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Robotic Surgery for Colorectal Cancer

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Abstract
Master-slave manipulators (otherwise known as telemanipulators) were introduced into minimally invasive surgery in the 1990s to overcome the limitations of laparoscopic surgery. This led to the development of the first robotic surgical systems which, over the last 10 years, have rapidly gained acceptance among colorectal surgeons. Advantages of robotic surgical systems such as superior instrumentation and field of vision enable precise dissection in confined spaces such as the pelvis, which make it a particularly attractive tool for rectal surgery. The feasibility and safety of robotic rectal surgery is now well established and there is increasing evidence that it might offer superior peri- and postoperative outcomes when compared to laparoscopic rectal surgery. Robotic rectal surgery is easier to learn than laparoscopic surgery and the creation of a structured training program for robotic rectal surgery in Europe has facilitated the learning of this technique in an environment that promotes patient safety and improved patient outcomes through equipment fidelity and operator skill. It is foreseeable that in the near future robotic systems will become part of routine surgical practice in colorectal surgery.

Background

Minimally invasive surgery has transformed general surgery over the last 2 decades. In fact, the benefits of minimally invasive surgery such as shorter hospital stay, earlier return to normal function, reduced postoperative pain, and improved cosmesis are now evident across almost all surgical subspecialties, including colorectal surgery.

Despite initial scepticism, laparoscopic colorectal surgery has progressively expanded since it was first described in 1991 and has now become the standard of care for benign and malignant colorectal diseases in most of the Western world [1]. However, laparoscopic colorectal surgery is limited by the inherent difficulties of conventional laparoscopy. These include two-dimensional (2-D) imaging (although 3-D platforms are becoming increasingly available), an unstable assistant-dependent camera, poor ergonomics, straight fixed tip instruments, and an enhanced tremor effect [2]. These challenges are especially relevant when operating in narrow spaces such as the pelvis, making laparoscopic rectal surgery particularly difficult. This is evident from the poor number of overall procedures, high conversion rates, and steep learning curve associated with laparoscopic rectal surgery.

Robotic surgical systems were designed to overcome the limitations of laparoscopic surgery by providing stable 3-D views from a surgeon-controlled camera, angulated instruments with 7 degrees of freedom, markedly improved ergonomics, and tremor filtering. This has led to the increasing adoption of robotic surgery across many surgical specialities over the last 10 years and its increasing application in colorectal, and in particular rectal surgery [3]. The effectiveness of robotic colorectal surgery is evident from the increasing number of research articles published on the subject every year since the first robotic colectomy was performed by Weber et al. [4] in 2002.

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Advantages and Disadvantages of Robotic Surgical Systems

The da Vinci robotic system addresses most of the limitations of conventional laparoscopic surgery while at the same time preserving the advantages of minimally invasive surgery. The surgeon has access to stable 3-D views of the anatomy and the camera is controlled by the primary surgeon. The instruments have flexible tips with a jointed wrist design that exceeds the natural range of motion of the surgeon's hand with 180° articulation and 540° rotation. Moreover, the robotic system is able to filter the physiological tremor of the surgeon's hand. These are features that may allow surgeons to perform procedures more skilfully. In addition, robotic surgery eliminates the fatigue associated with laparoscopy and results in reduced physical strain to the operating surgeon [5].

Limitations of the system include the complete loss of tactile feedback and potentially prolonged operative times due to the docking time of the robot (although this has significantly improved with the new Xi system). However, the main disadvantage of robotic surgery is that it is expensive as there are high costs for initial outlay, consumables, and servicing of equipment. Because of these disadvantages, for robotic colorectal surgery to become the preferred minimally invasive option of choice, its technological advantages will have to translate into validated clinical effectiveness.

Current Status and Adoption of Robotic Surgery

Since its introduction, robotic surgery has been accepted worldwide, especially in the field of urology. Though it has been used for colorectal surgery, its acceptance in rectal surgery is much more than in colon surgery due to its advantage in the preservation of nerves and working in narrow spaces like the pelvis because of its better manoeuvrability. According to the recent data there have been around 1 million cases of robotic surgery worldwide and there are more than 800 robots throughout Europe.

