Robot-Assisted Versus Standard Laparoscopic Colorectal Surgery

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ABSTRACT

Background and Objectives: Over the years, there has been a continual shift toward more minimally invasive surgical techniques, such as the use of laparoscopy in colorectal surgery. Recently, there has been increasing adoption of robotic technology. Our study aims to compare and contrast robot-assisted and laparoscopic approaches to colorectal operations.

Methods: Forty patients undergoing laparoscopic or robotic colorectal surgery performed by 2 surgeons at an academic center, regardless of indication, were included in this retrospective review. Patients undergoing open approaches were excluded. Study outcomes included operative time, estimated blood loss, length of stay, complications, and conversion rate to an open procedure.

Results: Twenty-five laparoscopic and fifteen robot-assisted colorectal surgeries were performed. The mean patient age was 61.1 ± 10.7 years in the laparoscopic group compared with 61.1 ± 8.5 years in the robotic group ($P = .997$). Patients had a similar body mass index and history of abdominal surgery. Mean blood loss was 163.3 ± 249.2 mL and 96.8 ± 157.7 mL, respectively ($P = .385$). Operative times were similar, with 190.8 ± 84.3 minutes in the laparoscopic group versus 258.4 ± 170.8 minutes in the robotic group ($P = .183$), as were lengths of hospital stay: 9.6 ± 7.3 and 6.5 ± 3.8 days, respectively ($P = .091$). In addition, there was no difference in the number of lymph nodes harvested between the laparoscopic group (14.0 ± 6.5) and robotic group (12.3 ± 4.2, $P = .683$).

Conclusions: In our early experience, the robotic approach to colorectal surgery can be considered both safe and efficacious. Furthermore, it also preserves oncologically sufficient outcomes when performed for cancer operations.

Key Words: Colorectal surgery, Robotic surgery, Laparoscopic, Robot, Colon resection.

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INTRODUCTION

In recent years there has been a shift toward minimally invasive surgical techniques. Included in this shift has been the widespread adoption of laparoscopy as an alternative to the open operative approach in colon and rectal surgery. With the advancement of laparoscopic techniques has also come improvement in outcomes. Compared with open surgery, laparoscopy has been shown to reduce intraoperative blood loss, length of incision, and length of hospital stay.[1,2] As was seen with the movement from purely open surgery to laparoscopy, we are now witnessing a rising popularity and acceptance of robot-assisted procedures in a variety of surgical fields.[3–6]

The approval and increasing use of robotic equipment among surgeons stem somewhat from the technologic advancements that robotic surgery provides over traditional laparoscopic surgery. Robotic surgery has been observed to be advantageous in its 3-dimensionally represented operating field, eliminating difficulties associated with depth perception as are seen with standard laparoscopy's 2-dimensional image.[7] In addition, a surgeon-operated camera allows for full control of the visual operating field, whereas the EndoWrist function (Intuitive Surgical, Sunnyvale, California) provides increased articulation and rotation in a confined space.[8]

Much of the controversy surrounding the robot pertains to the high cost and longer operative time associated with robotic procedures.[9,10] The learning curve associated with new technology, as well as the increased time involved in docking (and redocking in some cases), contributes to the overall operative time and, consequently, the cost of the procedure compared with traditional laparoscopy. In a study by Park et al,[9] a robotic right colectomy cost the

patient >$3600 more out of pocket than a laparoscopic right colectomy.

Although some of the technical limitations of standard laparoscopy may obviously be addressed with the robotic apparatus, whether these advantages are enough to offset the higher cost of the robot are still debatable. Furthermore, few studies have conclusively shown whether robot-assisted procedures yield different outcomes. Specifically, studies conducted primarily in Asia and Europe have been published, but there still remains a paucity of studies in the United States comparing outcomes such as length of hospital stay, estimated blood loss, duration of the procedure, and complications between a robotic approach and laparoscopy for colon and rectal operations.[11–13] The lack of comparative studies between robotic and laparoscopic approaches regarding specific outcomes, combined with the cost of new technology like the da Vinci robot (Intuitive Surgical), is a prohibitive factor for widespread adoption of the robot in many hospital centers.[14]

This study aims to compare and contrast our experience with robot-assisted and laparoscopic approaches to colon and rectal procedures to elucidate any differences in outcomes. Furthermore, we examined oncologic outcomes in operations performed for malignancy.

