Chapter 6

Robotic Splenic Flexure and Transverse Colon Resections

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Additional information is available at the end of the chapter

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Abstract

Since the 1990s, laparoscopic technique has become a standard approach for several surgical procedures in the field of colorectal surgery. Laparoscopic approach to splenic flexure and transverse colon cancer, however, is still a matter of debate and considered challenging for both anatomical and technical aspects. The relationship with the spleen and the absence of a consensus on the extent of surgery for splenic flexure cancer are two of several aspects that make splenic flexure surgery mostly debated. Robotic technique has overcome some pitfalls of laparoscopy, thanks to its stability of vision, tremor filtering, and fine movements of the robotic arms that can help in better identifying and managing both vascular structures and side organs, thus avoiding splenic and pancreatic injuries. In addition, robotic system can allow a better fashioning of the intracorporeal anastomosis, and the advent of fluorescence is useful to guide dissection and to evaluate the vascularization of the colon. Herein we discuss a standardized approach for robotic splenic flexure resection and transverse colon.

Keywords: splenic flexure cancer, transverse colon cancer, robotic colorectal surgery, robotic technique, robotic splenic flexure resection, robotic transverse colon resection, robotic intracorporeal anastomosis

1. Introduction

Since the 1990s, laparoscopic technique has become a standard approach for several surgical procedures in the field of colorectal surgery [1]. All the main prospective trials comparing open and laparoscopic technique for colorectal cancer have shown same clinical and oncological outcomes of the two approaches [2–5]. Laparoscopic approach to splenic flexure and transverse colon cancer, however, has not been investigated and it is still a matter of debate, mainly due to the rare incidence of the cancer of the left flexure, ranging approximately from 3 to 10% of all colon cancers, and to technical difficulties in approaching the transverse colon. Splenic flexure cancers are generally considered as all those cancers occurring between the distal part of the transverse colon and the proximal part of the descending colon [6]. Pure transverse colon cancers are commonly defined as all those cancers occurring in the middle part of the transverse colon. Surgical technique for this kind of tumors is not standardized yet, because of anatomical aspects and technical issues. Laparoscopic approach has been considered a challenging procedure, with longer operative time than in open surgery and a relative risk of splenic and pancreatic injuries, suggesting its use by expert surgeons and for early stage disease. Robotic surgery has been introduced in colorectal surgery about 15 years ago, and it is spreading worldwide, thanks to its advantages over laparoscopic technique.

2. Robotic splenic flexure resection

2.1. Patient positioning, robot docking, and operating theatre setup

2.1.1. Operative setting overview

Patient is placed in the reverse Trendelenburg position (15°), with a 30°-tilt to the right with the arms alongside the trunk and the legs abducted (**Figure 1**). The cart approaches the operative table from patient's left hip (**Figure 2**). The procedure is carried out with a five-trocar technique and begins with the insertion of the Veress needle in the left hypochondrium and the induction

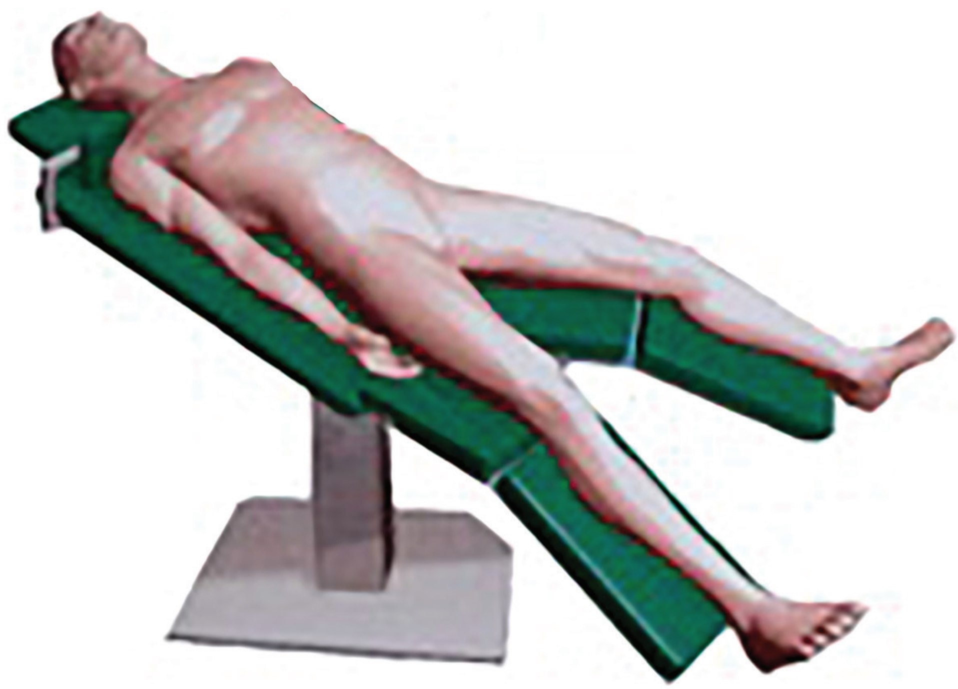

Figure 1. Position of the patient on the operative table.

of a 12-mmHg pneumoperitoneum. The optical trocart is placed 2 cm right and up the umbilical scar. The robotic trocarts R1, R2, and R3 are inserted in the right iliac fossa at the cross between the line passing through the antero-superior iliac spine and the umbilical scar, and the middle clavicular line; in the epigastrium/left flank between the midline and the left-middle clavicular line, and in the right hypochondrium 2 cm below the right rib margin along the middle clavicular line, respectively. A laparoscopic 12-mm trocart is placed in the right flank between R1 and R3, for the assistant at the operative table. Arm 1 is connected to R1, arm 2 is connected to R2, and arm 3 is connected to R3. The complete trocarts and operating theatre setups are shown in **Figures 3** and **4**.

2.1.2. Robotic instruments and setting

Robotic instruments used in this procedure are bipolar fenestrated forceps, for coagulation and traction, the ProGrasp for traction and exposure, and robotic scissors for cutting and blunt dissection (when used with closed jaws). The robotic monopolar scissors are mounted on arm 1, the robotic bipolar fenestrated forceps on arm 3, and the ProGrasp on arm 2 (**Figure 5**).

2.2. Exploration of the abdominal cavity, intraoperative hepatic ultrasonography and mobilization of the splenic flexure

A laparoscopic exploration of the abdominal cavity and an intraoperative ultrasonography of the liver are systematically performed to identify the site of the neoplasm (tattoo or the cancer itself) and to complete the staging of the disease. This is a fundamental step that allows also in finding out the connections between the splenic flexure and the inferior pole of the spleen. The

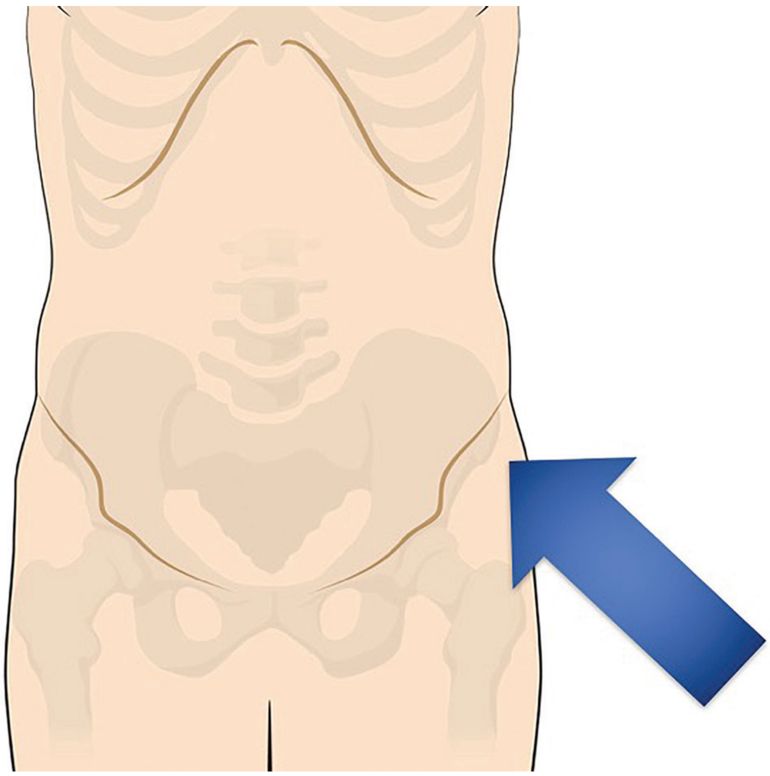

Figure 2. Direction of the docking of the robotic cart in left colic flexure resection.