Clinical Evidence regarding Robotic Colorectal Surgery

Many studies have failed to show the superiority of robotic surgery in pathological and short-term outcomes over conventional laparoscopic surgery, and instead, have shown longer operative times but with lower conversion rates to open surgery in robotic resections [6]. A few non-randomized studies have suggested that robotic surgery may offer better preservation of the bladder and sexual function [7].

In 2009, the UK Medical Research Council and National Institute of Health Research supported the Robotic vs. Laparoscopic Resection for Rectal Cancer (ROLARR) trial [8] in order to show the feasibility, efficacy, and short- and long-term oncological outcomes of robotic-assisted surgery compared to conventional laparoscopic rectal cancer surgery. This trial was an international multicentre randomized clinical trial as the use of robot was limited at the time. The ROLLAR trial failed to demonstrate the superiority of robotic surgery in terms of rate of conversion to open, oncological outcomes and complication rates. Furthermore, it was suggested that there was insufficient evidence to conclude that robotic-assisted laparoscopic surgery reduces the risk of conversion to open laparotomy when performed by surgeons of varying experience in robotic-assisted surgery. However, the sensitivity analysis exploring the learning effects suggested a potential benefit of robotic surgery when performed by surgeons with substantial prior robotic-assisted laparoscopic experience, regardless of their level of conventional laparoscopic exposure.

There have been a few recent meta-analyses comparing the outcomes of robotic versus laparoscopic and open surgery; of note is a study by Prete et al. [9]. This study showed that the main benefits of a robotic approach relative to conventional laparoscopy were with conversions and functional outcomes. Seven out of the 9 studies comparing robotic versus laparoscopic surgery in the meta-analysis reported significantly lower conversion rates with a robotic approach, while the remaining 2 studies showed lower rates of conversion to open surgery but these were statistically non-significant.

The increased precision offered by the robotic platform may allow for improved nerve preservation, which is evident by the studies reporting improved urogenital functions in the form of significantly better outcomes in continence and potency rates compared to open and laparoscopic approaches. Considering oncological outcomes, lymph node yields, circumferential resection margins, and 2- and 5-year survival rates, most of the studies in these reviews did not show any statistical difference between the two procedures.

In conclusion, these systematic reviews highlighted the benefits of robotic surgery, especially when working in narrow confined spaces such as the pelvis, which was evident by the fact that conversion rates and impotency rates are low compared to laparoscopic surgery, but the evidence is limited.

Oncological Outcomes

After initial enthusiasm, a limited number of studies have tried to explore the clinical/oncological benefits of robotic surgery in colorectal patients, but none have been

able to demonstrate the superiority of short-term outcomes of robotic surgery over laparoscopic surgery.

Some studies comparing laparoscopic and robotic rectal surgery have shown similar oncological outcomes, but significant evidence is lacking to prove the superiority of robotic surgery in this matter. Cho et al. [10] reported comparable short- and long-term outcomes between laparoscopic and robotic resections for rectal cancer in their study and found no statistically significant difference in the 5-year overall and disease-free survival rates between the two arms for total mesorectal excision.

Marginal Gains for Robotic Colorectal Surgery

Obesity

Surgery in obese patients has always been a challenge. Since the days before minimally invasive surgery was introduced and now even with laparoscopic surgery, obese patients are challenging to operate on with longer operative time, greater blood loss, higher conversion rate to laparotomy, increased postoperative complication rate, and longer length of hospital stay. Most of these complications have been thought to be the result of increased tissue fat, heavy omentum, and narrow space making tissue dissection more difficult. Along with the previously mentioned complications, several studies have documented a higher risk of ileus, wound infections, perioperative morbidity, and anastomotic leak rates in these patients [11].

