CHAPTER 8
Surgical treatment: robotic surgery

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The standard treatment for colon cancer is surgical resection. The advantages of the laparoscopic approach have been demonstrated in numerous publications when comparing short-term results. The benefits over open surgery are clear, taking into account the early recovery of bowel motility and the short hospital stay.[1,2] However, there are limitations associated with this approach, such as the high incidence of conversion to open surgery and the lack of evidence of superiority or non-inferiority observed in long-term oncological outcomes.[3–6]

Although the long-term superiority of the laparoscopic approach has not been demonstrated, its indication for patients with CRC has expanded worldwide over the past two decades. However, technical difficulties associated with this procedure have recently begun to be reported, mainly for the treatment of right-sided CRC.[7–9]

According to the 2020 annual report of the Japanese National Clinical Database, the rate of right hemicolectomy is only 54.2%, which is low compared with other procedures for CRC. The report also found that the 90-day postoperative mortality of right hemicolectomy is 2.2%, approximately 4 times higher than that of low anterior resection.[10]

With the advent and development of robotic-assisted surgery (RAS), it is hoped to overcome the disadvantages of conventional laparoscopic surgery, since with its three components (console, robotic cart and viewing tower), it allows the use of instruments with a greater range, rotation capacity (*endowrist*), multiple movements through the robotic arms and greater work stability without tremors due to stress or fatigue of the surgeon (Figs. 8.1 and 8.2). It also provides the possibility of performing delicate movements with greater skill, since the image is reproduced binocularly on the console by two 5 mm high-definition (3D) endocameras that also provide a stable view. All these factors make robotic surgery a more precise approach in trained hands that allows for obtaining a resection of oncological quality. This approach has gained popularity; although it was initially used for pathology confined to difficult-to-access spaces such as the pelvis, its results have led to its indication being extended to the rest of the pathology, especially CRC.[11–14]

Results using the da Vinci Xi system

The da Vinci Xi (dVXi) Surgical System is the fourth generation of the robotic platform from Intuitive Surgical, Inc. (Sunnyvale, CA, USA) and therefore the most developed and experienced, which attracted the attention of surgeons as soon as it was introduced to the market. This new system features increased versatility, including integrated table movement, more sophisticated arms, and complex imaging units that enable a wide range of colonic procedures, from complex multi-quadrant colectomies to intracorporeal anastomoses in a narrow space.[15]

Robots currently in development and new platforms

For a long time, robotics applied to colon surgery was synonymous with the da Vinci system. Currently, there are new robotic platforms that will grow in the near future, as several manufacturers are in different stages of either active development, launch, or awaiting regulatory approval. MicroHand S, a surgical robot from China, has entered several clinical trials and some have already reported good performance and application prospects. Yi et al.[16] reported 10 surgical procedures with the aid of MicroHand S without intraoperative complications or technical problems. Luo et al.[17] retrospectively analyzed 45 patients with sigmoid colon cancer who underwent robotic surgery with MicroHand S or da Vinci. The da Vinci system did not demonstrate obvious clinical advantages compared with MicroHand S. In contrast, MicroHand S was associated with lower cost and shorter postoperative hospital stay.

The novel Senhance robotic system (TransEnterix Surgical Inc., Morrisville, North Carolina, USA) has been used in Europe and was approved for limited treatment in the USA. Samalavicius et al.[18] performed a prospective survey of the first 100 surgeries with this robotic system in Lithuania, demonstrating that its use is feasible and safe in general surgery. Hugo RAS from Medtronic Inc. (Dublin, Ireland) and Versius from CMR Surgical Ltd. (Cambridge, UK), the latter recently incorporated in our country, have demonstrated promising results in the clinical field. The emergence of new platforms increases competition and generates greater access to robotic surgery by reducing the costs of the different systems and simultaneously increasing their quality.[15]

Evolution of robotic surgery

Between 2012 and 2020, the use of robotic technology for colectomies has increased, with approximately one in four cases being performed this way. The US National Cancer Database has shown that robotic surgery for colon cancer is increasing rapidly, particularly in younger, healthier patients.[14,19] In Japan, RAS has had coverage since 2018, leading to a rapid increase in the number of robotic rectal surgeries.[20]

Only in March 2022, following the first prospective multicenter study examining the short-term outcomes of robotic-assisted colectomies (RAC) for colon cancer in Japan, did this approach begin to be covered in that country. In this study, which evaluated patients with resectable stage II-III colon cancer, the conversion rate to laparotomy was zero, indicating noninferiority and demonstrating the safety and feasibility of the approach.[21]