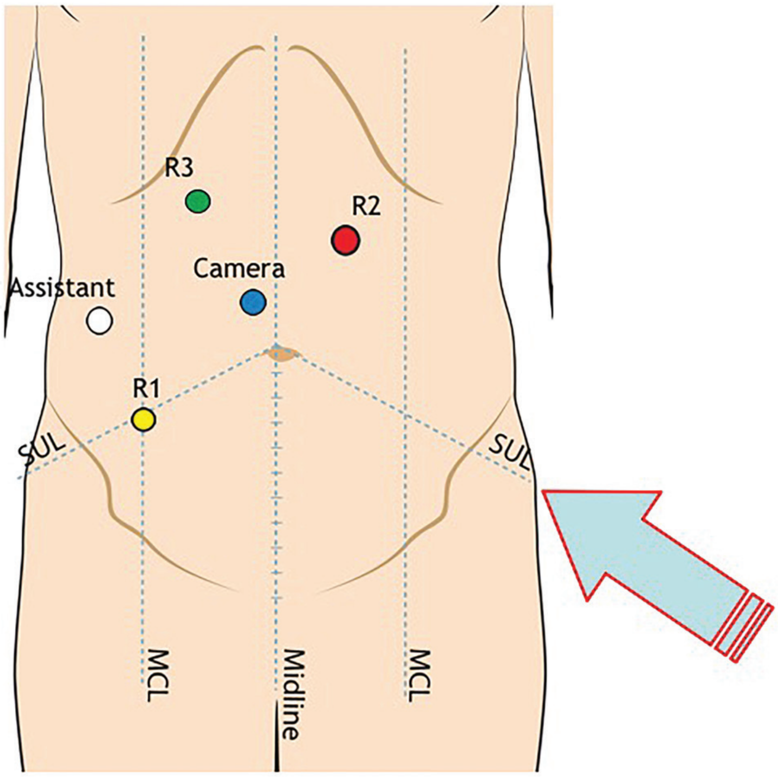

Figure 3. Trocarts position in left colic flexure resection. SUL, spine-umbilical line; MCL, middle clavicular line.

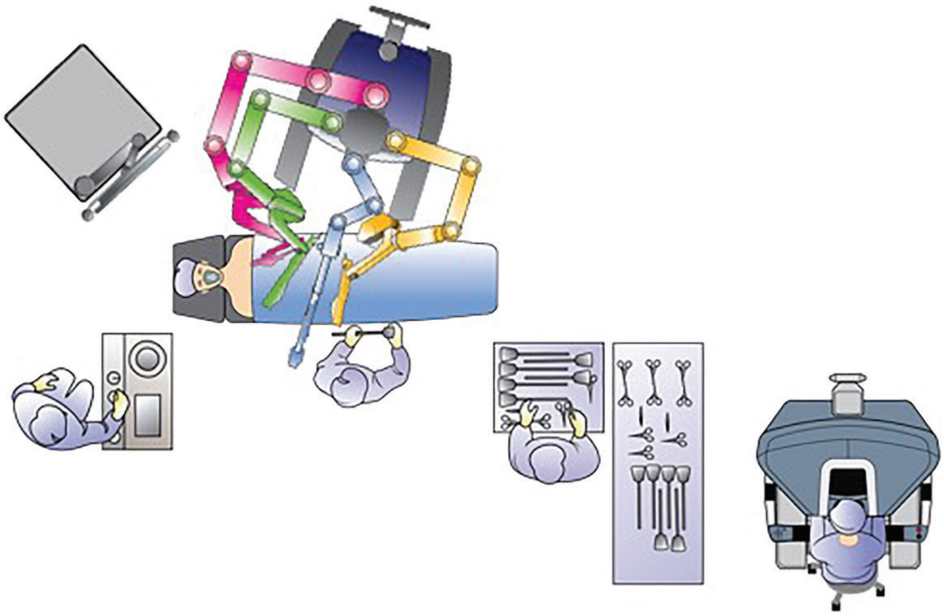

Figure 4. Operative theater setting.

robotic arms are connected to the trocarts (robot docking). The first step of the flexure takedown is the dissection of the gastrocolic ligament. The transverse colon is pulled down by the assistant with a laparoscopic grasper, while the stomach is pulled up by the bipolar forceps on arm 3, in order to maximize the exposition of the gastrocolic ligament and to identify the Bouchet's

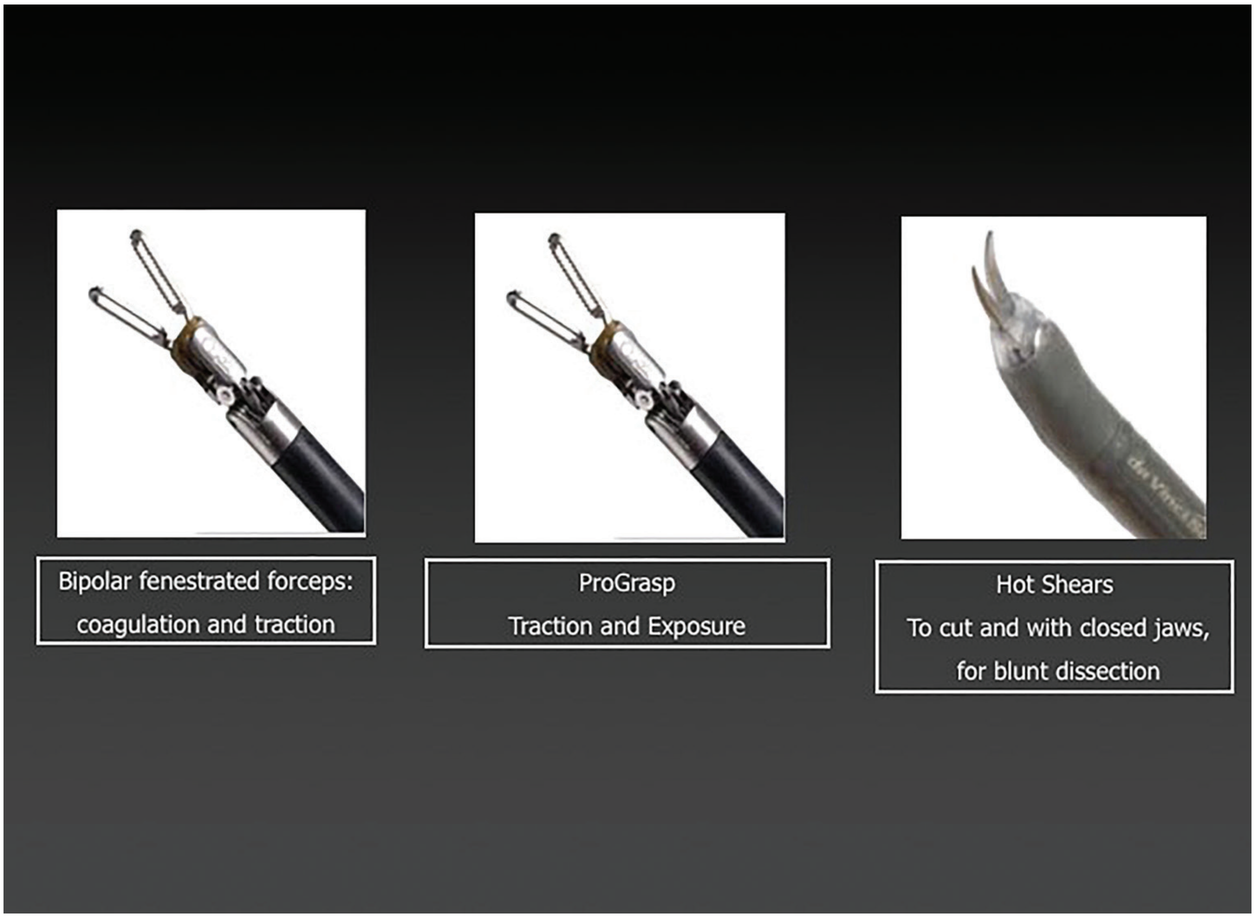

Figure 5. Robotic instruments used during robotic left colic flexure resection.

