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THE SURGICAL ANATOMY OF THE SPLEEN

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It is the position of the liver on the right side of the body that is the main cause for the formation of the spleen; the existence of which thus becomes to a certain extent a matter of necessity in all animals, though not a very stringent necessity.

ARISTOTLE, 384–322 BC

EMBRYOLOGY

The spleen is of mesodermal origin. It is formed from mesenchymal cells, located between the leaflets of the dorsal mesogastrium, and with participation from the coelomic epithelium of the dorsal mesentery. The organ makes its appearance at the fifth week of gestation. At the eighth to ninth week of development, thin blood vessels appear within the early splenic tissue according to Jones.[17] Lymphocytes are present during the fourth month of gestation according to Hayward and Ezer.[14]

The spleen's origin is neither midline nor bilateral, despite a report of a case of bilateral symmetric spleen and the suggestion of some scientists that supports potential failure of development of a right spleen. The spleen develops on the left side of the dorsal mesogastrium when the stomach starts its rotation approximately at the 6-mm stage. Differentia-

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tion into a true epithelium is evident at the 10- to 12-mm stage with a visible basement membrane that is obvious with development.

Sinusoids appear at the 11-mm stage. For all practical purposes, these are clefts of mesenchymal origin without endothelial lining but in communication with capillaries. The appearance of surface immunoglobulin-bearing B cells and erythrocyte rosette-forming T cells takes place around the 13th week according to Jones[17] and Owen and Jenkinson.[24] By the sixth month of fetal development, the red and white pulp has appeared. Wolf et al[34] believe IgA and perhaps IgE are not synthesized during fetal life, although IgM and some IgC antibodies are synthesized in the third trimester according to the same authors.

Wolf et al[34] suggest that it is likely that precursor cells in the fetal spleen are the result of filtration of the hematopoietic cells from the fetal blood.

Because of the relationship of the pancreatic and the splenic vessels to the retroperitoneal space during embryonic development, these vessels are heavily fixed with the posterior area of the retroperitoneal space. This fact should be remembered during possible mobilization of these vessels. The development of the spleen is illustrated in Figures 1 and 2.

SURGERY OF THE SPLEEN

Surgery of the spleen consists of total splenectomy, partial splenectomy, splenic repair, splenic fixation, distal pancreatectomy with splenic preservation, treatment of splenic artery aneurysm, staging laparotomy, and transplantation.

Knowledge of splenic anatomy and surgical techniques is imperative for good results. Yet, to present the splenic anatomy in toto would be impossible. To paraphrase Treves, we will present the anatomic entities upon the circumstances of practice, and to be more specific regarding the anatomic entities with which the surgeon should be very familiar.

The surgery of the spleen is the surgery of its ligaments, its vessels, and its segments.

TOPOGRAPHY AND RELATIONS

The spleen is surrounded, at the left hypochondrium, by the following: the diaphragm above and posterolaterally, the stomach medially and anterolaterally, the left adrenal gland and left kidney posteromedially, the phrenicocolic ligament below, and finally the chest wall laterally (see Fig. 1).

Surgical Applications

(1) A patient with fractures of the left lower ribs should be observed closely.

(2) A left thoracotomy tube introduced below the left hemidiaphragm may perforate the upper pole of the spleen.

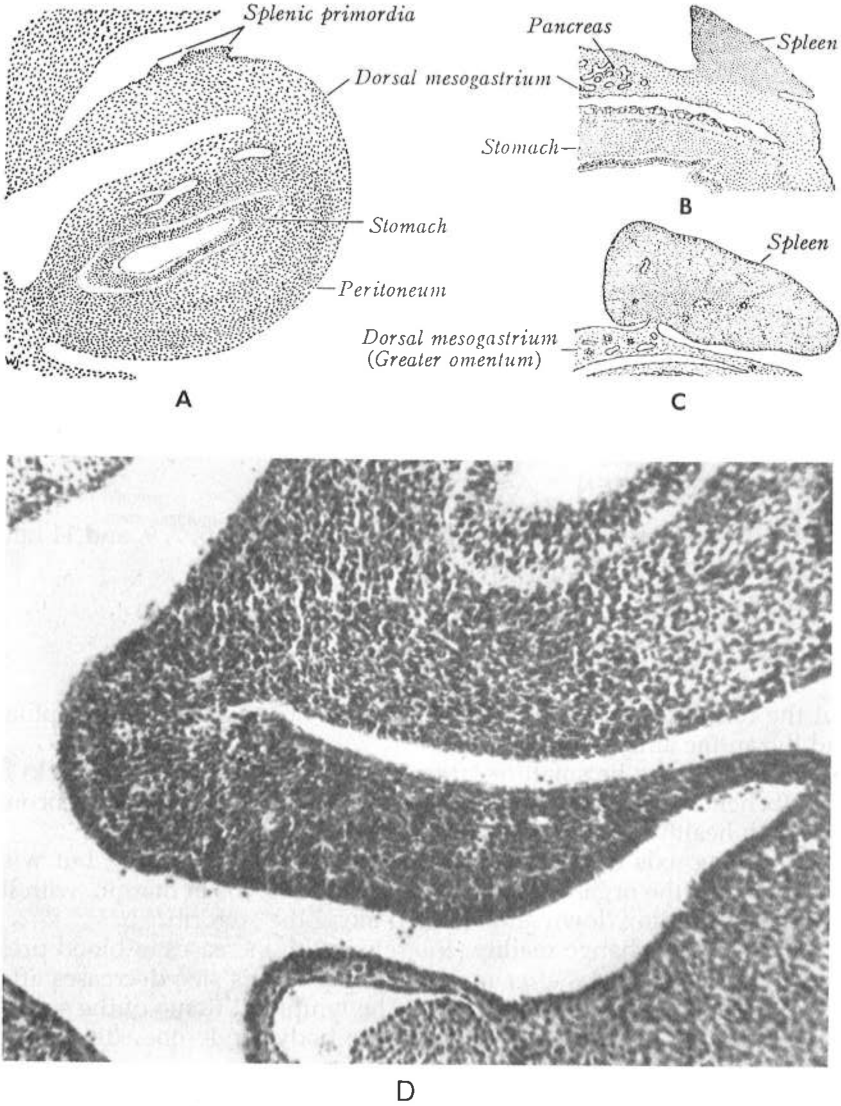

Figure 1. Development of the spleen. *A,* The splenic primordium as it appears on the dorsal mesogastrium's left side at 6 weeks. *B,* At 2 months. *C,* At 4 months. *D,* Angiogenesis is beginning in the early splenic primordium. (*A–C from* Arey LB: Developmental Anatomy, ed 6. Philadelphia, WB Saunders, 1954, p 392; *D from* Ivemark BI: Implications of agenesis of the spleen on the pathogenesis of cono-truncus anomalies in childhood. Acta Paediatr 44(Suppl 104):1–110, 1955; with permission.)

