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Complete Splenic Flexure Mobilization. Cadaver Based Simulation Applied to Surgical Approach

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ABSTRACT
Introduction: *Complete splenic flexure (SF) mobilization is a complex technique with a steep learning curve.*
Methods: *An anatomic study of the SF and its different approaches was conducted on a cadaver-based simulated model. Surgical technique with laparoscopic medial approach is shown.*
Results: *Five different approaches were identified: anterior trans-omental, anterior, lateral, medial infra-mesocolic and medial trans-mesocolic approach. Fixating ligaments, SF vascular anatomy and main anatomic relationships are described.*
Discussion: *Surgeons must know the anatomy, relationships and approaches to the SF. With cadaveric simulation we were able to reproduce a previously validated teaching and training model to achieve a complete SF mobilization.*
Conclusions: *Cadaver-based simulated model of complete SF mobilization is a helpful tool applied to surgical practice.*

Keywords: *Splenic Flexure; Complete Mobilization; Surgical Approach*

INTRODUCTION

The splenic flexure (SF) of the colon is an area of special anatomical complexity as a consequence of embryological development.[1] Its surgical approach constitutes one of the most challenging situations that occur in colorectal surgery, particularly due to the risk of pancreatic and/or splenic injury.[2]

Its mobilization can be partial or complete, depending on the pathology to be treated. In this case we will refer only to situations that require complete mobilization, either to remove an oncological pathology at that location, or to achieve a tension-free colorectal or coloanal anastomosis.[3]

Classically, 3 approaches have been described to mobilize the SF (anterior, medial and lateral), according to the access to the lesser sac or bursa omentalis.[4] Recently, García-Granero et al.[5] postulate 5 possible approaches based on some modifications to those mentioned above. In Uruguay, one of the main contributions to the knowledge of this anatomical region and its implications in the treatment of neoplastic pathology was made by Dr. Luis Praderi.[6]

All colorectal surgeons should know and be able to teach these technical alternatives, regardless of whether an open or laparoscopic approach to the peritoneal cavity is used. In any of these scenarios, be it learning, training and/or teaching, simulation is a tool of paramount importance. Specifically, the cadaveric model offers great fidelity given the possibility of exactly reproducing the human anatomy.[7]

The objective of this work was to carry out a descriptive anatomical-surgical study of AS, to describe the different approaches to carry out its complete mobilization and to analyze its usefulness applied to surgical practice. For this, a simulation human cadaveric model was used.

MATERIAL AND METHODS

The human cadaveric material used was obtained by the Department of Anatomy of the School of Medicine (Universidad de la República), in accordance with the regulations on donation of bodies for medical research and education.

The cadaveric fixation and conservation technique consisted of the injection and recovery of formalin solution through a femoral approach.

Approval was obtained from the Ethics Committee of the institution (Hospital Maciel).

Cadaveric dissection technique

After accessing the peritoneal cavity, all the fixation ligaments were identified and sectioned, indicating the main anatomical relationships of interest and describing all the possible approaches to the lesser sac.

A complete dissection of the entire mesocolon was performed, from the origin of the middle colic vessels to the superior rectal artery, identifying all its vascular structures.

The avascular space of the splenic flexure (ASSF) was defined as the area with the following limits: posteroinferior, the anterior or ventral edge of the pancreas; anterosuperior, the vascular arcade closest to the latter; medial, the

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Figure 1 (A-E): Simulation of the 5 approaches to access the lesser sac (see text).

left branch of the middle colic artery; lateral, the ascending branch of the left colic artery.

Surgical technique (see video)

We present the complete mobilization of the SF by laparoscopy, with an initially medial approach.

The patient is placed in supine anti-Trendelenburg position with lateralization to the right. Four trocars are used: one 10 mm umbilical, two 12 mm on the right flank and left paraumbilical, and one 5 mm on the left flank. The surgeon stands to the patient's right, the 1st assistant (camera) next to the surgeon, and the 2nd assistant to the patient's left.