METHODS

Data Collection and Statistical Analysis

We performed a retrospective review of 40 patients who underwent either standard laparoscopic or robotic colorectal surgery with the da Vinci Si robot (Intuitive Surgical) at Tulane Medical Center, New Orleans, Louisiana, between January 2008 and February 2013. Patients were randomly assigned to undergo either a standard laparoscopic or robotic procedure based on the availability of the robot apparatus. All open colorectal surgery cases were excluded. Indications for surgery were documented but did not factor into the inclusion or exclusion criteria for the study. The primary data points included operation time, estimated blood loss, length of stay, complications, and whether the procedure was converted to open. There was no standard protocol in place for advancement of the patients' diet postoperatively. When malignancy was the indication for surgery, additional data points including histologic diagnosis, clinical stage, and number of nodes collected were noted. Cases were performed by 1 of 2 authors (or both). The Student t test and χ^2 test (as well as

the Fisher exact test where appropriate) were used to examine the association between each of the independent factors and outcomes for continuous and categorical variables, respectively. Given the small sample size and varied procedure types, 2 subanalyses were performed for the aforementioned intraoperative and postoperative outcomes, one excluding procedures with concomitant liver resection and one solely for right hemicolectomy. All statistical analyses were performed by use of SPSS software (version 19; IBM, Armonk, New York).

Operative Technique

All procedures were performed by a single surgeon who had prior experience with the da Vinci Si robot in liver, spleen, pancreas, stomach, thyroid, and gallbladder procedures. In this series the surgical steps did not differ between the robotic and laparoscopic approaches, as has been described in previously published studies.[7,9,10,12,15,16] Port placement did, however, differ and can be found in prior publications. The differences in port placement between the laparoscopic and robot-assisted procedures are to accommodate the robotic arms, in addition to an extra port(s) for the surgeon's assistant. Port placement was standard for the type of procedure and for the approach (laparoscopic vs robot assisted), as has been described previously.[7,9,10,12,15,16]

RESULTS

Colon and rectal operations were performed in 40 patients during the study period. The mean age of the study population was 61.1 ± 9.8 years. Sixty-five percent of the patients were male patients with a mean body mass index (BMI) of 28.0 ± 5.8, and 37.5% had a history of abdominal surgery. Of the study population, 37.5% had a complication related to the operation.

In terms of operative technique, 25 patients underwent laparoscopic surgery whereas 15 underwent robotic surgery. Patient demographic data and characteristics of the 2 groups are shown in **Table 1**. There were no significant differences between the groups in terms of age, BMI, or history of abdominal surgery. The mean age of patients undergoing laparoscopic surgery versus robotic surgery was 61.1 ± 10.7 years versus 61.1 ± 8.5 years ($P = .997$), the mean BMI was 28.9 ± 6.3 versus 26.2 ± 4.2 ($P = .158$), and the percentage with a history of abdominal surgery was 44.0% versus 26.7% ($P = .273$). There was a significant difference in terms of sex, with more patients being male and undergoing robotic surgery (86.7% vs 52.0%, $P = .026$). There was no significant difference in surgical

Table 1.
Patient Characteristics of Laparoscopic and Robotic Groups

	Laparoscopic (n = 25)	Robotic (n = 15)	P Value
Age (y)	61.1 (10.7)	61.1 (8.5)	.997
Male [n (%)]	13 (52.0)	13 (86.7)	.026
Body mass index	28.9 (6.3)	26.2 (4.2)	.158
Previous abdominal surgery [n (%)]	11 (44.0)	4 (26.7)	.273
Diagnosis [n (%)]			.303
Malignant disease of colon	14 (56.0)	4 (27.0)	
Polyps	6 (36.0)	7 (60.0)	
Diverticular disease	2 (8.0)	2 (13.0)	
Other	3 (12.0)	2 (13.0)	
Types of operations (n)			
Right hemicolectomy	18	7	
Left hemicolectomy	0	2	
Sigmoidectomy	1	0	
Total colectomy	0	0	
Abdominoperineal resection	3	1	
Low anterior resection	3	5	
Concomitant liver resection	4	0	

Data are presented as mean (standard deviation) unless otherwise indicated.

indication between the 2 groups ($P = .303$). Eighteen patients underwent right hemicolectomy, 1 underwent a sigmoidectomy, 3 underwent abdominoperineal resection (APR), and 3 underwent low anterior resection (LAR) performed laparoscopically. In addition, 4 patients in the laparoscopy group underwent concomitant liver resection for metastases. In the robotic group, 7 patients underwent a right hemicolectomy, 2 underwent a left hemicolectomy, 1 underwent APR, and 5 underwent LAR. No patients in this group underwent simultaneous liver resection.