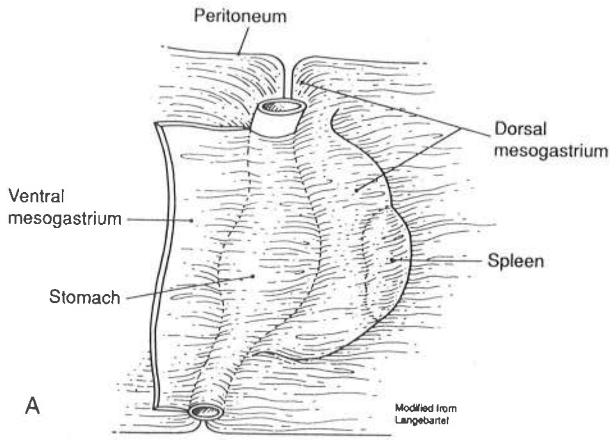

Figure 2. Development of the splenic ligaments. *A*, Gastric and splenic rotation.
Illustration continued on opposite page

SIZE OF THE SPLEEN

Last[20] shows that the odd numbers of Harris 1, 3, 5, 7, 9, and 11 help one to memorize average splenic dimensions:

$1 \times 3 \times 5$ inches = size
7 oz = weight
9-10-11 ribs = relation to left chest wall

But the normal conditions of this enigmatic organ are full of Delphian and Byzantine ambiguities.

A spleen may be small or large. It may range from 1 oz (Storck) to 20 lb (Schenck), as reported by Gould and Pyle.[12] These extremes encompass both healthy and diseased specimens.

The long axis of the spleen runs parallel to the 10th rib, but with splenomegaly the organ is palpable below the left costal margin, with its long axis extending down and forward along the 10th rib.[15, 20]

Its size may change readily, enlarging with increases in blood pressure. The size increases after meals. Conversely, its size decreases after exercise or immediately postmortem. The lymphoid tissue of the spleen, as with lymphoid tissue elsewhere in the body, undergoes diminution sometime after the 10th year.[1] Sometime after the age of 60 years there is some involution of the whole organ. Disease, the amount of blood within the spleen, the shape of the thorax, and obesity all play a role as to the normal or abnormal position of the spleen.

Surgical Applications

The size of the spleen will dictate the type of incision. Remember what Arthur H. Keeney stated, "God will not alter a faulty incision."

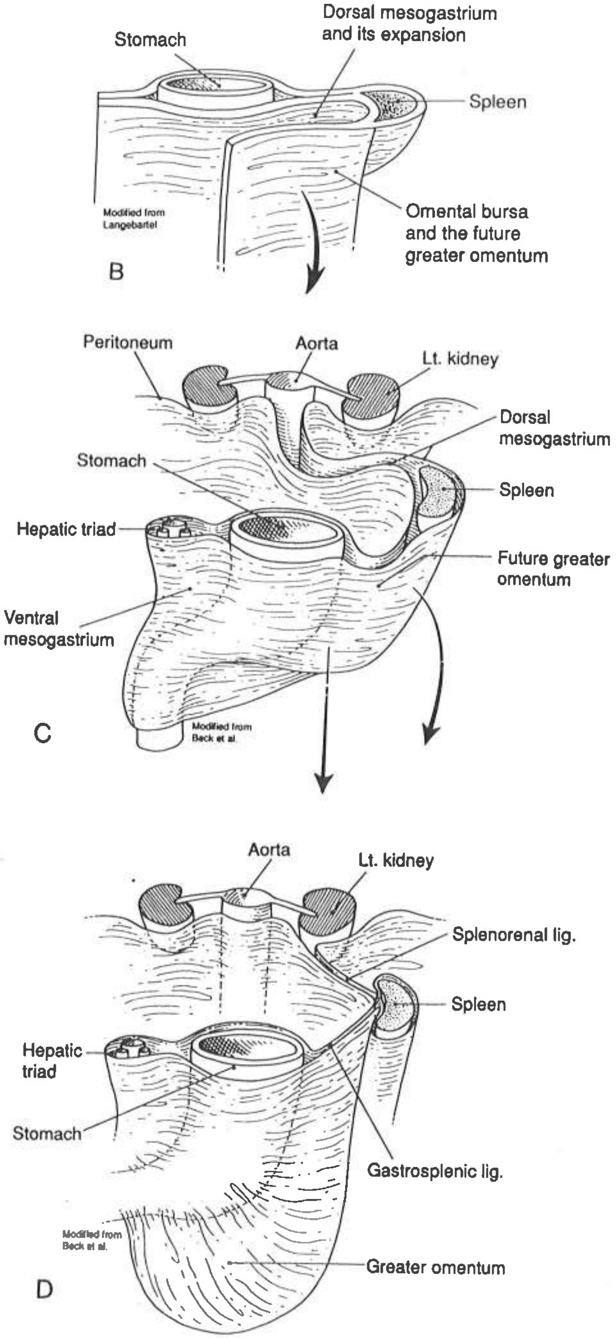

Figure 2 *(Continued). B,* Formation of omental bursa and its relation to the spleen. *C,* Beginning of formation of the greater omentum and its relationship to the spleen. *D,* Formation of two major splenic ligaments. (*From* Allen KB, Gay BB, Skandalakis JE: Wandering spleen: Anatomic and radiologic considerations. South Med J 85:10, 1992; with permission.)

SHAPE, SURFACES, AND BORDERS OF THE SPLEEN

Michels[22] presents two different models that describe the shape of the spleen.

In the first, the spleen has 3 forms (Fig. 3): wedge-shaped, 44%; tetrahedral, 42%; and triangular, 14%.