In a study by Harr et al. [12], the authors concluded that postoperative ileus is less likely to occur in obese patients undergoing a robotic approach. Despite this, there was no difference in other perioperative outcomes between non-obese and obese patients, contrary to prior publications. Improved visualization, instrumental dexterity, and enhanced surgeon ergonomics likely contribute to the improved outcomes in both obese and non-obese patients. Although there are few studies showing the benefits of robotic-assisted colorectal surgery, obese patients with higher risks for intra- and postoperative complications may see a greater benefit.

Urogenital Function

There has been much discussion about robotic rectal surgery resulting in better urological and sexual function. A recent literature search by Panteleimonitis et al. [7] showed early recovery of urogenital functions in males but stressed that further studies were necessary to validate the use of robotics in this regard.

High-Risk Patients

Ahmed et al. [13], a UK-based group, tried to look into the benefits of robotic surgery in high-risk patients (male patients with BMI >30, preoperative chemo-radiotherapy patients, and low rectal tumours <8 cm) and found a statistically significant improvement in sphincter preservation rate along with a lower conversion rate to open surgery.

Factors Responsible for Marginal Gains

Proctoring and mentoring are important factors which have the potential to decrease the learning curve with a positive impact on lowering the worst clinical outcomes, especially during the early learning phase, and this has been proven in many training programs involving minimally invasive surgery [14]. Standardization of a surgical procedure has many advantages, including the achievement of desirable clinical outcomes and providing the groundwork for structured training and research [15]. There are a number of factors responsible for the marginal gain in robotic surgery.

Structured Training Precision Surgery

Many of the limitations of laparoscopic surgery are overcome by the robotic system, especially in confined spaces difficult to access with laparoscopic straight instruments, such as the pelvis in males. It provides a 3-D stable view, better retraction, and 7-D articulating instruments with precise dissection, particularly of the right pelvic wall. Robotic rectal surgery offers better pelvic nerve preservation due to precision and excellent view, which leads to improved urogenital functions.

Robotic Colorectal Training in Europe

The need for standardized structured robotic training was felt in Europe as well, especially in colorectal surgery, and the first consensus meeting was held in Lisbon (Portugal) at the Champalimaud Foundation in 2014, where the foundation was laid for the European Academy of Robotic Colorectal Surgery (EARCS). It is a non-profit organization with the aim of providing training to European surgeons with a volume of colorectal practice and of controlling desirable surgical outcomes. A modular training system was introduced, in which the surgery was split into parts to facilitate training of delegates in a structured fashion. The program consists of a set of protocols from surgeon selection to training curriculum. It starts with case observation at the faculty member's institute and lectures on pelvic anatomy and total mesorectal excision surgery, followed by training on console. After this, hands-on training is provided to the delegates using cadaveric material at the designated training centres under the direct supervision of the EARCS faculty. The next step is clinical hands-on training under the mentorship of the EARCS faculty member, first at the faculty institute and later at the delegates' centre. At the end of each proctored (training) case, delegates and proctors both complete global assessment score (GAS) and interim robotic colorectal assessment tool (RCAT) forms. The final step in signing off the

delegates as competent robotic colorectal surgeons is the submission of two unsupervised and unedited low-anterior resections for blind assessment [16].

It is worth mentioning here that the introduction of the dual-surgeon console has enabled the use of an integrated teaching and supervising environment. The dual-console allows for one surgeon to operate under the direct supervision of the mentoring surgeon, who has the ability to take over the controls of the patient side cart at any time, similar to dual-control cars used to teach people how to drive.

Conclusion

Robotic surgery has yet to realize its true potential. As evidence regarding its potential benefits in rectal surgery is becoming more obvious, its acceptance in this field has been appreciated and is increasing. However, the evidence is of low quality and subject to significant bias, making it difficult to draw any substantial conclusion.

For the adoption of any new technique it should be linked to teaching and training. Though robotic surgery is being taught by a few centres around the world, there is still a lot of room for improvement. The only issue currently considered to be a hurdle in its world-wide acceptance and propagation is its cost, but this would be solved with the passage of time as more and more companies are making robots.

Disclosure Statement

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