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DYNAMIC MANUSCRIPT

A video guide of five access methods to the splenic flexure: the concept of the splenic flexure box

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Abstract

Aim The aim of this study was to describe all the possible approaches for laparoscopic splenic flexure mobilization (SFM), each suitable for specific situations, and create an illustrated system to show SFM approaches in an easy and practical way to make it easy to learn and teach.

Methods Two different phases. First part: Cadaver-based study of the colonic splenic flexure anatomy. In order to demonstrate the different approaches, a balloon was placed through the colonic hepatic flexure in the lesser sac without sectioning any of the fixing ligaments of the splenic flexure. Second part: A real case series of laparoscopic SFM.

Results First part: 11 cadavers were dissected. Five potential approaches to SFM were found: anterior, trans-omentum, lateral, medial infra-mesocolic, and medial trans-mesocolic. The illustrative system developed was named: Splenic Flexure "Box"(SFBox).

Second part: One of the types of SFM described in first part was used in five patients with colorectal cancer. Each laparoscopic approach to the splenic flexure was illustrated in a video accompanied by illustration aids delineating the access.

Conclusion With the cadaver dissection and subsequent demonstration in real-life laparoscopic surgery, we have shown five types of laparoscopic splenic flexure mobilization. The Splenic Flexure "Box" is a useful way to learn and teach this surgical maneuver.

Keywords Surgical anatomic · Colorectal cancer · Laparoscopy · Splenic flexure · Colon · Human anatomy

The splenic flexure mobilization (SFM) is one of the fundamental surgical steps in colorectal surgery. Embryological development of the abdominal cavity results in the fixation of the splenic flexure of the colon to different neighboring structures, and this can make its surgical mobilization difficult [1]. Laparoscopic SFM can carry a high risk of intraoperative complications such as splenic bleeding or pancreatic injury [2].

To date, three types of laparoscopic SFM have been described, defined by the anatomic trajectory used to access the lesser omental sac: an anterior approach (between the omentum and the transverse colon), lateral (through the greater omentum *on his lateral side or omental bursa*), and medial approach (between the transverse colon and the pancreas) [3]. However, there is still a controversy in the literature on the technical details of each approach, and which should be the first choice. Most authors stress that this surgical area is technically challenging, and how proper

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understanding of the area is needed to avoid the risk of intraoperative complications [4].

The aim of this study was to describe all the possible approaches for laparoscopic SFM, each suitable for specific situations, and provide a clear illustrative design of the surgical anatomy to make the SFM easy to learn and to teach.

Materials and methods

The current research was carried out in two different phases. The first part consisted of a cadaver-based study of the colonic splenic flexure anatomy, and the second part consisted of a real case series of laparoscopic SFM performed in a tertiary center with a multidisciplinary colorectal team during a 6-month period (September 2018–February 2019).

First phase

The anatomical phase of the study was performed in collaboration with the Department of Anatomy and Embryology of the University of Valencia. Cadavers were obtained through strict body donation legislation and regulations, which is subject to the Spanish National law. An ethics report was requested from the corresponding department of the University of Valencia, resolving that it was not necessary.

Cadavers were embalmed with a formalin solution injected into the carotid artery and drained from the jugular vein, and then preserved at 4 °C. Cadavers from subjects with previous abdominal diseases or abdominal surgery were excluded.

Dissections were carried out by two colorectal surgeons with expertise in applied human anatomy (AGG, GP) supervised by a human anatomist (AVN). Videos and pictures were taken throughout the dissections.

Method of dissection

Dissection of the different ligaments fixating the splenic flexure. Demonstration of the different ways of approaching the lesser sac and to perform the SFM: In order to demonstrate the different approaches, a balloon was placed in the lesser sac without sectioning any of the fixing ligaments of the splenic flexure or the descending colon. The balloon was placed through an anatomical access to lesser sac at the right side of middle colic vessels after the mobilization of the hepatic flexure of the colon (Fig. 1). Each of the approaches was recorded on video. Based on these dissections, a schematic and illustrated system was created to show the different laparoscopic SFM approaches in an easy and practical way.

Second phase

Confirmation in real cases of oncological colorectal surgery of the different types of SFM described in the first phase: The decision for surgery was taken in a multidisciplinary tumor board. All patients signed an informed consent form for the surgical intervention and laparoscopic approach. All operations were performed by the same surgeon (AGG). In each operation, one of the types of approach to the lesser sac described in the first phase was used. The decision to use one of the types of approaches was taken *prior to surgery depending on the location of the tumor or* intraoperatively by the surgeon (AGG) based on the anatomical characteristics of the patient in order to reduce the risk of intraoperative complications. To demonstrate the different approaches to the lesser sac, a gauze was placed in the lesser sac after access was achieved using one of the approaches. After this, the lesser sac was opened again through other ligament to show the previously placed gauze. Subsequently, the rest of fixating ligaments of the splenic flexure were cut to complete the SFM. Each operation was recorded and saved for further editing.

