Chapter 16
Robotic Costs

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Section 1: Introduction of Robotic-assisted Laparoscopic Surgery

Background

Colorectal surgery has historically embraced technology to improve efficiency and patient care. The introduction of laparoscopic colorectal surgery was a revolutionary technological advance for improving postoperative recovery, patient outcomes, and reducing overall healthcare costs compared to the open colorectal surgery [1–9]. Despite the proven benefits, recent studies show minimally invasive techniques are used in less than 50 % of total cases, less than 20 % for colon cancer, and less than 10 % for rectal cancer [10–12]. Robotic-assisted laparoscopic surgery (RALS) is a minimally invasive tool technology that could help expand the use of minimally invasive colorectal surgery, especially in the rectal diseases.

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Introduction of Robotic-assisted Laparoscopic Surgery

In 2001, the first robotic colorectal surgery was performed in the United States using the Intuitive Surgical's Da Vinci robotic system [13]. Since then, the use of RALS has continued to grow, increasing from 0.8% in 2008 to over 4% in 2009 for all general surgical procedures [14, 15]. For colorectal surgery specifically, an estimated 2.8 % of 130,000 annual procedures were performed through a RALS approach [14]. Several studies have evaluated outcomes with this promising tool, demonstrating equivalent safety with similar clinical and oncologic outcomes to traditional laparoscopic colorectal surgery [15–36].

Benefits of Robotic-assisted Laparoscopic Surgery

While reported outcomes are similar, there are distinct technical advantages with RALS that may help overcome limitations encountered with laparoscopic surgery, especially when operating in the pelvis [28, 37, 38]. The robot platform has a stable three-dimensional view and instruments offering improved ergonomics and motion. The increased precision and accuracy from these instruments may facilitate more complex pelvic dissections over the conventional laparoscopic surgery [26, 38]. RALS also has proven clinical advantages, such as lower estimated blood loss and lower conversion rates to open surgery in both benign and malignant colorectal conditions [14, 19, 23, 25, 26, 29]. It has been suggested the greatest benefit of RALS is in low anterior resections for rectal cancer [16, 28]. In such cases, the RALS platform may provide better postoperative nerve function and oncologic advantages of a higher quality Total mesorectal excision (TME) and lower local recurrence rates [19, 27, 39]. Despite the potential advantages to the surgeon and patient, RALS is still not widely utilized, one reason for which is the cost.

The Cost Challenge of RALS

The higher cost of RALS has been a major challenge to justifying widespread adoption [31]. Numerous studies have shown significantly higher costs for RALS over laparoscopic colorectal resections with similar outcomes, including comparable length of stay, readmission, and complication rates [14, 16, 25, 28, 32–34, 40–42]. Eight studies comparing RALS to the laparoscopic colorectal resections all supported higher direct and total costs, with no clear superiority in the short- or long-term outcomes (Table 16.1). Across these studies, the average increase in costs was $2142. In addition to higher total costs, consistently longer operative times for RALS compared to laparoscopy have also been reported [33]. Systematic review and meta analyses have also shown comparable oncological accuracy, circumferential

Table 16.1 Comparative analysis of RALS versus laparoscopic colorectal costs

Study (year)	RALS vs. LAP	Procedure	Benefit of RALS?	Total cost (RALS)[≠]	Total cost (Lap)[≠]	Difference
Delaney (2003)	6 vs. 6	RH, SC, RP	No	$3721[a]	$2946[a]	$776[a]
Rawlings (2007)	15 vs. 17 12 vs. 13	RC SC	No	$9255 $12,335	$8037 $10,697	$1182 $1638
deSouza (2010)	30 vs. 92	RH	No	$15,192[a]	$12,361[a]	$2831[a]
Haas (2011)	32 vs. 32	AR, LAR	No	$16,708	$15,401	$1307
Park (2012)	35 vs. 35	RH	No	$12,235	$10,320	$1915
Bae (2012)	154 vs. 150	TME	No	$14,647	$9978	$4669
Koh (2014)	19 vs. 19	TME	No	$12,460	$8560	$3000

