Title

Outcomes of Open, Laparoscopic, and Robotic Abdominoperineal Resections in Patients With Rectal Cancer

Journal

Diseases of the Colon & Rectum, 58(12)

ISSN

0012-3706

Authors

Moghadamyeghaneh, Zhobin
Phelan, Michael
Smith, Brian R
et al.

Publication Date

2015-12-01

DOI

10.1097/dcr.0000000000000475

Peer reviewed

Outcomes of Open, Laparoscopic, and Robotic Abdominoperineal ResectionsinPatientsWith Rectal Cancer

Zhobin moghadamyeghaneh, m.D.[1] • Michael Phelan, Ph.D.[2] • Brian R. Smith, M.D.[1] michael J. stamos, m.D.[1]

1 Department of surgery, school of medicine, university of California, irvine, orange, California 2 Department of statistics, university of California, irvine, irvine, California

BACKGROUND: there are limited available data comparing open, laparoscopic, and robotic approaches for rectal cancer surgery.

OBJECTIVE: We sought to investigate outcomes of different surgical approaches to abdominoperineal resection in patients with rectal cancer.

DESIGN: the nationwide inpatient sample database was used to examine the clinical data of patients with rectal cancer who underwent elective abdominoperineal resection between 2009 and 2012 in the united states. multivariate regression analysis was performed to compare outcomes of different surgical approaches.

SETTINGS: a retrospective review according to the national inpatient sample database was designed.

PATIENTS: We included patients with rectal cancer who underwent elective abdominoperineal resection between 2009 and 2012.

MAIN OUTCOME MEASURES: outcomes of different surgical approaches to abdominoperineal resection were investigated.

RESULTS: We sampled 18,359 patients with rectal cancer who underwent elective abdominoperineal resections. of these, 69.5% had open surgery, 25.8% had laparoscopic surgery, and 4.7% had robotic surgery. the rate of robotic procedures increased >4-fold, from 2.1% to 8.1%, from 2009 to 2012. the conversion rate in robotic surgery was significantly lower compared with laparoscopic surgery (5.7% vs 13.4%; $p < 0.01$). after risk adjustment, patients who underwent laparoscopic and robotic approaches had lower morbidity risks compared with those who underwent the open approach (adjusted oR = 0.77 (95% Ci, 0.65–0.92), 0.57 (95% Ci, 0.40–0.80); $p < 0.01$). there were no significant differences in the morbidity rate of patients who underwent laparoscopic or robotic approaches (adjusted oR = 0.79 (95% Ci, 0.55–1.14); $p = 0.21$). however, patients who underwent the robotic approach had significantly higher total hospital charges compared with those who underwent the laparoscopic approach (mean difference, $24,890; $p < 0.01$).

LIMITATIONS: We could not adjust the results with some important factors, such as the tumor stage and Bmi.

CONCLUSIONS: the use of robotic and laparoscopic approaches to abdominoperineal resection have increased between 2009 and 2012. Both minimally invasive approaches decrease morbidity rates of patients undergoing abdominoperineal resection. the robotic approach has a significantly lower conversion rate compared with the laparoscopic approach. however, it had significantly higher total hospital charges compared with the laparoscopic approach.

There have been significant improvements in the treatment of rectal cancer during the last few decades. neoadjuvant chemoradiation and total mesorectal excision have had significant effects on outcomes for patients with rectal cancer.[1–3] Robotic and laparoscopic approaches in surgical treatment of rectal cancer are 2 recent additions to the treatment algorithm; however, advantages and disadvantages of using laparoscopic and robotic approaches in rectal cancer surgery are not yet well defined.

a laparoscopic approach to rectal cancer surgery was introduced to decrease postoperative morbidity of the open approach. smaller incisions and quicker recovery are some advantages of laparoscopic surgery.[1] however, anatomic structures of the bony pelvis and consequent angling limits are some limitations of laparoscopic surgery for rectal cancer. With the development of new technologies, robotic surgery was introduced to overcome some of the challenges of laparoscopic surgery. Robotic surgery provides high quality, 3-dimensional visualization of the pelvic anatomy while providing easier dissection and suturing in the deep pelvis compared with laparoscopic techniques. however, there are limited data regarding the benefits of minimally invasive approaches, especially robotic surgery, and further studies are needed to affirm the role of minimally invasive surgery in the treatment of rectal cancer.