Results

First phase

Eleven cadavers were dissected, eight embalmed in formalin and three fresh cadavers. The different ligaments that need to be dissected and cut to achieve a complete SFM are described [5] (Fig. 2).

- Phrenicocolic ligament: attachment of the parietal peritoneum to the visceral peritoneum of the descending colon and splenic flexure of the colon.
- Gastrocolic ligament: attachments of the greater omentum to the cranial side of the transverse colon and splenic flexure of the colon.
- Splenocolic ligament: part of the greater omentum that keeps the spleen and the splenic flexure of the colon together. This anatomical area is also known as the omental bursa.
- Pancreatocolic ligament: attachments of the transverse mesocolon to the body and tail of the pancreas.

We observed that in order to obtain a complete mobilization of the splenic flexure, the inferior mesenteric vein (IMV) should be ligated at the inferior border of the pancreas.

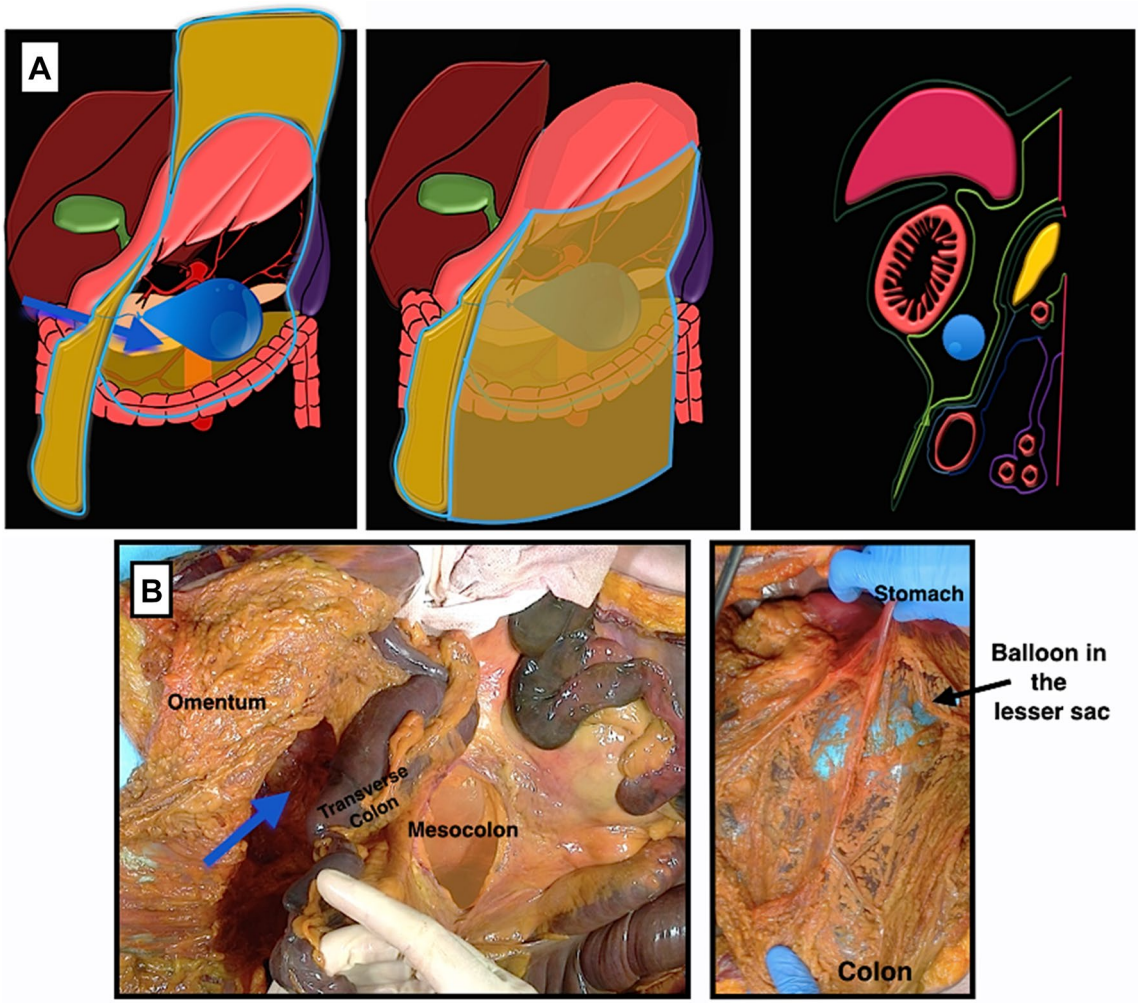

Fig. 1 **A** In order to demonstrate the different approaches, a balloon was placed in the lesser sac without sectioning any of the fixing ligaments of the splenic flexure or the descending colon. **B** The balloon was placed through an anatomical access to lesser sac at the right side of middle colic vessels after the mobilization of the hepatic flexure of the colon

Splenic Flexure "Box" model of surgical anatomy: (Figs. 3, 4) (Video 1)

Figure 3 shows an illustrative diagram of the anatomy of the splenic flexure and the possible maneuvers to perform a SFM. To simplify the learning and teaching of the different alternatives, we propose the concept of the Splenic Flexure "Box" (SFBox).

