

Introduction

The spleen is a solid organ about the size of the hand which is located under the diaphragm in the left upper part of the abdomen mostly covered by ribs.

The spleen is a part of the blood filtering system. Its main function is to identify and destroy old worn out blood cells, it also helps the immune system to identify and respond to some micro-organisms and helps our body to protect from them⁽¹⁾

Rupture of the spleen is the most common problem which lead to its removal, other causes which lead to its removal include splenic abscesses and infarctions, also removed for some malignancy like certain types of leukemia and lymphoma, some infectious diseases like mononucleosis, kala-azar and malaria and some types of certain blood diseases will lead to surgical removal of spleen like sickle cell disease, spherocytosis, thalassamia, ITP and hypersplenism ⁽²⁾.

There are two methods for surgical removal of spleen: Classical open method and Laparoscopic method.

Laparoscopic method is a safe procedure and can provide less postoperative morbidity in experienced hand, as open splenectomy. Most cases require splenectomy can be treated laparoscopically. Laparoscopic splenectomy is useful method for reducing hospital stay, complications and return to normal

activity. With better training in minimal access surgery now available, the time has arrived for it to take its place in modern surgery ⁽³⁾.

Small to moderate sized spleen is very easy to remove laparoscopically. The large sized spleen is difficult to remove by laparoscopic method, and better should be approached by open method and traumatic rupture spleen also should be approached by open method ⁽⁴⁾.

Relative contra-indications of laparoscopic splenectomy are poor risk of general anasesthesia, some cases of previous extensive abdominal surgery. Patients with cardiac disease and COPD should not be considered a good candidate for laparoscopic approach ⁽⁵⁾.

Laparoscopic splenectomy was first reported at the end of 1991, within just four years series were being reported from centers where the technique had become the method of choice for splenectomy ⁽³⁾.

Aim of the Work

The aim of this study is to review the recent advances in laparoscopic splenectomy. We will evaluate the new equipments, techniques, advantages, disadvantages of laparoscopic splenectomy, the role of laparoscopic splenectomy in elective splenectomy and their complications and their management.

Anatomy of the Spleen

Embryology

Consisting of an encapsulated mass of vascular and lymphoid tissue, the spleen is the largest reticuloendothelial organ in the body. Arising from the primitive mesoderm as an outgrowth of the left side of the dorsal mesogastrium, by the fifth week of gestation the spleen is evident in an embryo 8 mm long. The organ continues its differentiation and migration to the left upper quadrant, where it comes to rest with its smooth, diaphragmatic surface facing posterosuperiorly⁽⁶⁾.

Lymphocytes are present during the fourth month of gestation, then sinusoids appear which 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 take place around the 13th week⁽⁷⁾.

The red and white pulp appears by the 6th month. 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 retroperitoneal space, this fact should be remembered during possible mobilization of these vessels⁽⁸⁾.

Congenital abnormalities of the spleen

- 1- Splenic agenesis is rare but is present in 10% of children with congenital heart disease.
- 2- Polysplenia is a rare condition resulting from failure of splenic fusion.
- 3- Splenunculi are single or multiple accessory spleens that are found in approximately 10-30% of the population. They are located near the hilum of the spleen in 50% of cases and are related to the splenic vessels or behind the tail of the pancreas in 30%. The remainder are located in the mesocolon or the splenic ligaments. Their significance lies in the fact that failure to identify and remove these at the time of splenectomy may give rise to persistent disease.
- 4- Hamartomas are rarely found in life and vary in size from 1 cm in diameter to masses large enough to produce an abdominal swelling. One form is mainly lymphoid and resembles the white pulp whereas the other resembles the red pulp.
- 5- splenic cysts are rare. True cysts formed from embryonal rests and include dermoid and mesenchymal inclusion cysts. These should be differentiated from false cysts that may result from trauma and contain serous or haemorrhagic fluid⁽⁹⁾.

General description:

The spleen consists of a large encapsulated mass of vascular and lymphoid tissue situated in the left hypochondrium between fundus of the stomach and diaphragm and is not palpable under normal condition (10).

If we divide the spleen into three parts, the upper third is related to the lower lobe of left lung, the middle third to the left costophrenic sinus, and the lower third to the left pleura and costal origin of the diaphragm ⁽¹¹⁾.

