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REVIEW ARTICLE

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Robotic surgery for colorectal cancer

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Abstract

Minimally invasive surgery has demonstrated many benefits in general surgery, particularly in colon and rectal procedures. On the other hand, it has some limitations that must be taken into account, especially technical drawback. Robotic surgery has incorporated many improvements to overcome this disadvantage, such as 3D visualization, articulating instruments assisting complex and precise movements. As a result, robotic colorectal surgery shows less intraoperative blood loss, shorter time to oral tolerance and initial flatus (particularly associated with "Enhanced Recovery After Surgery" protocol), less conversion rate to open surgery, shortened hospital stay, and longer distal margins compared to laparoscopic and open surgery. This approach also shows a shorter learning curve. Some studies suggest that it could decrease perioperatively or 30 days after the intervention's mortality, raise overall survival, reduce wound infection, and improve functional results, while others show no significant difference. However, it lengthens surgical time. Otherwise, the studies included do not show statistically significant changes in the number of resected lymph nodes and anastomotic leaks. Economic costs remain one of the major concerns, although to date there are no large-scale studies that have evaluated this aspect from a global point of view. Robotic surgery represents a qualitative leap in surgical instruments and, although there is no strong evidence in favor of the use of robotic surgery over laparoscopic or open surgery, there is enough evidence to support its use in colorectal surgery, with potential advantages for patients.

KEYWORDS

colorectal cancer, colorectal surgery, review, robotic surgery

1 | INTRODUCTION

Throughout its more than 20 years of activity, surgical robot systems have been incorporating different improvements that replace the inherent limitations of laparoscopic surgery. Some of these improvements consist of changes in the ergonomics and reproduction of hand movements with articulated instruments. In addition, infrared technology and slimmer arms have been incorporated to facilitate procedures in multiple abdominal quadrants without requiring repositioning. This development in technology has meant that more robotic procedures are performed each year is in general surgery. It has experienced important growth in the colorectal field, where it is shown to be feasible and safe.

Robotic surgery, like open surgery or laparoscopic surgery, requires skill and a learning processes. The learning time for robotic surgery seems to be shorter ("shorter learning curve") than for laparoscopic surgery since simulators can easily be used and the computerized interface allows working with two consoles, which is a great teaching tool.[1,2] Currently, there is an increasing network of institutions that carry out an increasing number of training activities worldwide.[3]

Robotic procedures offer certain advantages over laparoscopic surgery since they allow an "immersive" 3D visualization that enhances depth perception, has articulating wrists, eliminates the surgeon's tremor, and allows more precise and complex movements (comparable to traditional open surgery instruments). Thereby it improves skill, facilitates the performance of complex procedures, provides easier access to narrow places (such as deep pelvis), and decreases the learning curve. It is particularly useful during pelvic surgery, where it enhances identification and manipulation of the nerves, vasculature, and nearby organs (gynecologic and urologic). Despite this, there are still unsolved problems, such as the docking and surgery time, and the absence of tactile sensation.[4]

The technological advantages and disadvantages of robotic surgery compared to conventional laparoscopic surgery are listed below (Table 1).[5]

2 | METHODS

2.1 | Search strategy

A comprehensive literature search in MEDLINE (PubMed) database was performed using the following search terms in combinations: "laparoscopic," "open," "robotic," "colorectal," "colorectal surgery," and "rectal."

TABLE 1 Current main advantages and disadvantages of Robotic Surgery

Advantages	Disadvantages
Better ergonomics	High acquisition and maintenance cost
Intuitive handling of instruments	Material with a limit of uses
3D Immersive view	Lack of tactile sensations
Seven degrees of freedom (Endowrist ®)	Device volume
Filtering of physiological tremor	Docking time
Faster learning curve	Risk of mechanical failure
Digital network	
Dual-Console	
Incorporation of other elements: Visualization with fluorescent, optical in the four trocars.	

2.2 | Inclusion criteria

A review of the literature between January 2012 and June 2020 was performed, identifying literature reviews, meta-analyses, and randomized clinical trials comparing robotic surgery with laparoscopic or open surgery.