The anatomic area of the splenic flexure of the colon and its attachments to neighboring structures is represented as a box. The inside of the box contains the body and tail of the pancreas. The frame of the box is made up by the distal part of the transverse colon and the proximal descending colon. The medial lid of the box is the transverse mesocolon located to the left of the middle colic vessels. The anterior lid of the box is the greater omentum. The lateral lid of the box is the omental bursa. The box is attached to the parietal peritoneum by the phrenicocolic ligament.

Five types of anatomical access to the lesser sac were found, *depending on which ligament was sectioned the first*, and therefore, five potential approaches to SFM (Fig. 4) (Video 2):

- Anterior approach: Sectioning the gastrocolic ligament.
- Trans-omentum anterior approach: Direct sectioning of the greater omentum.
- Lateral: Sectioning the omental bursa.
- Infra-mesocolic medial approach: Access to the lesser sac right on top of the inferior border of the pancreas without opening the transverse mesocolon.
- Trans-mesocolic medial approach: Direct sectioning of the transverse mesocolon on the left side of the middle colic vessels.

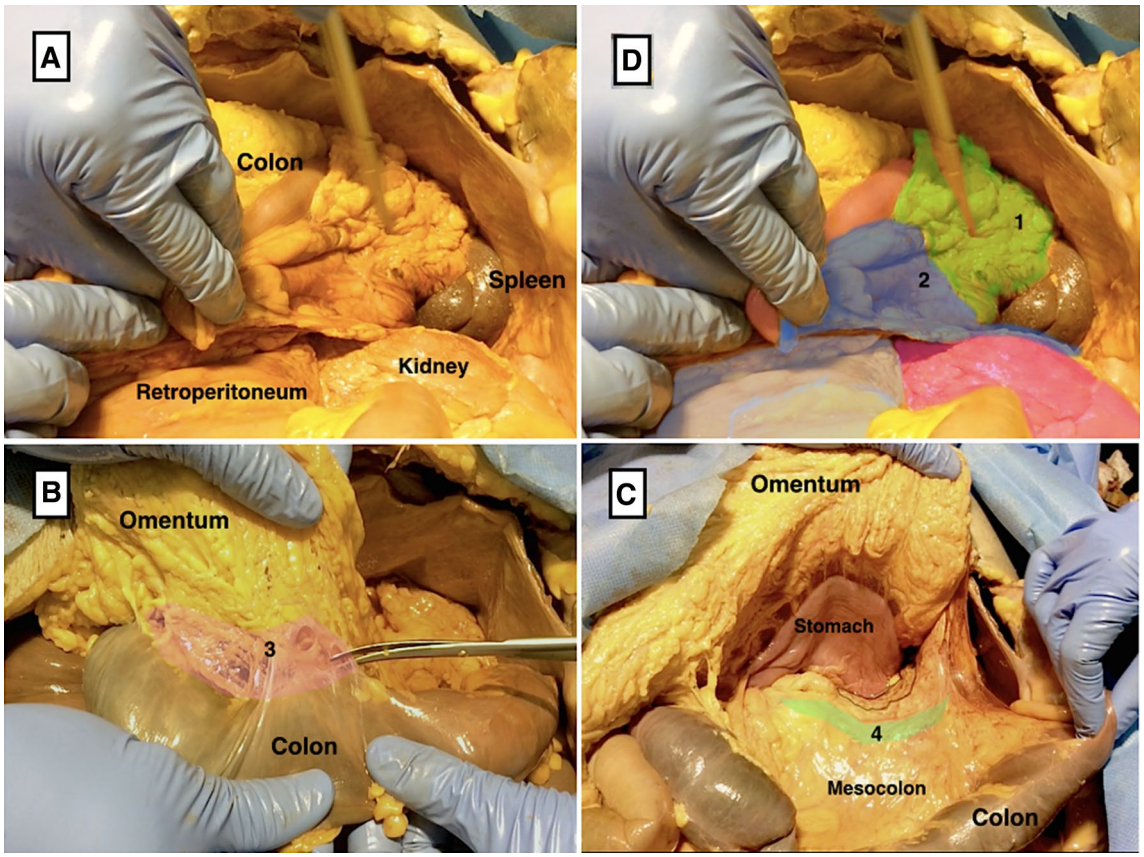

Fig. 2 The different ligaments that need to be dissected and cut to achieve a complete SFM are described. (1) Splenocolic ligament, (2) Phrenicocolic ligament, (3) Gastrocolic ligament, (4) Pancreatocolic ligament. **A** Anatomical structures. **B**, **C**, **D** Differents ligaments showed

