal carcinoma or endoscopically unresectable polyps and also if certain variables affected the rate of conversions. Our findings indicated that robotic surgery resulted in decreased conversion rates, even when BMI and number of previous operations were accounted for, as patients in the robotic-arm group actually had more prior laparoscopic operations than the patients undergoing laparoscopic resection. When examining prior open procedures and BMI, both were similar between the two groups.

Previous studies comparing conversion to an open procedure in colorectal cancer surgery found that it was often due to serious intraoperative complications such as severe haemorrhage from the lateral pelvic wall or rectal perforation.\[9\] Further, converted patients often have a higher post-operative complication rate than non-converted patients.\[13,14\] Rottoli et al. showed conversion leads to higher morbidity and tumour recurrence.\[14\] Thus, comparing conversion rates are an important component of outcomes when comparing two different minimally invasive techniques.

Other studies have compared the conversion rates in laparoscopic versus robotic colorectal surgery. In contrast to our study that found reduced conversion rate in the robotic approach, some studies found no difference between the two methods.\[15,16\] More recent studies have found decreased conversion rates in colorectal surgery.\[8,11,13,17–19\]

---

**Table 3: Comparisons of patients undergoing laparoscopic and robotic surgeries for patients who converted to open**

| Characteristic                      | Total (n=55) | Laparoscopic (n=48) | Robotic (n=7) | \( P^* \) |
|------------------------------------|--------------|---------------------|--------------|----------|
| BMI (kg/m\(^2\))**; median (IQR)  | 28.50 (25.00, 34.00) | 28.00 (24.00, 34.00) | 41.00 (25.00, 44.00) | 0.075    |
| Previous laparoscopic surgery, n (%) | 19 (34.55)  | 16 (33.33) | 3 (42.86) | 0.68     |
| Yes                                | 36 (65.45)  | 32 (66.67) | 4 (57.14) |          |
| No                                 | 13 (24.07)  | 13 (27.66) | 0 (0.00)  | 0.18     |
| Previous open surgery, n (%)***    | 41 (75.93)  | 34 (72.34) | 7 (100.00) |          |
| Yes                                |              |                  |             |          |
| No                                 |              |                  |             |          |

*Derived from Fisher’s exact test for categorical variables and Mann-Whitney U-test for continuous variables. **1 missing BMI; Mann-Whitney U-test produces mean scores: Laparoscopic group mean score=26.02 and robotic group mean score=37. IQR: Interquartile range, BMI: Body mass index.
This may be due to the continued improvement in robotic technology as well as some of the advantages of robotic surgery including improved visualisation of the operative field secondary to three-dimensional viewing, an additional operating arm and the increased range of motion of the operative instruments.[7,13]

While oncologic outcomes were often similar between the two methods,[10,11,18] the lower conversion rate of the robotic group often translated to better intraoperative outcomes and less serious post-operative complications in various studies.[8,9,17,20] Park et al. found that men with erectile dysfunction following robotic resection experienced earlier restoration of sexual function than those in the laparoscopic group although urinary function was similar between the two groups in the 12 months following surgery.[28] Another study by Corrado et al. reveals decreased fistulas, bowel perforations, wound dehiscence, paresthesia and sciatic pain following robotic approaches to surgery versus laparoscopic.[17] On the other hand, some groups did not see significant differences in post-operative outcomes between the two groups despite lowered conversion rates.[10,11,13,18]

Despite the advantages of robotic-assisted surgery, there are disadvantages. One major drawback of robotic procedures is their increased cost relative to laparoscopic procedures. Baek et al. found that the average hospital costs were higher for the robotic group (83,915 vs. 62,601).[21] The price of one robotic system alone is more than 2,000,000 US dollars.[9] However, some of the cost can be offset by the decreased conversion rate, as studies have shown the decreased rate of complications and shorter hospital stays in patients operated on by minimally invasive techniques.[4,6,12]

Given some of the drawbacks of robotic surgery, such as increased cost and potentially increased operative time,[22] some have suggested it may be best to utilise the robotic approach in specific situations (i.e., pelvic surgery), while relying on laparoscopic procedures for others. Each platform may best serve a distinct demographic and disease profile.[18] Importantly, BMI could be an indication toward a robotic approach, as laparoscopic surgery is challenging in obese patients, especially when operating in confined spaces that make manoeuvring the rigid instruments difficult.[16] While studies have yet to prove that there is a significant difference in conversion rate or post-operative complication rate in the robotic approach versus the laparoscopic approach in obese patients, robotic surgery has the potential to overcome the limitation associated with obesity and provide better post-operative outcomes, as other studies have shown BMI to be a predictor of conversion to an open procedure in patients undergoing laparoscopic surgery.[6,23] Cunningham et al. showed that despite increasing BMI (ranges from 19 to 71), there was not an increased conversion rate in patients undergoing robotic operations for endometrial cancer.[24]