In the second, it is divided into two parts: The first has even borders and narrow hilus in which the arterial branches are few and large (30%), and the other has notched borders and large hilus with numerous small arteries (see Fig. 3). Michels found that the notched border spleen has multiple arteries that enter the spleen through the medial surface. He concludes that a notched anterior border most likely represents a difficult splenectomy (Fig. 4).

The spleen has two borders: the superior or anterior, and the inferior or posterior.

Surgical Applications

(1) A notched spleen has multiple arteries that should be ligated carefully close to the splenic portas and one by one.

(2) The concave visceral surface also should be handled with care. The small gastric veins retract instantly and should therefore be ligated one by one, and the tail of the pancreas should be separated from the

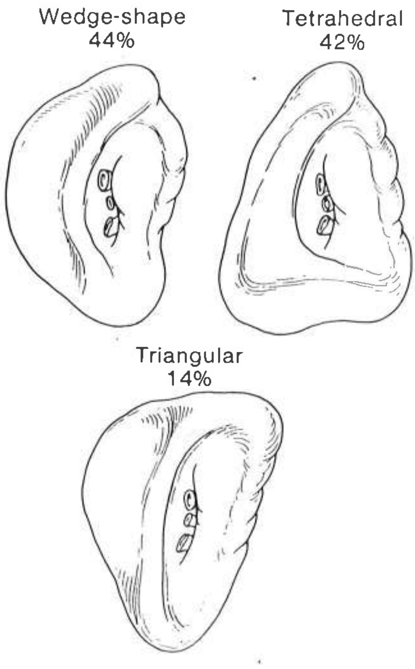

Figure 3. Shapes of the spleen. (*From* Skandalakis JE, Colborn GL, Pemberton LB, et al: The surgical anatomy of the spleen. Problems in General Surgery 7:1, 1990; with permission.)

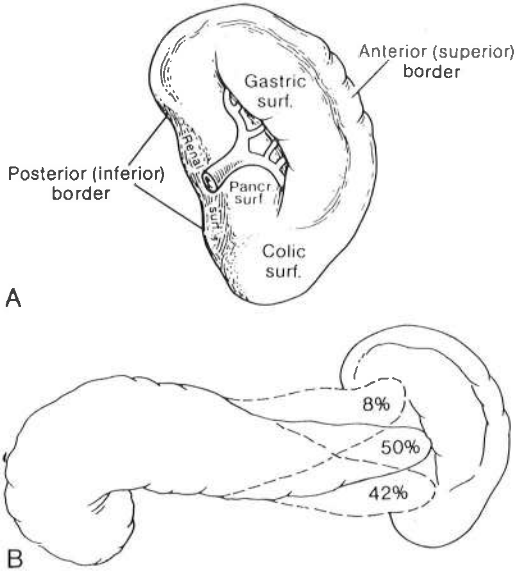

Figure 4. Splenic borders. *A*, Anterior and posterior border. *B*, Relations of the tail of the pancreas to the spleen. (*From* Skandalakis JE, Colborn GL, Pemberton LB, et al: The surgical anatomy of the spleen. Problems in General Surgery 7:1, 1990; with permission.)

spleen, again with care to avoid pancreatic injury. If present, the pancreaticosplenic ligament should be ligated.

The convex parietal surface related to the diaphragm is in most cases avascular, but it would be wise to ligate the short or long splenophrenic ligament.

(3) The posterior splenic border is related to the renal and diaphragmatic area, and separation should be toward the diaphragm to avoid injury of the renal capsule.

The shape, surfaces, and borders of the spleen should be considered for potential trouble that may arise during splenectomy. If the surgeon is careful and proceeds slowly, he or she will avoid bleeding from the spleen, the greater curvature of the stomach, and perhaps from the capsule of the left kidney.

THE LIGAMENTS OF THE SPLEEN

The spleen is covered entirely by the peritoneum in a double layer except for the hilus (Figs. 5 and 6).

The embryonic dorsal mesentery is responsible for the production of the splenic ligaments. After separation into two leaflets, the mesogastrium envelops the organ, producing the two chief ligaments, gastrosplenic and splenorenal, plus perhaps the other ligaments of the spleen (Figs. 7 and 8).

The spleen has eight ligaments: (1) gastrosplenic, (2) splenorenal, (3) splenophrenic, (4) splenocolic, (5) presplenic fold, (6) pancreaticosplenic,

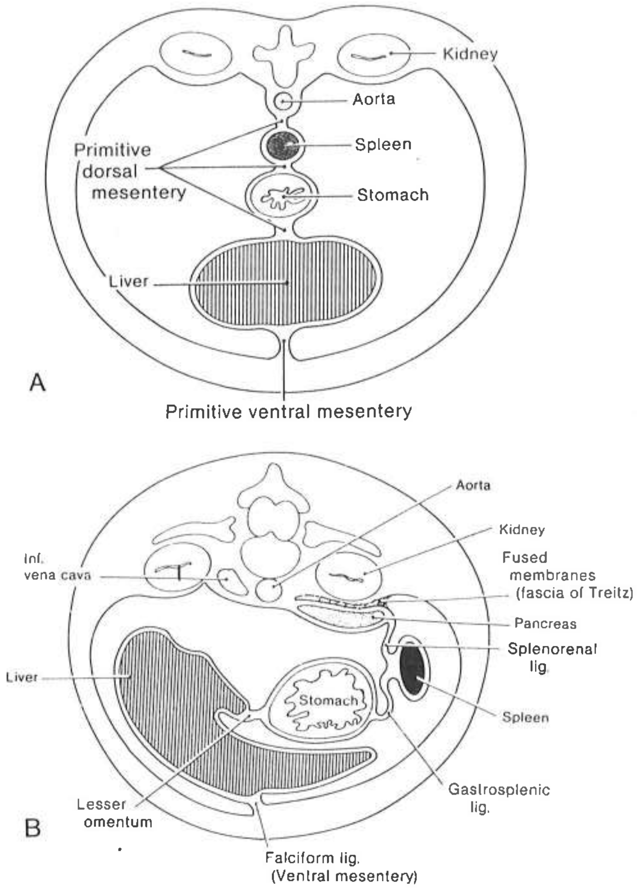

Figure 5. The peritoneal reflections of the spleen develop from the primitive dorsal mesentery. *A*, Diagram of primitive embryonic relations. *B*, Diagram of adult relations. (*From* Skandalakis JE, Gray SW, Rowe JS Jr: Anatomical Complications in General Surgery. New York, McGraw-Hill, 1983, p 177; with permission.)