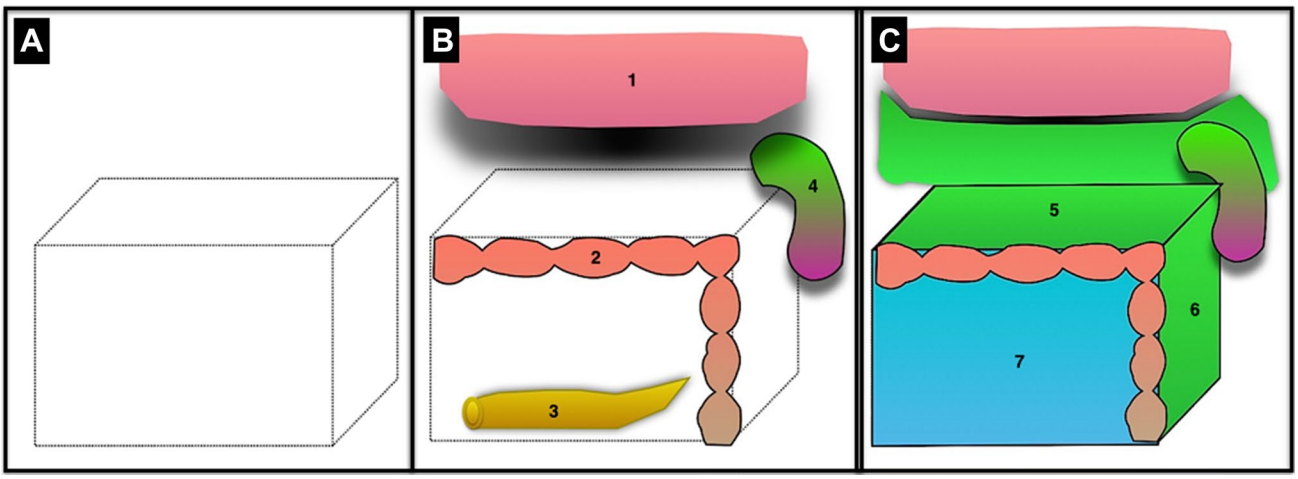

Fig. 3 Splenic Flexure "Box": Illustrative diagram of the anatomy of the splenic flexure to simplify the learning and teaching of the different alternatives of mobilization. (1) Stomach, (2) Colon, (3) Pancreas, (4) Spleen, (5) Greater omentum, (6) Omental bursa, (7) Transverse mesocolon. **A** Box. **B** Box with landmarks. **C** Completed SF Box