AR: anterior resection; *LAR*: low anterior resection; *RH*: right hemicolectomy; *RP*: rectopexy; *TME*: total mesorectal excision.
[a]Represents median cost
[≠]Represents total direct cost

resection margin involvement, distal resection margin, and lymph node yield compared to the laparoscopic proctectomy for rectal cancer [25, 29]. In a time of increasing pressure on healthcare utilization, it is necessary to ask if the increased costs are worthy for outcomes of lower intra-operative conversion and transfusion rates? And, do these perceived benefits warrant the investment to purchase and train on the robot?

Section 2: Changing the Paradigm

Defining the Optimal Model for RALS: Evaluating Success in Other Fields

Despite the current concerns regarding its cost, RALS continues to grow. Therefore, it is necessary to change the paradigm to make RALS cost-effective. The best clinical model for effective integration of RALS into practice is in urology. Recognizing a need, with the large amount of suturing required and the lack of progression to laparoscopy, there was wide and rapid adoption of robotic surgery in urology [43]. Robot-assisted radical prostatectomy increased from 1% in 2001 to more than 50% of all prostatectomies performed in the United States in 2009 and is currently recognized as the gold standard [44]. Even in this optimal model, robotics is associated with higher costs than open and laparoscopic prostatectomy, predominantly from higher surgical supply and

	Break-even calculation (illustrative)		
	Example A	**Example B**	**Basis for assumption**
Robotic cases per year	*126*	*330*	Bolenz et al[48]; Anderberg et al[50]
Hospital days saved with robotic procedure (per case)	*1.0*	*4.0*	Bolenz et al[48]; Anderberg et al[50]
Hospital days saved (additional over-night capacity available)	126	1,320	
Nights stay after average surgical procedure	*1.0*	*1.0*	Varies by hospital and procedure
Number of procedures made possible by freed up beds	126	1,320	
Average contribution margin per procedure (including stay)	*$3,500*	*$3,500*	Varies by hospital and procedure
Annual value (CM) created from increased bed capacity	$441,000	$4,620,000	
Less annual incremental costs of using robot			
Maintenance	*($340,000)*	*($340,000)*	Bolenz et al[48]
Disposable/limited use instruments	*($60,000)*	*($60,000)*	Ficarra et al[12]
Net annual benefit (capacity value minus incremental cost)	$41,000	$4,220,000	
Upfront investment to acquire and install robot	*$1,500,000*	*$1,500,000*	Bolenz et al[48]
Years to pay off acquisition	36.6	0.4	
ROI	2.7%	281.3%	

Notes: A model to evaluate the financial impact of a surgical robot on a hospital. A key assumption in this model is that surgical procedures can be gained by increasing hospital bed availability. The numbers in italics represent the variables for the model. The reference supporting each variable is listed in the final column. The "Years to pay off acquisition" decreases and the "Return on Investment (ROI)" increases as the number of robotic cases per year increases, the hospital days saved with robotic procedure increases and the contribution margin per procedure increases. Example A is based on the number of robotic cases per year and number of hospital days saved with robotic prostatectomy in the paper by Bolenz et al.[48] Example B is based on the number of robotic cases per year and number of hospital days saved with robotic fundoplication in the paper by Anderberg et al.[50] The average contribution margin to the hospital is an arbitrary value that is fixed as equal in each example as are the maintenance, instrument and initial investment costs. Based on these hypothetical situations the ROI in Example A is very poor at 2.7% with a prohibitively high number of years to pay of acquisition. Whereas, in Example B the ROI is 281.3% and the initial investment would be paid off in 0.4 years.