Intraoperative and postoperative outcomes were recorded and are compared in **Table 2**. Operative time was similar between the laparoscopic and robotic groups (190.8 ± 84.3 minutes vs 258.4 ± 170.8 minutes, $P = .183$), with similar estimated blood loss (163.3 ± 249.2 mL vs 96.8 ± 157.7 mL, $P = .385$). In the laparoscopic group, 16.0% of cases were converted to open compared with 20.0% in the robotic group ($P > .99$). The mean time until postoperative passage of stool was 4.6 ± 1.9 days in the laparoscopic group versus 4.2 ± 0.83 days in the robotic group ($P = .427$); the mean time until the initiation of a regular diet (4.5 ± 1.5 days vs 5.8 ± 3.2 days, $P = .159$) was not

significantly different between the 2 groups. Furthermore, the mean length of stay after laparoscopic surgery was 9.6 ± 7.3 days and was not different from the mean length of stay after robotic surgery (6.5 ± 3.8 days, $P = .091$). The rate of complications was similar for patients undergoing the laparoscopic approach versus those undergoing the robotic approach (36.0% vs 20.0%, $P = .457$) (**Table 2**). Of note, 1 patient undergoing the robotic procedure had an intraoperative splenic injury, which was repaired with splenorrhaphy. In addition, 1 patient—a 67-year-old woman undergoing a robot-assisted APR—died 1 day postoperatively as a result of a myocardial infarction.

The oncologic characteristics of the colorectal operations performed for cancer resection were also noted (**Table 3**). There was no significant difference in tumor stage ($P = .4882$) or histologic grade ($P > .99$) between the 2 groups. In addition, there was no significant difference in the number of lymph nodes harvested between the laparoscopic group (14.0 ± 6.5) and the robotic group (12.3 ± 4.2, $P = .683$). No resections performed for malignancy yielded positive margins in either group.

Table 2.
Intraoperative and Postoperative Outcomes

	Laparoscopic (n = 25)	Robotic (n = 15)	P Value
Duration of operation (min)	190.8 (84.3)	258.4 (170.8)	.183
Blood loss (mL)	163.3 (249.2)	96.8 (157.7)	.385
Conversion to open surgery [n (%)]	4 (16.0)	3 (20.0)	>.99
Time to passage of stool (d)	4.6 (1.9)	4.2 (0.83)	.427
Time to resume regular diet (d)	4.5 (1.5)	5.8 (3.2)	.159
Length of stay (d)	9.6 (7.3)	6.5 (3.8)	.091
Complication [n (%)]	9 (36.0)	3 (20.0)	.457
Wound infection (n)	4	0	.278
Anastomotic leak (n)	1	0	>.99
Ileus (n)	3	1	>.99
Intra-abdominal abscess (n)	1	0	>.99
Intraoperative spleen injury (n)	0	1	.375
Death (n)	0	1	.375

Data are presented as mean (standard deviation) unless otherwise indicated.

Table 3.
Pathologic Characteristics for Colorectal Cancer Operations

	Laparoscopic (n = 13)	Robotic (n = 3)	P Value
No. of retrieved lymph nodes (SD)	14.0 (6.5)	12.3 (4.2)	.683
Histology (n)			>.99
Well differentiated	1	0	
Moderately differentiated	7	2	
Poorly differentiated	3	1	
Other	2	0	
Tumor stage (n)			.4882
I	1	0	
II	6	1	
III	3	2	
IV	3	0	

Subanalyses

The subanalysis for outcomes of procedures excluding concomitant liver resections is shown in **Table 4**. No liver resections were performed robotically; thus the data in the subanalysis only varied in the laparoscopic arm. The duration of laparoscopic procedures averaged 175.2 ± 67.6 minutes versus 258.4 ± 170.8 minutes for robotic procedures (P = .183). Furthermore, blood loss in the laparoscopic group (69.7 ± 74.2 mL) was not different from that in the robotic group (96.8 ± 157.7 mL, P = .544). For all other parameters—rate of conversion to laparotomy, time to passage of stool, time until resumption of a regular diet, length of stay, and complications—there remained no statistically significant differences or any large changes to the raw data.