area, the starting point of the dissection carried out by the robotic scissors on arm 1 in a right-to-left direction (**Figure 6**). The dissection continues till the lower pole of the spleen is reached, then the splenocolic ligament and the superior part of the left paracolic gutter are incised. The access to the lesser sac is achieved. The inferior margin of the pancreas is identified and the root of the mesocolon is incised 1 cm below the pancreatic margin by the robotic scissors on arm 1, from left to right, till reaching the first jejunal loop, at the Treitz area. The transverse and left colon are medialized by the assistant and the separation of the Toldt's fascia from the Gerota's fascia is carried out in a lateral-to-medial direction; during this step, the paracolic gutter is completely incised up to the sigmoid colon. The takedown of the splenic flexure is completed.

2.3. Vascular dissection and lymphadenectomy

2.3.1. Brief summary of the vascular and lymphatic drainage anatomy of the left colic flexure

Vascular anatomy of the left colic flexure is constituted by secondary branches of the two main intestinal vascular trunks; blood supply is provided by the left branch of the middle colic artery originating from the superior mesenteric artery, and by the left colic artery (LCA), originating from the inferior mesenteric artery (IMA); venous drainage flows into the superior mesenteric vein, through the left branch of the middle colic vein, and into the inferior mesenteric vein (IMV), through the left colic vein (LCV).

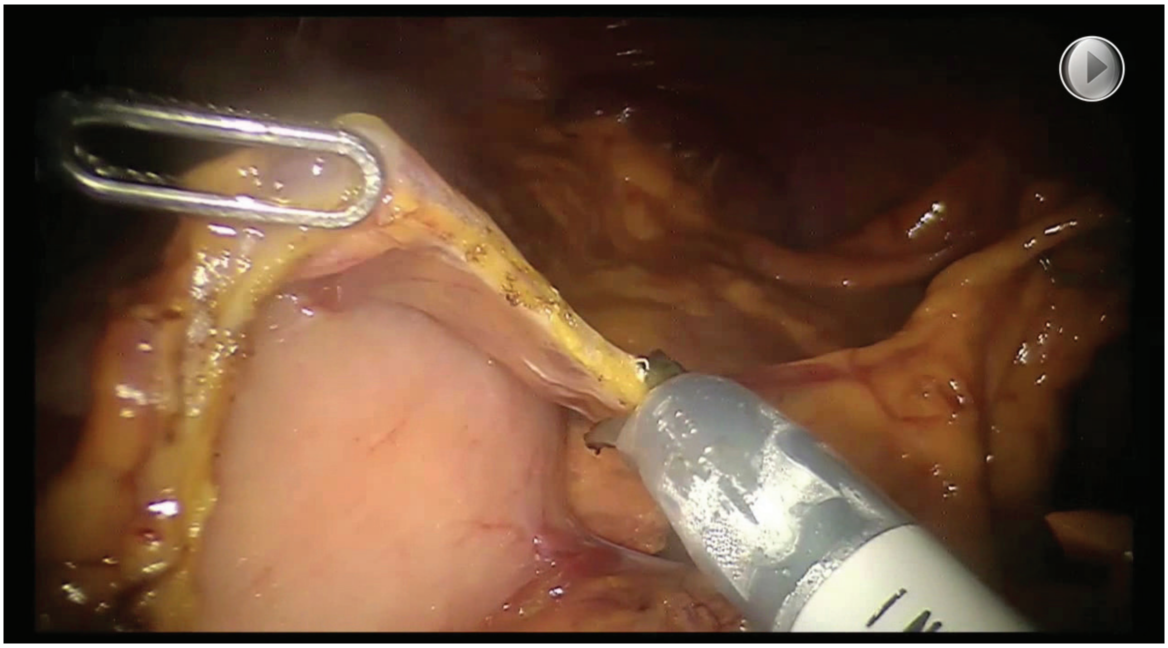

Figure 6. Dissection of the gastrocolic ligament. The transverse colon is pulled down by the assistant with a laparoscopic grasper, while the stomach is pulled up by the bipolar forceps on arm 3, in order to maximize the exposition of the gastrocolic ligament and to identify the Bouchet's area.

Splenic flexure cancer has various lymphatic drainage pathways. The standard lymphatic way is satellite to the left branch of the middle colic artery and left colic artery, but lymphatic metastases to the infrapancreatic lymph node region and the splenic hilum have been reported. Indocyanine green (ICG) fluorescence may help analyzing metastatic lymphatic spread, if injected subserosally or submucosally. The optimal dose range is between 0.1 and 0.5 mg/kg and should not exceed 2 mg/kg. For the detection of the lymph flow, a dose of ICG of 2.5 mg/1.0 mL is injected into the subserosal-submucosal layer around the tumor at two points after trocar insertion; the lymph flow is observed using the robotic integrated near-infrared system (NIR) 30 min after ICG injection.

2.3.2. Description of the vascular dissection

The transverse colon is pulled upward by the assistant with the laparoscopic grasper, and the left colon is lifted up and laterally by the ProGrasp on arm 2. The inferior mesenteric vein (IMV) is identified at the inferior margin of the pancreas. The dissection starts at the lateral margin of the IMV in order to identify the left colic vein (LCV). An accurate lymphadenectomy of the root of the IMV is performed. The left mesocolon is lifted up by the ProGrasp on arm 2, while the IMV is medialized by the assistant with a laparoscopic grasper. The dissection continues till the LCV is identified and isolated between non-adsorbable clips, applied by the assistant or by the robotic clip applier on arm 1, and cut by the assistant or by the scissors on arm 1 (**Figure 7a** and **b**). The dissection is carried out with a medial to lateral direction, joining the previous plane between Toldt's and Gerota's fascia. The sigmoid colon is completely mobilized, preserving the left gonadal vessels and the ureter, lying down Gerota's fascia (**Figure 8**).