the relative merits of robotic surgery versus laparoscopic surgery are controversial.[4] higher cost and operation length of robotic surgery compared with laparoscopic surgery have been subjects of concern.[5–8] as surgeons become more experienced in robotic techniques, the length of the procedure decreases significantly; however, the high cost of robotic procedures is still an important issue.[5,6,8] in the field of rectal cancer surgery there are a number of studies comparing the safety, feasibility, and efficacy of robotic surgery versus laparoscopic surgery, however, the numbers of cases are usually small. using a large national database, we aimed to compare outcomes of open, laparoscopic, and robotic abdominoperineal resections in patients with rectal cancer. We focused exclusively on abdominoperineal resection (aPR) as an international Classification of Diseases, 9th Revision, Clinical modification (iCD-9-Cm), procedure code exists for this operation conducted laparoscopically, which is critical for accurate data collection and analysis. such a code is lacking for low anterior resection.[9]

MATERIALS AND METHODS

This study used data from the national (nationwide) inpatient sample (nis) database for the years 2009 to 2012. the nis database is the largest inpatient care database in the united states, developed for the healthcare Cost and Utilization Project. The NiS contains information from nearly 8-million hospital stays each year across the united states with an ≈20% stratified sample of the american community, nonmilitary, and nonfederal hospitals, resulting in a sampling frame that approximates 95% of all hospital discharges in the united states.[10] the nis database

is exempt to obtain informed consent from individual patients and is covered within the individual hospital's patient consent forms. for the purpose of this study, iCD-9-Cm procedure codes were pulled to select patients who underwent aPR with the diagnosis of rectal cancer using the appropriate codes as specified by iCD-9-Cm diagnosis codes of 154, 154.0, 154.1, 154.2, 154.3, 154.8, and 230.4. Patients who underwent aPR were defined based on the iCD-9-CM procedure codes of 48.50 through 48.59. Patients <18 years of age and nonelectively admitted patients were excluded from the study. also, we used an original variable of nis ("Cm_mets") to exclude patients with metastatic cancer from the study. this variable shows the presence of metastatic cancer according to iCD-9-Cm diagnoses and the Diagnosis Related Group in effect on the discharge date. Robotic procedures were defined as both pure robotic and robotic-assisted procedures according to iCD-9-Cm procedure codes of 17.41 and 17.42. laparoscopic procedures were defined according to iCD-9-Cm procedure code 48.51. Clinical parameters and demographic data analyzed include age, sex, and race, as well as comorbidity conditions, which include history of congestive heart failure, renal failure, obesity, hypertension, diabetes mellitus, coagulopathy, and chronic pulmonary disease. the hospital factors include the bed size of the hospital (small, medium, or large) according to the definition of healthcare Cost and utilization Project,[10] the teaching status/location of the hospital (rural hospital, nonteaching urban hospital, and teaching urban hospital), and the hospital volume (we divided the hospitals into 2 groups of hospitals, those with less than 49 aPR operations and those with 50 or more aPR operations during the study period). outcomes investigated include mortality, overall morbidity, thromboembolic events (deep vein thrombosis and pulmonary embolism), respiratory complications (pneumonia and respiratory failure), paralytic ileus, hemorrhagic complications, urinary tract infection, cardiac complications (myocardial infarction and arrhythmia), acute renal failure, intra-abdominal or surgical site infections, accidental puncture during operation, conversion of minimally invasive approaches to open, total hospital cost, and prolonged hospitalization (>7 days). the overall rates of each complication by surgical approaches were examined. Risk-adjusted analysis was performed to compare the outcomes by surgical approaches.

Statistical Analysis

all of the statistical analyses were conducted with SPSS version 22 (SPSS inc, Chicago, iL). Weighted analysis were based on the nis 2-stage clustered sampling design with hospital identification as cluster, nis stratum as stratum, and trend weights as weights. trend weights were used to account for changes in the nis sampling design in the period from 2009 to 2012, as per the recommendation of nis report on weighted trends.[10] multivariate analysis was used to compare postoperative complications by type of surgical approach, based on logistic regression for dichotomous outcomes and linear regression for continuous outcomes, such as hospitalization length and total hospital charge. adjustment was made for key patient characteristics (age, sex, and race), all comorbidities, and hospital factors. statistical significance was based on the α level of 0.05. for each dichotomous or continuous outcome, estimates of the adjusted oR (aoR) or mean difference were calculated and reported with 95% Ci for the population association.

RESULTS

The study population consisted of 18,359 patients (se = 523) with the diagnosis of rectal cancer who underwent elective aPR between 2009 and 2012. of these, 69.5% had open surgery, 25.8% had laparoscopic surgery, and 4.7% had robotic surgery. the median age of patients was 64 years; the majority of the patients were white (68.7%) and men (60.3%). most common comorbidities included hypertension (50.5%) and diabetes mellitus (18.5%). the patient characteristics are shown in table 1.