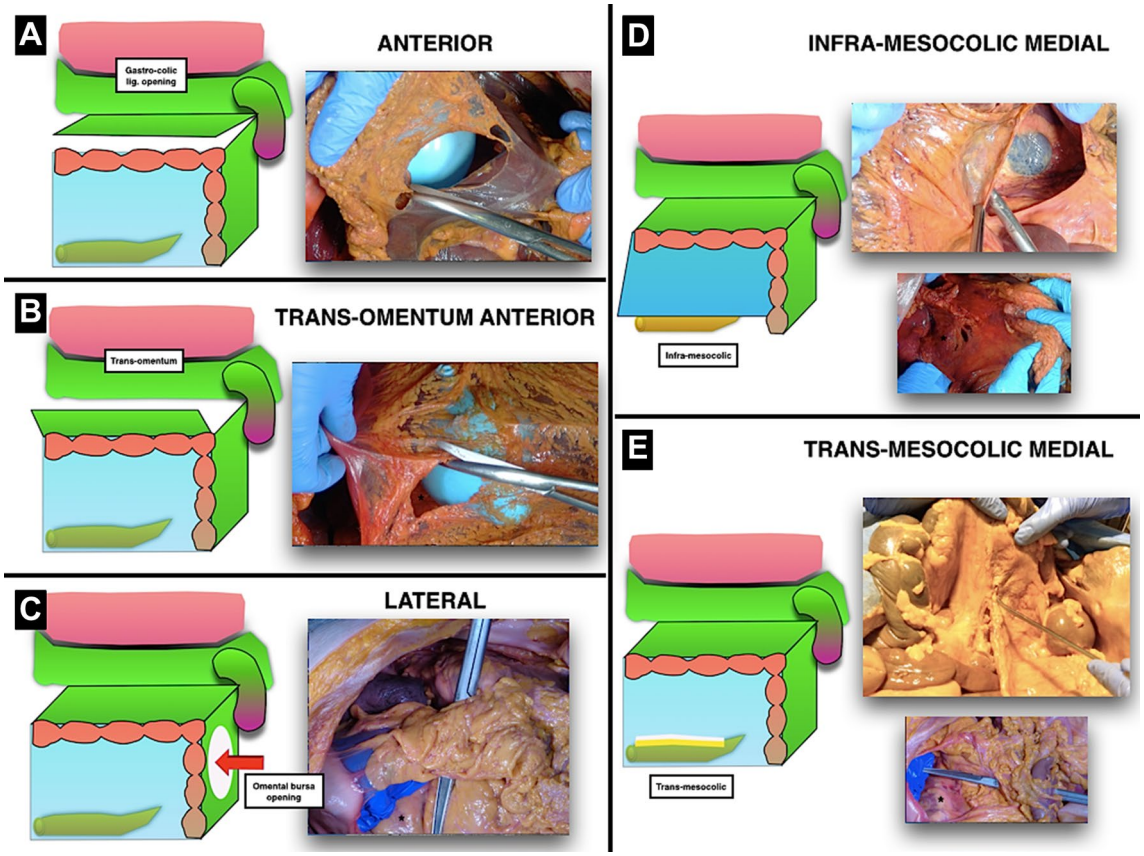

Fig. 4 Five types of anatomical access to the lesser sac were found. **A** *Anterior approach*: Sectioning the gastrocolic ligament, **B** *Trans-omentum anterior approach*: Direct sectioning of the greater omentum, **C** *Lateral*: Sectioning the omental bursa, **D** *Infra-mesocolic medial approach*: Access to the lesser sac right on top of the inferior border of the pancreas without opening the transverse mesocolon and **E** *Trans-mesocolic medial approach*: Direct sectioning of the transverse mesocolon on the left side of the middle colic vessels

Second phase

Five patients with colorectal cancer were operated on using a laparoscopic approach. One of the types of SFM described in the first phase was used in each case. (Video 3).

The first step of SFM in all cases was sectioning the phrenicocolic ligament. SFBox: Detaching the box without opening it. (Fig. 5).

The second step was insufflating the pneumoperitoneum into the SFBox by one of the five types of SFM described in the first phase. This is what will determine the type of SFM.

Finally, the mobilization was completed by cutting the rest of the attachments of the splenic flexure of the colon.

Ligation of the IMV was performed at different points according to the surgeon´s choice and did not directly influence the type of approach selected.

Anterior Laparoscopic SFM (Fig. 6A) (Video 3)

Male patient with a T2N0M0 lower third rectal cancer. A low anterior resection was performed with the aim of achieving a tension-free anastomosis.

Approach: access to the lesser sac after sectioning the gastrocolic ligament.

SFBox: Opening of the box after lifting the anterior lid.

Operative time for SFM was 35 min. No intra- or postoperative complications during SFM occurred.