In areas like functional outcomes or oncological outcomes in which the published information was scarce, additional manuscripts were used.

3 | RESULTS

Several randomized controlled trials and reviews confirmed that laparoscopic colorectal resection produces better early postoperative results, including reduced morbidity, less intraoperative blood loss, postoperative pain, ileus, fewer wound infections, and length of hospital stay. Time to pass flatus, to bowel movement, to oral fluid intake, and return to diet was shorter in laparoscopic approach in comparison with open surgery. Besides time to defecation, use of analgesia and onset of independent mobilization was longer with open surgery.[6,7,8,9,10] However, others were unable to demonstrate the non-inferiority of laparoscopy with respect to the open approach in terms of long-term outcome (locoregional recurrence, port-site or wound metastases, distant metastases, 3-year overall survival, 3-year disease-free survival, 5-year disease-free survival).[6,11,12]

Although laparoscopic colorectal surgery has been introduced for almost three decades, its application has not increased significantly until the last 10 years and it still represents less than 50% of all surgeries for colorectal cancer in many European and US centers.[13]

This is mainly for technical reasons. In the case of rectal cancer surgery, this can be a very complex procedure that involves radically removing the cancer and its lymphatic drainage without damaging the surrounding tissue. Pelvic dissection for rectal carcinoma is technically challenging due to limited visual exposure, operating within a narrow space, and the possibility of local invasion of the surrounding structures.[14] Laparoscopic dissection during total mesorectal excision (TME) and can overcome some of these difficulties by offering better visual angles in the pelvis compared to open surgery.[15] Unfortunately, this approach also has several technical barriers to overcome:

1. The assistant must achieve adequate rectosigmoid retraction to provide exposure and tissue tension for dissection.
2. The narrow confines of the pelvis limit the mobility of the standard laparoscopic instruments. When an anterior resection is performed, current laparoscopic stapling devices are difficult to maneuver in a narrow pelvis and position for a perpendicular staple line, leading to suboptimal distal rectal transection of multiple firings of the linear staplers. More than two fires have been associated with an increased risk of anastomotic complications.

Furthermore, patients with high body mass index, male sex, narrow pelvis, tumor diameter (≥6 cm), tumor invasion, and tumor location (lower rectum) increase the difficulty of a laparoscopic pelvic dissection for rectal cancer. Difficult dissection often results in an increased risk of incomplete TME or inadequate circumferential resection margin (CRM). This is observed more frequently in patients with these characteristics when the procedures are performed by inexperienced surgeons.

During the last decade, transanal TME was introduced in order to overcome some of the limitations of laparoscopic TME. Though initial reports seemed promising, more recent publications from national medical societies have recommended to pause the introduction of this approach because of safety concerns.[16,17]

Below we will list different aspects analyzed in the literature in more detail, comparing colorectal robotic surgery with both laparoscopic and open approaches.

3.1 | Intraoperative blood loss

Generally speaking, the different published studies report statistically significant differences in favor of robotic surgery, both with respect to open and laparoscopic surgery.[18,19,20,21,22,23]

3.2 | Postoperative days until the first oral diet and first flatus

Various systematic reviews of the literature agree that robotic surgery is associated with a significantly shorter time to oral diet tolerance or first flatus in patients with colorectal cancer.[19,20,23] When associated with ERAS protocols, robotic surgery seems to have an added value in this field.[24,25]

3.3 | Mortality (perioperative or 30 days after the intervention)

There is controversy in the literature regarding the association or not with lower postoperative mortality of robotic surgery. Two recently published studies[19,26] found that robotic surgery was associated with a significant reduction in the mortality rate, although this was not corroborated in other systematic reviews/meta-analyses.[20,23,27,28]

3.4 | Conversion to open surgery

In the various systematic reviews of the literature, there is consistency in stating that robotic surgery is associated with a statistically significant reduction in conversion to open surgery compared to laparoscopy. This is most striking in high-risk groups, that is, in men with narrow pelvises, obese men with bulky low rectum tumors, or those who have received neoadjuvant therapy.[19,21,22,27,28,29,30,31]

Paradoxically, in the Robotic vs Laparoscopic Resection for Rectal Cancer[32] – the only multicenter randomized clinical trial conducted to date comparing the robotic with the laparoscopic approach in rectal cancer, whose main objective was to measure the rate of conversion to open surgery – this reduction was not confirmed. Only after performing subgroup analysis was this benefit of robotic surgery seen in obese or male patients. Among other reasons, it is thought that the study lacked statistical power to detect these differences and that the recruited patient population was insufficient.