Overall, 30.5% of aPR procedures were performed with minimally invasive approaches. of these 25.8% were laparoscopic and 4.7% were robotic. there was a steady increase in the number of robotic procedures from 93 (2.1%) in 2009 to 365 (8.1%) in 2012 (fig. 1). also, the use of laparoscopic surgery has increased from 21.5% in 2009 to 26.9% in 2012. as estimated, the rate of open procedures decreased from 76.4% in 2009 to 65% in 2012.

Overall, 69% of laparoscopic procedures were performed in hospitals with large bed size, 21.9% were per-

TABLE 1. Demographics and clinical factors of patients with a diagnosis of rectal cancer who have undergone abdominoperineal resection

Variables	*Open approach (N = 12,750)*	*Laparoscopic approach (N = 4737)*	*p*[a]	*Robotic approach (N = 872)*	*p*[a]
Age					
Mean ± SD, y	64 ± 13	62 ± 13	<0.01	64 ± 12	0.66
Median, y	65	62	–	64	–
Sex, n (%)					
Women	5074 (39.8)	1893 (40.1)	0.85	316 (36.2)	0.34
Race, n (%)					
White	8636 (77.5)	3377 (77.1)	0.85	608 (76.1)	0.69
Black	1055 (9.5)	348 (7.9)	0.19	45 (5.6)	0.11
Hispanic	832 (7.5)	353 (8.0)	0.62	61 (7.6)	0.95
Asian	299 (2.7)	125 (2.9)	0.82	46 (5.7)	0.06
Other	328 (2.9)	178 (4.1)	0.10	40 (5.0)	0.17
Comorbidity, n (%)					
Chronic pulmonary disease	1657 (13.0)	584 (12.3)	0.60	87 (10.0)	0.24
Coagulopathy	413 (3.2)	145 (3.1)	0.77	15 (1.7)	0.24
Renal failure	488 (3.8)	176 (3.7)	0.87	34 (3.9)	0.97
Diabetes mellitus	2341 (18.4)	900 (19.0)	0.67	154 (17.6)	0.80
Congestive heart failure	586 (4.6)	83 (1.8)	<0.01	20 (2.3)	0.15
Obesity	1383 (10.8)	455 (11.5)	0.60	59 (6.8)	0.07
Hypertension	6626 (52.0)	2232 (47.1)	0.01	409 (46.9)	0.17
Hospitalization length					
Mean ± SD, d	10 ± 7	8 ± 6	<0.01	8 ± 6	<0.01
Median, d	8	6	–	6	–
Hospital bed size, n (%)					
Small	1238 (9.9)	430 (9.2)	0.64	86 (9.9)	0.98
Medium	2692 (21.4)	1027 (21.9)	0.85	165 (19.1)	0.59
Large	8629 (68.7)	3244 (69.0)	0.91	615 (71.0)	0.67
Hospital volume, n (%)					
Less than 50 APR operations during the study	10080 (81.6)	3585 (77.9)	<0.01	648 (76.2)	<0.01
50 or more APR operations during the study	2270 (18.4)	1018 (22.1)	<0.01	202 (23.8)	<0.01
Teaching/location status, n (%)					
Rural hospitals	1012 (8.1)	187 (4.0)	<0.01	11 (1.2)	<0.01
Urban nonteaching hospital	3845 (30.6)	1510 (32.1)	0.57	185 (21.3)	0.10
Urban teaching hospital	7701 (61.3)	3004 (63.9)	0.36	671 (77.5)	<0.01
Hospital charge, $					
Mean ± SD	75,109 ± 63,680	77,127 ± 77,411	0.66	99,472 ± 76,969	<0.01
Median	57,678	57,634	–	79,513	–

APR = abdominoperineal resection.

[a]Compared to open approach

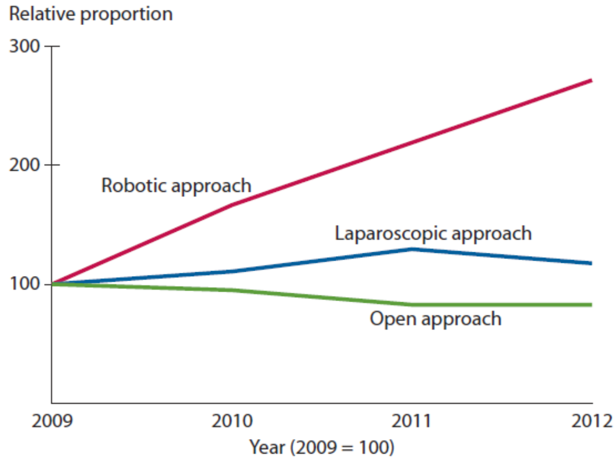

FIGURE 1. Trends in the relative weighted number of cases in each surgical approach to abdominoperineal resection, National (Nationwide) Inpatient Sample (NIS) 2009 to 2012. Year 2009 equals 100.