Robotic surgery may be more easily passed on to future surgeons. There are known learning curve challenges associated with traditional laparoscopy, which increased the conversion rates.[15] Mak et al. reported that the learning curve may not be as steep with robotic versus laparoscopic surgeries.[10] Lujan et al. estimated the learning curve for laparoscopic colectomies to be between 55 and 70 cases.[15] Mak et al. reports the learning curve for robotic colectomies to be 22 cases.[10] The decreased learning curve has been evaluated in other procedures. Lim et al. found robotic hysterectomy had a faster learning curve than laparoscopic hysterectomy when utilised to treat endometrial cancer.[26]

Limitations of this study include the retrospective nature of the data collection and the inherent bias associated with this particular study design. Patients selected in one group or the others were not controlled, and hence, selection bias plays a large role in the current study. Operator experience was also not known, although given that operative time did not decrease over time, it can be hypothesised that surgeons were well trained in the earliest timeframe of the study. Furthermore, all procedures were performed by fellowship-trained specialists. It can be hypothesised that as the number of cases performed robotically increases, the rate of conversion may decrease; however, this would further strengthen our results that robotic surgery results in lower conversion rates. The low number of patients is also a limitation of the current study. The number of pelvic/rectal operations was too low to examine statistically. It is felt by many surgeons that robotic-assisted surgery is especially suited for pelvic operations, where the majority of its benefit is obtained. The low sample number also makes examining right versus left colectomies difficult statistically. This is just stating that the conversion rate to an open procedure in the laparoscopic group was higher than one might expect and this could be a limitation. The reason for this unexpectedly high rate is unclear and may be related to surgeon experience and potentially patient selection.