3.5 | Surgical time

This literature review shows longer operative time for robotic surgery with significant differences from open or laparoscopic surgery in all systematic reviews as well as in randomized trials.[19,20,21,22,23,27,28,31,33]

This association is thought to be related to the early learning phases of the surgeons that performed the studies. The majority of these reviews and published clinical trials collect data from surgeons on their learning curve.

3.6 | Days of hospital stay

When reviewing the literature, we frequently find shorter stays in relation to robotic surgery in the different systematic reviews. These results are statistically significant in approximately half of the cases.[19,20,21,22,23,27,28,31]

3.7 | Anastomotic leak

None of the systematic reviews published in the literature or the published multicenter randomized trial observed differences with respect to anastomotic leakage, probably because the type of approach to date had not been related to the way of preparing the anastomosis. It is possible that in the future the use of new robotic stapling systems or new technologies incorporated into robotics may contribute something to this issue.

3.8 | Surgical wound infection

Only in the systematic review published by Ng et al in 2019[19] were significant differences in favor of the robotic approach found. The rest of the published reviews or trials did not show differences.

In the case of surgical wound infection, very few studies have looked into the impact of robotic surgery on intracorporeal anastomosis. Robotic approach could have an added value for performing intracorporeal anastomosis and subsequently for reducing surgical wound infection.[34]

3.9 | Functional results

No significant differences regarding the incidence of urinary dysfunction or erectile dysfunction have been observed in systematic reviews of the literature.[19,20,21,22,23,27,28,31]. On the other hand, there are isolated publications suggesting that robotic approach decreases incidence of partial or complete erectile and sexual dysfunction compared with laparoscopic surgery.[35,36]

3.10 | Resection margins

In a recently published systematic review and network meta-analysis comparing robotic approach with other approaches, no difference regarding the involved resection margins was found.[6] Previous meta-analyses had pointed in the direction of significantly lower incidence of involved resection margins associated with robotic surgery.[37,38] Moreover, the recently published systematic review identified statistically significant longer distal margins compared with open or laparoscopic approaches.[6]

The difference observed regarding circumferential resection margins are key because of their potential implications in local recurrence or long-term oncological outcomes.

3.11 | Resected lymph nodes

To date, no differences have been observed in lymph nodes resected using the different approaches, although the robotic approach is favored.[19,20,21,22,23,27,28,31]

As in the case of surgical wound infection, it will be interesting to keep an eye on the future impact of robotic surgery in the standardization of minimally invasive complete mesocolic excision or lateral lymph node resection in areas of the world like Europe or the United States where these techniques are not fully implemented. This might lead to an increase in the rate of harvested lymph nodes when the robotic approach is used.

3.12 | Overall survival

No significant differences regarding overall survival have been observed in systematic literature reviews,[19,20,21,22,23,27,28,31] although there are isolated publications that establish that robotic surgery could be a predictor of better overall survival.[39]

Therefore, we can conclude that although there is no strong evidence in favor of the use of robotic surgery over laparoscopic or open surgery, there is enough evidence to support its use in colorectal surgery, with potential advantages for patients, especially if we consider that many of the reviews analyzed include articles from initial experiences or during the learning curve of surgeons.