The left mesocolon is then lifted up by the ProGrasp on arm 2 to identify the inferior mesenteric artery (IMA): the dissection follows the lateral aspect of the IMA till reaching the origin

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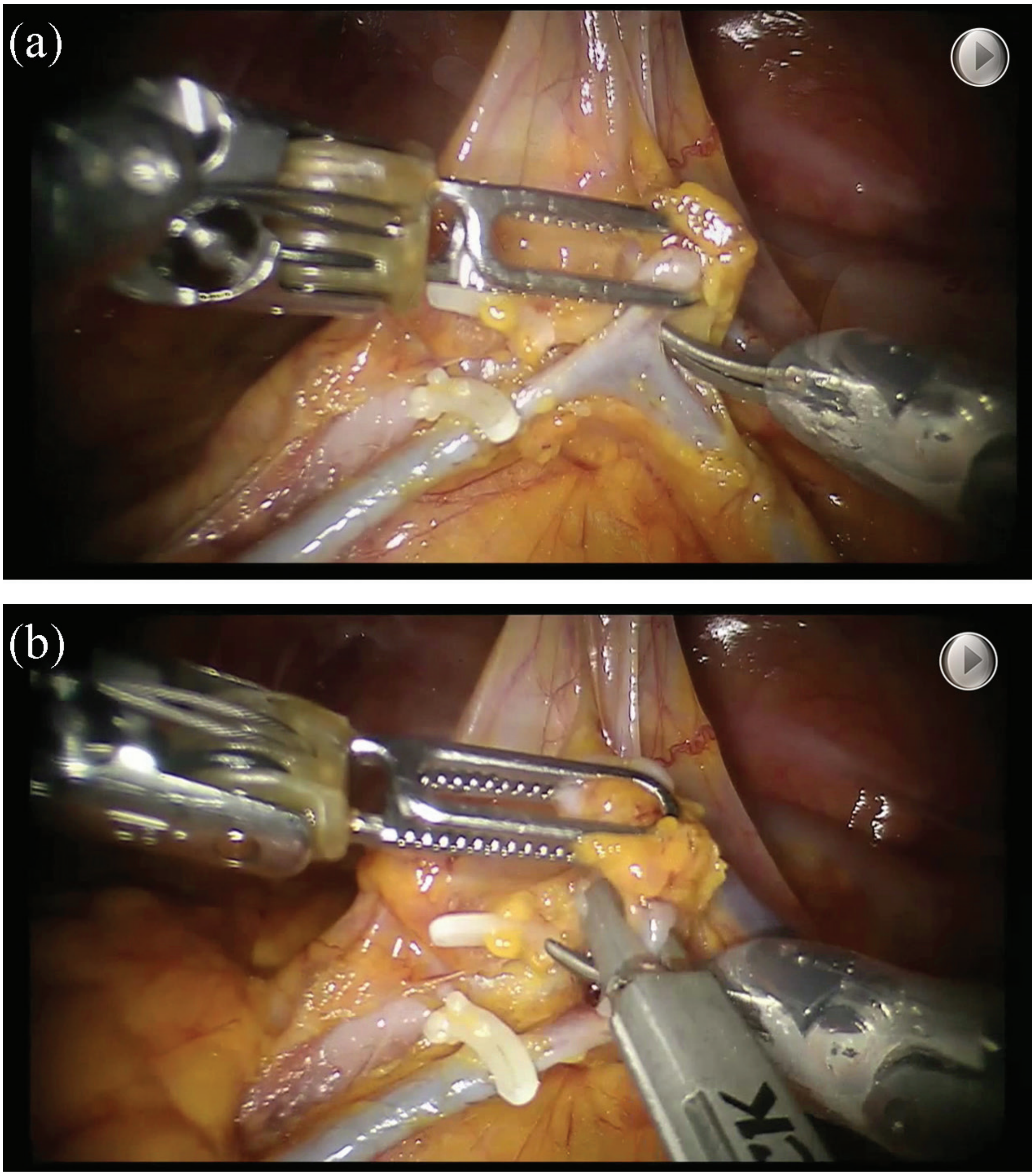

Figure 7. Vascular dissection. the LCV is identified and isolated between non-adsorbable clips, applied by the assistant or by the robotic clip applier on arm 1, and cut by the robotic scissors on arm 1. LCV, left colic vein.

of the left colic artery (LCA). An accurate lymphadenectomy of the origin of the IMA is performed. The LCA is isolated between non-adsorbable clips and cut by the assistant or by the robotic scissors on arm 1 (**Figure 9**).

The vascular dissection continues with the isolation of the left branches of the middle colic vessels (LMCV) (**Figure 10a**). The transverse mesocolon is pulled upward by the ProGrasp on arm 2,

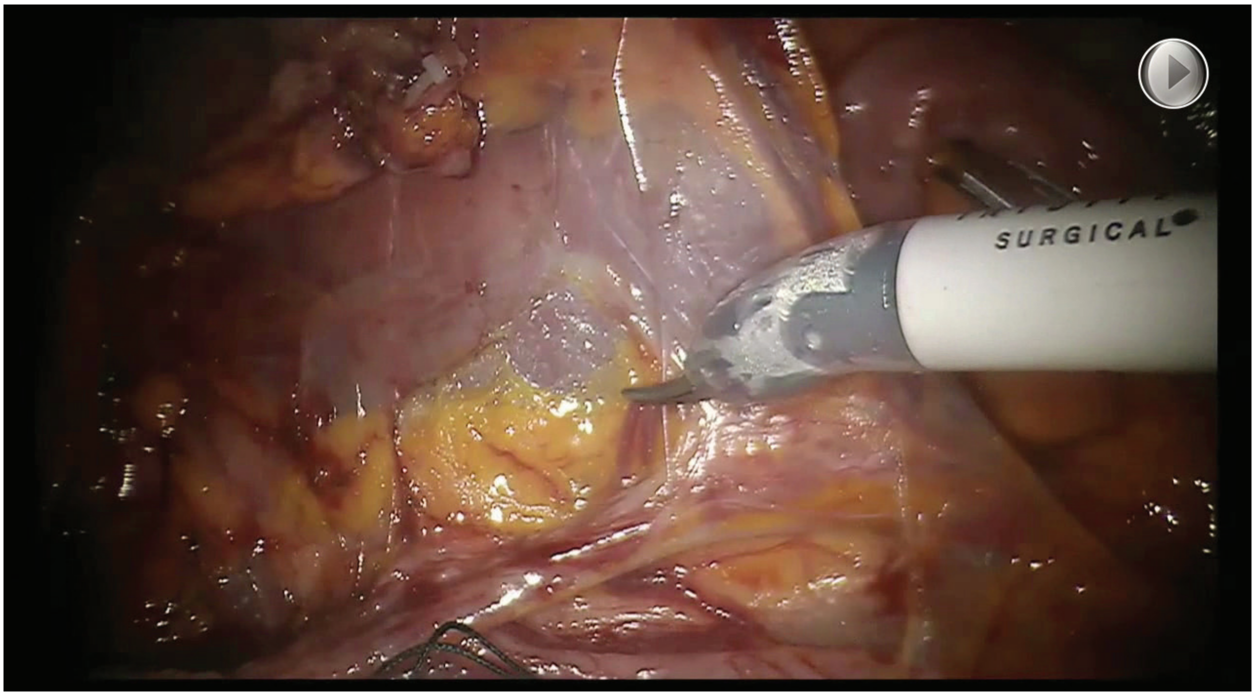

Figure 8. Mobilization of the sigmoid colon. The left gonadal vessels and ureter are preserved under Gerota's fascia.

and the identification of the main trunk of the middle colic vessels starts at its origin from the superior mesenteric vein (SMV), upward. The dissection is carried out by the robotic bipolar forceps on arm 3 and the robotic scissors on arm 1. After identification of the main trunk, the left branch is dissected and freed from the surrounding lymphatic and fatty tissue, and cut by the assistant or by the scissors on arm 1, after being isolated between clips, as well (**Figure 10b** and **c**).

Lymphadenectomy and vascular dissection have been completed.