JCOG0404,[6] is a multicenter study that demonstrated non-inferiority of the laparoscopic approach in patients with stage II/III colon cancer compared to open surgery. This study determined that the conventional laparoscopic approach can be performed safely without increasing postoperative complications, although with longer operating times. Furthermore, it is associated with better recovery of bowel function, lower analgesic requirements, and shorter hospital stay. However, non-inferiority of the laparoscopic approach could not be demonstrated in long-term outcomes, with a survival rate of 90.4% in the open group comparable to 91.8% in the laparoscopic group. Despite the results of most studies, the favorable results made laparoscopic surgery an acceptable alternative.

When RAS was compared to this historical baseline, the data showed a conversion rate of zero, blood loss of 0 mL, complication rate of 4%, median operative time of 211 min, bowel transit recovery time of 3 days, and hospital stay of 6 days, all similar to previous studies.[21]

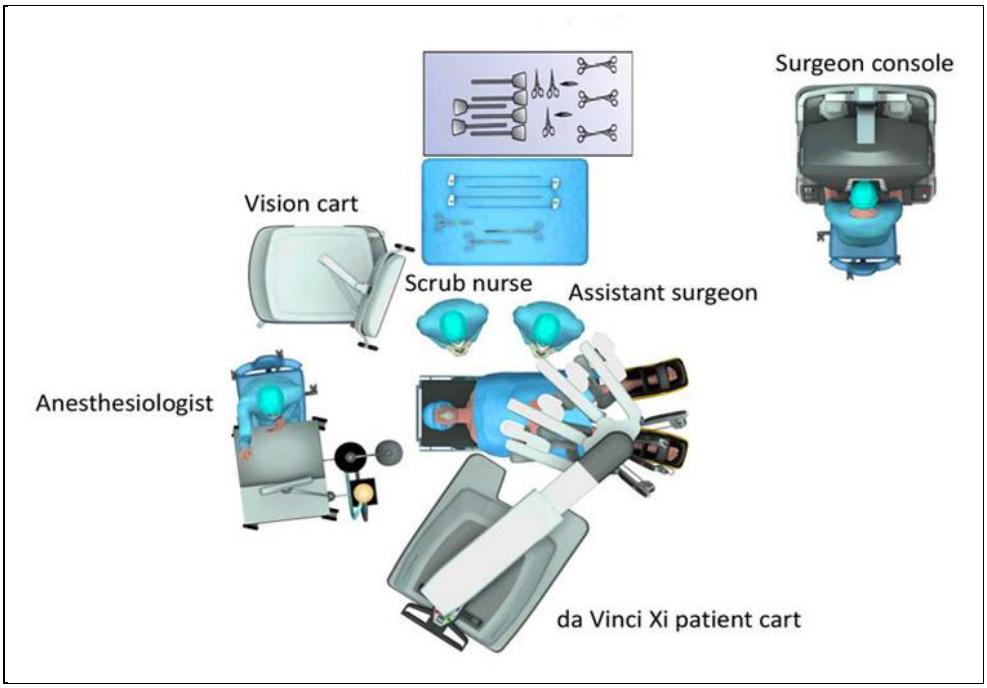

Figure 8.1. *Components and organization of the operating room for robotic colectomy.*

Figure 8.2. *Preoperative assembly. Operating table in Trendeleburg/Fowler >10º as required. Rotation >10º. Height of the operating table as low as possible. Implantation of the robotic system. Implantation of the robotic arms. Location of the laparoscope cart. Adjustment of the multiport and variation of the arms.*

Although long-term results are still expected, as patient registration was completed in 2022, the number of centers that started to introduce this approach is gradually increasing in Japan since it is covered by insurance. Although several studies have shown a lower conversion rate of RAC compared to laparoscopic colectomy (LC),[22] since robotics has just been introduced in Japan and is still in the learning curve stage, the study was designed to verify the non-inferiority of the safety of the new technology compared to existing ones.