3.13 | Contributions of robotic colorectal surgery to traditional surgery

In recent years, more and more robotic systems have been introduced. Intuitive Surgical recently introduced the "SP system," a robotic single-port system that allows multiple complex procedures to be performed using a single 2.5 cm diameter incision. This again opens the possibility of considering complex procedures through a minimal incision, as well as performing transanal robotic mesorectal total excision (Robotic TaTME), a technique that, until now, was limited to experts in robotics and transanal mesorectal total excision due to its technical complexity. The clinical use of the SP system in the transanal approach to rectal cancer has just started in the United States, while in Europe it is still under pre-clinical evaluation.[40]

Cambridge Medical Robotics recently introduced the Versius system, a system with 5-mm instruments in all its arms that, although lacking energy or stapling instruments, possibly allows procedures of intermediate complexity to be performed with an adequate cost-benefit ratio.

In September 2019, Medtronic presented its robotic system that seems to be close to being launched; other manufacturers such as Johnson & Johnson have recently stated that their robotic system projects are also in advanced stages of development and are expected to be presented in the next two years.

Among the opportunities offered by these new robotic systems, it is essential to list the incorporation of image-guided surgery, the possibility of remote surgery and remote mentoring, as well as the incorporation in the near future of more or less complex artificial intelligence systems.

3.14 | Indications for robotic surgery in colorectal field

Returning to what is already a reality, robotic systems are already used today in the field of colorectal cancer surgery with success in total excision of the mesorectum, as well as in complete excision of the mesocolon. Both are technically demanding procedures in which the robot trains the surgeon to perform them more precisely. Intracorporeal anastomoses, vascular dissection, and lymphadenectomy in complex anatomical spaces like lateral side walls of the pelvis or due to their location or proximity to vascular structures are facilitated with the assistance of the robot. In many centers where the colorectal surgeons have access to the robotic approach, this has become the standard approach for rectal resections.

To improve many of the technical skills necessary for these procedures, current simulation systems allow the surgeon to train without risk to the patient in this field. In the future, incorporating rendered images from real patients into the simulation systems or creating hydrogel simulated physical models will allow colorectal surgeons to rehearse the procedures as many times as needed before doing the real cases. This will have clear benefits for the patients treated with this technology and is already being used in the field of urology.[41]

Economic costs remain one of the major concerns, although evaluation should not only consider the capital cost of acquisition, or the costs related to the procedure, but also the benefits from the different aspects related to the patient treatment, such as oncological outcomes. To date, there are no large-scale studies that have evaluated this aspect from a global point of view.[42]

4 | DISCUSSION

Robotic surgery represents a qualitative leap in surgical instruments, as well as in the possibility of offering a minimally invasive approach to our patients despite the fact that the procedures to be performed are technically complex or in anatomical locations "uncomfortable" for the mean surgeon. Robotic approach does not make the procedure simple or easy, but it makes more minimally invasive surgery feasible by less experienced surgeons in more patients, shortening their learning curves.

As seen to date, there are still several controversies related to the benefits of laparoscopic TME or TaTME surgery over the open procedure. The technological advantage incorporated by the robot-assisted approach may solve some of the technical difficulties underlying laparoscopic TME, like the use of straight instruments or surgeon's fatigue during a long case with adverse anatomical conditions (narrow pelvis, obese patients, low tumor...), leaning the balance towards minimally invasive procedure. In contrast with TaTME, robotic-assisted TME maintains the anterior approach for TME, avoiding the need to re-learn the anatomy of the pelvis from a different view and avoiding a long learning curve filled with potential new complications for the patient.

When looking for an approach that offers the best combination of oncological, functional, and patient-recovery outcomes, robotic approach seems to be the best option for rectal cancer treatment when compared with open, laparoscopic, or transanal approach. Hopefully, research studies like Rectal Surgery Evaluation Trial will be able to objectively show this in the near future.[43]

The computerized interface of surgical robots also makes a change in the paradigm of surgical training possible through shortening learning curves to make them more complete, and, above all, reducing the morbidity and mortality associated with them. Surgical societies should lead this change and establish efficient training programs in the field of colorectal robotic surgery.[44]

DISCLOSURE

MGR received grants from Intuitive Surgical and Medtronic and currently is Medical Advisor to Intuitive Surgical, Medtronic, and Johnson & Johnson.

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