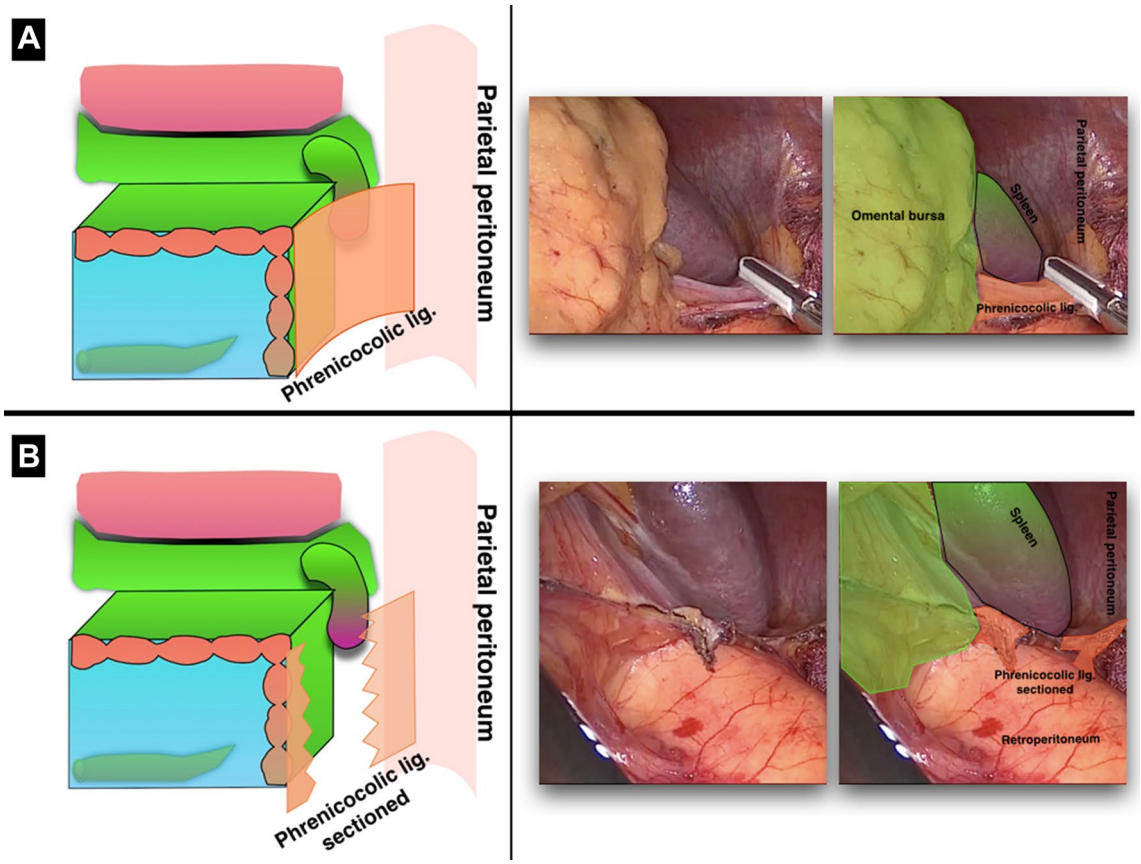

Fig. 5 The phrenicocolic ligament. **A** The box is attached to the parietal peritoneum by the phrenicocolic ligament. **B** The first step of SFM in all cases was sectioning the phrenicocolic ligament

Trans-omentum anterior laparoscopic SFM (Fig. 6B) (Video 3)

Male patient with a T4N + M0 colon cancer located at the splenic flexure. A segmental colonic resection was performed with a complete mesocolic excision.

Approach: Access to the lesser sac after a direct opening of the greater omentum including the gastroepiploic arcade and the greater omentum in the surgical specimen.

SFBox: Opening of the box directly through the anterior lid.

Operative time for SFM was 80 min. No intra- or postoperative complications occurred.

Lateral laparoscopic SFM (Fig. 6C) (Video 3)

Patient with a T3N1M0 middle third rectal cancer operated on after receiving neoadjuvant chemoradiation. A low anterior resection was performed with the aim of achieving a tension-free anastomosis.

Approach: Access to the omental lesser sac after opening the omental bursa. A gauze was left in the lesser sac. Subsequently the gastrocolic ligament was cut and the gauze can be seen.

SFBox: Opening of the box directly through the lateral lid.

Operating time for SFM was 60 min. No intra- or postoperative complications occurred.

Infra-mesocolic medial laparoscopic SFM (Fig. 6D) (Video 3)

Patient with a T3N + M0 middle third rectal cancer operated on after receiving neoadjuvant chemoradiation. A low anterior resection was performed with the aim of achieving a tension-free anastomosis.

Approach: Access to the lesser sac above the inferior border of the pancreas without opening the transverse mesocolon. A gauze was left in the lesser sac. Subsequently the gastrocolic ligament was cut and the gauze can be seen.

SFBox: Opening of the box by lifting the medial lid.

Operative time for SFM was 44 min. No intra- or postoperative complications occurred.