The size and weight of the spleen vary with age, In the adult it is usually 12 cm long, 7 cm broad and 3-4 cm wide. It tends to diminish in size and weight in older people. Its average adult weight is about 150g (normal range: 80 - 300g, largely reflecting its blood content) ⁽¹²⁾.

Surfaces and relations of the spleen:

For all practical purposes the spleen has two surfaces: parietal (diaphragmatic) and visceral surfaces, superior and inferior borders and anterior and posterior extremities.

- 1. The diaphragmatic surface**, which is convex and smooth, faces posterosuperiorly and to the left, except at its posterior edge which faces slightly medial. It is related to abdominal surface of the diaphragm which separates it from the lowest part of left lung, pleura and the ninth to eleventh left ribs.

The pleural costodiaphragmatic recess extends down as far as its inferior border ⁽¹³⁾.

2. **The visceral surface** facing the abdominal cavity, presents gastric, renal, pancreatic and colic impression. The gastric impression directed anteromedially and upwards, is broad and concave where the spleen abuts on the posterior aspect of the stomach, from which it is separated by a recess of the greater sac. Near the inferior border of the spleen is the hilum, a long fissure pierced by several irregular apertures through which vessels and nerves of the spleen enter and leave. The renal impression is slightly concave, is located on the lowest part of the visceral surface and is separated from gastric impression above by a raised margin. It faces inferomedially and slightly backwards, being related to the upper and lateral area of the anterior surface of left kidney and sometimes to the superior pole of left suprarenal gland ⁽¹⁴⁾.

The colic impression at the extreme lateral end of the spleen, is usually flat and is related to the left colic flexure and phrenicocolic ligament. The pancreatic impression, small when present, it is situated between colic impression and the lateral part of the hilum; it is related to the tail of pancreas which lies in the lienorenal ligament. The superior border, separating the diaphragmatic surface from gastric impression, is usually convex and near its lateral end has one or two notches indicating lobulated form of the spleen in early fetal life ⁽¹³⁾.

The inferior border separates the renal impression from the diaphragmatic surface and lies between the diaphragm and the upper part of the left kidney's. lateral border It corresponds in position to the lower margin of eleventh rib. The posterior extremity usually faces the rounded vertebral column. The anterior extremity is more expanded and commonly forms a margin connecting the lateral ends of upper and lower borders. It is related to left colic flexure and the phrenocolic ligament⁽¹²⁾.

Splenic ligaments:

The peritoneum covers the entire spleen in a double layer, except for the hilum. At the hilum, the visceral peritoneum joins the right layer of the greater omentum (omental bursa) and forms the gastrosplenic and the splenorenal ligaments. These two ligaments are the chief ligaments of the spleen and form the splenic pedicle⁽⁸⁾.

1. **The splenorenal ligament** envelops the splenic vessels and the tail of the pancreas. The outer layer of splenorenal ligament forms the posterior layer of the gastrosplenic ligament. Careless division of the former may injure the short gastric vessels. Bleeding from these vessels may be the result of too-enthusiastic deep posterior excavation by the index and middle fingers of an operator seeking to mobilize and retract the spleen to the right. The splenorenal ligament itself is nearly

avascular, except in patients with portal hypertension and may be incised, but the fingers should stop at the pedicle⁽¹¹⁾.

2. The gastrosplenic ligament contains the short gastric arteries above and left gastroepiploic vessels below; it should be incised only between two clamps or preferably after the vessels are ligated one by one. Transfixion sutures may be used ⁽¹³⁾.

The spleen has several minor ligaments, and except for the presplenic fold, their names indicate their connections: the splenophrenic, splenocolic, pancreaticosplenic, phrenicocolic and pancreatocolic ligaments ⁽¹¹⁾.

- **The splenophrenic 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 area of the upper pole of the spleen close to the stomach. It is usually avascular, but it should be inspected for possible bleeding after section ⁽¹⁵⁾.

