

Review Article

A Role of Robotic Surgery in Colorectal Cancer Therapy - Past, Present and Future

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Abstract

The evolution of minimally invasive laparoscopic technology in the field of surgery has revolutionized how surgeons pursue surgical treatment options in colorectal cancer. With several major randomized controlled trials to date, laparoscopic colectomies have shown to be equal, if not superior, to open colectomies in regards to oncologic outcome and complications. The introduction of robotic technology in 2000 with the da Vinci S Surgical System, da Vinci Si in 2009 and its latest alteration da Vinci Xi (Intuitive Surgical, Sunnyvale, CA, USA) in 2014 have expanded minimally invasive surgical options. Robotic surgery is a natural evolution of minimally invasive surgery. This paper reviews the contribution and impact of robotic surgery and reflects on future considerations of robotics in colorectal cancer therapy.

ABBREVIATIONS

CLASICC: Conventional Versus Laparoscopic-Assisted Surgery in Colorectal Cancer; COLOR: COLon cancer Laparoscopic or Open Resection; COLOR II: COLOR (Laparoscopic Versus Open Rectal Cancer Removal); COST: Clinical Outcomes of Surgical Therapy; CRM: Circumferential Resection Margin; NIS: Nationwide Inpatient Sample; LOS: Length of Stay; MIS: Minimally Invasive Surgery; ROLLARR: Robotic Versus Laparoscopic for Rectal Cancer; taTME: Transanal Total Mesorectal Excision

INTRODUCTION

The quest for minimally invasive techniques dates back to the time of Hippocrates with his reference to use of an endoscope [1]. However, the modern minimally invasive era starts with the introduction of laparoscopic cholecystectomy in the late 1980s [2]. Minimally invasive surgery (MIS) has continued to evolve with new emerging technologies in all aspects of surgery. The numerous benefits of laparoscopic surgery including fewer wound complications, reduced use of post-operative narcotics, and shorter hospital stay make it an attractive surgical option for colorectal cancer treatment [3,4]. Fowler and Jacob et al., described the first laparoscopic colectomy for both benign and malignant colorectal disease process the same month in 1991 [5]. Since then, several major randomized clinical trials have been conducted to further evaluate the oncologic safety of the laparoscopic approach.

LAPAROSCOPIC COLECTOMY IN COMPARISON TO OPEN COLECTOMY

In 2004, the Clinical Outcomes of Surgical Therapy (COST)

trial established laparoscopic surgery as an equally effective modality of oncological treatment with the added benefit of a shorter length of stay (LOS) when compared to open colectomies [4]. Similar results were shown in the COLon cancer Laparoscopic or Open Resection [COLOR] trial performed in Europe [5]. Following these trials, the Conventional versus Laparoscopic-Assisted Surgery in Colorectal Cancer (CLASICC) trial from the United Kingdom Medical Research Council was one of the first trials that included patients with rectal cancer (48%). This trial highlighted a higher circumferential resection margin (CRM) achieved with laparoscopic-assisted approach [6]. However, there was no significant difference in overall survival between the open and laparoscopic-assisted groups. Furthermore, it showed that the laparoscopic converted to open patients had the higher surgery-related complications and mortality. This raised questions regarding whether laparoscopy had a role in rectal cancer therapy, which led to further trials in rectal cancer patients [6,7].

To address the oncologic safety and non-inferiority of laparoscopic resections in rectal cancer, the COLOR II (Laparoscopic Versus Open Rectal Cancer Removal) trial evaluated 1044 rectal cancer patients from 30 international centers. This trial did not show any difference in local recurrence, disease-free state, or overall-survival rate between the open and laparoscopic group [8]. Similarly, the COREAN trial (Comparison of Open versus Laparoscopic Surgery for mid or low rectal cancer after neoadjuvant chemotherapy) highlighted the shorter LOS and lower estimated blood loss while achieving equivalent 3-year oncologic outcomes of laparoscopic resection when compared to open surgery [9,10].

Despite these promising results validating non-inferiority of laparoscopic resection to open surgery in colorectal cancer management, the adoption of minimally invasive approach has been low. Yeo et al., reported slow rise of utilization of laparoscopic colorectal resection of 35% in 2006 to only 51% in 2010 across all NCCN (National Comprehensive Cancer Network) centers [11]. Similarly, data from the NIS (Nationwide Inpatient Sample) database from 2009-2012 showed that only 37.2% of patients needing an elective colorectal operation for ulcerative colitis had a minimally invasive resection (both laparoscopic and robotic surgery) [12]. Furthermore, Reames et al., shows wide geographic variation in utilization of laparoscopic colectomy for Medicare patients diagnosed with colon cancer. This was largely attributed to provider skills, resources and surgeon preference based familiarity [13]. Clearly, excellent results and extensive experiences with laparoscopic colorectal surgery exist. We have performed over 2500 laparoscopic colorectal cases and reported on 10 years of laparoscopic total mesorectal excision data, with a local recurrence of 5.3% and a 5 year survival rate of 84.8% [14].