formed in hospitals with medium bed size, and 9.2% were performed in hospitals with small bed size. also, 63.9% of laparoscopic procedures were performed in urban teaching hospitals, 32.1% in urban nonteaching hospitals, and 4.0% in rural hospitals. Regarding robotic aPR procedures, 71% of procedures were performed in hospitals with large bed size, 19.1% in hospitals with medium bed size, and 9.9% in hospitals with small bed size. also, 77.5% of robotic procedures were performed in urban teaching hospitals, 21.3% in urban nonteaching hospitals, and 1.2% in rural hospitals (table 1).

the conversion rate of robotic procedure to open was 5.7%, whereas the conversion rate of laparoscopic procedures to open was 13.4%. the difference is statistically significant (aoR = 0.40; $p < 0.01$). the median total hospital charges for patients who underwent open, laparoscopic, and robotic procedures were $57,678, $57,634, and $79,513. Patients who underwent a robotic approach had higher mean total hospital charges compared with those who underwent a laparoscopic or open procedure (mean difference = $24,890, and $24,626; $p < 0.01$).

the median hospitalization lengths for open, laparoscopic, and robotic aPR were 8, 6, and 6 days. The robotic approach and laparoscopic approach had significantly shorter hospitalization lengths compared with the open approach (mean differences = 2 days; $p < 0.01$).

the risk-adjusted analysis for outcomes of laparoscopic and robotic approaches compared with an open approach is reported in table 2. Respiratory complications (aoR = 0.70, $p = 0.04$), surgical infections (aoR = 0.52; $p < 0.01$), and hospitalization >1 week (aoR = 0.45; $p < 0.01$) were significantly lower in laparoscopic surgery compared with open surgery. also, urinary tract infection (aoR = 0.37; $p = 0.04$) and hospitalization >1 week (aoR = 0.42; $p < 0.01$) were significantly lower in the robotic approach compared with the open approach. When comparing postoperative complications of the laparoscopic approach with the robotic approach, there were no significant differences in postoperative complications (Table 3).

Mortality rates of open, laparoscopic, and robotic approaches were 0.9%, 0.6%, and 0.5%, which were not significant (table 2). overall morbidity of open, laparoscopic, and robotic approaches were 39.7%, 32.5%, and 26.9%. Both laparoscopic and robotic approaches had lower morbidity compared with the open approach (table 2). However, there was no significant difference between the morbidity risk of laparoscopic aPR and robotic aPR (Table 3).

DISCUSSION

The minimally invasive approaches to aPR are safe techniques for the treatment of rectal cancer with a number of advantages over open surgery. although the mortality rates of minimally invasive approaches and the open approach were not significantly different, the morbidity rates of patients who underwent laparoscopic or robotic surgery were significantly lower than those of patients who underwent open aPR. Mortality and morbidity of the laparoscopic approach are not significantly different than with a robotic approach. however, laparoscopic surgery has a significantly higher conversion risk compared with robotic surgery. Conversely, robotic surgery has significantly higher total hospital costs compared with laparoscopic surgery. our data reinforce the benefits of minimally invasive approaches to aPR. However, the type of surgical approach for aPR should be decided separately for each case. When both laparoscopic and robotic aPR are possible, the robotic approach does not provide any advantage, and it will increase the hospital cost significantly. for patients with unsuitable pelvic anatomy or patients at high risk of conversion, a robotic approach can significantly decrease the risk of conversion.

our study results show that minimally invasive approaches to aPR are associated with a significant decrease in morbidity of patients. We found that the laparoscopic approach was associated with a decrease in overall morbidity, as well as the rate of respiratory complications, surgical infections, and prolonged hospitalization compared with open aPR. also, robotic surgery was associated with lower overall morbidity, prolonged hospitalization, and urinary tract infection. the lower morbidity of minimally invasive approaches compared with the open approach in rectal surgery has been cited multiple times.[11–13] however, the inability to control the disease stage and comorbid conditions in patients who had different surgical approaches makes it difficult to draw firm conclusions. in addition, our results show that patients who underwent minimally invasive aPR had fewer comorbid conditions. in fact, we found that the rate of open surgery was higher than robotic surgery in obese patients. this could be related to the difficulties of minimally invasive approaches in the pelvis of obese patients. obesity has been reported as an

TABLE 2. Risk-adjusted analysis of outcomes of laparoscopic and robotic abdominoperineal resection compared with open surgery