A second subanalysis was performed examining solely right colectomies (**Table 5**). The mean operative time was 146.9 ± 50.0 minutes in the laparoscopic group compared

Table 4.
Intraoperative and Postoperative Outcomes for Operations Excluding Concomitant Liver Resection

	Laparoscopic (n = 21)	Robotic (n = 15)	*P* Value
Duration of operation (min)	175.2 (67.6)	258.4 (170.8)	.102
Estimated blood loss (mL)	69.7 (74.2)	96.8 (157.7)	.544
Conversion to open surgery [n (%)]	4 (19.0)	5 (20.0)	>.99
Time to passage of stool (d)	4.7 (2.0)	4.2 (0.8)	.395
Time to resume regular diet (d)	4.5 (1.6)	5.8 (3.2)	.188
Length of stay (d)	9.0 (7.0)	6.5 (3.8)	.226
Complication (%)	28.6	26.7	>.99
Wound infection (n)	3	0	
Anastomotic leak (n)	1	0	
Ileus (n)	3	1	
Intra-abdominal abscess (n)	1	0	
Other (n)	1	2	
Death (n)	0	1	

Data are presented as mean (standard deviation) unless otherwise indicated.

Table 5.
Intraoperative and Postoperative Outcomes for Right Hemicolectomy

	Laparoscopic (n = 15)	Robotic (n = 7)	*P* Value
Duration of operation (min)	146.9 (50.0)	145.4 (39.9)	.945
Estimated blood loss (mL)	78.1 (79.6)	43.6 (29.8)	.288
Conversion to open surgery (d)	2 (13.3)	0 (0.0)	>.99
Time to passage of stool (d)	4.1 (1.7)	4.0 (0.6)	.902
Time to resume regular diet (d)	4.0 (1.3)	4.7 (1.0)	.309
Length of stay (d)	9.4 (8.1)	6.1 (2.7)	.180
Complication (%)	20.0	0.0	.523
Wound infection (n)	1		
Ileus (n)	2		
Other (n)	1		

Data are presented as mean (standard deviation) unless otherwise indicated.

with 145.4 ± 39.9 minutes in the robotic group (*P* = .945). Mean blood loss was likewise not statistically different between the laparoscopic group (78.1 ± 79.6 mL) and robotic group (43.6 ± 29.8 mL, *P* = .288). The times to passage of stool were similar between the laparoscopic group (4.1 ± 1.7 days) and the robotic group (4.0 ± 0.6 days), and the finding was not significant (*P* = .902). The remaining outcomes examined, including conversion to laparotomy, length of stay, and complications, continued to be similar to the aggregate analysis and were not statistically significant.

DISCUSSION

Interest in use of the robot in colorectal procedures has increased in recent years. For any new operative technique to become an accepted alternative to traditional methods, it must be proved safe and must result in com-

parable outcomes. For instance, studies have emerged since the adoption of laparoscopy for colorectal operations that have shown that it can yield a decreased length of hospital stay, oncologically adequate resection, and no differences in postoperative complications or in-hospital deaths when compared with a traditional open approach. Because of studies like these, laparoscopy is now considered an acceptable alternative to an open approach in colorectal resection.[17,18]

Our current experience shows many of the similarities between patients undergoing laparoscopic colorectal surgery and those undergoing robotic-assisted colorectal surgery and suggests that robot-assisted colon and rectal surgery is a safe and feasible alternative to the conventional laparoscopic approach. This study was conducted in groups of patients that were similar in terms of demographic characteristics and indications for operation. There was no significant difference between the robotic and laparoscopic groups in terms of age, BMI, or history of abdominal surgery. Regarding operative outcomes, no significant difference was noted between the 2 groups in terms of complication rate, estimated blood loss, conversion to open procedure, or length of hospital stay. Return of bowel function and resumption of a regular diet were also noted to be similar between the 2 groups. Across all operations and approaches, the surgeon performed commonly used techniques for port placement and procedural steps. The number and location of ports did not appear to have a clinically observable effect on intraoperative and postoperative outcomes including the need to convert to laparotomy, complications, and length of hospital stay. Consequently, this study of well-matched patients establishes the equivalence in outcomes that can be achieved between laparoscopic and robotic approaches to colon and rectal surgery.