The biggest issue, however, is that 25 years after the first laparoscopic colectomy was performed by Weber et al., less than 50% of colorectal cancer cases are done as minimally invasive surgery. Limitations of laparoscopy include limited range of motion, 2-D vision and requirement of a highly trained assistant [15]. Many surgeons have also reported a long learning curve with laparoscopic surgery, particularly with operations of the pelvis, due to difficulty maneuvering in the pelvis with conventional laparoscopic instruments [16]. Furthermore, the low ergonomics of laparoscopic instruments both limit dexterity and intensify physiologic tremor [17]. Robotic technology offers a means of overcoming these laparoscopic limitations and has expanded the role of MIS in the surgical armamentarium [18,19].

INTRODUCTION OF ROBOTIC SURGERY

In 2000, the US Food and Drug Administration approved the use of the da Vinci Robot by Intuitive Surgical (Sunnyvale, CA, USA). Its vision included four major product pillars: 1. A reliable and failsafe device 2. Intuitive control of the instruments 3. Instrument tips with six-degrees-of-freedom dexterity and 4. Compelling 3D vision. Equipped with these design goals, the da Vinci system was introduced to appeal to the open surgeons who may not perform laparoscopic surgery [20]. Although revolutionary, the first da Vinci surgical system came with limited range of motion that necessitated hybrid approaches, such as combining laparoscopic colonic dissection with robotic pelvis dissection for minimally invasive rectal surgery. In 2006, the da Vinci S model focused on improving patient-side experience by fixing these issues with streamlined robotic arms and more length to increase intra corporeal range of surgical motion and with a standard issue of a fourth robotic arm that allows for increased retraction [17,20,21-23]. In 2009, da Vinci Si was introduced to improve the surgeon console and vision cart with high-definition 3D stereo vision. Along with these improvements, two operating consoles linked to a single patient-side system enabled a better surgeon training experience [20]. With the latest introduction of the da Vinci Xi, in 2014, docking has improved, allowing for multi-quadrant operation and closer placement of ports while avoiding external arm collision [24,25].

With these advantages of robotic technology, robotic colorectal surgery has gained popularity since its first use. The Xi platform has greatly facilitated multiport surgery and has led to marked reviews in robotic colorectal surgery. Weber et al., reported the first robotic colectomy for benign disease and Hashizue et al., for malignant disease in 2002 [26,27]. Since then there has been an increased utilization of robotic techniques in a wide range of colorectal operations [28]. The adoption of robotic surgery is attributed partly to its ergonomically favorable design and to the higher degrees of freedom using the EndoWrist instruments, and elimination of tremor, all of which facilitate working in a deep, narrow pelvis [18,19]. Moreover, a recent systematic literature review highlighted favorable oncologic outcomes of robotic colorectal surgery, acceptable operative times and low conversion to open rate [29]. Oldani et al., also demonstrated safety and feasibility of robotic techniques in elderly patients (older than 70 years-old) [30].

Despite many advantages of robotic surgery, its limitations exist. Lack of tactile feedback, the learning curve, longer operative time and high cost associated with purchasing and maintaining the robotic system are challenges that are being addressed. To date, Intuitive Surgical has been alone in the robotic surgical realm. The virtual monopoly by Intuitive Surgical in the robotic surgery industry may be inflating costs [31]. However, the next two years promise to see an additional three to six new platforms available to colorectal surgery.

FUTURE DIRECTIONS

Robotic surgery is constantly evolving along with new robotic technology. New developments will introduce haptic, tactile feedback and smart technology to the surgeon to further guide in a safe operation. Logically, combination of smart interactive technology to the current robotic system will pave the way for a better robotic operative experience. Cost remains a concern for the progression of the robotic surgery. In the future, the introduction of newer robotic systems by other companies may reduce the price of robots by competition and pave the way for newer technology [31]. Furthermore, there are two current multicenter randomized controlled trials comparing robotic versus laparoscopic surgery for rectal cancer that will add more data to our current experience: the Robotic Versus Laparoscopic Resection for Rectal Cancer (ROLARR) study and A Trial to Assess Robotic-assisted Surgery and Laparoscopy-assisted Surgery in Patients with Mid or Low Rectal Cancer (COLRAR) study [32,33].

Recently, single-port robotic surgeries utilizing the dexterity and accuracy of robotic technology have garnered increased interest [34]. Specifically, the increasing interest in single-port surgery and taTME will drive robotic utilization. We recently reported our pre-clinical data on the use of a robotic single arm, single-port system (da Vinci SP Surgical System) on four cadavers. On all types of resections, the single-port system performed well with no fragmented resections, easy set-up and precision in its dissection and suturing [35]. Another recent study described a successful robotic single-port taTME and radical proctectomy using the robotic single-site plus one-port (R-SSPO) technique for low rectal cancer patients [36].

CONCLUSION

Robotic surgery is a natural evolution of minimally invasive surgery. By addressing many of the limitations of traditional laparoscopy, the benefits of robotics are well suited to overcome many challenges inherent to colorectal cancer treatment. As new robotic platforms and smart technology become available, enhanced utilization of robotic approaches promises to usher in an exciting new era of improved surgical care for the colorectal cancer patients.

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