Chapter 1

Robotic Assisted Laparoscopic Surgery: A Review of its Application and Impact on Pelvic Colorectal Surgery

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Abstract

Laparoscopy was a major technical advance for colorectal surgery, with great clinical and financial benefits compared to open surgery for both benign and malignant colorectal diseases. Despite proven clinical advantages, the rate of laparoscopy for pelvic colorectal surgery remains low. The technical advantages of robotic assisted laparoscopic surgery may help overcome the limitations of other minimally invasive techniques in pelvic colorectal surgery. The safety, feasibility, and comparative effectiveness has been proven compared to open and laparoscopic approaches, and specific advantages and technical applications continue to evolve. The goal of this paper is to review the history, benefits, clinical outcomes, and future direction for RALS in pelvic colorectal surgery.

Keywords

Robotics, Pelvic Surgery; Rectal Cancer; Minimally Invasive Surgery; Colorectal Surgery

Introduction

Minimally invasive colorectal surgery has valuable benefits over open procedures, including decreased postoperative pain, shorter lengths of stay, lower complication rates, and faster recovery of bowel function [1-11]. The transition to minimally invasive rectal resection has been a slower process. Initial concerns over oncologic adequacy, recurrence and survival rates, and sexual dysfunctiondelayed widespread acceptance compared to colon cancer [12].While the safety, feasibility, and oncologic equivalence have beenproven in multiplecontrolled studies, approximately 50% of total colorectal cases and less than 10% of rectal cancer cases are performed through a laparoscopic approach [13-15]. A major reason for the low number of minimally invasive pelvic cases may be the technical challenges of operating deep in the confined, narrow pelvis [16,17]. Robotic assisted laparoscopic surgery (RALS) has emerged as a minimally invasive platform with specific benefits in pelvic colorectal cases. The goal of this paper is to review the history, benefits, clinical outcomes, and future direction for RALS in pelvic colorectal surgery.

History of RALS in Colorectal Surgery

In 2000, Intuitive Surgical's DaVinci robotic system was FDA-approved for intrabdominal applications in the United States. The first colorectal RALS was performed in 2001, [18]. Since that time, continued growth has been seen, from 0.8% in 2008 to over 4% in 2009 for all general surgical procedures [19,20]. In colorectal surgery specifically, an estimated 2.8% of the 130,000 annual minimally invasive procedures were performed through a robotic approach [19]. With the rapid growth of this minimally invasive platform, there has been substantial research into the outcomes and benefits of the robot for colorectal procedures.

Technical Limitations of Traditional Laparoscopy and Benefits of RALS

The anatomy of the narrow, deep pelvis results in a confined operative field that makes visualization and dissection difficult, [21,22]. Laparoscopy is limited by tremor, assistant-dependent unstable 2-dimensional optics, the inability to perform high-precision suturing, poor ergonomics, and limited dexterity of surgical instruments [23,24]. In pelvic colorectal surgery, these limitations become more relevant; dissection is limited by retraction of the rectum, crowding and clashing of instruments, and fumes in the confined spaces fogging the camera, [18,25]. These challenges can be overcome by expert technique and experience, but for widespread adoption, they are a limitation of laparoscopy in pelvic cases. The robot is well suited for surgery in confined spaces, such as the pelvis. The robot allows a 3-dimensional view, controlled by the operating surgeon, a stable retraction platform, enhanced dexterity, and an endoscopic articulated wrist that allows seven degrees of freedom. Increased precision and accuracy from the instruments allow for a still visibility of the field and gives the surgeon equal access to the both sides of the pelvis [26,27]. These technical advantages translate to clinical advantages in technically demanding pelvic surgery, which may help overcome the limitations of laparoscopy in the pelvis [28].

Outcomes of RALS in Rectal Cancer

Most reports describe consistently better outcomes with RALS than open colorectal surgery, and comparable outcomes to laparoscopic colorectal surgery with higher costs and longer operative times [23,29-43] (Table 1).

Table 1: Robotic Assisted Laparoscopic Surgery in the Literature.

