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ORIGINAL ARTICLE

Index cost comparison of laparoscopic vs robotic surgery in colon and rectal cancer resection: a retrospective financial investigation of surgical methodology innovation at a single institution

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Abstract

Background Robotic assisted colorectal cancer resection (R-CR) has become increasingly commonplace in contrast to traditional laparoscopic cancer resection (L-CR). The aim of this study was to compare the total direct costs of R-CR to that of L-CR and to compare the groups with respect to costs related to LOS.

Methods Patients who underwent colon and/or rectal cancer resection via R-CR or L-CR instrumentation between January 1, 2015 and December 31 2018, at our institution, were evaluated and compared. Primary outcomes were overall cost, supply cost, operating time and cost, postoperative length of stay (LOS), and postoperative LOS cost. Secondary outcomes were readmission within 30 days and mortality during the surgery.

Results Two hundred forty R-CR (mean age 64.9 ± 12.4 years) and 258 L-CR (mean age 66.4 ± 15.5 years) patients met the inclusion criteria. The overall mean direct cost between R-CR and L-CR was significantly higher ($8756 vs $7776 respectively, p=0.001) as well as the supply cost per case ($3789 vs $2122, $p < 0.001$). Operating time was also higher for R-CR than L-CR (224 min vs 187 min, $p = 0.066$) but LOS was slightly lower (5.08 days vs 5.55 days, $p = 0.113$).

Conclusions Cost is the main obstacle to easy and widespread use of the platform at this junction, though new developments and competition could very well reduce costs. Supply cost was the main reason for increased costs with robotic resection.

Keywords Robotic · Laparoscopic · Cost · Comparison · Cancer · Resection

Introduction

The advantages of laparoscopic colorectal surgery over open procedures have been well documented in the in the COLOR trials [1]. Robotic assisted procedures have become increasingly commonplace and the ease of use with the da Vinci robot has led to widespread acceptance among multiple surgical specialties. Efforts to improve clinical outcomes have prompted surgeons to adopt minimally invasive innovations and this has held true for specialists performing colorectal operations [2–4].

Studies have shown that robotic-assisted colorectal cancer resections (R-CR) have postoperative outcomes and conversion rates that are comparable to laparoscopic colorectal cancer resections (L-CR), with longer operative times and relatively shorter lengths of stay (LOS) [2, 5]. To date, there is no clear consensus as to the superior surgical approach, but differences between the cost efficiencies of robotic versus laparoscopic approaches are commonly debated. Multiple specialties including urology, gynecologic oncology, and cardiac surgery, have noted higher costs for robotic operations compared with laparoscopic ones [6–9]. The relatively few studies in the US literature looking at cost comparisons between R-CR and L-CR have identified higher robotic costs with equivalent healthcare outcomes [10, 11]. Many of these cost studies are limited as to how the costs are defined and the complexities of what is being charged or reimbursed is not always well explained [12].

One way to accurately assess actual procedure costs is to use the measurement of the direct costs attributed to the operation itself. The primary objective of our study was to

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compare the total direct costs of R-CR to that of L-CR. Our secondary objective was to compare the groups with respect to costs related to LOS.

Materials and methods

Patient selection

After institutional review board approval and in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards, a prospectively maintained database at Royal Oak, William Beaumont Hospital was retrospectively queried to identify patients who underwent colon or rectal cancer resection between January 1, 2015 and. December 31, 2018. Patients were excluded if the procedure was not classified as a laparoscopic or robotic cancer resection. Other exclusion criteria included minimally invasive procedures converted to open, and/or an additional procedure from the index surgery was required during or after the initial surgery. Of the initial 847 patients, 498 patients met the final inclusion criteria. The term "costs" for this study refers to the actual variable direct cost to the institution with each individual patient encounter. "Costs" were NOT the charges to the payor. The overall direct variable costs for each patient encounter included direct variable supply costs (including disposables), other direct variable costs that included operating room (OR) costs and costs related to time in the OR, and other accrued direct costs secondary to the patient's length of stay (LOS) postoperatively. In a subset analysis costs related to time spent in the hospital LOS were also compared. Again, all costs were actual variable direct costs to the institution and not charges to the payor. Cost variables were acquired from the director of financial decision and support at Royal Oak, William Beaumont Hospital.

Cost data acquisition

Costs represent direct variable costs for the patient encounter, including overall direct costs, direct variable supply and disposables cost, and other direct variable costs including operating room (OR) cost and time, and LOS. All costs were actual variable direct cost to the institution and not charges to the payor. Cost variables were acquired from the director of financial decision and support at our institution.