Although most of the published works are retrospective, there are certain prospective results that jointly demonstrate less blood loss, lower intraoperative transfusion rate, lower conversion rate and fewer complications such as ileus and anastomotic leak, indicating better short-term results with the robotic approach.[23,24]

To date, there are few studies with significant evidence or that have evaluated oncological results. Park et al. found no short-[23] or long-term[25] differences between RAC and LS, although the sample analyzed was small. A more recent study that includes prospective data is that of Schootman et al.,[26] who used the American College of Surgeons database between 2013-2015 to compare 2233 cases of RAC vs. 10844 cases of LS, with adjustment for selection bias based on a propensity score. The results showed a lower conversion rate (5.7 vs. 18.6%; $p < 0.05$) and shorter hospital stay (5.1 vs. 5.3 days; $p < 0.05$) in the robotic group. Kulaylat et al.[27] used the same database and the same methods to compare 3864 cases of RAC vs. 40,063 cases of LS, and reported a significantly lower conversion rate in RAC (6 vs. 11.5%; $p < 0.001$).

Some meta-analyses suggest that robotic right hemicolectomy contributes to reduce the risk of conversion and has an earlier postoperative recovery.[22] Ma et al.[28] reported a longer hospital stay in the laparoscopic group and lower complication rate, less blood loss, shorter time to recovery of intestinal transit and lower conversion rate in the robotic group (OR 0.34; $p = 0.008$). Solaini et al.2[2] demonstrated a higher risk of conversion (RR 1.7; $p = 0.020$) and a longer time until recovery of bowel transit in LC.

Just as favorable long-term results of LC vs. open surgery have not yet been demonstrated, OS and DFS data provided to date are comparable between LC and RAC.

The true goal of surgery for malignant tumors is overall survival. However, a long period of observation is required before obtaining results. The conversion rate, which can be assessed in a short period, has served as a surrogate endpoint in certain studies and has been reported to be associated with postoperative complications, mortality, increased blood transfusions, and recurrence due to residual tumor.[29] Although several studies have shown a lower conversion rate in RAC compared with LC, in certain series, such as the Japanese one that is still in the learning curve, conversion rates were similar with both approaches.[9]

On the other hand, cost has not been analyzed in most studies. The disadvantages of robotic surgery are associated with longer operating time and costs, but these can be overcome by shortening operating time and decreasing the incidence of complications through improved surgeon skills.[26,27]

The advantages of the robotic approach include improved postoperative recovery and therefore shorter hospital stay, factors that should be taken into account when making a cost/benefit assessment. To determine the real disadvantages of the robotic approach, along with the longer operating time, variables such as the learning curve (inversely proportional to operating time) and long-term results should also be included. Comparative data between RAC and LC are shown in Table 8.1.

Table 8.1. Comparison of robot-assisted right (CDAR) and left (CIAR) colectomy with laparoscopic Colectomy (LC).

Comparison with CL	CDAR	CIAR
Advantages	- Lower conversion rate - Lower complication rate, including anastomotic leak - Greater number of lymph nodes removed	- Lower conversion rate - Better mobilization ofthe splenic flexure
Disadvantages	Higher cost	Higher cost
No differences	Long-term results	Complication rate

Optimizing robotic surgery

- Suprapubic surgical approach

Like any other approach, robotic surgery has been exploring trocar placement, depending not only on the available platform, but also on the location of the tumor. An optimal surgical approach can increase the fluidity of the operation and reduce the collision of the internal and external robotic arms, which directly impacts short- and long-term results.

In the suprapubic approach, especially applied in robotic right hemicolectomy (RRHC), colonic resection is performed with horizontal linear placement of ports in the suprapubic area (Fig. 8.3).

Hamilton et al.32 reviewed the techniques and perioperative outcomes using the dVXi and da Vinci Si (dVSi) systems, with either suprapubic port (SPP) or traditional placement in 138 patients undergoing RRHC. They reported that the SPP technique had more advantages, with less console time and shorter hospital stay. Yeo et al.[33] developed a SPP strategy for robotic colectomy with CME and central vascular ligation using the dVXi robotic system in cadaveric models. Lee et al.[34] from Korea, and Schulte et al.[35] from Germany, separately described RRHC using the suprapubic access strategy with relatively satisfactory perioperative outcomes. Long-term results and further application are awaited to broadly determine its benefit.[15]

- Application of single-port (SP) robotic surgery

The intention of surgeons to reduce the number of ports in robotic colonic resection is due to its cosmetic effect and early recovery. SP has begun to be applied through a single incision. Juo et al.[36] completed one case of SP total colectomy and reported that it was a feasible procedure associated with a shorter operation time. Marks et al.[37] reported 2 cases and Bae et al.[38] from Korea, 23 cases of SP left colectomy, indicating that it is a feasible and safe method. Spinoglio et al.[39] successfully performed 3 right colectomies with intracorporeal anastomosis (ICA) using the da Vinci SP platform. A systematic review of current studies revealed that SP surgery for colon diseases is feasible and safe, with acceptable perioperative outcomes (complications 0-36.4% and hospital stay 2-9 days) and comparable with those of multiport robotic surgery.[40]