The para-aortic peritoneum is incised behind the inferior mesenteric vein (IMV), dissecting the left Toldt's fascia, identifying the ureter and gonadal vessels, elevating the mesocolon and leaving Gerota's pararenal fascia behind. The left colic artery (LCA) is sectioned at its origin, as well as the IMV at this same level, below the lower border of the pancreas. The gastrocolic ligament is then divided moving to the left, until reaching the lateral limit of the bursa omentalis corresponding to the splenocolic li-

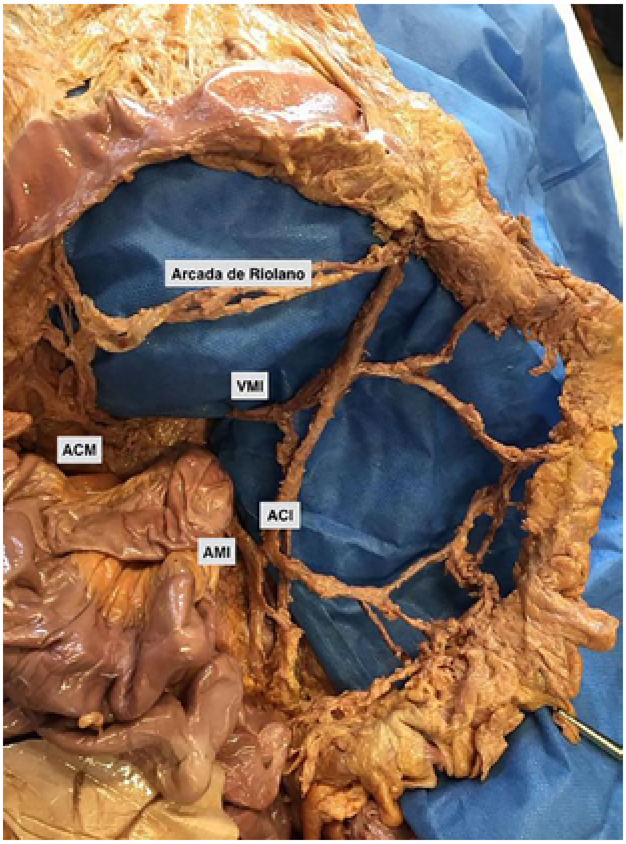

Figure 2: Vascular anatomy of the splenic flexure. ACM = middle colic artery; VMI = inferior mesenteric vein; ACI = left colic artery; AMI = inferior mesenteric artery.

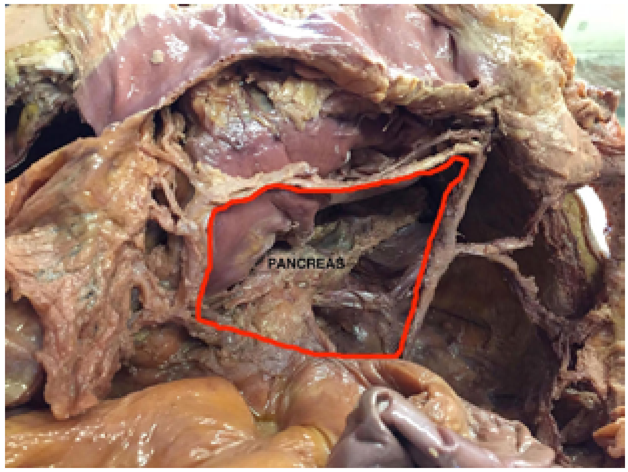

Figure 3: Avascular space of the splenic flexure.

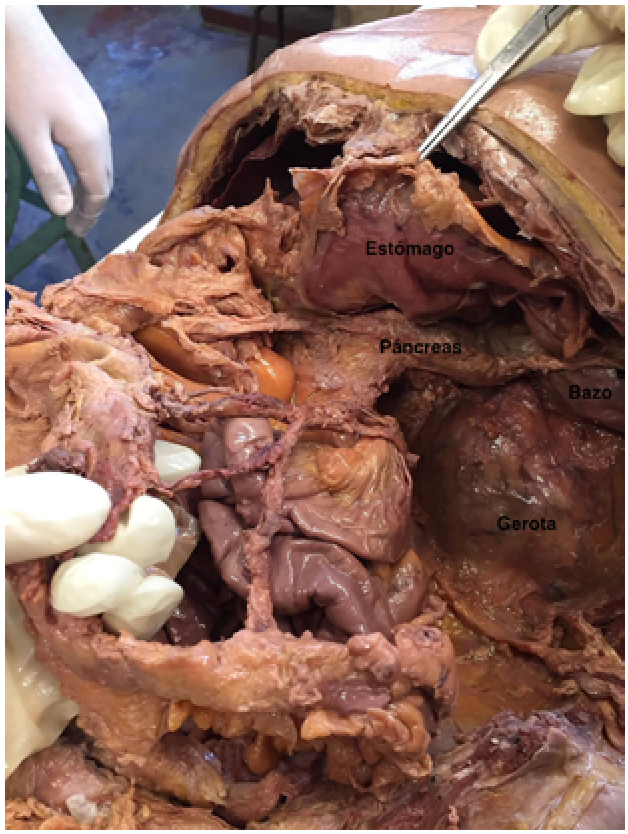

Figure 4: Posterior relationships of the splenic flexure.

gament. Finally, the release is continued by sectioning the paracolic and phrenocolic ligaments, until complete mobilization of the SF is obtained.