2.4. Transverse and left colon transection, anastomosis

Once the mobilization of the splenic flexure and the vascular dissection are completed, the evaluation of the vascularization of the colon with ICG is performed to identify the correct site of transection (**Figure 11a**). After intravenous injection, in a time interval between 5 and 30 s, ICG reaches the arterial and venous vessels. The assistant, then, cut the transverse colon and the proximal sigmoid colon by a laparoscopic linear stapler (**Figure 11b**). A robotic linear stapler can be used if available on arm 1. A recheck of both the two colonic stumps is carried out to avoid postoperative risk of anastomotic or stumps dehiscence, mainly caused by tissue devascularization (**Figure 11c** and **d**). The specimen is inserted into an endobag for further removal. The two colonic stumps are approached. The robotic bipolar forceps on arm 3 holds the descending colon stump and a colotomy is performed at the level of the tenia, with the robotic scissors on arm 1, as well as for the transverse colon stump. The laparoscopic linear stapler is introduced into both the two colostomies while the surgeon at the console helps the introduction of the two branches of the stapler inside the colonic stumps with the robotic bipolar forceps on arm 3. A colocolic side-to-side antiperistaltic mechanical anastomosis is then

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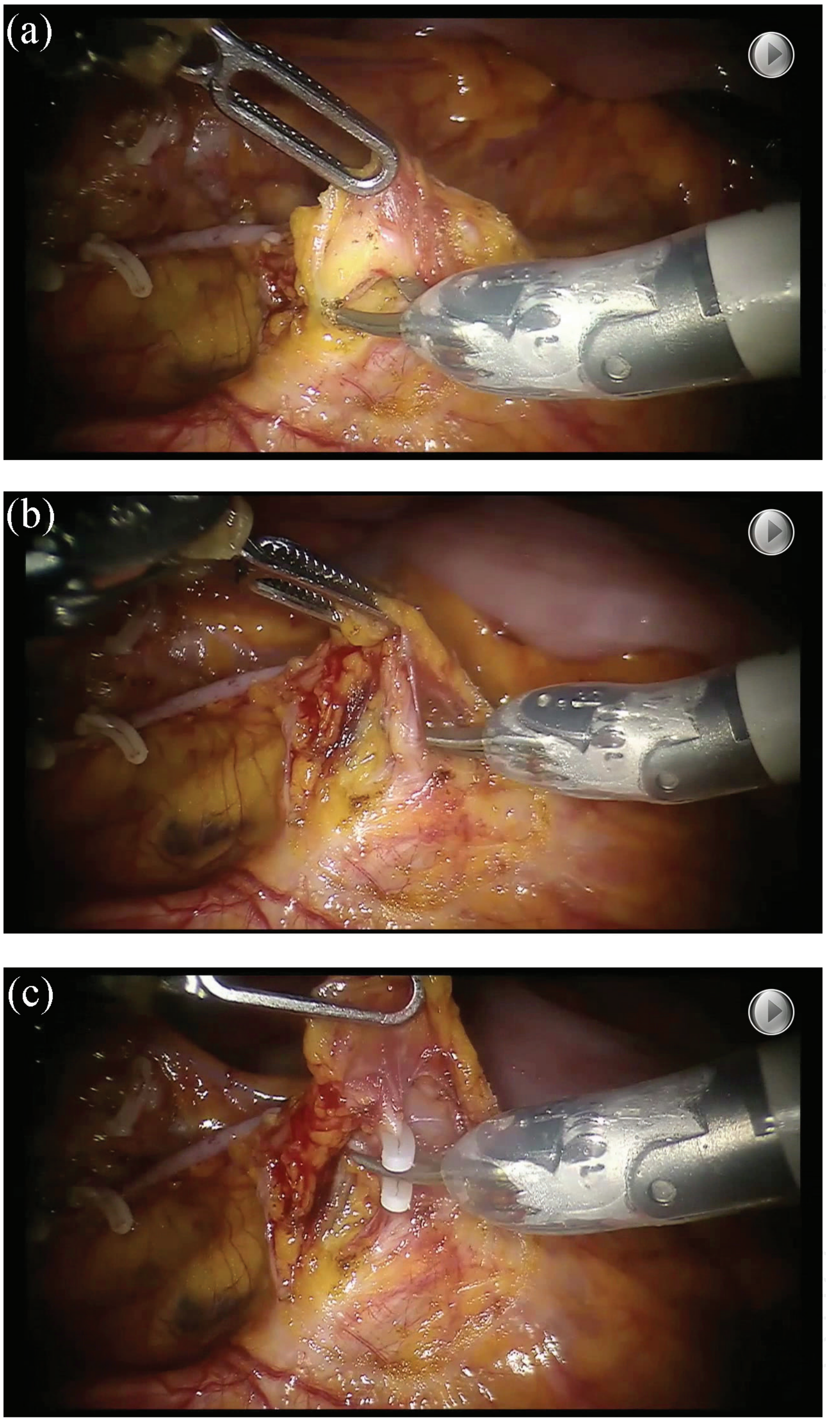

Figure 9. Vascular dissection. The LCA is isolated between non-adsorbable clips and cut by the robotic scissors on arm 1.

performed (**Figure 12**). The entry hole of the stapler is closed by two running barbed sutures starting from the opposite angles. The first running suture is performed from the inferior angle upward. The second suture is performed from the upper angle downward (**Figure 13a** and **b**). Afterwards, the robotic system is undocked and a Pfannenstiel incision is performed for specimen extraction.

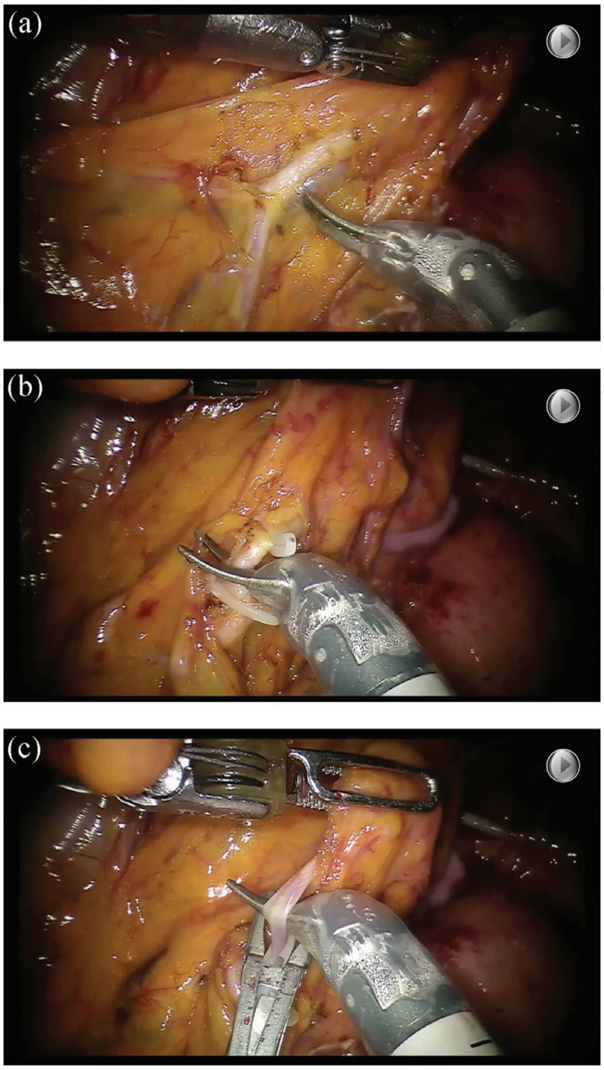

Figure 10. Vascular dissection. Identification of the left middle colic vessels (a), isolation between clips (b) and section (c).

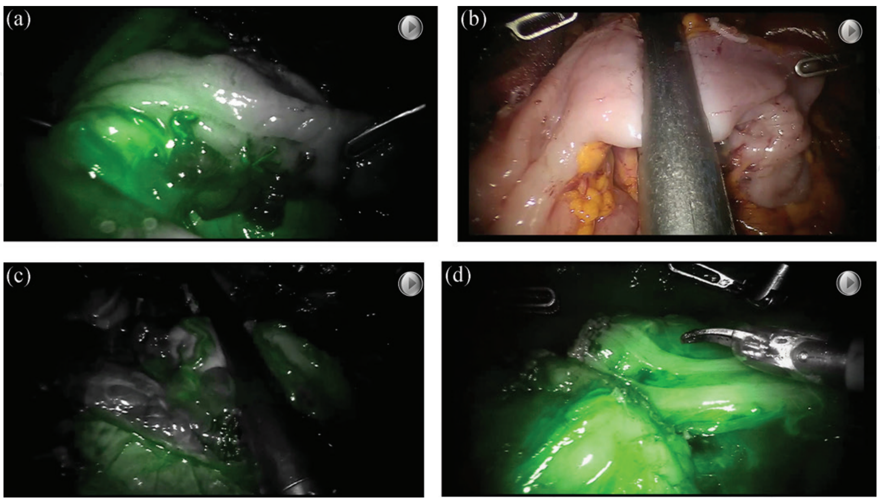

Figure 11. Evaluation of the vascularization of the colon with ICG (a), section of the colon (b), recheck of the two colonic stumps (c-d).