- Use of ICA

ICA is a relatively new surgical method that has modified the way the surgical specimen is removed through the abdominal surgical incision (Fig. 8.4). This anastomosis decreases the traction of the bowel to be anastomosed, which may reduce postoperative complications. A systematic review and meta-analysis from Italy found a higher rate of ICA in RRHC.[22] Ngu et al.[41]reported shorter operative time and higher number of lymph nodes removed with statistically significant values, and similar rates of postoperative recovery and complications in RRHC with ICA. Some studies have verified the safety. Other studies have reported not only the feasibility and safety of robotic ICA, but its association with a shorter incision length to remove the specimen, earlier bowel recovery, fewer complications (including anastomotic leak, surgical site infection and incisional hernia) and lower conversion rate, but longer operative time, compared with extracorporeal anastomosis (ECA). Long-term results comparing ICA vs. ECA in robotic colonic resections are pending.[15]

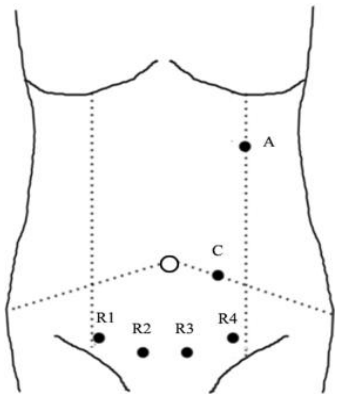

Figure 8.3. *Suprapubic robotic approach.*

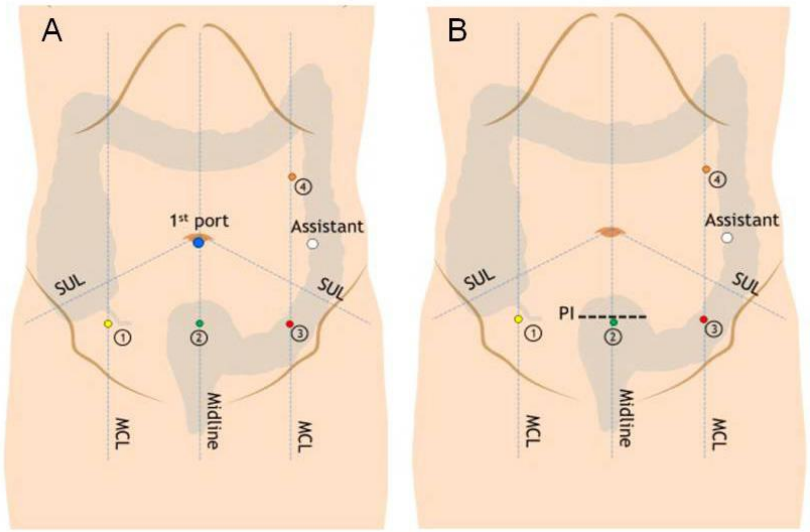

Figure 8.4. *Placement of robotic ports for right colectomy with extracorporeal* ***(A)*** *and intracorporeal* ***(B)*** *anastomosis. MCL: Midclavicular line. UCL: Umbilicospinous line. PI: Pfannenstiel incision.*

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- Use of tracers

In recent years, the use of tracers has changed, especially in colorectal surgery, for which indocyanine green (ICG) is the most commonly used tracer. Currently, ICG is used to assess anastomotic vascularity, as it delineates the blood supply and avoids anastomosis of nonperfused segments. Several studies demonstrate its utility and benefits in LC.[42–44] Furthermore, it is used as a lymph node marker in lateral lymphadenectomies and may improve performance in D3 lymphadenectomy.[44] Robotic platforms feature *Firefly* technology integrated into the dVXi, allowing efficient ICG identification for assessing colon perfusion and lymph node dissection. This suggests that in future publications, tracers will begin to appear alongside the robotic approach.[15]

Future of robotic surgery in colon cancer

Robotic platforms are expected to reduce intraoperative adverse events and provide a higher level of safety by generating ergonomic improvements in the robot and promoting

greater surgical performance, which will continue to impact short-term outcomes. Meanwhile, long-term oncological results are expected to demonstrate the cost-benefit and non-inferiority of the robotic approach for colon cancer compared to LC.

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