RESULTS

Cadaveric dissection

After dissection, the following ligamentous fixation structures were identified:

- Gastrocolic ligament: extends from the greater gastric curvature to the transverse colon.
- Splenocolic ligament: from the lower pole of the spleen to the colon. It constitutes the lateral limit of the lesser sac.
- Phrenocolic ligament: from the diaphragm to the colon.
- Parietocolic ligament: continuation of the previous one, from the abdominal wall to the descending colon.
- Pancreatocolic ligament: from the anterior aspect of the pancreas to the transverse mesocolon.

Regarding the possible approaches to fully mobilize the SF, a simulation of access to the lesser sac was performed, finding 5 possible ways to do it (Fig. 1):

- Anterior transomental approach: sectioning the gastrocolic ligament (Fig. 1A).
- Anterior approach: separating the greater omentum from the transverse colon or coloepiploic decoupling (Fig. 1B).
- Lateral approach: sectioning the parietocolic, phrenocolic and splenocolic ligaments (Fig. 1C).
- Medial inframesocolic approach: sectioning the pancreatocolic ligament (Fig. 1D).
- Medial transmesocolic approach: sectioning the transverse mesocolon on the left of the middle colic vessels (Fig. 1E).

After dissection of the mesocolon, the following vascular structures were recognized (Fig. 2):

- *Inferior mesenteric artery (IMA):* arises from the aorta and runs downward.
- *ICA:* originates in the IMA and after a short journey it divides into an ascending and descending branch.
- *Superior rectal artery (SRA):* continuation of the IMA after emergence of the sigmoid artery.
- *Marginal artery of Drummond:* parallel to the medial border of the colon.
- *Arc of Riolan:* anastomotic artery between the left branch of the middle colic artery and the distal part of the ascending branch of the left colic artery.
- *Superior rectal vein:* after receiving the sigmoid veins and the left colic vein, it gives rise to the IMV, which intersects with the ICA forming the so-called vascular arch of Treitz, to finally head towards the lower border of the pancreas where it joins the splenic vein.

Figs. 3 and 4 show the anatomical relationships that the SF maintains backwards with the body and tail of the pancreas, lower pole of the spleen, Gerota's fascia, ureter, and left gonadal vessels. Also the area called avascular space of the splenic flexure.

Surgical technique (video)

In the video you can see all the steps of the surgical technique of complete mobilization of the SF preceded by cadaveric dissection.

DISCUSSION

The surgical approach to SF is a challenge for several reasons, among which highlights its deep and high location in the left thoraco-abdominal region and its complex anatomical relationships derived from embryological development. Moreover, in neoplastic pathology, there are added controversies regarding the extramesocolonic lymphatic drainage of tumors[8] and the relative low frequency of this location.

Classically, 3 approaches are described to perform the complete mobilization of the SF: anterior, medial and lateral, based on the first maneuver that determines access to the lesser sac.[9] However, it is a "mixed" or combined technique in which all approaches are finally carried out, regardless of the order in which they are performed.

Besides, the mobilization of the SF admits variants depending on the type of pathology to be treated. Specifically, we refer to two scenarios: the first is the need to perform a complete resection of the mesocolon and the greater omentum in the case of a malignant tumor in that location;[10] the second is the imobilization of the flexure to achieve a tension-free anastomosis during a resection of the rectum or a restoration of the intestinal transit.

Following this premise, García-Granero et al.[5] describe all the possible approaches in a cadaveric dissection model, as well as during the course of surgical procedures, determining that there are 5 access to the omentum cavity (and therefore 5 approaches), whose feasibility will depend on the scenario proposed (resection vs. mobilization of the SF). This cadaveric model has been called by the authors the "box of the SF" (in reference to the lesser sac), and was proposed to facilitate and standardize the teaching of this procedure.