The 2 subanalyses sought to create better-matched patient groups and decrease the large standard deviations as a result of aggregating a broad range of procedures. Two ways of accomplishing this were to (1) eliminate procedures with concomitant liver resection and (2) include only right colectomies, the most commonly performed procedure in our study. In the subanalysis of outcomes, excluding cases with concomitant liver resection yielded a large drop in estimated blood loss, as well as duration of the procedure. However, there continued to be no statistically significant difference in any of the outcomes. Likewise, although the subanalysis of right colectomies showed nearly identical operative times, greatly decreased blood loss (laparoscopy-associated blood loss again greater than robotic), and smaller standard devia-

tions, none of the differences were significant. Thus, despite attempting to better match the patient groups, the results remained similar between the laparoscopic and robotic procedures.

Our results are similar to those shown in the randomized clinical trial by Park et al[9] that compared outcomes of robot-assisted and laparoscopic approaches for right-sided colon cancer. They showed no difference in complications, blood loss, conversion to open surgery, time to passage of flatus, or time to resume a regular diet between the 2 groups. Other studies, by Rawlings et al[15] and D'Annibale et al,[10] have also shown similar findings. In the study by Rawlings et al, when examining right colectomy operations, no difference was seen between the laparoscopic and robot-assisted groups in terms of length of hospital stay and estimated blood loss. At present, the literature shows conflicting results in terms of the duration of the operation between the 2 surgical techniques. Similar to our findings, D'Annibale et al noted no significant variation in operative times between the robotic and laparoscopic groups. In contrast, Park et al found that the duration of the operation was significantly shorter in the laparoscopic group compared with the robot-assisted group (130 minutes vs 195 minutes, $P < .001$). Likewise, Rawlings et al noted a significant difference in operative time (mean of 169 minutes in laparoscopic group vs 219 minutes in robotic group, $P = .002$). Further well-matched studies are needed to truly elucidate whether there is a significant difference in operative times between the 2 surgical approaches.

Whether patients had a history of abdominal surgery was also investigated in this report. The fact that patients in both study arms had similar histories of abdominal operations suggests that prior abdominal surgery is not a contraindication to robotic-assisted surgery. In addition, the rate of conversion to an open procedure was not significantly different between the laparoscopic and robot-assisted groups. This finding is comparable with results reported in studies by Park et al[9] and Trastulli et al,[16] both of which examined patients undergoing robotic right colon resections. In the comparative study by Park et al, there was no difference in the number of cases converted to an open procedure: none of the 35 robot-assisted cases were converted to open surgery; nor were any of the 35 laparoscopic cases. Likewise, in the study by Trastulli et al examining a consecutive series of 20 patients, none were converted to open surgery. In our study, none of the robotic right colon resections were converted to an open procedure, whereas in the laparoscopic group, only 1

patient, who also underwent concomitant liver resection, was converted to open surgery.

In contrast to the aforementioned results, a study of rectal cancer resections in 84 patients (laparoscopic in 37 and robot assisted in 47) by Baek et al[12] found a significantly higher rate of conversion to open surgery in the laparoscopic group compared with the robotic group ($P = .020$). Together, these findings indicate that conversion to an open procedure likely occurs at similar rates between the 2 approaches and that there may in fact be superior outcomes after a robotic approach for colon and rectal surgery.

When operations are performed for cancer resection, new techniques must not only be safe but also provide a comparable outcome for oncologic resection. In this study we performed a subanalysis comparing laparoscopic versus robotic surgery that examined oncologic outcome. There was no difference in the number of lymph nodes harvested in cases performed as a result of colorectal malignancy, and both approaches yielded an average number of lymph nodes >12, proving the techniques oncologically sufficient. Similarly, studies by D'Annibale et al[10] and Park et al[9] reported no difference between the approaches in harvesting nodes. In these studies, robot-assisted resection obtained, on average, 17 nodes and 29.9 nodes, respectively. The series of 20 patients undergoing robotic right colectomy reported by Trastulli et al[16] also showed oncologic sufficiency by harvesting an average of 17.6 lymph nodes.