Fig. 16.1 Break-even analysis for robotic surgery. From Leddy LS, Lendvay TS, Satava RM. Robotic surgery: applications and cost-effectiveness. Open Access Surgery. 2010;3:99–107

OR cost due to increased operative time [45]. The value comes from reducing the length of stay, with cost savings realized when enough nights in the hospital are saved to overcome the increased cost of the robotic procedure [46]. The shorter length of stay and faster recovery when transitioning from open to robotic models has been proven in multiple studies [47–51]. Study has found the length of stay for RALS was 1 day shorter than laparoscopic and 2 days shorter than open prostatectomy [45]. When determining if there is a value in integrating RALS into clinical practice, a break-even analysis is beneficial. An example of the cost–benefit analysis for integration of RALS is shown in Fig. 16.1.

Targeting Open Surgery

Minimally invasive procedures are the most overall cost effective. Most reports on the cost concerns of RALS compare laparoscopic and robotic colorectal resections [14, 32, 41, 42]. However, these comparisons are short sighted. RALS is a minimally invasive tool; it is not intended to steal market share from laparoscopic surgery. Despite proven benefits of minimally invasive rectal cancer surgery, its use is still estimated at 10% nationwide; 90% of rectal cancer cases are still performed open [10]. The value of RALS is in converting *open* to robotic surgery and expanding the use of minimally invasive procedures in general. National studies on robotic trends further that benefits are most pronounced when robotics is used in procedures previously performed open [15, 52]. For all common general surgery procedures, length of stay was shorter, with fewer complications and lower or equivalent mortality in the RALS compared to open cases [52]. The trends of shorter length of stay with lower complication and mortality rates were also seen in RALS versus open surgery in colorectal procedures specifically [15]. Compared to open surgery, the improved functional outcomes, reduction in post-operative pain, faster time to recover normal bowel function, and shorter length of stay make the value proposition against the cost for purchasing and integrating RALS in colorectal surgery [53]. When overall costs were considered, RALS appears more cost-effective than open surgery for colorectal procedures [15]; this same value proposition was seen during the evolution from open to laparoscopic surgery. As RALS enables open surgeons to perform more minimally invasive procedures, it can follow the model of urology, reaching overall cost reductions in length of stay and faster recovery.

Creating a Market Niche

Recognizing laparoscopic surgery for rectal cancer continues to be associated with low national adaption rates, RALS may be positioned as tool for increasing minimally invasive rectal cancer resections [10, 28, 41, 54]. RALS has definite advantages over open TME for rectal cancer, including significantly more lymph nodes harvested, less estimated blood loss, a shorter length of stay, faster postoperative recovery, and a significantly lower local recurrence rate [39, 55]. The robot system may overcome challenges associated with difficult pelvic anatomy, which could increase the percent of patients that undergo a minimally invasive resection [38]. The RALS approach even has benefits over laparoscopy for TME including lower conversion rates, better quality of the TME specimen, and faster recovery of urinary and sexual function, increasing the value proposition [27, 56–58]. Several characteristics have been defined as selection criteria for robotic surgery to justify its increased cost, including obesity, male sex, preoperative radiotherapy, and tumors in the lower two-thirds of the rectum [59]; rectal cancer patients with these characteristics should be considered prime candidates for RALS. RALS may be the means to increase MIS for rectal procedures. Using the platform to allow a skilled laparoscopic surgeon to overcome the barriers of pelvic surgery and offer a minimally invasive approach to rectal cancer patients is a true benefit of RALS. RALS could feasibly transition a 10% increase in utilization of minimally invasive surgery for rectal cancer cases. At 20%, the paradigm shift from open to minimally invasive surgery occurs, and true economic benefits are realized.