- **The pancreaticosplenic ligament** exists when the tail of the pancreas doesn't touch the spleen. The presplenic fold is a peritoneal fold anterior to the gastrosplenic ligament, often containing the left gastroepiploic vessels. Excessive traction on this fold during upper abdominal operations can result in a tear in the splenic capsule. The pancreatocolic ligament is a bridge of the tail or body of pancreas to the splenic flexure ⁽¹⁶⁾.

- **The phrenicolic ligament** is not a splenic ligament, but the spleen rests upon it. It extends between the splenic flexure of the colon and the diaphragm, opposite the tenth and eleventh ribs and constitute the "splenic floor". It is not connected to the spleen. It is the rudimentary left end of the transverse mesocolon containing smooth muscle cells that migrate into the ligament from the mesocolic taeniae ⁽¹⁷⁾.

This ligament acts as barricade at the left gutter, in most instances, it is responsible for prohibiting blood from a ruptured 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. During surgery, injury of the lower pole of the spleen or the splenic flexure of the colon may result if this ligament is short or fused ⁽⁸⁾.

Blood supply

Splenic artery and its branches:

The spleen receives its blood supply from splenic artery and its branches. The splenic artery, in most people, is a branch of the caeliac trunk together with the hepatic and left gastric arteries. The artery originated from the celiac trunk in 90% of people followed by abdominal aorta in 8%, and other sites in 2% ⁽¹⁸⁾.

The artery varies in length from 8 to 32 cm and in diameter from 0.5 to 1.2 cm. The normal course of splenic artery crosses the left side of aorta, passes along upper border of pancreas reaching the tail in front, then crosses the upper pole of left kidney, After giving off various minor branches to the pancreas and stomach, this vessel divides in the lienorenal ligament shortly before reaching the spleen into two or three lobar arteries, which supplies its corresponding lobe; each lobar artery subsequently divided into two to four lobular branches. Six to twelve lobular branches were observed entering the splenic substance at the hilum. Lobar arteries did not anastomose with each other; hence, the lobes of the spleen are also termed segments. Within each segment, the artery ramifies in the trabeculae to supply the parenchyma of the spleen ⁽¹⁹⁾.

Obstruction of the smaller branches of the splenic arteries leads to infarction of the corresponding splenic tissue due to absence of anastomosis between these branches ⁽²⁰⁾.

The left gastroepiploic artery arises most often from splenic trunk. Less often it arises from the inferior terminal or its branches, and rarely it arises from the middle splenic trunk or the superior terminal branch ⁽²¹⁾.

There is no question that the spleen can tolerate ligation of splenic artery because of the available collateral circulation .It was said that ligation of splenic artery near its origin can result in hyperamylasemia resulting from deterioration of pancreatic blood supply ⁽²²⁾.

Splenic vein and its tributaries:

The minor veins pass from the red pulp of the spleen into the trabeculae, and then into segmental veins running alongside the segmental arteries ⁽¹⁰⁾.

On leaving the hilum, the splenic veins travel with the splenic artery, sometimes crossing over or under it. The anatomy of splenic veins is highly variable, and as in arteries, no one vein resembles the next. The single characteristic of most of short gastric veins is that they communicate directly with the spleen, entering at its upper part, rather than through the extrasplenic venous vessels. The left gastroepiploic venous drainage is into the splenic veins. After receiving venous tributaries from various sources, the splenic vein passes behind the pancreas and lies below the splenic artery. Behind the neck of the pancreas it joins the superior mesenteric vein to form the portal vein; in its course it receives the inferior mesenteric vein. Splenic vein accounts for as much as 40 percent of portal venous blood flow ⁽¹³⁾.

Lymphatics:

The lymphatic vessels of the spleen, once thought to be an insignificant component draining the capsule and thickest trabeculae, has recently been shown (at least in some species) to be an important feature of all parts of the tissue. Extensive blind ending (efferent) lymphatic vessels are present in the

white pulp, running in tortuous fashion alongside the arterioles. These drain along splenic trabeculae to pass out of the hilum into the lymphatic vessels accompanying the splenic artery and vein. They take splenic lymph to pancreaticosplenic and caeliac nodes. No afferent lymphatic vessels are present ⁽¹²⁾.