CONCLUSION

Robotic surgery may offer low rates of conversion to an open procedure, especially in patients with higher BMIs,
resulting in lower post-operative complications, earlier return of function and reduced narcotic use. Randomised trials are required before any definitive conclusion can be made about the use of robotic surgery over laparoscopic surgery.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES
1. Kang SB, Park JW, Jeong SY, Nam BH, Choi HS, Kim DW, et al. Open versus laparoscopic surgery for mid or low rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): Short-term outcomes of an open-label randomised controlled trial. Lancet Oncol 2010;11:637-45.
2. Veldkamp R, Kuhry E, Hop WC, Jeekel J, Kazemier G, Bonjer HJ, et al. Laparoscopic surgery versus open surgery for colon cancer: Short-term outcomes of a randomised trial. Lancet Oncol 2005;6:87-94.
3. Lacy AM, García-Valdecasas JC, Delgado S, Castells A, Taurá P, Piqué JM, et al. Laparoscopy-assisted colectomy versus open colectomy for treatment of non-metastatic colon cancer: A randomised trial. Lancet 2002;359:2224-9.
4. Duepree HJ, Senagore AJ, Delaney CP, Fazio VW. Does means of access affect the incidence of small bowel obstruction and ventral hernia after bowel resection? Laparoscopy versus laparotomy. J Am Coll Surg 2003;197:177-81.
5. Vignali A, Braga M, Zuliani W, Frasson M, Radaelli G, DeCarlo V. Laparoscopic colorectal surgery modifies risk factors for post-operative morbidity. Dis Colon Rectum 2004;47:1683-93.
6. Aimaq R, Akopian G, Kaufman HS. Surgical site infection rates in laparoscopic versus open colorectal surgery. Am Surg 2011;77:1290-4.
7. Lanfranco AR, Castellanos AE, Desai JP, Meyers WC. Robotic surgery: A current perspective. Ann Surg 2004;239:14-21.
8. Allemann P, Duvoisin C, Di Mare L, Hübner M, Demartines N, Hahnloser D, et al. Robotic-assisted surgery improves the quality of total mesorectal excision for rectal cancer compared to laparoscopy: Results of a case-controlled analysis. World J Surg 2016;40:1010-6.
9. Baik SH, Kwon HY, Kim JS, Hur H, Sohn SK, Cho CH, et al. Robotic versus laparoscopic low anterior resection of rectal cancer: Short-term outcome of a prospective comparative study. Ann Surg Oncol 2009;16:1480-7.
10. Mak TW, Lee JF, Futaha K, Hon SS, Ngo DK, Ng SS, et al. Robotic surgery for rectal cancer: A systematic review of current practice. World J Gastrointest Oncol 2014;6:184-93.
11. Ortiz-Oshiro E, Sánchez-Egido I, Moreno-Sierra J, Pérez CF, Díaz JS, Fernández-Represa JA, et al. Robotic assistance may reduce conversion to open in rectal carcinoma laparoscopic surgery: Systematic review and meta-analysis. Int J Med Robot 2012;8:360-70.
12. Suda K, Man-I M, Ishida Y, Kawamura Y, Satoh S, Uyama I, et al. Potential advantages of robotic radical gastrectomy for gastric adenocarcinoma in comparison with conventional laparoscopic approach: A single institutional retrospective comparative cohort study. Surg Endosc 2015;29:673-85.
13. Bianchi PP, Ceriani C, Locatelli A, Spingoli G, Zampinto MG, Sonzogni A, et al. Robotic versus laparoscopic total mesorectal excision for rectal cancer: A comparative analysis of oncological safety and short-term outcomes. Surg Endosc 2010;24:2888-94.
14. Rottoli M, Bona S, Rosati R, Elmore U, Bianchi PP, Spinelli A, et al. Laparoscopic rectal resection for cancer: Effects of conversion on short-term outcome and survival. Ann Surg Oncol 2009;16:1279-86.
15. Lujan HJ, Maciel VH, Romero R, Plaseneia G. Laparoscopic versus robotic right colectomy: A single surgeon's experience. J Robot Surg 2013;7:95-102.
16. Gorgun E, Ozben V, Costedio M, Stoechi L, Kalady M, Remzi F, et al. Robotic versus conventional laparoscopic rectal cancer surgery in obese patients. Colorectal Dis 2016;18:1063-71.
17. Corrado G, Cuttillo G, Pomati G, Mancini E, Spenduti I, Patrizi I, et al. Surgical and oncological outcome of robotic surgery compared to laparoscopic and abdominal surgery in the management of endometrial cancer. Eur J Surg Oncol 2015;41:1074-81.
18. Keller DS, Flores-Gonzalez JR, Ibarra S, Madhoun N, Tahilramani R, Mahmood A, et al. Evaluating quality across minimally invasive platforms in colorectal surgery. Surg Endosc 2016;30:2207-16.
19. Serin KR, Gultekin FA, Batman B, Ay S, Kapran Y, Saglam S, et al. Robotic versus laparoscopic surgery for mid or low rectal cancer in male patients after neoadjuvant chemoradiation therapy: Comparison of short-term outcomes. J Robot Surg 2015;9:187-94.
20. Park SY, Choi GS, Park JS, Kim HJ, Ryu JK, Yun SH, et al. Urinary and erectile function in men after total mesorectal excision by laparoscopic or robot-assisted methods for the treatment of rectal cancer: A case-matched comparison. World J Surg 2014;38:1834-42.
21. Back JH, Pastor C, Pigazzi A. Robotic and laparoscopic total mesorectal excision for rectal cancer: A case-matched study. Surg Endosc 2011;25:521-5.
22. Roh HF, Nam SH, Kim JM. Robot-assisted laparoscopic surgery versus conventional laparoscopic surgery in randomized controlled trials: A systematic review and meta-analysis. PLoS One 2018;13:e0191628.
23. Tekkis PP, Senagore AJ, Delaney CP. Conversion rates in laparoscopic colorectal surgery: A predictive model with, 1253 patients. Surg Endosc 2005;19:47-54.
24. Cunningham MJ, Dorzin E, Nguyen L, Anderson E, Bunn WD Jr. Body mass index, conversion rate and complications among patients undergoing robotic surgery for endometrial carcinoma. J Robot Surg 2015;9:339-45.
25. Hockstra AV, Jairam-Thodla A, Rademaker A, Singh DK, Butzin BM, Lurain JR, et al. The impact of robotics on practice management of endometrial cancer: Transitioning from traditional surgery. Int J Med Robot 2009;5:392-7.
26. Lim PC, Kang E, Park DH. A comparative detailed analysis of the learning curve and surgical outcome for robotic hysterectomy with lymphadenectomy versus laparoscopic hysterectomy with lymphadenectomy in treatment of endometrial cancer: A case-matched controlled study of the first one hundred twenty two patients. Gynecol Oncol 2011;120:413-8.