(7) phrenicocolic, and (8) pancreaticocolic. Three to eight are the so called minor ligaments, which, however, may produce problems in the operating room.

The ligaments may be normal or may be too long, too short, too narrow, too wide, or abnormally fused. All these embryologic phenomena may be quite benign or perhaps may produce problems in the operating room (bleeding), or the pathologic entities of splenic ptosis, torsion, and wandering spleen. However, splenic mobility depends on the laxity of the splenic ligaments and the length of the splenic vessels.

The Gastrosplenic Ligament

The gastrosplenic ligament (Fig. 9) is located between the stomach and the spleen, and embryologically is the product of the dorsal mesen-

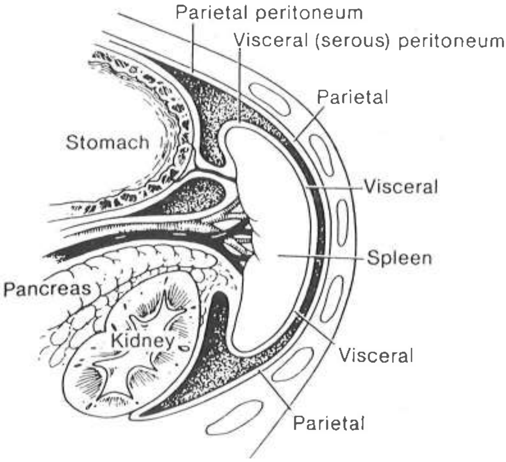

Figure 6. Sagittal view of peritoneum covering the spleen. (*From* Skandalakis JE, Colborn GL, Pemberton LB, et al: The surgical anatomy of the spleen. Problems in General Surgery 7:1, 1990; with permission.)

tery. For all practical purposes, according to Whitesell,[32] this ligament has the form of a triangle located between the stomach and spleen. The upper splenic pole lies close to the greater curvature of the stomach at the triangle's apex. Its base has a length of 5 to 7 cm, which is the distance of the lower splenic pole from the greater curvature.

The short gastric vessels and the gastroepiploic vessels are contained within this ligament.

The Splenorenal Ligament

Embryologically, this ligament is formed by the posterior part of the dorsal mesogastrium. It envelops the splenic vessels and the tail of

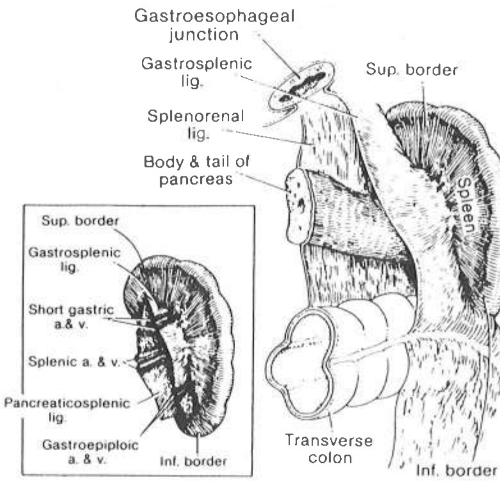

Figure 7. The peritoneal attachments of the spleen. Inset: The hilum of the spleen, showing the short gastric and gastroepiploic vessels in the gastrosplenic ligament. (*From* Skandalakis JE, Gray SW, Rowe JS Jr: Anatomical Complications in General Surgery. New York, McGraw-Hill, 1983, p 173; with permission.)

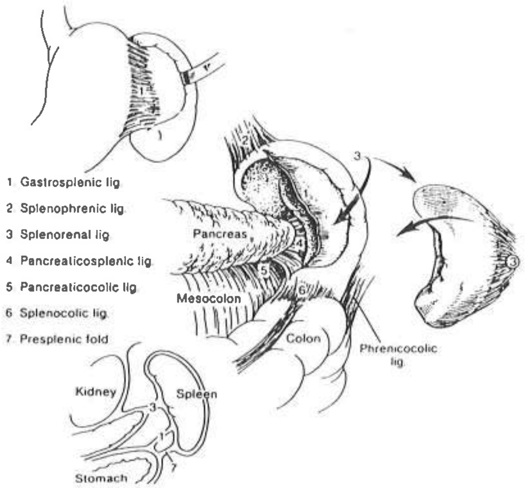

Figure 8. Minor splenic ligaments. (*From* Skandalakis JE, Colborn GL, Pemberton LB, et al: The surgical anatomy of the spleen. Problems in General Surgery 7:1, 1990; with permission.)

the pancreas. Because of the peculiar formation of the omental bursa, the outer layer of the splenorenal ligament forms the posterior layer of the gastrosplenic ligament.

The Splenophrenic Ligament

In a previous publication[26] we reported that this ligament is the reflection of the leaves of the mesentery to the posterior body wall and to the inferior surface of the diaphragm at the vicinity of the upper splenic pole close to the stomach. In reality, we do not know if this ligament is responsible for the genesis of the splenorenal ligament from its lower part.[11] Perhaps the splenophrenic ligament is a reflection of the gastrosplenic ligament to the diaphragm. Remember the presence of this anatomic entity during surgery of the spleen.

Some authors[25] suggest that this ligament contains the tail of the pancreas and all the splenic vessels including the root of the left gastroepiploic artery.

Still we believe the splenorenal ligament is the home of the splenic vessels and the tail of the pancreas.

The Splenocolic Ligament

Embryologically, this ligament is thought to be a remnant of the left end of the transverse mesocolon that developed a secondary attachment to the lower spleen during the fixation of the colon to the body wall. Occasionally a lower polar artery or even a curved left gastroepiploic artery is very close to this ligament.