Cost definitions

Direct costs are thought to be a more accurate representation of true costs [13]. For this study, total direct costs are the sum of the variable expenses directly related to patient care. Variable direct costs represent incremental costs which would not have occurred if the surgery was not performed. These costs vary with patient activity (i.e., medications and medical tests). Included in these costs are labor wages for all of the personnel required for patient care of each surgical patient being treated, supplies (gowns, drapes IV equipment, etc., including robotic instruments), and drugs. To contrast, fixed direct costs (which were not evaluated in our study) represent incremental costs that would still have occurred even if the surgery was not performed. This includes ongoing equipment costs (depreciation, maintenance contracts and repairs), consulting fees, and administrative costs for both personnel (office manager, secretarial staff, etc.) and the office supplies/furnishings required to support this staff. Finally, the total direct costs were a summation of direct supply costs and the direct cost of operative time. Both variables were evaluated independent of the total cost and were compared between R-CR and L-CR. LOS costs were available for a subset of patients and comparisons were made as appropriate.

The surgeon's professional expenses were irrelevant to this analysis given the institution's private practice model and thus these expenses are not part of the OR cost. Capital investment for both laparoscopic and robotic setups were not included in our summaries. Indirect costs that were not directly related to individual patient care were not included in this study.

Surgical technique

All robotic procedures were performed using the Da Vinci Xi robotic system (Intuitive Surgical Inc., Sunnyvale, CA, USA). Laparoscopy was performed with the use of a laparoscopic tower and the associated equipment that was supplied by Olympus Corp. Stapling devices included those supplied by Intuitive, Ethicon and Medtronic as contracted through Beaumont Health and were used at the discretion of the individual surgeon. Surgeon variability existed, but surgical approaches, and the equipment used, were identical for each surgeon regardless of whether the procedure was accomplished via a laparoscopic or robotic approach. In other words, a surgeon who created a pneumoperitoneum via the Veress needle technique would use this same technique in both robotic and laparoscopic surgeries. This remained consistent with respect to their choice of staplers, electrosurgical equipment, and wound retractors. Variability with respect to the specifics of each surgery existed among surgeons with regards to mobilization, isolation of the vessels, methods of reconstruction, and splenic flexure takedown, but again, each surgeon maintained an identical standardized approach for their minimally invasive procedures. The operating time was recorded from time of the initial skin incision to the time of skin closure.

Statistical analysis

Primary outcomes were the overall direct internal costs from the institution to compare the two surgical approaches. This included direct OR costs and supply costs. Secondary outcomes included LOS and 30-day mortality and unexpected readmissions. Costs related to LOS were also analyzed. For analysis we used SPSS Version 25 (IBM Corp., Armonk, NY, USA). Comparisons between surgical types for these variables were analyzed using a Student's *t* test or a gamma distribution with a log link for skewed distributions. The categorical variables were analyzed using a Fisher's exact test and the other continuous variables were compared using a two-sample *t* test. For all analyses, a *p* value of < 0.05 was considered statistically significant.

Results

Demographics

Patient demographics are presented in Table 1. Mean age for R-CR ($n=240$) and L-CR ($n=258$) was 64.9 ± 12.4 years and 66.4 ± 15.5 years, respectively ($p=0.212$). Mean BMI for R-CR and L-CR was 28.8 ± 6.4 kg/m^2 and 28.0 ± 6.3 kg/m^2, respectively ($p=0.151$). There was a significant difference in the sex of the surgery recipients with R-CR 53% male (127), 47% female (113)) and L-CR (42% male (109), 58% female (149)) ($p=0.020$). There was no difference in race/ethnicity or American Society of Anesthesiologists (ASA) class ($p=0.250$, $p=0.955$, respectively). There was a significant difference in the distribution of surgery performed between the methodologies with 42% (207) of the procedures being a hemicolectomy or greater of which more than half (127) were done laparoscopically (Table 2).