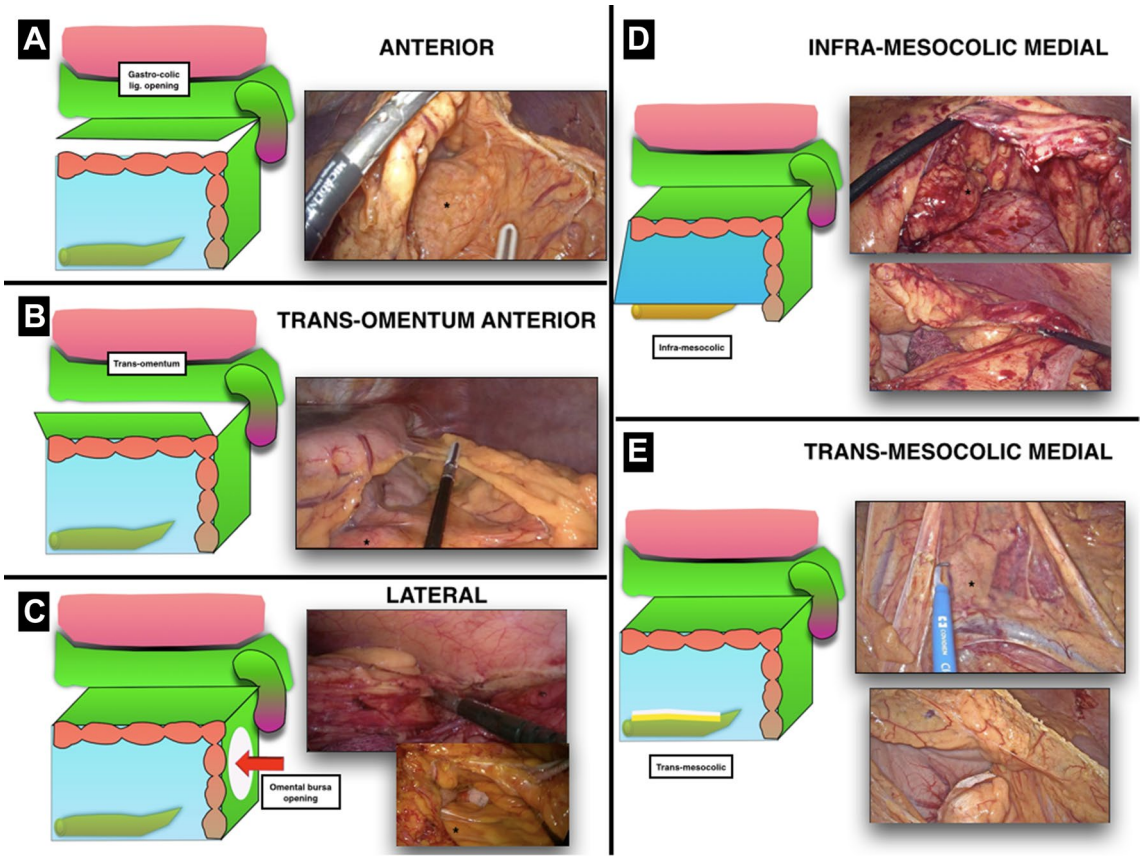

Fig. 6 Confirmation in real laparoscopic procedures for the different types of splenic flexure mobilization described in Figure 4. **A** *Anterior approach*: Opening of the box after lifting the anterior lid, **B** *Trans-omentum anterior approach*: Opening of the box directly through the anterior lid, **C** *Lateral*: Opening of the box directly through the lateral lid, **D** *Infra-mesocolic medial approach*: Opening of the box by lifting the medial lid and **E** *Trans-mesocolic medial approach*: Opening of the box directly through the medial lid

Trans-mesocolic medial Laparoscopic SFM (Fig. 6E) (Video 3)

Patient with a T2N0M0 upper third rectal cancer. A low anterior resection was performed with the aim of achieving a tension-free anastomosis.

Approach: access to the lesser sac after direct section of the transverse mesocolon below the Drummond marginal arcade and above the inferior border of the pancreas. A gauze was left in the lesser sac. Subsequently the gastrocolic ligament was cut and the gauze can be seen.

SFBox: Opening of the box directly through the medial lid.

Operative time for SFM was 52 min. No intra- or postoperative complications occurred.

Discussion

In the present study, we show five different ways to perform laparoscopic SFM using a cadaver model demonstration and subsequent real-life demonstration in surgery; each type of SFM could be used in determined circumstances.

A laparoscopic SFM is necessary when the tumor is located in this anatomical area and in many cases can also be necessary after rectal resection to achieve a tension-free anastomosis.[6]. In cases of inflammatory bowel disease, it is performed during total colectomy.

The increasing focus on surgical technique as an independent variable in the outcome of cancer surgery

highlights the need for detailed knowledge of the underlying anatomy [4].

SFM is one of the most demanding surgical maneuvers in colorectal surgery, and the learning curve can be steep because of the complexity of the anatomical area and the possibility of intraoperative complications such as splenic or pancreatic injury [7].

Complete SFM includes division of the splenocolic and phrenicocolic ligaments (partial mobilization) in addition to division of the gastrocolic and pancreato-mesocolic attachments [8].

The inferior mesenteric vein (VMI) should always be ligated close to the inferior border of the pancreas, regardless of the reason to perform SFM. The timing of the ligation does not influence the type of SFM performed. It has been shown that when the aim is to achieve a tension-free colorectal or coloanal anastomosis, there is a 10–12 cm difference when the IMV has been ligated during the SFM [9].

Three types of laparoscopic SFM have been described: anterior, lateral, and medial. This classification depends on the anatomic route chosen to access the lesser sac [10].

At this point, the introduction of the pneumoperitoneum causes the virtual embryological space to turn into a real space. This space reminds us of a box, and this is why we chose the term SFBox. In our opinion, *first ligament cut to* access to the SFBox is what should give the name to the type of splenic flexure mobilization. After entering the box, SFM is completed by cutting all attachments of the splenic flexure.

This model could clarify the controversy among colorectal surgeons regarding the type of splenic flexure mobilization used. It also facilitates communication between the trainer surgeon and the trainee.

In the anterior approach, the gastrocolic ligament, the embryological attachments between the greater omentum and the transverse colon, should be cut. In the lateral approach, the omental bursa is directly opened; and in the medial approach, the access to the lesser sac is performed through the transverse mesocolon just above the inferior border of the pancreas.

Benseler et al. found a lower rate of intraoperative complications and a shorter hospital stay when the anterior approach was used. The authors suggest that this could be due to a better visualization of the pancreas and spleen using this approach [3]. *For this reason, we do not recommend lateral approach as first choice.*

In the cadaver dissection, we show that the anterior approach can also be performed directly through the greater omentum; we call this access the anterior trans-omentum approach. This approach could be used in colonic tumors located at the splenic flexure. These tumors present an incidence of omental implants of up to 15%, and therefore this part of the omentum should be included in the surgical specimen. Furthermore, they present an incidence of affected lymph nodes in the gastroepiploic arcade of up to 25%. These lymph nodes should also be included in the specimen [11].

This approach should not be used in cases where the aim is a tension-free colorectal or coloanal anastomosis, because part of the ischemic omentum could stay attached to the splenic flexure. This could cause necrosis, infection, and may result in a post-operative intraabdominal abscess.