Although the technical limitations of standard laparoscopy are addressed with the robotic apparatus by using a 3-dimensional field and improved instrument articulation and rotation, there remain certain disadvantages to consider. Because robot-assisted operations are still relatively new, the process to set up and dock robotic arms increases the length of time in the operating room.[9,10] Even with an experienced team, the prolonged time is a drawback compared with conventional laparoscopy. Perhaps more important than operating room time, however, is the duration of the procedure because it is of greatest importance to the patient that prolonged risks of anesthesia are mitigated. It has been shown that colorectal surgery is associated with cardiac complications that are exacerbated by longer operative times and are associated with mortality rates of 20% to 40%.[19,20] The single patient death in this study, as a result of cardiac arrest, occurred in a 67-year-old woman undergoing a particularly complicated robotic APR for squamous cell carcinoma of the anal canal that lasted 492 minutes. As was seen in this study, however, as well as other studies of right colectomies, the duration of

the operation overall was not significantly different between the laparoscopic group and the robotic group.[15] When the robotic operative time is averaged after excluding this APR case, the time is 240.5 ± 160.3 minutes, a nonsignificant difference from the laparoscopic time. This time is similar to average operative times for robotic colorectal procedures published in the current literature.[9,10,15,16,21,22] Although some surgeons may question, on the basis of this instance of death after a robotic APR, the safety of the robot as a surgical modality, studies have shown low mortality rates. A systematic review by Kanji et al[22] of robot-assisted colorectal procedures encompassing 854 patients yielded no reported deaths. Similarly, Salman et al,[23] in an assessment of the Nationwide Inpatient Sample, found a mortality rate of 79.1 per 10 000 laparoscopic colorectal procedures compared with a rate of 0.0 per 10 000 robotic cases ($P < .05$). Thus, despite the single case of death in our study, both laparoscopic colorectal surgery and robotic colorectal surgery have been shown to have low in-hospital mortality rates.

Multiple studies have shown that robot-assisted surgery is significantly more costly than standard laparoscopic surgery.[9,15,21] We did not analyze cost in our study, but prior publications showed a greater expense of thousands of dollars when using the robotic approach compared with traditional laparoscopy. In addition to cost being a limitation to the robotic approach in hospitals, robotic surgery also results in a greater out-of-pocket expense for patients.[9] Although many studies, including our study, have shown that in most aspects, outcomes are similar between both modalities, significant advantages and benefits to the robotic approach over the laparoscopic approach may be necessary to justify the use of the robot in some centers. In other centers, however, the standardization of robotics in surgery may lead to cost savings over time.

The small sample size and retrospective nature of our study present some inherent limitations. At our institution, the robotic approach to colorectal surgery has not become widely adopted, and as such, there are fewer of these procedures being performed. However, this study and its exploratory nature serve as preliminary evidence in the comparison of laparoscopic and robotic colorectal surgery through an appropriate design. At the same time, this study establishes a basis for larger-scale investigation with wider financial and organizational resources. The study design was limited by the availability of the robot and could be remedied by a future prospective randomized study. As mentioned previously, the additional costs incurred when using the robot are a prohibitive factor, especially at an urban academic medical center such as

ours that typically treats underinsured patient populations. Furthermore, right hemicolectomy was the predominantly performed operation in this study, a procedure that is technically less challenging than an APR, for example. As such, this has a number of implications regarding operative time, blood loss, and perioperative and postoperative complications.

Although our study is a small retrospective comparison and thus subject to the limitations of such a study, it presents promising data on the efficacy of robotic surgery at institutions similar to ours. Further investigation into the comparative costs and into the magnitude of the effects in a larger patient population is necessary to better elucidate the differences between laparoscopic and robot-assisted techniques in colon and rectal operations.

CONCLUSION

In our early experience, the robotic-assisted technique is a safe and efficacious approach to colorectal surgery, in addition to preserving oncologically sufficient outcomes.

References:

1. Fung AK, Aly EH. Robotic colonic surgery: is it advisable to commence a new learning curve? *Dis Colon Rectum*. 2003;56:786–796.

2. Lacy AM, García-Valdecasas JC, Delgado S, et al. Laparoscopy-assisted colectomy versus open colectomy for treatment of non-metastatic colon cancer: a randomized trial. *Lancet*. 2002;359:2224–2229.