Complication	Open approach (N = 12,750), n (%)	Laparoscopic approach (N = 4737)			Robotic approach (N = 872), n (%)		
		Rate, n (%)	AOR and 95% CI	p	Rate, n (%)	AOR and 95% CI	p
Mortality	109 (0.9)	28 (0.6)	0.81 (0.31–2.05)	0.65	[a]	0.94 (0.12–7.26)	0.95
Overall morbidity[b]	5064 (39.7)	537 (32.5)	0.77 (0.65–0.92)	<0.01	235 (26.9)	0.57 (0.40–0.80)	<0.01
Respiratory complications[c]	916 (7.2)	221 (4.7)	0.70 (0.49–0.99)	0.04	43 (4.9)	0.72 (0.38–1.39)	0.33
Urinary tract infection	715 (5.6)	219 (4.6)	0.81 (0.55–1.19)	0.29	19 (2.2)	0.37 (0.13–1.05)	0.04
Surgical infections[d]	861 (6.8)	175 (3.7)	0.52 (0.36–0.76)	<0.01	43 (4.9)	0.69 (0.34–1.40)	0.31
Hospitalization >7 d	6668 (52.3)	1520 (32.1)	0.45 (0.38–0.53)	<0.01	263 (30.2)	0.42 (0.28–0.62)	<0.01
Hemorrhagic complications	368 (2.9)	128 (2.7)	0.94 (0.60–1.46)	0.78	[a]	0.17 (0.02–1.29)	0.08
Sepsis	315 (2.5)	60 (1.3)	0.58 (0.30–1.12)	0.10	15 (1.7)	0.78 (0.24–2.50)	0.68
Thromboembolic complications[e]	130 (1.0)	49 (1.0)	1.14 (0.53–2.44)	0.72	0	–	–
Renal failure	713 (5.6)	205 (4.3)	0.86 (0.59–1.26)	0.45	33 (3.8)	0.77 (0.34–1.72)	0.53
Accidental puncture[f]	507 (4.0)	188 (4.0)	1.04 (0.71–1.53)	0.81	41 (4.8)	1.18 (0.60–2.32)	0.62
Cardiac complications[g]	490 (3.8)	117 (2.5)	0.67 (0.43–1.06)	0.09	30 (3.5)	0.94 (0.39–2.26)	0.89
Paralytic ileus	2665 (20.9)	910 (19.2)	0.93 (0.75–1.16)	0.56	131 (15.1)	0.67 (0.43–1.04)	0.07

[a]Data are too small to report.

[b]Respiratory complications, renal failure, cardiac complications, thromboembolic complications, intra-abdominal or wound infections, hemorrhagic complications, urinary tract infection, paralytic ileus, accidental puncture, and sepsis are included.

[c]Pneumonia and acute respiratory failure are included.

[d]Intra-abdominal and wound infections are included.

[e]Deep vein thrombosis and pulmonary embolism are included.

[f]Accidental puncture and laceration during the procedure are included.

[g]Myocardial infarction and arrhythmia are included.

independent risk factor of conversion of minimally invasive approaches to open colectomy.[14,15] additional prospective case-matched studies are indicated to compare outcomes of the 3 surgical approaches in 3 homogenous groups of patients. there is a steady increase in the use of minimally invasive surgery in rectal cancer. We found an increase in the use of minimally invasive approaches and conversely a decrease in the proportion of open aPR from 2009 to 2012 (Fig. 1). this is in line with a previous report on the increasing rate of robotic surgery in different colorectal operations.[16] in addition, we found the overall rate of minimally invasive approaches increased from 23.6% in 2009 to 35.0% in 2012. our observation of a 30.7% overall rate of use of minimally invasive approaches is in line with the reported overall rates of minimally invasive approaches for colorectal resection from the same period of time (37.3%–43.5%),[15,17] as well as the Surgical Care and outcomes assessment Program Collaborative report in 2010 (41.6%).[18] in addition, our study results show that there is a broad difference in the use of the laparoscopic approach foraPR in the United States, ranging from 26.5% for urban teaching hospitals to 15.5% for rural hospitals. however, there is homogeneous accessibility of surgeons to laparoscopic equipment in the united states.[19] The variation in the use of laparoscopic aPR in the United states is therefore likely related to the relatively higher levels of laparoscopic skills needed for laparoscopic aPR. additional efforts are needed to reduce the wide variation in use of the laparoscopic approach to aPR.