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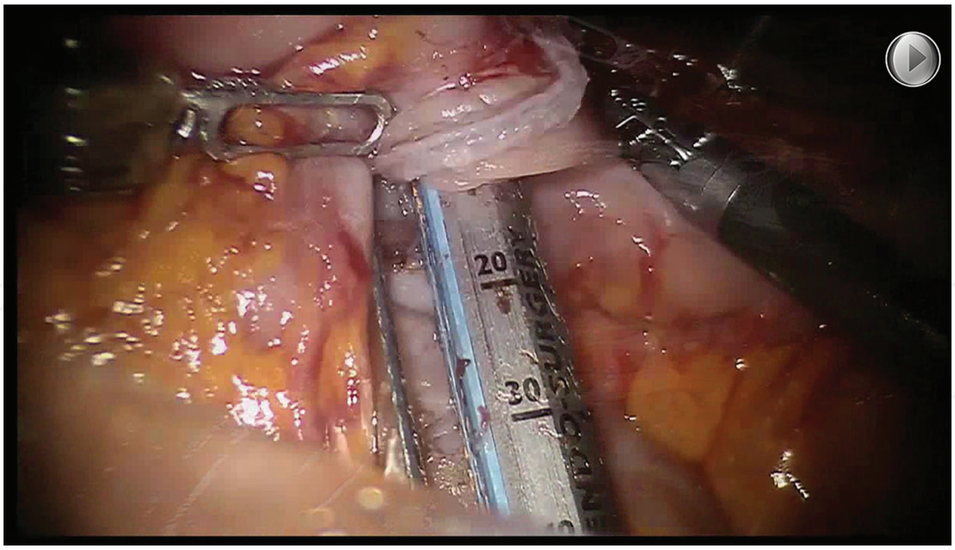

Figure 12. Fashioning of the colo-colic side-to-side mechanical anastomosis.

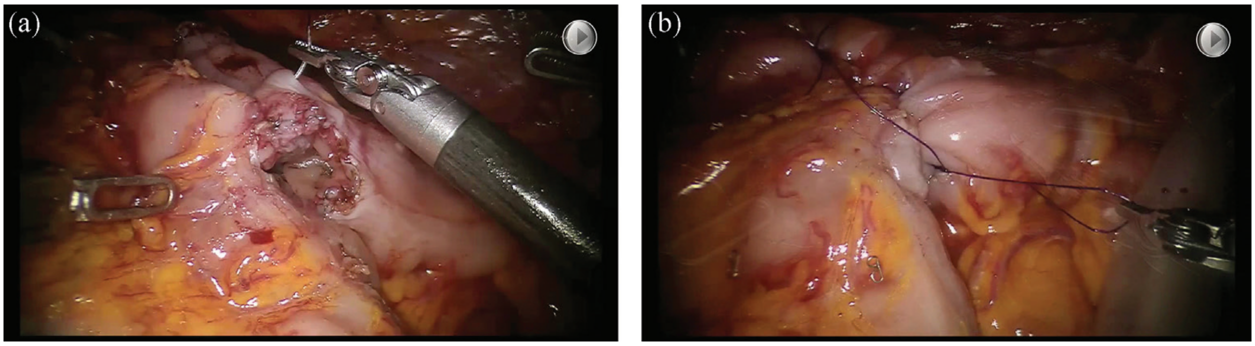

Figure 13. Closure of the entry hole.

3. Transverse colon resection

3.1. Patient positioning, robot docking, and operating theatre setup

3.1.1. Operative setting overview

Patient is placed in anti-Trendelenburg position with the arms along the trunk and the legs abducted. The robotic cart approaches the operative table from patient's head (**Figure 14**). The procedure is carried out with a five-trocar technique and begins with the insertion of the Veress needle in the left hypochondrium and the induction of a 12-mmHg pneumoperitoneum. The optical trocart is placed 2 cm right the umbilical scar. Three robotic trocarts are placed in the right (R2) and left (R1) hypochondrium 2–3 cm under the rib margin and in the right flank (R3) along the middle clavicular line 2 cm below the transverse umbilical line. A laparoscopic 12 mm trocart is inserted in the left flank along the middle clavicular line 2 cm

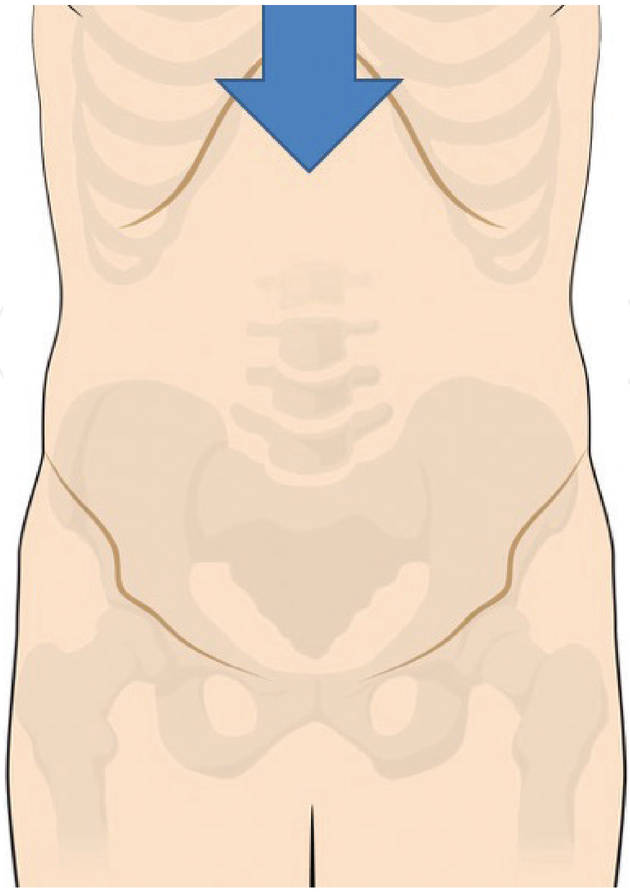

Figure 14. Direction of the docking of the robotic cart in transverse colon resection.

below the transverse umbilical line for the assistant. Arm 1 is connected to R1, arm 2 is connected to R3, and arm 3 is connected to R2. The complete trocarts and operating theatre setup are shown in **Figures 15** and **16**.

3.1.2. Robotic instruments and setting

As for splenic flexure procedure, robotic instruments used in transverse colon resection are bipolar fenestrated forceps, for coagulation and traction, the ProGrasp for traction and exposure, and robotic scissors for cutting and blunt dissection (when used with closed jaws). The robotic monopolar scissors are mounted on arm 1, the robotic bipolar fenestrated forceps on arm 2, and the ProGrasp on arm 3.