Streamlining Instrumentation

As we work to change the paradigm from open to robotic colorectal surgery, there are methods to streamline costs now. Standardizing and reducing instrumentation is a way to reduce the unnecessary costs. The Da Vinci surgical system has no third-party disposables available, offering an ability to standardize equipment that laparoscopic surgery could never offer. For example, the proprietary EndoWrist 45 (Intuitive Surgical, Inc.) robotic stapler may be more cost-effective than a separate

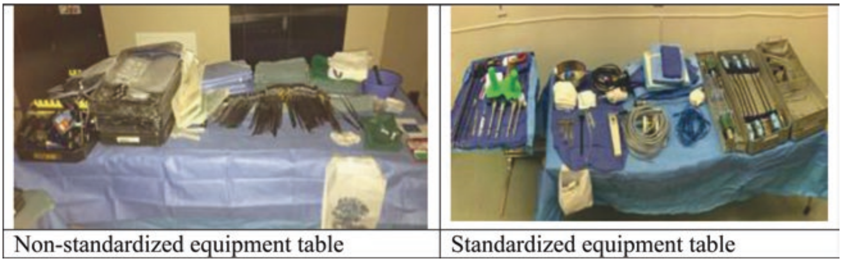

Fig. 16.2 Standardized versus non-standardized equipment table

Table 16.2 Example of a standardized equipment pack for robotic-assisted laparoscopic surgery

1 BLADE SURG SS 15	3 GOWN SURGICAL XL
1 CHLORAPREP 25ML ORANGE	1 COVER MAYO STAND 23X54IN REINF
1 TUBING SUCTION 1/4X144IN	1 BOWL GRADUATED 32Z
2 SYRINGES 10ML L/L	1 BAG SUT BLU FL
1 DRAPE LAP W/PCH 11X72X124IN	10 GAUZE 4X4 16PLY XR
2 DRAPE LAP 60X76IN	5 SPONGE LAP 18X18
12 TOWEL OR BLUE	2 COVER LT HNDL RIGID
1 CAUTERY BUTTN W PENCIL W EZ CLN	1 YANKAUER SUCTION TIP W/O VENT
1 CORD MONOPOLAR	1 SYRINGE BULB BLUE 60CC
1 NDL CNTR MEG/ FM 10CT	1 SKIN MARKER RND DUAL TIP
1 NDL NEG BVL 25GA 1.5IN	1 COVER TABLE 44X88FF
1 NDL NEG BVL 18GA 1.5IN	1 CVR BK TBL 60X90IN ZONE REINF

laparoscopic instrument. Holzmacher et al. retrospectively compared the EndoWrist 45 to laparoscopic staplers in patients who underwent RALS colorectal procedures [60]. The laparoscopic stapler group required significantly more fires per patient than the robotic stapler group (2.69 vs. 1.86; $p=0.001$) and had significantly higher stapler cost per patient ($631.45 vs. $473.28; $p=0.001$), demonstrating the cost-effectiveness of the robotic accessory [60]. Delto et al. demonstrated the impact of streamlining equipment to optimize the cost–benefit of robotic technology without negatively impacting operative time, blood loss, or intra-operative complications [47]. By eliminating a laparoscopic energy source in lieu of inexpensive tools (such as Hem-o-lock clips), instrumentation costs were reduced by approximately 40% [47]. Each robotic case across all service lines uses the same basic instruments, so a standardized peel pack and instrument table can reduce unnecessary equipment costs. An example of a standardized and non-standardized equipment table, and the contents of a standardized peel pack for RALS are seen in Fig. 16.2 and Table 16.2. The robotic instruments are also highly multi-functional and can be exploited to perform more tasks and contain costs. For example, using the hook instead of monopolar shears will save $120 per procedure. At a hospital that performs 100 colorectal procedures annually, this change on just 50% of the procedures will save $6000. Utilizing the suturing capabilities of the robot instead of a laparoscopic tacker in cases that use mesh fixation, such as a rectopexy, will save $500–700 per procedure. Depending on the volume of the institution, streamlining and maximizing the capabilities of the robotic instruments can result in significant cost savings.