We found that a lower conversion rate is the only advantage of robotic aPR over laparoscopic aPR. our multivariate adjustment analysis shows that there is no significant difference in postoperative complications between robotic and laparoscopic aPR, and the differences in rates of postoperative complications in laparoscopic and robotic aPR are not statistically or clinically significant. However, a laparoscopic aPR has more than double the rate of conversion compared with robotic aPR. Lower conversion rate to open for robotic surgery compared with laparoscopic surgery in rectal surgery has been previously reported multiple times.[7,20,21] the lower conversion rate in robotic approach may be influenced by technological advantages of the robotic system, which provides high-quality 3-dimensional vision, better depth perception, better definition of tissue planes, easier suturing, and precise dissection in the pelvis compared with standard 2-dimensional laparoscopic images.[6,22] Conversion rates of robotic and laparoscopic rectal surgery have been reported in the range of 0% to 9.4% and 0% to 22.0% previously.[7,23] We found conversion rates of 5.7% and 13.4% for robotic and laparoscopic aPR. However, surgical expertise and case selection might lead to an underestimate of the difference of conversion rates of robotic and laparoscopic aPR. Usually only highly experienced surgeons perform aPR laparoscopically, whereas the robot approach hypothetically tries to bridge the learning gap and make minimally invasive approaches easier for surgeons with less experience.

The robotic approach to aPR is associated with a significant increase in total hospital cost. We found a 37% increase in total hospital cost for robotic surgery compared with laparoscopic surgery. this is in line with previous reports.[13,24] The benefit of the robotic approach to aPR, which is a lower conversion rate, should be contrasted with the disadvantage of the approach, which is the higher cost. overall, minimally invasive approaches to aPR have better outcomes compared

TABLE 3. Risk-adjusted analysis of outcomes of robotic abdominoperineal resection compared with laparoscopic approach

Complication	*Laparoscopic approach (N = 4737), n (%)*	*Robotic approach (N = 872), n (%)*	*Adjusted OR*	*95% CI*	*p*
Mortality	28 (0.6)	[a]	0.65	0.02–14.64	0.78
Overall morbidity[b]	537 (32.5)	235 (26.9)	0.79	0.55–1.14	0.21
Conversion to open	634 (13.4)	50 (5.7)	0.40	0.20–0.78	<0.01
Respiratory complications[c]	221 (4.7)	43 (4.9)	0.89	0.41–1.89	0.76
Urinary tract infection	219 (4.6)	19 (2.2)	0.47	0.15–1.49	0.20
Surgical infections[d]	175 (3.7)	43 (4.9)	1.33	0.57–3.10	0.49
Hospitalization >7 d	1520 (32.1)	263 (30.2)	0.98	0.64–1.49	0.93
Hemorrhagic complications	128 (2.7)	[a]	0.18	0.01–1.87	0.15
Sepsis	60 (1.3)	15 (1.7)	1.42	0.39–5.07	0.58
Thromboembolic complications[e]	49 (1.0)	0	[f]	[f]	[f]
Renal failure	205 (4.3)	33 (3.8)	0.94	0.41–2.17	0.90
Accidental puncture[g]	188 (4.0)	41 (4.8)	1.31	0.62–2.77	0.47
Cardiac complications[h]	117 (2.5)	30 (3.5)	1.67	0.65–4.25	0.27
Paralytic ileus	910 (19.2)	131 (15.1)	0.78	0.49–1.24	0.29

[a]Data are too small to report.
[b]Respiratory complications, renal failure, cardiac complications, thromboembolic complications, intra-abdominal or wound infections, hemorrhagic complications, urinary tract infection, paralytic ileus, accidental puncture, and sepsis are included.
[c]Pneumonia and acute respiratory failure are included.
[d]Intra-abdominal and wound infections are included.
[e]Deep vein thrombosis and pulmonary embolism are included.
[f]There was no case to compare in at least 1 group.
[g]Accidental puncture and laceration during the procedure are included.
[h]Myocardial infarction and arrhythmia are included.

with open aPR. in patients who cannot be operated on laparoscopically and for patients at high risk of conversion, choosing a robotic approach may be reasonable (we found a significantly lower conversion rate for the robotic approach compared with the laparoscopic approach). however, the inability to control for the disease stage and all of the comorbid conditions makes it difficult to draw firm conclusions. When both laparoscopic and robotic surgeries can be performed, robotic surgery may not have an advantage over laparoscopic surgery, and it will increase the expenses for patients.

among surgical approaches to aPR, robotic approach has the lowest hemorrhagic complications. Rates of postoperative hemorrhagic complications for open, laparoscopic, and robotic aPR were 2.9%, 2.7%, and 0.5% in our study. We confirm previous reports regarding a lower hemorrhagic complication rate of robotic rectal surgery compared with laparoscopic resection.[25,26] this could be related to the technological advantages of the robotic system, which provides better vision, easier dissection, and suturing compared with the laparoscopic approach.[6,22] however, after multivariate analysis, there were no significant differences in hemorrhagic complications among open, laparoscopic, and robotic approaches, and the difference in rates of hemorrhagic complications among surgical approaches is not clinically significant (tables 2 and 3).