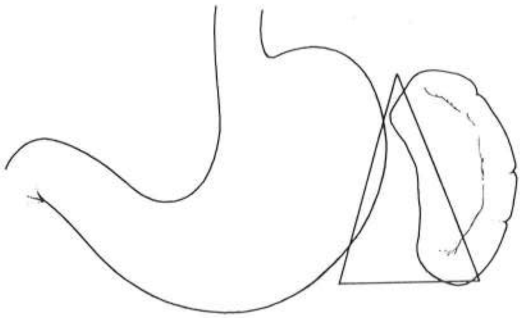

Figure 9. The gastrosplenic ligament connects the stomach and spleen. Superiorly the two organs may be in contact; the ligament is short. Inferiorly the two organs are 5 to 7 cm apart; the ligament is longer. (*From* Skandalakis JE, Gray SW, Rowe JS Jr: Anatomical Complications in General Surgery. New York, McGraw-Hill, 1983, p 177; with permission.)

The Presplenic Fold

According to Henry,[16] this is a peritoneal fold in front of the gastrosplenic ligament. The presplenic fold (Fig. 10) again may contain the left gastroepiploic vessels. With splenomegaly the fold may be fixed with the spleen.

The Pancreaticosplenic Ligament

If the tail of the pancreas does not touch the spleen, then occasionally there is a cord-like formation. This thin, rarely thick, structure is the pancreaticosplenic ligament (see Fig. 8).

The Phrenicocolic Ligament

The phrenicocolic ligament develops at the area of junction of the midgut and the hindgut after the descending colon has become retroperitoneal. It is the rudimentary left end of the transverse mesocolon. Smooth-muscle cells migrate into the ligament from the mesocolic taeniae. The ligament anchors the splenic flexure. The development of the upper abdominal organs results in a descent of the spleen and contact of the lower pole of the spleen with the ligament. The phrenicocolic ligament, deformed by continued spleen growth, forms a pocket for this organ.[30]

This ligament, the "splenic floor," extends between the splenic flexure and the diaphragm. The spleen rests upon it, but it is not connected to the spleen.

The phrenicocolic ligament acts as a barricade at the left gutter. In most instances, it is responsible for prohibiting blood from a ruptured

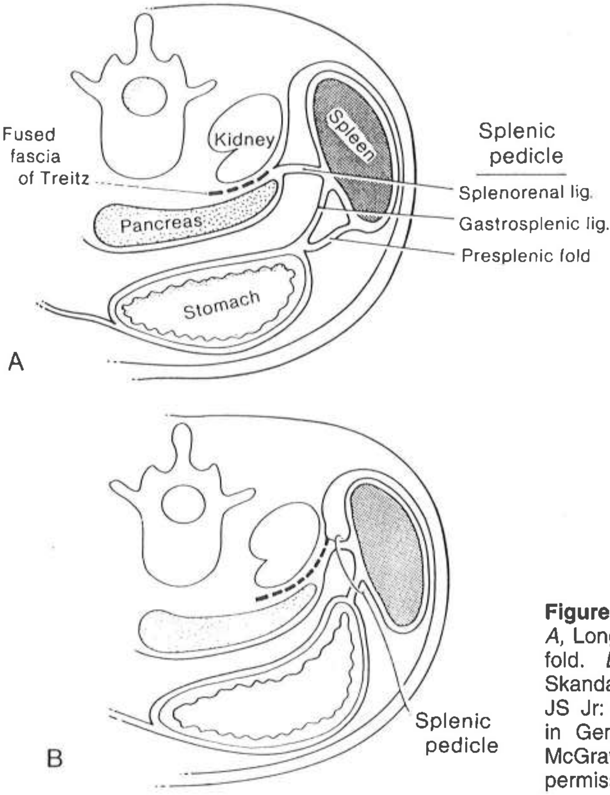

Figure 10. The splenic pedicle. *A*, Long pedicle with a presplenic fold. *B*, Short pedicle. (*From* Skandalakis JE, Gray SW, Rowe JS Jr: Anatomical Complications in General Surgery. New York, McGraw-Hill, 1983, p 178; with permission.)

splenic artery or from the spleen itself from traveling downward. Such blood collects in the anterior pararenal space retroperitoneally or around the spleen at the left upper quadrant by displacing the colon laterally. There is only one phrenicocolic ligament, which is on the left side, and therefore it is erroneous to refer to this ligament as the "left" phrenocolic ligament (see Fig. 8).

The Pancreaticocolic Ligament

This ligament is the upper extension of the transverse mesocolon.

There is ambiguity surrounding the three "colic" ligaments: the pancreaticocolic, splenocolic, and phrenicocolic. There is debate whether these peritoneal folds belong to the transverse mesocolon. We believe they most likely do (Fig. 11).

Surgical Applications

(1) Ligate the short gastric vessels and the left gastroepiploic separately and incise the gastrosplenic ligament between clamps.

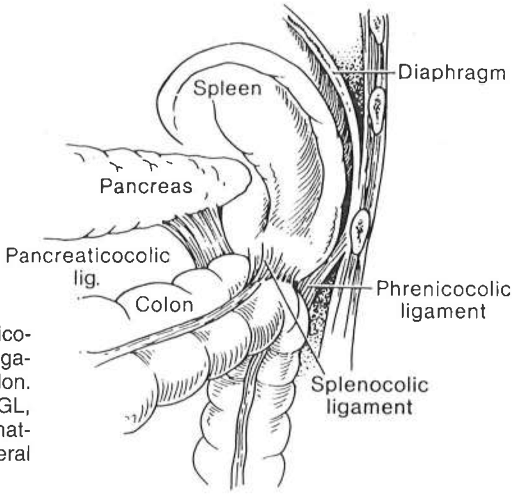

Figure 11. Relation of the pancreaticocolic, phrenocolic, and splenocolic ligaments to the transverse mesocolon. (*From* Skandalakis JE, Colborn GL, Pemberton LB, et al: The surgical anatomy of the spleen. Problems in General Surgery 7:1, 1990; with permission.)

(2) The splenorenal ligament is avascular, but it envelops the splenic vessels and the tail of the pancreas. Incision and finger excavation to mobilize the organ should be done with care.

(3) The splenophrenic ligament, if short, may produce bleeding owing to a tear of the capsule. If so, apply more traction than usual.

(4) The splenocolic ligament, in close relation to the lower polar and left gastroepiploic vessels, should be incised between clamps.

(5) The presplenic fold is close to the left gastroepiploic vessels, and excessive traction may produce bleeding.