Table 1 Demographics

Characteristics	Robotic CR (*n*=240)	Laparoscopic CR (*n*=258)	*P* value	Total (*n*=498)
Age, years (mean ± SD)	64.9 ± 12.4	66.4 ± 15.5	0.212	65.7 ± 14.1
Sex	Male: 127 (53)	Male: 109 (42)	0.020	Male: 236 (47)
	Female: 113 (47)	Female: 149 (58)		Female: 262 (53)
Race/Ethnicity	White/Caucasian: 182 (76%)	White/Caucasian: 201 (78%)	0.250	White/Caucasian: 383 (77)
	Black or African/American: 33 (14)	Black or African/American: 40 (16)		Black or African/American: 73 (15)
	Other: 25 (10)	Other: 17 (7)		Other: 42 (8)
Initial BMI (mean ± SD)	28.8 ± 6.4	28.0 ± 6.3	0.151	28.3 ± 6.3
ASA class	I–1 (0.3)	I–2 (1)	0.955	I–3 (0.6)
	II–69 (29)	II–78 (30)		II–147 (29)
	III–152 (63)	III–160 (62)		III–312 (63)
	IV–17 (7)	IV–18 (7)		IV–35 (7)
	V–1 (0.3)	V–0		V–1 (0.2)

Values reported as *n* (%) unless otherwise indicated

CR cancer resection, *BMI* body mass index, *ASA* American Society of Anaesthesiologists physical status classification, *SD* standard deviation

Table 2 Surgery performed

Surgery type	Robotic CR (*n*=240)	Laparoscopic CR (*n*=258)	*p* value	Total (*n*=498)
Hemicolectomy or greater	80 (33)	127 (49)	**< 0.001**	207 (42)
Less than hemicolectomy	73 (30)	85 (33)		158 (31)
Total proctectomy	23 (10)	8 (3)		31 (6)
Partial proctectomy	60 (24)	34 (13)		94 (19)
Proctocolectomy	4 (2)	4 (2),		8 (2)

Values reported as *n* (%). Bolded values are statistically significant at 95% confidence

CR cancer resection

Table 3 OR cost data

	Robotic CR ($n=240$)	Laparoscopic CR ($n=258$)	P	Total ($n=498$)
Total direct cost	\$8756 ± 3694	\$7776 ± 4457	**0.001**	\$8247 ± 4133
Supplies direct cost	\$3793 ± 1794	\$2107 ± 1729	**< 0.001**	\$2919 ± 1950
OR time direct cost	\$1070 ± 378	\$1067 ± 421	0.931	\$1068 ± 401
Average time per case (minutes)	227 ± 83	213 ± 91	0.066	219 ± 87

Values reported as mean ± SD. Bolded values are statistically significant at 95% confidence

CR cancer resection, *OR* operating room, *LOS* length of stay

Table 4 Hospital LOS

	Robotic CR ($n=240$)	Laparoscopic CR ($n=258$)	P
LOS per case (days)	5.09 ± 4.51	5.55 ± 4.45	0.113
Postoperative LOS cost per case**	\$1230 ± 1927	\$1597 ± 2879	0.156

Values reported as mean ± SD

CR cancer resection, *LOS* length of stay, *OR* operating room

**Only 99 robotic cases, and 131 laparoscopic cases, had an associated post-op LOS. Tabulated figures reflect this

Primary outcomes

Cost data are presented in Table 3. There was a significant difference in overall mean direct cost between R-CR and L-CR (\$8756 vs \$7776 respectively, $p=0.001$). There was a significant difference in mean supply cost of R-CR vs L-CR (\$3793 vs \$2107, $p<0.001$). However, there was no difference in the mean OR time direct cost for R-CR compared to L-CR (\$1074 vs \$1129, $p=0.931$).OR time and hospital LOS data is presented in Table 4. There was no difference between R-CR and L-CR in mean OR duration (227 min vs 187 min, $p=0.066$), LOS (5.08 days vs 5.55 days, $p=0.113$) or postoperative LOS cost (\$1230 vs \$1567, $p=0.156$).

Secondary outcomes

There were 27 cases of unplanned readmissions in the entire cohort (5.4%) (Table 5). R-CR had a lower case of unplanned readmissions ($n=11$, 5%) than L-CR ($n=16$, 6.2%). In the entire cohort, there were only four mortalities, with all being in L-CR cases.

Discussion

Laparoscopic surgery comes with limitations, including limited range of motion, straight nonarticulated instruments, and two-dimensional imaging. The introduction of robotic surgery with improved three-dimensional visualization, remote center technology, better range of motion with articulated instruments and improved surgeon ergonomics has made the practice a mainstay in certain surgical specialties, in particular gynecology and urology [4, 14]. Use in colorectal cancer resection remains controversial with little evidence to definitively advocate for it as opposed to conventional laparoscopy [5]. Along with patient outcomes, the issue of cost is critically important to hospital administrators and third party payors. As such, our study primarily looked to evaluate direct costs to an institution with healthcare outcomes as a secondary outcome.