3.2. Vascular dissection and lymphadenectomy

3.2.1. Brief summary of the vascular and lymphatic drainage anatomy of the transverse colon

Transverse colon receives blood supply from the two main intestinal trunks: the superior mesenteric artery (SMA) and the IMA, via the middle colic arteries and the left colic artery, as well as the venous drainage is tributary of both the two vascular systems (SMV and IMV). Venous drainage, however, is especially variable and closely related to pancreatic and omental

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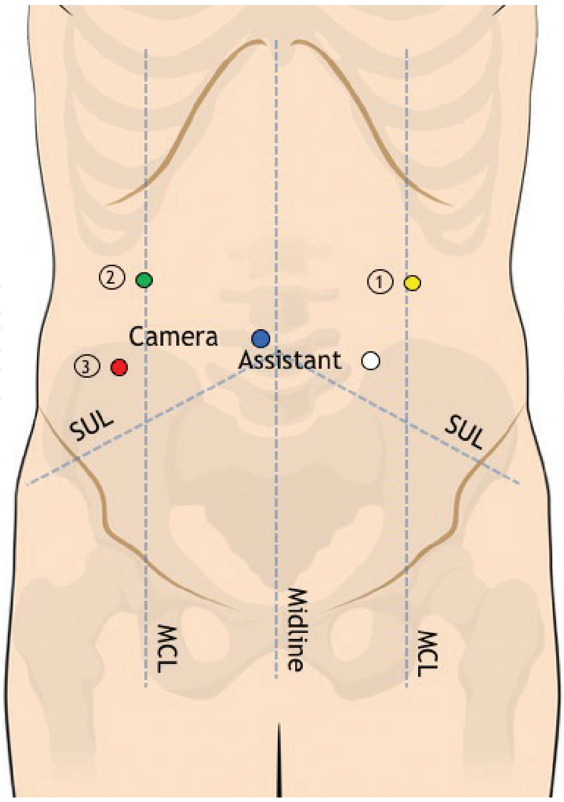

Figure 15. Trocarts position in transverse colon resection. SUL, spine-umbilical line; MCL, middle clavicular line.

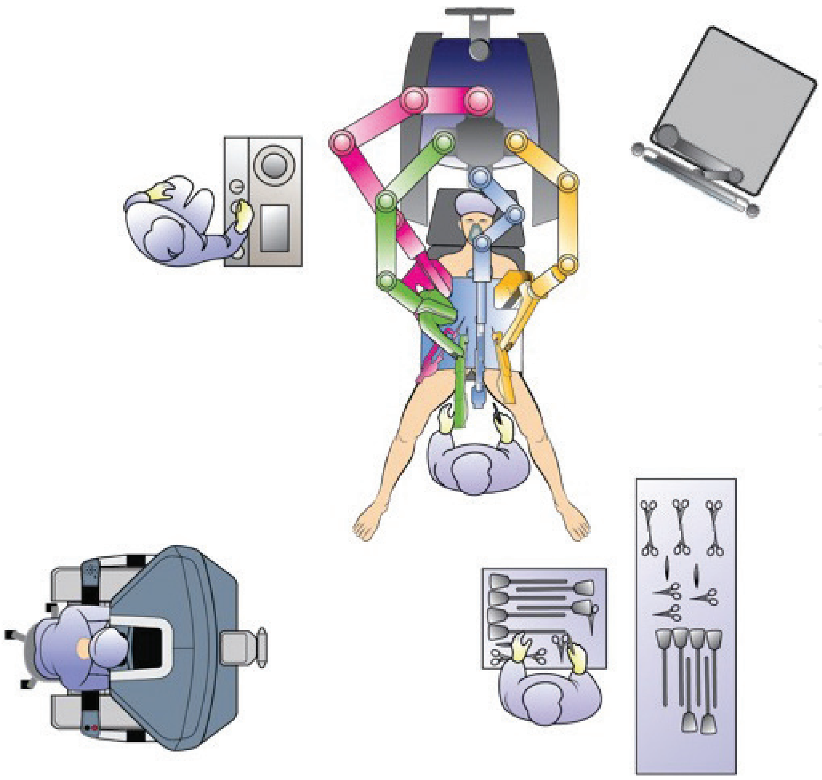

Figure 16. Operative theater setting.

veins, as for the close relationship of the transverse colon with the greater omentum, the pancreas, and the stomach. Even though locoregional lymphadenectomy of the root of the SMV and SMA is commonly considered oncologically adequate, some authors suggest exploring and dissecting lymph nodes of the infrapancreatic and gastroepiploic region.

3.2.2. Description of the vascular dissection

The first step of the procedure is the dissection of the gastrocolic ligament carried out by the robotic scissors on arm 1. The stomach is pulled up by the surgeon with the robotic ProGrasp on arm 3, and the transverse colon is pulled downward by the assistant. The dissection continues laterally to the sigmoid colon on the left side to the cecum on the right: the phrenicocolic and splenocolic ligament, and the parietocolic ligament are sectioned on the left; on the right, the gastrocolic ligament is dissected below the gastroepiploic vessels, performing a locoregional lymphadenectomy. The right colon is then retracted medially by the assistant and by the robotic ProGrasp on arm 3, and the dissection of the right parietocolic ligament is performed by the robotic scissors on arm 1. A blunt dissection is performed lateral-to-medial from both sides and over the pancreas till reaching the Treitz area and the origin of the middle colic vessels. Then, the transverse colon is pulled up by the robotic ProGrasp on arm 3, enhancing the main trunk of the middle colic vessels. The dissection of the root of the transverse mesocolon is completed toward the end of the pancreatic tail. The root of the main trunk of the middle colic vessels is clipped by the assistant or by the robotic clip applier and sectioned by the assistant or by the robotic scissors on arm 1, and the locoregional lymphadenectomy is carried out. The incision of the transverse mesocolon is performed by the robotic scissors, starting from the middle colic vessels straight to the flexure on both sides.

3.3. Transection of the transverse colon and anastomosis

The transection of the colon is performed by the assistant with a laparoscopic flexible stapler or by the surgeon with the robotic stapler on arm 1, and it includes both the two flexures. The left and the right colon are joined and a colotomy is carried out at the closed margin of both the two colonic stumps. The right colon is held by the surgeon with the ProGrasp on arm 2, the left colon by the assistant. A double running suture colocolic end-to-end anastomosis is performed with two needle-holders on arms 1 and 3. Afterward, the robotic system is undocked and a Pfannenstiel incision is performed for specimen extraction.

4. Generic considerations, technical review, and future perspectives

The role of minimally invasive surgery has been recently established in the colorectal field thanks to a series of randomized clinical trials that compared laparoscopic and open techniques. Their results definitely eliminated any doubts concerning the oncological adequacy of minimally invasive treatment. The spread of minimally invasive surgery may be also justified by the reduced postoperative pain, decreased hospital stay and faster postoperative recovery, reduced incidence of postoperative complications, improved cosmetic outcome, and decreased incidence of incisional hernias. Alongside these encouraging results, technologic innovations have been introduced in minimally invasive surgery. Robotic technique has spread worldwide thanks to its advantages over standard and advanced laparoscopy (three-dimensional (3D)). Several generic aspects of robotic assistance, such as three-dimensional view, better ergonomics, magnified vision, and articulated tips of the robotics instruments are reported to be significant technical advantages in colorectal surgery. Splenic flexure and transverse colon resections seem to be challenging procedures, which robotics may help with. Surgical approach of left flexure and transverse colon cancers is not standardized yet, due to the rare incidence of the flexure cancer and the technical difficulties of the latter. Left colic flexure cancers have an incidence ranging from about 3–10% of all colon cancers [7] and were initially correlated to a poor prognosis and a high risk of obstruction [8]. This correlation has been recently overcome by some studies showing comparable survival outcomes to those of other colonic cancers, and demonstrating that neither the splenic flexure site nor colonic obstruction has an independent influence on patient survival after surgery [8–10]. One of the aspects that remain controversial is the extension of lymphadenectomy [6, 11]. As previously reported, the classic pathways follow the main nourishing arterial trunks: the middle colic vessels, essentially the left branch, and the left colic artery. Some authors argue that lymphatic spread may follow the IMV and the IMA, thus requiring their ligation and a consequent standard left colectomy in order to achieve an oncologically adequate lymphadenectomy; aberrant metastatic pathways to the infrapancreatic lymph node region and the splenic hilum have been reported [12], even though no systematic data in the literature regarding the frequency of lymphatic drainage roots at this site have been clarified yet. Recently, indocyanine green fluorescent imaging (ICG) in colorectal cancer has been used to evaluate the blood flow, but there are few reports on the lymphatic flow [13–15]. Some authors conducted a study on the pattern of lymph flow for splenic flexure colon cancers with ICG on 31 consecutive patients [15]. The amount of ICG injected was 2.5 mg (1 mL of solution) into the subserosal-submucosal layer. The main lymphatic diffusion was observed through the IMV and LCA areas, with or without the presence of aberrant vascularization. The conclusion was that lymph node dissection of the root of the IMV area is important and it should be always performed, avoiding ligation of both the left middle colic artery (lt-MCA) and LCA, in those cases without widespread lymph node metastases. Unnecessary splenectomy is one of the main complications reported on laparoscopic studies for splenic flexure colon cancers, due to the anatomical relations between these two organs, and the characteristics of the laparoscopic instruments. Poor dexterity, instrument stiffness, and a limited range of motion make splenic flexure resection a challenging procedure, requiring also several modification of patient's position. Moreover, the use of 3D laparoscopy is controversial as it seems to fail showing any advantages in colonic resection or other more complex procedures, as it is in its infancy and further comparative studies are necessary to assert whether it can reduce learning curve [16–18]. Robotic assistance may help performing an accurate lymphadenectomy thanks to motion scaling, tremor filtering, 7-degrees of freedom and the 3D magnified view, avoiding unnecessary vessel ligation or inadverted injuries to the surrounding organs. These results suggest that robotic assistance, associated to ICG imaging, may introduce the concept of "tailored" surgery and can facilitate surgical resection of splenic flexure colon cancer. Further studies on lymph flow pattern may lead to a "standardization" of this procedure. Fluorescence was integrated into the da Vinci Si HD System (Intuitive Surgical, Sunnyvale, CA, USA) in 2010. The surgeon can quickly switch between normal viewing mode to fluorescence (near-infrared light) by pressing the pedal on the surgical console (**Figure 17**). Indocyanine green is a sterile, water-soluble protein-binding dye with low toxicity and fast biliary excretion. ICG fluorescence imaging system is a simple, safe, useful method and can be used in several fields of general surgery, particularly in oncologic surgery [13].