Increasing Case Volume

The cost of each RALS case is determined by robotic system value/ the number of cases performed. Therefore, increasing the number of cases is a method to reduce the cost per case and make the tool more cost-effective. A recent review of the Premier Persepectives® database found only 13% of hospitals and 4.4% of surgeons performed a high volume of robotic colorectal cases [61]. The majority of colorectal RALS were performed by low volume surgeons (less than or equal to five cases) at low volume hospitals (less than or equal to ten cases). Furthermore, low volume providers were associated with significantly more overall complications, longer length of stay, and higher costs at both the hospital and surgeon level [61]. In addition, increasing use of robotics in other service lines will increase the total case numbers and ability to profit through economies of scale. A study has shown the technology can become cost-effective in high-volume centers with high-volume surgeons [62]. Thus, increasing individual case volumes and/or regionalizing RALS cases to a high volume center could reduce the individual cost per procedure and increase the overall revenue.

Instituting Quality Control Metrics

Facility costs can be impacted by shorter console/operative times. The attenuated learning curve with RALS has already been discussed. Another way to reduce the operative times and realize cost savings is to institute quality control measures around docking time. Docking times have been reported as a median of 10 min, but with a wide variation (range: 2–70 minutes) [63]. Docking should be a 3–5 min drill regardless of the case. Establishing docking time as a best practice, and tracking docking times against the benchmark has the potential to dramatically reduce costs. For example, if docking currently takes 15 min, at an average cost of $60 per operating room minute, in a practice that performs 2 RALS cases per operating day, and operates 100 days a year, the cost is: 15 min × ($60/min) × 2 cases/operative day × 100 operative days = 180,000. By reducing the docking time to an average of 3 minutes, the costs are reduced to $36,000, for a cost savings of $144,000.

Marketplace Competition

To reduce the capital cost, advances in robotic technology and competition in the marketplace to reduce the cost of the surgical robotic and its equipment are needed. Although costs are currently high, increased competition from

Table 16.3 Definitions of the cost model

Total cost (TC): Sum of direct cost and indirect cost (TC = DC + IC)
Direct cost (*DC*): Sum of variable cost and fixed direct cost (DC = VC + FDC)
Variable (*supply*) *cost* (*VC*): Charges incurred for supplies during hospital course (labs, medications, robotic instruments, surgical drapes, blood transfusions, etc.)
Fixed direct cost (*FDC*): Unvaried charges associated with depreciation of surgical equipment and payment of indirect treatment-related personnel salaries/benefits (operating room supervisor, nursing managers, etc.)
Indirect cost (*IC*): Overhead, expenses of operating the hospital (hospital administration salaries/benefits, utilities, etc.)
Charges (*Ch*): Gross billing for costs incurred from surgical procedure and hospital course
Net revenue (*NR*): Received payment based on applicable payer contracts with institution
Contribution margin (*CM*): Difference between net revenue and direct cost (CM = NR – DC); allocated to pay indirect cost (associated non-treatment-related expenses)

manufacturers and wider dissemination of the technology could drive down the costs [64]. Intuitive Surgical's robotic system currently dominates the market, but Titan Medical (Toronto, Ontario) has an alternative, the Single Port Orifice Robotic Technology (SPORT™) Surgical System, in clinical trials.

Putting It All Together to Maximize Profitability

In sum, understanding the cost model is paramount to making RALS a cost-efficient tool in every institution. The key to a profitable program is the contribution margin. The contribution margin is defined as the net revenue minus the direct costs (Table 16.3). To increase the contribution margin, RALS can increase reimbursement by improving the payor mix and the related reimbursement. RALS may have higher costs, but there is the ability to improve other variables in the cost model to make RALS more cost-effective. Variables to factor into the cost model include:

- Fixed capital costs (cost of the amortized equipment)
- Maintenance costs
- Consumables
- Facility costs

Fixed capital and maintenance costs can be addressed with advances in robotic technology and increased competition. Streamlining instrumentation can optimize the cost of consumables. Reducing operative and docking times to increase the number of total cases performed can reduce the facility costs. In addition, increasing use of robotics in other service lines will increase the total case numbers and ability to profit through economies of scale.