(6) The pancreaticosplenic ligament, if present and long enough, should be incised between clamps. If absent or short, careful separation of the pancreatic tail from the spleen is necessary to avoid pancreatic or splenic injury.

(7) If the phrenicocolic ligament is short or fused, injury of the lower pole or the splenic flexure of the colon is remote but possible.

(8) A short or fused pancreaticocolic ligament also may lead to colonic or pancreatic injury with careless traction.

THE VASCULAR SYSTEM OF THE SPLEEN

The Splenic Artery

According to Michels,[23] the splenic artery arises from the celiac trunk in 82% of cases (per VanDamme and Bonte[28] in 86%) together with the hepatic and left gastric artery, which together form a tripod. However, a dipodal or tetrapodal form may result when there is an atypical source of these or other associated vessels of the upper abdominal organs.[28] The splenic artery is the most peculiar (Fig. 12). It is never the same, being the most unpredictable and perhaps the most difficult to describe owing to its length, its relation to the splenic vein, its branching, its termination, and finally its multiple variations.

Its course is again very peculiar, crossing the left side of the aorta as soon as it springs from the celiac axis, in most of the cases related close to the upper border of the pancreas and occasionally in front or behind or partially or totally within the pancreatic parenchyma in very rare cases. Its termination, also in the splenic portas, is totally unpredictable owing to its number of branches to the spleen or even to neighboring organs, such as the left kidney, stomach, and omentum.

The length of the artery varies from 8 to 32 cm, and its diameter is approximately 0.5 to 1.2 cm. Michels[23] has questioned why such a large artery supplies a small organ. The splenic peritoneal fold results from the fixation of the splenic artery to the posterior wall of the retroperitoneum, and one can observe its snake-like (tortuous) elevation from the celiac axis to the splenic portas when the unpredictable branching of this artery begins. The loop of Weizer, present in approximately 30%, is a curving loop to the right immediately after the splenic artery emerges from the celiac axis. In a previous publication[26] we followed the segmental classification of Michels, but we strongly advise reading the classical work of VanDamme and Bonte.[29] In a recent publication by Kornblith et al,[19] the authors also followed the classification of Michels,[23] who divided the artery into four segments: suprapancreatic, pancreatic, prepancreatic, and prehilar.

In our publication,[26] we listed in order of appearance the segmental origin of the splenic arterial branches (Table 1) according to Michels.[23] We wish to add the posterior gastric artery[2] to both the suprapancreatic and pancreatic segment, because the length of the first segment is 1 to 3 cm, and we have found this artery to originate within 3 cm from the celiac artery (see Table 1).

Several authors[10, 13, 18, 23, 28] agree that in most cases (75%) the splenic artery bifurcates into two major divisions. With this in mind, one can consider the multiple variations of branching that occur as the artery travels toward the splenic portas. Michels noted, from the literature and his own studies, that extremes of splenic artery branching at the portas range from 3% to 38%.

Garcia-Porrero and Lemes[10] dissected 181 fresh spleens and reported trifurcation of splenic artery in 16.7% of females and 4.0% of males, superior polar artery in 29.3% of cases, and inferior polar artery in 44.8% of cases. Michels found a superior polar artery in 65% of the cases and an inferior polar artery in 82% of the cases.

Our purpose here is not to describe the other branches of the splenic artery on its course to the spleen, but we mention the following: dorsal pancreatic artery, anterior pancreatic magna, caudal pancreatics, left gastroepiploic artery, and short gastric arteries. Again, space does not permit us to present extrasplenic or intrasplenic arterial collateral circulation in detail.

For all practical purposes, the "main splenic arteries" are the terminal branches of the splenic artery, which are responsible for the arterial blood supply of the organ, and which originate from the superior and inferior terminal arteries or from other terminal branches. The superior and inferior polar arteries, which penetrate the splenic

Table 1. SEGMENTAL ORIGIN OF SPLENIC ARTERIAL BRANCHES

The suprapancreatic segment*
Left inferior phrenic a.
Dorsal pancreatic a.
Superior polar a.
Posterior cardioesophageal a.
Accessory gastric or hepatic a.
Inferior mesenteric a.
Posterior gastric a.
The pancreatic segment
Great pancreatic a. (frequent)
Superior polar a. (infrequent)
Left gastroepiploic a. (rare)
Posterior cardioesophageal a. (rare)
One or more short gastric aa.
Accessory left gastric a.
Posterior gastric a.
The prepancreatic segment
70% of the time, the terminal divisions begin here
Inconstant branching patterns with several combinations, such as:
Upper arterial trunk
Middle arterial trunk
Lower arterial trunk
Left gastroepiploic a.
Caudal pancreatic a.
Superior polar a.
Inferior polar a.
The prehilar segment
More branching if the branching started in pancreatic segment
30% of the time, terminal branching starts here, not in pancreatic segment
In the 30%, the branches enter spleen into a limited hilus

*Listed in order of appearance or of number of branches.

parenchyma above and below the portas and which originate usually from the prehilar segment, should be considered part of the main splenic artery.

The superior polar artery is nearly always present.

VENOUS DRAINAGE

The Splenic Vein

This vein is formed by variable tributaries such as veins from the splenic parenchyma, the left gastroepiploic vein, and very rarely by one or two short gastric veins.

The splenic vein begins with the coalescence of five or six branches emerging from the splenic portas and the left gastroepiploic vein, which together form a large-caliber, nontortuous vein.[33] It receives tributaries from the pancreas on its way to join the superior mesenteric vein, where they form the portal vein.