Several authors defend the medial approach as the first-choice approach, as it seems to reduce the probability of injury of other peritoneal structures [12]. The medial approach is based on access to the lesser sac through the avascular space located between the pericolic vascular arcade (marginal or Drummond's arcade) and the inferior border of the pancreas [13]. However, as we show in the present study, this approach can be performed in two different ways. If the splenic flexure mesocolon needs to remain intact, the access can be underneath the mesocolon; we call this the undermesocolic medial approach. This approach should be used when a complete mesocolic excision of the splenic flexure mesocolon is indicated, in colon cancers located in this area [14, 15]. The other type of medial approach described is the trans-mesocolic approach. A direct incision in the transverse mesocolon allows access to the lesser sac. This approach could be used when the aim of the SFM is to achieve a tension-free colorectal or coloanal anastomosis after proctectomy for rectal cancer. When performing either of these medial approaches, it is important to remember the possibility of Moskowitz artery that connects the proximal portion of the middle colic artery with the left colic artery. It is present in 10% of patients and it is located just above the inferior border of the pancreas. When present, it can make the medial approach more difficult and increase the risk of intraoperative bleeding [13]. Some authors recommend not using the medial approach in obese patients due to the risk of injury to the marginal arcade [12], or in patients with a prior history of acute pancreatitis [15]. On the other hand, it seems that entering the lesser sac from medial aspect is especially helpful in robotic surgery since patient repositioning is not possible once robot is docked [16].

In the study published by Benseler et al., the authors concluded that the lateral approach presented a longer operating time and a higher risk of bleeding. As we found in the present study, this could be due to the need to enter into the lesser sac through the omental bursa, which has an important vascularization through connections between the short gastric vessels and the splenic hilum. It also seems contraindicated in patients with important attachments between the colon and the spleen [3].

Many prior articles have studied the risk of injury to the neighboring structures such as the spleen and the pancreas

during SFM, in an attempt to facilitate training of digestive surgeons. A survey of colorectal surgeons revealed that they scored the highest difficulty degrees for laparoscopic colorectal procedures requiring SF mobilization [1].

The difficulty of this anatomical area is related to its embryological development. The fascial composition between the stomach and the transverse colon is complex. In this area, the omentum consists of the dorsal mesentery, and the fourth sheet of the dorsal mesentery forms the fusion fascia with the ventral mesocolon of the transverse colon during fetal life. It is therefore necessary to understand the fascial relationships between the transverse colon, diaphragm, and spleen [5].

Multivariate analysis demonstrated that operating room times are longer and superficial surgical site infections are more common when the splenic flexure is mobilized. This highlights the importance of performing a safe SFM [17].

In the present study, we propose a novel and easy way to learn and teach SFM, using a "box" analogy. This "box" is attached to the parietal peritoneum by the colophrenic ligament. As we show in the study, this ligament is made up of the left parietocolic ligament in the splenic flexure. It is formed by the fusion of the visceral peritoneum of the colon and the parietal peritoneum and reaches from the rectosigmoid junction to the splenic flexure. In our diagram, once this ligament is cut, the "box" would be freed, and we propose that it should be the first maneuver in SFM.

The lesser sac is a virtual space that can be converted to a "box" once the laparoscopic pneumoperitoneum enters into it. Access to the "box" can be performed through three of its sides: anterior, lateral, and medial. Once the pneumoperitoneum enters the EF "box", the rest of the attachments should be cut. Many authors [3, 12], with whom we agree, state that in reality a "mixed" approach is always used. It is therefore very important to be familiar with all the different variations, and be able to individualize the type of SFM needed for each patient.

Summarizing the indications of each kind of SFM, if the main aim is to get a tension-free anastomosis for rectal cancer, we recommend anterior or both medial approaches. In obese patients or in those with previous pancreatitis, we would discourage medial SFM. For those cancers located at the splenic flexure, medial infra-mesocolic or anterior transomentum approach should be the first choice, because complete excision of the SF mesocolon and omentum is required. Lastly, we would not recommend lateral approach as first choice because of higher risk of complications, leaving it as a last recourse.

In conclusion, with the cadaver dissection and subsequent demonstration in real-life laparoscopic surgery, we have shown five types of laparoscopic splenic flexure mobilization. The Splenic Flexure "Box" is a useful way to learn and teach this surgical maneuver.

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Compliance with ethical standards

Disclosures Alvaro Garcia-Granero, Vicent Primo Romaguera, Monica Millan, Gianluca Pellino, Delfina Fletcher-Sanfeliu, Matteo Frasson, Blas Flor-Lorente, Noelia Ibañez-Canovas, Omar Carreño Saenz, Luis Sanchez-Guillen, Jorge Sancho Muriel, Eduardo Alvarez Sarrado, Alfonso A. Valverde-Navarro have no conflict of interest or financial ties to disclose.

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