Laparoscopic transverse colon resection for middle cancers is a rare procedure as population suffering with it is too small. Moreover, transverse colectomy requires advanced laparoscopic surgical skills and, consequently, a longer learning curve than other colorectal procedures. Dissection of the middle colic vessels and locoregional lymphadenectomy are more challenging than in other laparoscopic colectomies as well as the complete mobilization of hepatic and splenic flexures, which is an essential step of transverse colectomy. Colic flexures takedown may help anastomosis fashioning; even though there is no statistical difference between the advantages of intracorporeal versus extracorporeal anastomosis, it is preferable to perform an intracorporeal colocolic end-to-end anastomosis because of some well-known advantages: better chance to choose the site of the minilaparotomy (suprapubic or median), especially in obese patients, low traction on the mesentery and avoidance of twisting of the mesentery [19–21]. Some authors argue that excessive mobilization of the colon, without the flexures

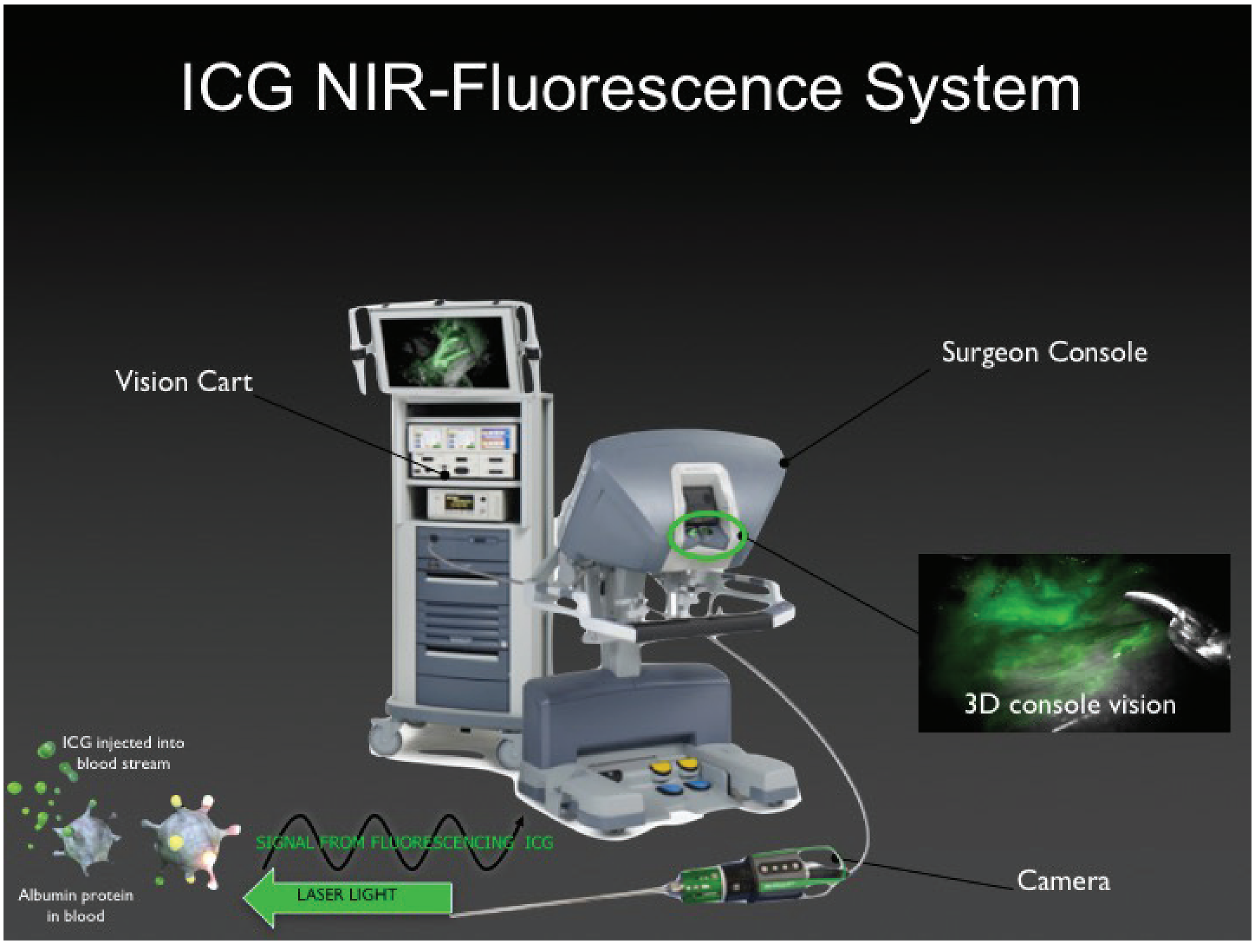

Figure 17. ICG NIR-Fluorescence System. Fluorescence was integrated into the da Vinci Si HD System (Intuitive Surgical, Sunnyvale, CA, USA) in 2010. The surgeon can quickly switch between normal viewing mode to fluorescence (near-infrared light) by pressing the pedal on the surgical console.

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takedown, can be avoided when adopting an intracorporeal anastomosis [22], but it can result in a unadverted traction on the anastomosis itself and a moderate risk of dehiscence in the postoperative, then, it is always preferable to take down both the two flexures even in an intracorporeal anastomosis. Robotic approach provides specific advantages in intracorporeal anastomosis sewing, thanks to the endo-wrist function and the stability of the robotic arms, thus reproducing all the steps as in open surgery, and the 3D magnified view. Initially, the lack of tactile sensation was considered a pitfall of the robotic system, and several studies of engineering are still ongoing in order to provide a tactile sensation by the robotic system. This aspect, however, was recently confuted as it was shown that visual feedback of an expert surgeon can successfully replace tactile sensation, without the need of a tactile-feedback device [23].

In conclusion, few cases have been reported on robotic splenic flexure and transverse colon resection, but robotic assistance seems to provide several advantages on performing these procedures. Further studies are necessary to assess the real role of robotics in the treatment of the splenic flexure and mid-transverse colon cancers.

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