Author (Year)	Type of Study	n	Operative Time, Min	Length of Stay, Days	Complications	Lymph Nodes
Delaney et al (2003)	Case-Control	6 RALS	165 (115-220)	3 (2-5)	1 (atelectasis)	—
		6 Lap	108 (74-125)	2.5 (2-7)	1 (incisional hernia)	
Baek et al (2012)	Comparative	154 RALS	285.2 ± 69.1	11.1 ± 7	30 (32.1%)	20.0 ± 9.1
		150 Lap	219.7 ± 71.2	10.8 ± 8.6	41 (27.3%)	17.4 ± 10.6
Baik et al (2008)	Randomized Control Trial	18 RTME	217.1 ± 51.6	6.9 ± 1.3	22.20%	20 ± 9.1
		18 LTME	204.3 ± 51.9	8.7 ± 1.3	5.50%	17.4 ± 10.6
Baik et al (2009)	Comparative	56 R LAR	190.1 ± 45	5.7 ± 1.1	6 (10.7%)	18.4 ± 9.2
		57 L LAR	191.1 ± 65.3	7.6 ± 3	11 (19.3%)	18.7 ± 12
D'Annibale et al (2004)	Case Series	53 RALS	240 ± 61	10 ± 4	4	17 ± 10
		53 Lap	222 ± 77	10 ± 6	9	16 ± 9
D'Annibale et al (2013)	Case Series	50 R TME	270 (240-315)	8 (7-11)	5 (10%)	16.5 ± 7.1
		50 L TME	280 (240-350)	10 (8-14)	11 (22%)	13.8 ± 6.7
Park et al (2011)	Comparative	RALS 52	232.6 (52.4)	10.4 (4.7)	10 (19.2%)	19.4 (10.2)
		Lap 123	158.1 (49.2)	9.8 (3.8)	15 (12.2%)	15.9 (10.1)
		Open 88	233.8 (59.2)	12.8 (7.1)	18 (20.5%)	18.5 (10.9)
Park et al (2013)	Comparative	40 RALS	235.5 (57.)	10.6 (4.2)	6 (15%)	12.9 (7.5)
		40 Lap	185.4 (72.8)	11.3 (3.6)	5 (12.5%)	13.3 (8.6)
Keller et al (2013)	Comparative	744 RALS	261 (253, 269)	7.46 (6.90)	35.90%	—
		17, 265 Lap	201 (198, 203)	6.13 (6.05)	29.90%	

RALS-Robotic Assisted Laparoscopic Surgery; Lap- Laparoscopic; RTME-Robotic Total Mesorectal Excision

Intra-Operative Outcomes

The majority of rectal cancer resections are still performed via an open fashion [19]. Studies comparing open versus robotic procedures have demonstrated similar intra-operative outcomes, except for longer operative time [38,44]. Yang et al reported a decrease in blood losswith RALS [42], with the reduction in blood loss stemming from improved visualization and detection of blood vessels in the narrow pelvis [45].

Peri-operative Outcomes

The majority of studies reported similar hospital length of staybetween RALS and traditional multiport laparoscopy [19,32,34-37,40-42], with two studies reporting shorter length of stay for RALS [31,33]. No difference in recovery of bowel function has been shown between groups [19,30,35,37,41,42]. Post-operative complications rateshave generally been found equivalent between RALS and laparoscopy {[19,33-35,39-41], with two studies citing higher rates of post-operative bleeding with RALS [19,34].

Oncological Outcomes

RALS has been demonstrated safe and oncologically comparable to laparoscopic outcomes [27,30-33,37,38,40,41]. Recent studies have even reported some oncologic advantages with RALS, including a higher rate of negative circumferential margins [33,41,46], a better TME specimen [31], a lower recurrence rate compared to laparoscopy [44].

Genitourinary Outcomes

There is an increased risk of bladder and sexual dysfunction following TME due to the anatomy, especially following radiation. Robotic TME enables better visualization of the autonomic plexus in the pelvis, leading to improved preservation of genitourinary, erectile, and voiding function [16]. Kim et al demonstrated patients who underwent robotic TME for rectal cancer has faster recovery than those who underwent laparoscopic procedures [46]. Other studies support a loweroverall incidence of erectile dysfunction with RALS [33,41].