Based on this model, we performed a cadaveric dissection that allowed us to identify the fixation ligaments, as well as to make a detailed description of the vascular anatomy of the left angle and its approaches. Among them we were able to recognize the following:

- *Anterior transomental (Fig.1A):* by opening the gastrocolic ligament. It can be used when an excision with oncological criteria is required, given the possibility of tumor implants in the greater omentum or even in the gastroepiploic artery.[8] However, it is not recommended in case of preserving the angle, since can leave an ischemic greater omentum.
- *Anterior (Fig. 1B):* through a coloepiploic detachment. Unlike the previous approach, it preserves the integrity of the greater omentum.
- *Lateral (Fig. 1C):* through the splenocolic ligament. This approach is not recommended initially, since bleeding may occur at from the spleen dissection or venous vascular connections of the ligament itself, both difficult to control if no other previous release has been done.
- *Medial:* access normally used for the laparoscopic approach and which we prefer. Its main advantage is allowing adequately identify the retroperitoneal structures, which for some authors reduces the probability of iatrogenic injuries.[11] The IMV must be ligated and divided in 2 different sectors, one close to the ligation and section of the LCA and the other at the lower edge of the pancreas,[12] a maneuver that allows an additional mobilization of the angle.[13] Once the lower border of the pancreas is identified, there are 2 options or variants of the medial approach:
    - A. *Inframesocolic:* sectioning the pancreatocolic ligament.
    - B. *Transmesocolic:* entering the lesser sac through the transverse mesocolon itself, through the avascular space immediately to the left of the left branch of the middle colic vessels.

Knowledge of the vascular anatomy of the SF is of great importance, particularly with regard to the medial approach, as it is a segment located on the border that separates the territories of the superior mesenteric artery (SMA) and the IMA. The connections between both are variable and there has not always been consensus about their denomination,[14-16] but we must be attentive to them since can be the cause of hemorrhagic accidents during section of the mesocolon. The following are recognized:

1. Marginal artery of Drummond: it is the most constant and runs close to the edge of the colon, connecting the left branch of the MCA with the ascending branch of the LCA.
2. Arc of Riolan: It also connects the MCA with the LCA, but runs in the middle of the mesocolon.
3. Artery of Moskowitz: connects the ascending branch of the LCA with the origin of the MCA. Unlike the previous mention arteries, its trajectory is very close to the anterior border of the pancreas, running at 0.2-0.4 cm from it.[17] Therefore, if it is present, the ASSF is practically non-existent and considerably increases the risk of bleeding, which would generate a contraindication for the medial approach, or at least make it difficult.

It is not clear whether the Moskowitz artery is simply an anatomical variant or a collateral circulating artery in pathologic circumstances, such as obstruction or previous ligation of the IMA.[18] The possibility of its preoperative detection using high-definition imaging studies such as 3D computed tomography angiography has also been investigated, with the consequent reduction in the risk of intraoperative complications and also an increase in the harvesting of lymph nodes.[19]

The need to know precisely the embryological development, the vascular anatomy, the SF relationships, the fixation ligaments and, fundamentally, all the possible approaches, their indications, risks and possible contraindications is fully justified.

The mobilization of the SF is a complex maneuver that requires systematization, experience, and training, which translates into a slow learning curve. It requires an average of 47 minutes,[20] and can significantly increase the total operative time in procedures such as rectal resection, where it has been shown to be an independent variable of complications such as anastomotic leak.[21]

In addition, detailed and correctly applied anatomical knowledge aims to reach other goals. One of them is to achieve an excellent surgical technique that meets quality standards, especially in cases of oncological pathology, such as performing a complete mesocolic excision with central vascular ligation.[22] Other objective is framed within the concept of safety of the patient, assuming that a good mastery of the technique and simulated training are fundamental precepts to reduce the rate of complications derived from iatrogenic injuries to the spleen, pancreas and ureter.

The simulation model in a human cadaver offers some advantages for the acquisition of this knowledge. It has a very good fidelity in the exact reproduction of the human anatomy and allows the design of quite attractive and reproducible teaching and training strategies ("box" of SF), as we have been able to demonstrate in our experience.

However, the cadaveric model also has certain limitations. To begin with, its availability is variable and often subject to ethical and legal restrictions. In addition, it does not offer the possibility of reuse and, therefore, its applicability is restricted to a specific training session rather than a continuous practice in which progression over time can be observed.[23,24]

On the other hand, the rigidity and poor adaptability of cadaveric tissues subject to fixation (even in the fresh cadaver) make it difficult to use them for the simulation of laparoscopic procedures. An alternative is preservation with the method described by Walter Thiel,[25] in which immersion in a specific solution preserves the physical properties of tissues and therefore makes them more suitable for training in invasive procedures.

In our country, with a small population and centers that are usually low volume, it is essential that surgeons know this type of tools if they want to make learning about highly complex surgical procedures more effective. This is a simulation and teaching model that has already been validated,[5] and that we have been able to reproduce, demonstrating its application and good correlation with the real scenario.

CONCLUSION

The cadaveric model allows a detailed study of the vascular anatomy of the SF, its means of fixation and relationships and to simulate the different approaches for its complete mobilization. This knowledge facilitates the surgical approach, which is still a technical challenge to perform laparoscopically.

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