Nerves:

The spleen is supplied from celiac plexus with sympathetic fibers only. The celiac sympathetic plexus gives off nerve fibres which pass along the splenic artery and its branches, as a surface plexus, to enter the hilum and run with segmental arteries and their branches. These fibers appear to be mainly noradrenergic vasomotor, concerned with the regulation of blood flow through the spleen, in man nerve distribution is confined mainly to the branches of splenic arteries. In other mammals they also supply the non-striated muscle in the capsule and trabeculae ⁽¹²⁾.

Segmental anatomy:

There is evidence that the human spleen, like that in other species, consists of separate "segments" each served by a hilar branch of the main splenic artery and vein. These segments were defined as anatomically distinct areas of splenic tissue running from the anterior to the posterior border perpendicular to the long axis of the spleen. Studies indicate that 84% of the population has two splenic segments-superior and inferior and 16% has three segments-superior, middle, and inferior ⁽²³⁾.

The segments are separated from each other by avascular planes. Subsequent divisions with independent blood supply were also identified ⁽¹⁶⁾. **(Fig 1)**

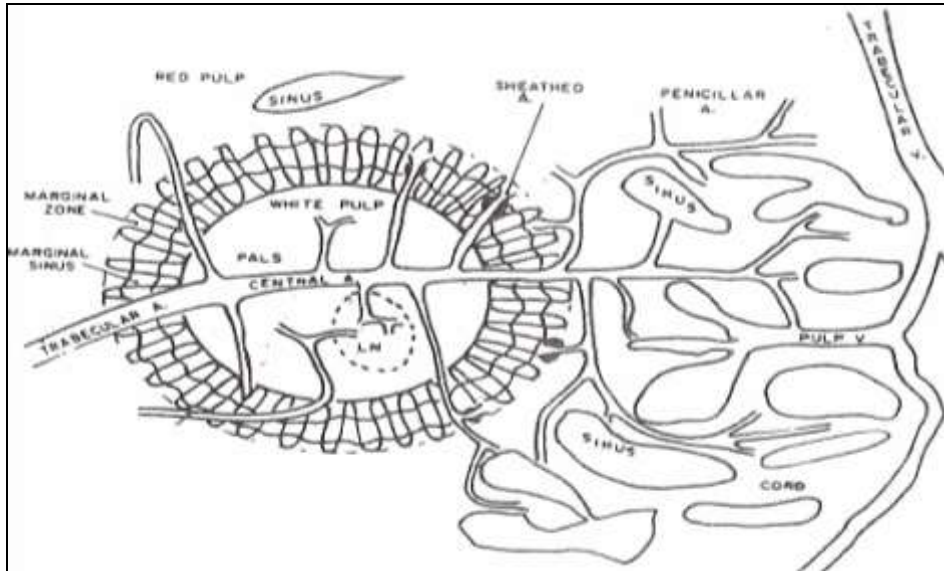


Fig (1): Diagram illustrating splenic compartments and potential vascular supply routes. As artery or arteriole, V = vein, LN = lymphatic nodule which may include germinal center, PALS = periarterial lymphatic sheath ⁽³⁴⁾.

Histology of spleen

Microscopically, the parenchyma of the spleen consists of two major components, known as white pulp and red pulp, denoting their appearance when the freshly excised spleen is transected. The white pulp is composed of lymphoid tissue in which B and T lymphocyte can mature and proliferate under antigenic stimulation⁽²⁴⁾.

The red pulp constitutes the majority of the total splenic volume (about 75%). Within it lie large numbers of venous sinuses draining into tributaries of the major splenic veins. The sinuses are separated from each other by a fibrocellular network, the reticulum, formed by numerous fibroblasts (reticular cells) and small fibres of delicate collagen fibres, In the meshes of which lie splenic macrophages. These intersinusal regions called the splenic cords of Billroth ⁽²⁵⁾.

The red pulp is a unique filtration device which enables macrophages in the spleen to extract particulates from the blood as it perfuses this organ. Red pulp is composed of a complex system of interconnected spaces inhabited by a large numbers of phagocytic macrophages. These cells remove and dismantle effete red blood cells, micro-organisms, cellular debris and other particulates from the circulation ⁽²⁶⁾.

White pulp: Within the spleen, the branches of the splenic artery radiate out from the hilum within trabeculae,