Its fellow traveler is the splenic artery (Fig. 12), which may be anterior, posterior, or around the splenic vein (54% posterior, 44% around

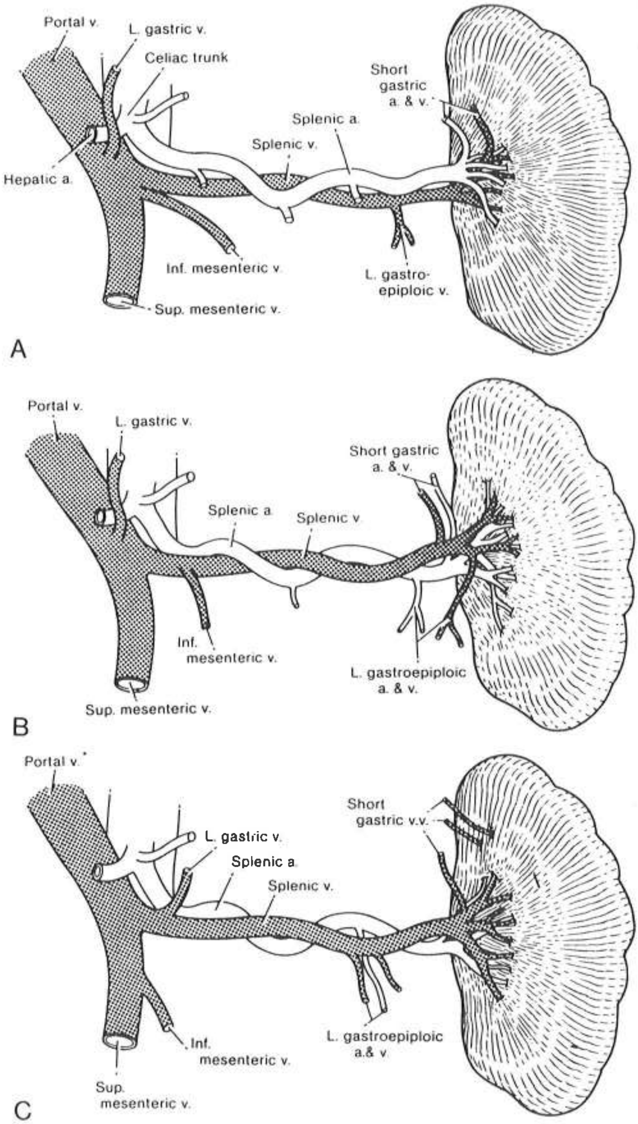

Figure 12. Relationship of splenic artery and splenic vein. *A,* Artery anterior to vein (this is the usual pattern); *B,* artery both anterior and posterior to vein; *C,* artery posterior to vein (this is the least common configuration). (*From* Skandalakis JE, Gray SW, Rowe JS Jr: Anatomical Complications in General Surgery. New York, McGraw-Hill, 1983, p 181; with permission.)

the artery, and 2% anterior). The student of splenic anatomy should remember that most of the short gastric veins enter the upper part of the spleen directly from the greater curvature of the stomach.[6]

Surgical Applications

(1) If the spleen has not been mobilized, ligation of the splenic arteries is permissible and the spleen remains viable if the collateral circulation is intact (polar arteries, short gastric arteries, and left gastroepiploic arteries). If the color of the spleen is changed, however, and there is evidence of ischemia, a splenectomy should be performed. In general, ligation of the splenic artery should be done only if absolutely necessary (i.e., during splenectomy).

(2) Proximal double and distal ligation of the artery is advisable.

(3) Ligation of the splenic vein alone should be avoided.

(4) Total splenectomy is indicated with splenic vein thrombosis.

(5) As a rule, the ligation of the artery should precede the ligation of the vein.

(6) The tortuous splenic artery should be ligated with care, avoiding pancreatic and splenic vein injury. The elevated segments of the tortuous splenic artery facilitate ligation of the artery without anatomic complications.

(7) Isolate and ligate the terminal arterial and venous branches close to the splenic portas to avoid bleeding, because the origin and ultimate termination of these vessels are unpredictable.

Lymphatic Drainage

The splenic chain (Fig. 13), according to Rouviere, is composed of the suprapancreatic nodes, infrapancreatic nodes, and afferent and efferent lymph vessels.[31]

Weiss et al state that pancreatic tumors divide the splenic nodes into two groups: nodes of the splenic hilum and nodes of the tail of the pancreas.[31]

The largest group of "splenic lymph nodes," the splenopancreatic nodes, is located along the splenic artery. A small number, however, can be found near the short gastric vessels.

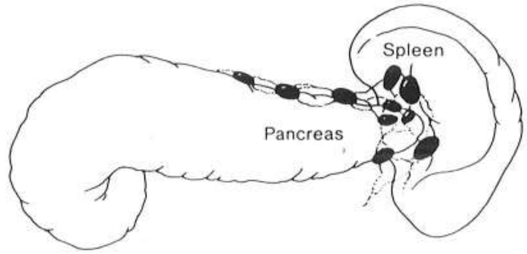

Figure 13. Lymphatic drainage of the spleen. (*From* Skandalakis JE, Colborn GL, Pemberton LB, et al: The surgical anatomy of the spleen. Problems in General Surgery 7:1, 1990; with permission.)

The splenic lymphatics have their origin in the splenic capsule and the trabeculae. The stomach and pancreas also drain into the splenic nodes (see Fig. 13).

Collateral Circulation

The organ receives blood from several sources. In addition to the splenic artery, the inferior or transverse pancreatic artery, short gastric arteries, left gastroepiploic artery, and other pancreatic arteries provide a supply of blood.

Use of a preoperative arteriogram is vital in determining the point of ligation of the splenic artery. This is necessary because the origins of the splenic branches are unpredictable. The collateral circulation ensures that the organ can tolerate ligation of the splenic artery. It is, therefore, possible to save the spleen if necessary. Ligation of the splenic artery near its origin, however, can result in hyperamylasemia. This is caused by compromise of the pancreatic blood supply.[25] Fujitani et al[9] recommend preoperative splenic arterial occlusion as an adjunct to high-risk splenectomy. The absence of anastomoses between the smaller branches of the splenic arteries results in the obstruction leading to infarction of the spleen.[33] Interestingly, Dumont and Lefleur[8] suggest that increased splenic arterial flow occurs in patients with isolated obstruction of the splenic vein.

SPLENIC INNERVATION

The more medial and anterior portions of the celiac plexus are the origin of the splenic plexus (Fig. 14). Splenic vessels and visceral nerve fibers from this plexus go to the splenic hilus. Fibers from the right vagus nerve or posterior vagal trunk also pass to the spleen, according to *Morris' Human Anatomy*.[1] Results of nerve degeneration studies after vagotomy in cats have led others[27] to question this configuration. Histology may be used to identify a few myelinated fibers, probably sensory in function, in a ratio of about 1:20 to unmyelinated autonomic fibers.