3. Hassanein AH, Bailey BA, Dobke MK. Robot-assisted plastic surgery. *Clin Plast Surg*. 2012;39:419–424.

4. Khan F, Pearle A, Lightcap C, Boland PJ, Healey JH. Haptic robot-assisted surgery improves accuracy of wide resection of bone tumors: a pilot study. *Clin Orthop Relat Res*. 2013;471:851–859.

5. McClain PD, Mufarrij PW, Hemal AK. Robot-assisted reconstructive surgery for ureteral malignancy: analysis of efficacy and oncologic outcomes. *J Endourol*. 2012;26:1614–1617.

6. Lambaudie E, Houvenaeghel G, Walz J, et al. Robot-assisted laparoscopy in gynecologic oncology. *Surg Endosc*. 2008;22:2743–2747.

7. Rockall TA, Darzi A. Robot-assisted laparoscopic colorectal surgery. *Surg Clin North Am*. 2003;83:1463–1468.

8. Lanfranco AR, Castellanos AE, Desai JP, Meyers WC. Robotic surgery: a current perspective. *Ann Surg*. 2004;239:14–21.

9. Park JS, Choi GS, Park SY, Kim HJ, Ryuk JP. Randomized clinical trial of robot-assisted versus standard laparoscopic right colectomy. *Br J Surg*. 2012;99:1219–1226.

10. D'Annibale A, Morpugo E, Fiscon V, et al. Robotic and laparoscopic surgery for treatment of colorectal diseases. *Dis Colon Rectum*. 2004;47:2162–2168.

11. Makino T, Milsom JW, Lee SW. Feasibility and safety of single-incision laparoscopic colectomy: a systematic review. *Ann Surg*. 2012;255:667–676.

12. Baek SJ, Al-Asari S, Jeong DH, et al. Robotic versus laparoscopic coloanal anastomosis with or without intersphincteric resection for rectal cancer. *Surg Endosc*. 2013;27:4157–4163.

13. Al-Asari S, Min BS. Robotic colorectal surgery: a systematic review. *ISRN Surg*. 2012;2012:293894. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3359666. Accessed August 28, 2013.

14. Yang TX, Chua TC. Single-incision laparoscopic colectomy versus conventional multiport laparoscopic colectomy: a meta-analysis of comparative studies. *Int J Colorectal Dis*. 2013;28:89–101.

15. Rawlings AL, Woodland JH, Vegunta RK, Crawford DL. Robotic versus laparoscopic colectomy. *Surg Endosc*. 2007;21:1701–1708.

16. Trastulli S, Desiderio J, Farinacci F, et al. Robotic right colectomy for cancer with intracorporeal anastomosis: short-term outcomes from a single institution. *Int J Colorectal Dis*. 2013;28:807–814.

17. Biondi A, Grosso G, Mistretta A, et al. Laparoscopic-assisted versus open for colorectal cancer: short- and long-term outcomes comparison. *J Laparoendosc Adv Surg Tech A*. 2013;23:1–7.

18. Vendramini DL, Albuquerque MM, Schmidt EM, Rossi-Junior EE, Gerent Wde A, Cunha VJ. Laparoscopic and open colorectal resections for colorectal cancer. *Arq Bras Cir Dig*. 2012;25:81–87.

19. Skipworth J, Srilekha A, Raptis D, O'Callaghan D, Siriwardhana S, Navaratnam R. Combined lumbar spinal and thoracic high-epidural regional anesthesia as an alternative to general anesthesia for high-risk patients undergoing gastrointestinal and colorectal surgery. *World J Surg*. 2009;33:1809–1814.

20. Lang M, Niskanen M, Miettinen P, Alhava E, Takala J. Outcome and resource utilization in gastroenterological surgery. *Br J Surg*. 2001;88:1006–1014.

21. Keller DS, Senagore AJ, Lawrence JK, Champagne BJ, Delaney CP. Comparative effectiveness of laparoscopic versus robot-assisted colorectal resection. *Surg Endosc*. 2014;28:212–221.

22. Kanji A, Gill RS, Shi X, Birch GW, Karmali S. Robotic-assisted colon and rectal surgery: a systematic review. *Int J Med Robotics Comput Assist Surg*. 2011;7:401–407.

23. Salman M, Bell T, Martin KJ, Bhuva K, Grim R, Ahuja V. Use, cost, complications, and mortality of robotic versus nonrobotic general surgery procedures based on a nationwide database. *Am Surg*. 2013;79(6):553–560.