Learning Curve of RALS

There is always a learning curve with new technology, and the learning curve of RALS has been well described. Bokhari et al evaluated performance across several types of pelvic robotic procedures, finding a 3 phase learning curve: the initial learning curve which spanned 15 cases; a plateau phase that demonstrated increased competence with use; and mastery of more challenging cases achieved after 25 cases [47]. Several other studies support the multiphasic learning curve, with improvement first noted after 9-15 cases, mastery and ability to handle more challenging cases after 20-25 cases, and more challenging cases with

expected increased overall operative time thereafter [47-50]. Robotic pelvic surgery demonstrates a faster learning curve than laparoscopic surgery making it a more effective method of practice.

Future Direction of Pelvic Robot Use: Robotic Transanal TME

Robotic assisted transanal surgery (RATS) is a natural evolution of transanal minimally invasive surgery (TAMIS), a hybrid of transanal endoscopic microsurgery and single incision laparoscopic surgery [51]. RATS was originally described in a cadaveric model in 2011 [52], with promising early results in clinical application [53]. In 2013, the technology was pushed to TAMIS robotic TME, with promising results reported by Atallah et al in their pilot study [54]. The patients had a 6.7% anastomotic leak rate and 85% had “near complete” or “complete” pathological specimen grading [54]. Two small subsequent studies described the patient experience with robotic-assisted TME, reporting “complete” pathological specimen grading and negative margins for all patients in these series (Table 2) [55,56].

Table 2: Robotic-Assisted Transanal TME.

Author (Year)	n	Operative Time (minutes)	Blood Loss (milliliters)	Length of Stay (days)	Negative Margins	Pathologic Grade of TME Specimen	Complications
Atallah et al (2014)	4	376 (140-409)*	200 (50-300)	4.3 (4-5)	100% (4/4)	100% complete (4/4)	3/4; pulmonary embolism, hematoma, dehydration
Gomez Ruiz et al (2015)	5	398 ± 88**	Not Reported	6 ± 1	100% (5/5)	100% complete (5/5)	1/5; anastomotic leak

A Word on Cost Effectiveness of Robotics in Colorectal Surgery

Robotic surgery is more expensive than laparoscopy, which has raised concerned regarding utilization. Pai et al attributed the higher costs to fixed costs of purchase and maintenance of equipment, consumables, and increased operative time, but argue that cost must be weighed against benefits including shorter length of stay and oncologic outcomes [16]. It is feasible that with increased experience, operative time will be shorter and higher case volumes will be possible, potentially leading to cost effectiveness. There are clear technical benefits to this approach, which indicate that further research on cost effectiveness is warranted.There should also be a paradigm shift in the cost comparison across platforms. Currently, most reports compare costs between laparoscopy and RALS [19,29,34,57]. However, RALS is a platform meant to increase overall use of minimally invasive surgery, not convert laparoscopic users to robotics. Therefore, the cost comparison should be between open colorectal surgery and RALS. Studies comparing these platforms have demonstrated faster recovery, reduced postoperative pain, shorter length of stays, lower complications, and lower mortality rates with RALS, resulting in an overall cost benefit forRALS than opencolorectal surgery [20].

Figure 1: Robotic Set Up.

Figure 2: Internal and External Working Views.

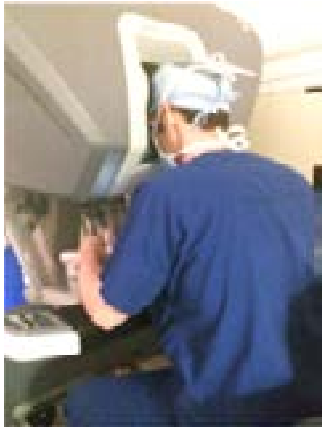

Figure 3: Console Surgeon View.

Conclusions

Pelvic robotic colorectal surgery is safe and effective. Current studies demonstrate equivalent outcome to laparoscopic surgery, with certain RALS advantages over traditional laparoscopy. Data from the ROLARR trial [58] will help confirm these benefits and further utilization of this minimally invasive platform in pelvic colorectal surgery.

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