Study Limitations

this is a retrospective analysis of a national database and is subject to inherent selection bias of retrospective studies. Be-cause the nis database is compiled from discharge abstract data, coding errors may exist in collecting of the data.[27] the wide variation in hospital setting, hospital quality, and surgeon expertise in our database may have affected some of the indexes, such as the operation time and conversion rate. the main limitation of the study was the exclusion of patients who underwent anterior resection of rectum from the study because of the lack of a reliable iCD-9-Cm code for laparoscopic anterior resection of rectum. our previously published article with unspecified iCD-9-Cm codes for anterior resection may underestimate the use of laparoscopic surgery for anterior resection of rectum.[9] We used iCD-9-Cm procedure codes of 17.41 and 17.42 to find patients who underwent robotic procedure. Considering that the mentioned codes are not specific for rectal surgery, coding errors are possible in case selection, although the high profile of robotic operations because of cost issues makes this less likely. nis does not provide any information regarding details on the characteristics of the rectal cancer (eg, the cancer stage). the 3 groups of patients compared in the study were not 3 homogeneous groups of patients, and their disease stage may vary. although we excluded patients with metastatic cancer and nonelectively admitted patients from the study and we adjusted the results with comorbid conditions, we could not adjust our results with the tumor characteristics, which is an important factor in choosing the surgical approach. although we adjusted the results for the presence or absence of a number of comorbid conditions, we did not have any information regarding the severity of comorbid conditions or surgeon operation volume. in addition, our study intended to investigate out-comes of aPR by surgical approaches; however, perioperative factors, such as the operation duration, surgeon specialization, and long-term oncologic outcomes, could not be evaluated.[8,23,28] nevertheless, this retrospective review is presently one of the most comprehensive and largest studies comparing open, laparoscopic, and robotic approaches with aPR in rectal cancer surgery.

CONCLUSION

there is a steady increase in the rate of minimally invasive approaches to aPR for rectal cancer surgery. We found both minimally invasive approaches to aPR to have better outcomes compared with open aPR. However, the inability to control for the disease stage and comorbid conditions in patients, including degree of obesity, who underwent different types of approaches makes it difficult to draw firm conclusions. Robotic surgery has a lower conversion rate compared with laparoscopic aPR; however, it has significantly higher hospital charges. overall, using minimally invasive approaches to aPR is reasonable in some situations. Considering the similar outcomes in laparoscopic and robotic aPR, deciding between these 2 surgical approaches should be done according to the possibility of laparoscopic approach and the risk of conversion to open surgery.

REFERENCES

1. Rosin D, lebedyev a, urban D, et al. laparoscopic resection of rectal cancer. *Isr Med Assoc J*. 2011;13:459–462.
2. macfarlane JK, Ryall RD, heald RJ. mesorectal excision for rectal cancer. *Lancet*. 1993;341:457–460.
3. Kim nK, Baik sh, seong Js, et al. oncologic outcomes after neoadjuvant chemoradiation followed by curative resection with tumor-specific mesorectal excision for fixed locally advanced rectal cancer: impact of postirradiated pathologic downstaging on local recurrence and survival. *Ann Surg*. 2006;244:1024–1030.
4. liao G, Zhao Z, lin s, et al. Robotic-assisted versus laparoscopic colorectal surgery: a meta-analysis of four randomized controlled trials. *World J Surg Oncol*. 2014;12:122.
5. heemskerk J, de hoog De, van Gemert WG, Baeten CG, Greve JW, Bouvy nD. Robot-assisted vs. conventional laparoscopic rectopexy for rectal prolapse: a comparative study on costs and time. *Dis Colon Rectum*. 2007;50:1825–1830.
6. heemskerk J, Zandbergen R, maessen JG, Greve JW, Bouvy nD. advantages of advanced laparoscopic systems. *Surg Endosc*. 2006;20:730–733.
7. trastulli s, farinella e, Cirocchi R, et al. Robotic resection compared with laparoscopic rectal resection for cancer: systematic review and meta-analysis of