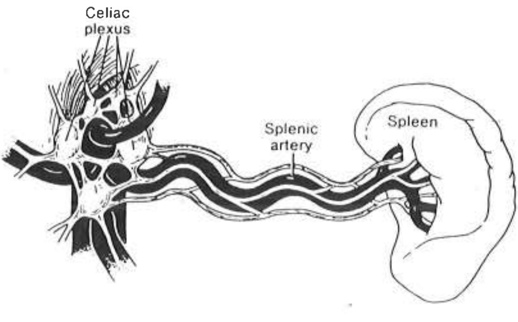

Figure 14. Splenic innervation. (*From* Skandalakis JE, Colborn GL, Pemberton LB, et al: The surgical anatomy of the spleen. Problems in General Surgery 7:1, 1990; with permission.)

The spinal cord at the level of the sixth to eighth thoracic vertebrae is the termination point for these fibers. The preganglionic sympathetic neurons arise in the intermediolateral cell column from this same level.

These neurons pass within the greater thoracic splanchnic nerve to the celiac ganglion, from which extensions of these nerve fibers then travel along the splenic artery. In some mammals, the autonomic fibers terminate in the smooth muscle of the splenic capsule, trabeculae, arteries, and veins.[3] In humans, however, distribution of the autonomic fibers is limited mostly to the branches of the splenic artery.[33] However, more work must be done for a better knowledge of the anatomic system along the greater curvature of the stomach and the vessels responsible for the blood supply of the lower esophagus, stomach, spleen and pancreas.

SEGMENTAL ANATOMY

Corrosion casts of human splenic arterial trees showed a superior and an inferior splenic segment in 84% of specimens, and a superior, a middle, and an inferior in 16% of specimens. Avascular planes separate these arterial segments.

The plane of separation of adjacent lobes passes completely through the spleen transversely to the longitudinal axis of the organ. The planes separating segments or subsegments are generally obliquely situated with respect to the long axis of the trunk. They often do not transverse the full depth of the spleen from the visceral to the parietal surface.[4] Radiopaque injection media were used by Garcia-Porrero and Lemes[10] to find that anastomoses between splenic arterial branches, especially between secondary branches, occur in about 30.5% of specimens. They also noted anastomoses of vessels supplying adjacent segments within the spleen in about 16.7% of specimens.[10] This frequency of intrasplenic anastomoses also was reported by Mandarim-Lacerda et al.[21] In their study of 66 full-term newborn infants, in whom they also noted an incidence of two lobar (segmental) branches in 68.2%, three branches in 10.6%, and four branches in 4.5%, the authors determined that segmental splenic resection also is possible in infants.

A number of studies have reported the separation of the spleen into lobes and segments by its arterial supply. Fewer have noted that the same segmental pattern may be observed, based upon its venous drainage, in obvious keeping with the embryologic development of the organ, by the fusion of vascularized, isolated mesenchymal aggregates. Dawson et al,[4] in their study of veins in unfixed, injected spleens, reported 71% had two lobes and 29% had three lobes. The lobes were further subdivided into two segments in 50% of the specimens. The avascular lines of separation of the lobes followed those of the arteries. The lines of lobar separation could be equated to marginal matching of the splenic border in more than half of the specimens. The veins were accessible at the hilus. Neither the arterial supply nor the venous supply to lobes or segments crossed to adjacent parenchyma in doubly injected (arterial

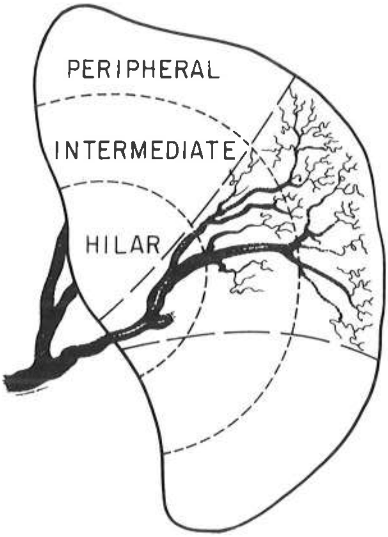

Figure 15. Regions indicated are shaped as a three-dimensional cone described by the length of the radius originating at the point of entrance of the major artery into the spleen. All regions contain penicilli, venules, and sinuses with addition of larger vessels as the hilus is approached. (*From* Dixon JA, Miller F, McCloskey D, et al: Anatomy and techniques in segmental splenectomy. Surg Gynecol Obstet 150:516–520, 1980; with permission.)

and venous vessels) specimens. Apparent venous segmentation also was described in earlier studies by Dryer and Budtz-Olsen.[7]

Intrasplenic vessels are lobar, segmented, and generally without intersegmental communication according to Dixon et al[5] (Fig. 15). These authors divided the spleen into three-dimensional cones with hilar, intermediate, and peripheral zones. A special technique for hemostasis is required by each zone. The same authors advised conservative treatment.

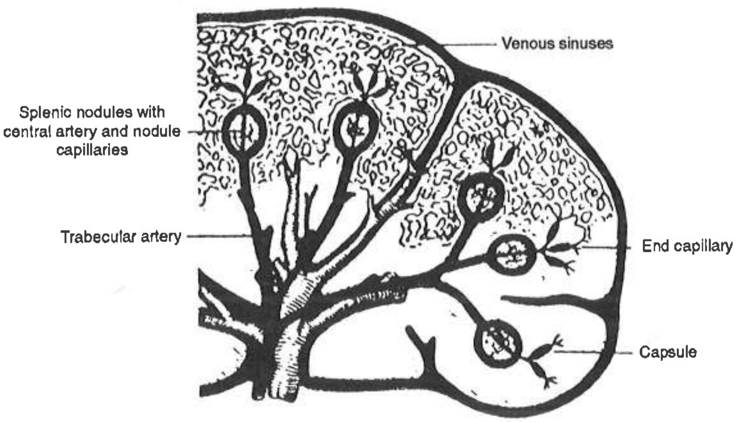

Figure 16. Schematic representation of the human spleen. Arteries are in black; veins are cross-hatched. (*From* Bargmann W: Histologie und mikroskopische Anatomie des Menschen, ed 7. Stuttgart, Thieme, 1977; with permission.)

They advocate a microfibrillar collagen for the peripheral zone (arterioles and venous injury), and ligation for the intermediate and hilar zone to take care of the trabecular and segmental vessels (Fig. 16).

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