We found that our institution's mean variable direct cost was higher for R-CR compared to L-CR, with the main factor being the increased supply cost associated with the robot. Though not significant, robotic surgery led to decreased LOS by almost a day, but this was not enough to ameliorate the overall cost. With this clear increased cost associated with robotic surgery, it is difficult to see a solid economic rationale in advocating for it over laparoscopic cancer resections. These findings are in line with the general cost analyses looking at robotic vs laparoscopic methods across specialties

Table 5 Readmission and mortality within 30 days

	Robotic CR ($n=240$)	Laparoscopic CR ($n=258$)	P value	Total ($n=498$)
Not readmitted	229 (95)	242 (93.3)	0.553	471 (94.6)
Unplanned readmission	11 (5)	16 (6.2)		27 (5.4)
Mortality	0	4 (0.7)	0.1245	4 (0.8)

Values reported as n (%)

CR cancer resection

[6–9, 15], and among the limited colorectal cancer resection cost-analysis studies. In one of the first cost-analysis studies of rectal cancer, out of Korea, Baek et al. found increased robotic resection OR costs compared to laparoscopic secondary to increased including labor and supply costs, along with reduced hospital income [16]. Similarly, 2 studies from Taiwan by Lee et al., one looking at colon and the other at rectal cancer, found equivalent clinical outcomes with robotic resections with lower LOS but higher costs [10, 11]. An additional study from Korea in 2015 looking at rectal cancer did not find a significant LOS but again found increased costs associated with robotic resection [17]. There was no difference in OR time direct cost between R-CR and L-CR, though it should be noted that our institution did not track surgeon or anesthesia expense in these variables and it only accounts for other direct labor costs in the OR.

We did not find a significant difference between R-CR vs L-CR in OR time (227 min vs 213 min) or LOS for (5.09 days vs 5.55 days). Previous studies have generally found R-CR to have longer OR times and shorter LOS [18], but the findings on LOS have been more variable with many studies finding no difference [2, 5, 10, 19, 20]. We were able to isolate the LOS cost post-operatively for only 230 patients in our cohort, looking for variation. There was no significant difference for cost postoperatively in our cohort.

The price of a da Vinci Xi is approximately $2.0–$2.5 M, with an estimated annual $200,000 service charge in addition to the cost of the limited-use instrument arms [21]. Even assuming equivalent operative costs and disregarding maintenance prices, the cost of robot acquisition and reusable equipment would have to decrease significantly to maintain economic efficiency. Per the ROLARR trials there is little potential for additional clinical improvement with the robot [5]. These additional costs are therefore absorbed by the healthcare facility, without any increase in reimbursement, and any advantage related to reduction in LOS is still unclear. The financial feasibility of robotic colorectal surgery requires increased volume, a reduction in the initial cost and reusable equipment, or increased competition and wider propagation of this newer technology.

Surgeon preference and convenience are other factors. At our institution, most surgeons who utilize the robot enjoy the maneuverability and additional ergonomic comfort during extended cases. Marketing and hospital reputation regarding use of cutting edge technology, patient perception of robotic surgery, and recruitment of talented surgeons are various factors that may play a role in deciding whether introducing robotic surgery is worthwhile for a specific health care system. Surgical volumes prior to and after introduction of the robot may be changed. At this juncture however, there is no clear economic benefit for the institution, nor additive positive clinical outcomes for patients.

There are several limitations to the study. Our study is based on retrospective data and carries with it the standard weaknesses inherent to this design, including potential for selection bias and unmeasured confounding or contributing effects. We minimized this by setting strict inclusion criteria. Large multicenter randomized trials are more ideal to characterize robotic colorectal cancer resection. The hospital database lacks information on specific training, subspecialty and experience of surgeons, and volume of surgery by the specific surgeons involved, which may influence the operative times and complication rates. Additionally, cost data were not available for all cases, specifically with post-operative LOS cost; only 230/498 patients had these values available for retrieval. We did not evaluate longer term outcomes and costs such as complications and additional episode of care costs.

Lastly, there are several hidden costs which were not taken into consideration for robotic surgery such as personnel training cost, along with robot repair and maintenance. These costs were not readily obtainable at our institution. Our results should be interpreted accordingly.

Conclusions

Cost is the main obstacle for easy and widespread use of the platform at this junction, though new developments and competition could very well reduce costs. There was a significant overall direct cost difference at our institution especially due to supply cost between the two methodologies (R-CR vs L-CR. Other institutions may need to take a closer financial look at this more novel instrumentation before adopting it as common practice.

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Declarations

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