short-term outcome. *Colorectal Dis*. 2012;14:e134–e156.
8. Kim CW, Baik sh. Robotic rectal surgery: what are the benefits? *Minerva Chir*. 2013;68:457–469.
9. Kang CY, Halabi WJ, Luo R, Pigazzi a, Nguyen NT, Stamos MJ. laparoscopic colorectal surgery: a better look into the latest trends. *Arch Surg*. 2012;147:724–731.
10. Healthcare Cost and Utilization Project (HCUP). overview of the national (nationwide) inpatient sample (nis). www.hcup- us.ahrq.gov/nisoverview.jsp. accessed april 25, 2015.
11. da Luz Moreira a, Mor i, Geisler DP, Remzi FH, Kiran RP. Laparoscopic resection for rectal cancer: a case-matched study. *Surg Endosc*. 2011;25:278–283.
12. ohtani h, tamamori y, azuma t, et al. a meta-analysis of the shortand long-term results of randomized controlled trials that compared laparoscopy-assisted and conventional open surgery for rectal cancer. *J Gastrointest Surg*. 2011;15:1375–1385.
13. Kim CW, Kim Ch, Baik sh. outcomes of robotic-assisted colorectal surgery compared with laparoscopic and open surgery: a systematic review. *J Gastrointest Surg*. 2014;18:816–830.
14. Tekkis PP, Senagore aJ, Delaney CP. Conversion rates in laparoscopic colorectal surgery: a predictive model with, 1253 patients. *Surg Endosc*. 2005;19:47–54.
15. moghadamyeghaneh Z, masoomi h, mills sD, et al. outcomes of conversion of laparoscopic colorectal surgery to open surgery. *JSLS*. 2014;18.
16. halabi WJ, Kang Cy, Jafari mD, et al. Robotic-assisted colorectal surgery in the united states: a nationwide analysis of trends and outcomes. *World J Surg*. 2013;37:2782–2790.
17. masoomi h, moghadamyeghaneh Z, mills s, Carmichael JC, Pigazzi a, Stamos MJ. Risk factors for conversion of laparoscopic colorectal surgery to open surgery: does conversion worsen outcome? *World J Surg*. 2015;39:1240–1247.
18. Kwon s, Billingham R, farrokhi e, et al. adoption of laparoscopy for elective colorectal resection: a report from the surgical Care and outcomes assessment Program. *J Am Coll Surg*. 2012;214:909–918.e901.
19. tsui C, Klein R, Garabrant m. minimally invasive surgery: national trends in adoption and future directions for hospital strategy. *Surg Endosc*. 2013;27:2253–2257.
20. Patriti a, Ceccarelli G, Bartoli a, Spaziani a, Biancafarina a, Casciola l. shortand medium-term outcome of robot-assisted and traditional laparoscopic rectal resection. *JSLS*. 2009;13:176–183.
21. Baik sh, Kwon hy, Kim Js, et al. Robotic versus laparoscopic low anterior resection of rectal cancer: short-term outcome of a prospective comparative study. *Ann Surg Oncol*. 2009;16:1480–1487.
22. Cadière GB,himpens J,Germayo,etal.feasibilityof roboticlaparoscopic surgery: 146 cases. *World J Surg*. 2001;25:1467–1477.
23. araujo se, seid Ve, Klajner s. Robotic surgery for rectal cancer: current immediate clinical and oncological outcomes. *World J Gastroenterol*. 2014;20:14359–14370.
24. Delaney CP, Lynch aC, Senagore aJ, Fazio VW. Comparison of robotically performed and traditional laparoscopic colorectal surgery. *Dis Colon Rectum*. 2003;46:1633–1639.
25. Popescu i, Vasilescu C, Tomulescu V, Vasile S, Sgarbura o. The minimally invasive approach, laparoscopic and robotic, in rectal resection for cancer: a single center experience. *Acta Chir Iugosl*. 2010;57:29–35.
26. Kang J, yoon KJ, min Bs, et al. the impact of robotic surgery for mid and low rectal cancer: a case-matched analysis of a 3-arm comparison–open, laparoscopic,

and robotic surgery. *Ann Surg*. 2013;257:95–101.
27. Lorence DP, ibrahim ia. Benchmarking variation in coding accuracy across the united states. *J Health Care Finance*. 2003;29:29–42.
28. Rea JD, lu KC, Diggs Bs, Cone mm, hardiman Km, herzig Do. specialized practice reduces inpatient mortality, length of stay, and cost in the care of colorectal patients. *Dis Colon Rectum*. 2011;54:780–786.

Financial Disclosure: Dr stamos received educational grants and speaker fees paid to the Department of surgery, university of California, Irvine, from Ethicon, Gore, Covidien, and Olympus.

Presented at the meeting of the Southern California Chapter of The american College of surgeons, santa Barbara, Ca, January 16 to 18, 2015.

Correspondence: michael J. stamos, m.D., 333 City Blvd West, suite 1600, orange, Ca 92868. e-mail: mstamos@uci.edu.