Section 3: RALS Versus Laparoscopic Surgery: An Institutional Study of Patients and Financial Outcomes

To evaluate the cost-effectiveness of robotics at our institution, we performed a case-matched review of RALS versus laparoscopic low anterior and anterior resections. Patients were matched on body mass index (BMI), surgeon, indication for operation, and procedure performed. Clinical and financial outcomes were analyzed. The main outcome measures were the conversion rates, length of stay, complications, charges, revenue, total costs, and contribution margin in each cohort. During the study period, 32 RALS and 32 laparoscopic patients were evaluated. The patients were well matched in all demographics (Table 16.4). The RALS group had significantly longer operative times than the laparoscopic group ($p<0.001$), but they had equivalent conversion rates. The length of stay, complications, and readmission rates were comparable (Table 16.5). The total cost and charges were higher in the RALS cohort, but the net revenue and

Table 16.4 Patient demographics

Parameters	RALS ($n=32$)	LAP ($n=32$)	p-value
Gender	9 females (28.1%)/23 males (71.9%)	13 females (40.6%)/19 males (59.4%)	0.30
Age (years)	53.9 ± 11.7 (range: 30–82)	59.1 ± 13.0 (range: 32–88)	0.10
BMI (kg/m^2)[a]	28.9 ± 6.0 (range: 16.0–46.9)	28.4 ± 5.9 (range: 18.5–48.8)	0.75
ASA	2.5 ± 0.5 (range: 2–3)	2.4 ± 0.5 (range: 2–3)	0.62
Pathology[a,b,c]	24 benign (75 %)/8 malignant (25 %)	24 benign (75 %)/8 malignant (25 %)	1.0
Procedure[a]	25 AR (78.1 %)/7 LAR (21.9 %)	25 AR (78.1 %)/7 LAR (21.9 %)	1.0

[a]Matching criteria (surgeon and hospital were also matched)
[b]Benign pathology included recurrent and complicated diverticulitis
[c]All malignant cases were adenocarcinoma of the rectum and rectosigmoid

Table 16.5 Clinical outcome data

Parameters	RALS ($n=32$)	LAP ($n=32$)	p-value
OT (min)	230.9 ± 51.4 (range: 135–330)	166.2 ± 48.3 (range: 75–279)	<0.001[*]
EBL (mL)	96.9 ± 46.6 (range: 25–200)	108.1 ± 79.6 (range: 25–300)	0.49
Conversion	0(0.0 %)	0(0.0 %)	1.0
LNE[a]	17.0 ± 4.5 (range: 10–23)	17.4 ± 4.2 (range: 12–23)	0.99
LOS (days)	3.9 ± 2.9 (range: 2–14)	3.6 ± 2.0 (range: 2–12)	0.58
Complications[b]	9 (28.1 %)	7 (21.9 %)	0.57
Readmission[b]	4 (12.5 %)	3 (9.4 %)	0.69

[a]For malignant cases only
[b]During 30-day follow-up
[*]Statistical significance

Table 16.6 Financial outcome data

Parameters	RALS ($n=32$)	LAP ($n=32$)	Mean difference (RALS − LAP)	p-value
Charges	$50,839.59 ± 16,882.75	$43,824.12 ± 17,389.30	$7015.47	0.11
Total cost	$16,708.40 ± 4592.21	$15,401.69 ± 4744.07	$1306.71	0.27
Net revenue	$17,660.27 ± 12,600.13	$13, 546.75 ± 7499.64	$4113.52	0.12
Contribution margin	$8702.51 ± 11,708.48	$5360.91 ± 5534.32	$3341.60	0.15

contribution margin were also higher in RALS than the laparoscopic group. While not statistically significant, the values were economically different, with a profit of $3,341 per patient and $106,973 for the series (Table 16.6). Even with a higher total cost, RALS can be profitable in colorectal surgery when evaluating the entire cost model.

Conclusions

Robotic-assisted laparoscopic surgery is an evolving tool that can further the capabilities and outcomes of traditional laparoscopic surgery. Widespread utilization has been limited by higher total costs of RALS. Changing the paradigm to focus on transitioning open procedures to RALS and using simple methods to optimize profitability can make RALS a cost-effective and efficient minimally invasive tool.

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