Study of the Polar Arteries Supplying the Spleen and Their Significance in Its Viability

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Abstract

Background: To study the blood supply of the spleen and its segmental distribution, with a particular interest on the presence and adequacy of collateral vessels supplying the spleen.

Methods: The study was performed at the Department of Anatomy, Faculty of Medicine, King Abdul-Aziz University, Jeddah, Saudi Arabia during the years 2004-2007. In this study, the blood supply of the spleen was studied in 15 human stillbirths and 10 adult cadavers of different ages and sexes. The study involved dissection, radiological and injection-corrosion techniques. In addition, an experimental study was carried out on twelve albino rats which were divided into 3 groups. In the first group, the splenic artery was ligated. In the second group, the terminal splenic branches were ligated and the third group was left as a control. Two weeks after ligation, the spleens from different rats were removed and examined.

Results: In the human specimens, the results showed that the medial end of spleen was found to receive one or more polar arteries arising from the following sources; the upper short gastric artery (40%), both upper short gastric artery and arterial network at the stomach fundus (48%), the phrenic artery (8%) or from the aorta (4%). The lateral end of spleen was also found to receive lateral polar artery which arose in all cases from the left gastroepiploic artery. Regarding the rats, the results showed that in the first group, the spleen looked normal except in one case where an infarction was produced. In the second group, the terminal splenic branches were ligated and the third group was left as a control. Two weeks after ligation, the spleens from different rats were removed and examined.

Conclusions: It was concluded that the spleen is supplied by polar arteries in addition to the terminal splenic branches and that arteries can maintain viable and functioning spleen even after ligation of the splenic artery or its terminal branches.

Key words: Polar Arteries, Spleen, Splenic artery, Corrosion Technology.

Introduction

Indications for splenectomy are numerous. It may be done for the treatment of specific splenic pathology as sickle cells anemia \(^1\), hypersplenetic thrombocytopenia\(^2\), and hereditary spherocytosis\(^3\) or as a component of surgical procedures on other organs. The removal of the tail of the pancreas, for example, involves the removal of the spleen which shares its artery and vein. This is because the dissection of the splenic vessels from the pancreas is tedious, time consuming, productive of pancreatitis and difficult \(^4\). The spleen is removed also as a part of gastrectomy\(^5\). Post-splenectomy overwhelming infection \(^6\) and the decreased immunity after splenectomy \(^7\) forced the surgeons to evaluate the old concept that consider splenectomy as the only legitimate operation on the spleen \(^8\).

The rationale for splenic preservation and the success of splenic salvage in children has prompted the surgeons to adopt the same policy in adults \(^9\). Nyhus and Baker \(^10\) mentioned that preservation of the traumatized spleen is not only safe and possible but should now be considered of good surgical practice.

Splenic preservation is based on the presence of collateral branches from the short gastric vessels to the spleen. The presence of these vessels was confirmed by many authors\(^11,12\). However, textbooks of anatomy and surgery mentioned nothing about the short gastric vessels as a source of collateral supply to the spleen.

Partial splenectomy was tried by many surgeons in order to preserve the functions of the spleen. The principle of partial splenectomy is based on the segmental distribution of the splenic vessels as well as on the presence of avascular planes separating these segments \(^13,14\). However, the pattern of splenic segments and their number is poorly studied and needs further investigations \(^15,16\).

Therefore, this work was carried out with an
aim directed to the study of the blood supply of the spleen and its segmental distribution, with a special attention to the presence and adequacy of collateral vessels supplying the spleen for splenic preservation.

**Patients and Methods**

The current study was carried out in the mortuary of the Faculty of Medicine, King Abdul Aziz University. Experiments were performed with the understanding and consent of the subject’s relatives. The study was ethically approved by the Bioethics Committee of the Faculty of Medicine, King Abdul Aziz University.

**ANATOMICAL STUDY:** An anatomical study was carried out on 15 full term stillbirths and 10 human cadavers of different sexes and ages (21-53 years) obtained according to the followed ethical rules. In each case, the splenic artery was dissected from the celiac trunk till its termination at the hilum of the spleen. All its branches, as well as its accompanying veins, were examined and their relations to the different parts of the spleen were recorded.

Radiological, injection and injection-corrosion techniques were used in the study of splenic artery and its branches in the stillbirths. In each case, a midline incision in the anterior abdominal wall of the trunk was made. The descending aorta was exposed and 2 ligatures were applied to it: one below the arch of the aorta and another just below the renal arteries. A cannula was introduced in the thoracic part of the aorta and injected with the following:

In 5 stillbirths: the aorta was injected with lead oxide in turpentine oil (40%) and x-ray films were prepared for celiac trunk and all its branches.

In 5 stillbirths: the aorta was injected with neoprene latex using hand pressure until resistance was complete and the splenic artery and all its branches were seen to be completely filled. The aorta, celiac trunk, stomach, duodenum, pancreas and spleen were removed en-bloc. The specimen was left in a basin filled with water at room temperature for two weeks to allow for putrefaction of the specimen. After 2 weeks, water was replaced by 30% sodium hydroxide to macerate the residual tissues. The obtained plastic cast was washed under running tap water. The splenic artery and its branches were examined.

In 5 stillbirths: the aorta was injected with barium sulfate in order to impart the splenic artery and its branches white color so as to be easily identified. Dissection of the splenic artery and its branches was done.

**EXPERIMENTAL STUDY:**

It was done on 12 albino rats (180-250 grams) to verify the presence of collateral arteries supplying the spleen and to access their adequacy to keep the spleen viable. The rats were divided into 3 groups. In each rat of the first and second groups the following was done:

The rat was anesthetized using ether inhalation. A midline incision of the anterior abdominal wall was made. The splenic artery and its branches were dissected and examined carefully. In the first group (4 rats) the splenic artery was ligated. In the second group (4 rats), the terminal splenic branches were ligated at the hilum of the spleen. The abdominal incision was sutured in layers and the animal was left to live for 2 weeks before sacrifice. The third group (4 rats) was left as a control.

After 2 weeks of ligation of the arteries, the preliminary operative steps were repeated in each animal to expose the spleen. The spleen was grossly examined for any pathological changes. Warm India ink was injected in the inferior vena cava and the spleen was noticed until it became dark in color indicating its uptake to the ink. The animal was sacrificed and the spleen was removed.

**HISTOLOGICAL STUDY:** In each case of all groups, the spleen was divided into 3 parts: upper part including the upper pole (medial end), middle part including the hilum and lower part including the lower pole (lateral end). Paraffin blocks and paraffin sections 8 µ in thickness were prepared as usual. The sections were stained with hematoxylin and eosin and were examined for any pathological changes and to access the phagocytic activity of the spleen to India ink.

**Results**

**ANATOMICAL STUDY:**

**Polar arteries of the spleen:**

In all cases of the present study (100%) each end of the spleen was found to receive one or more arteries which will be referred to as polar arteries.

**Medial polar arteries**

The medial end of the spleen was found to supplied by one polar artery in 8 cases (32%), 2 polar arteries in 5 cases (20%) and 3 polar arteries in 12 cases (48%). The source of the polar arteries was as follows: in 10 out of 25 cases (40%), they arose from the upper...
short gastric artery (Fig. 1). In 12 out of 25 cases (48%) they arose from the upper short gastric and from the

Fig. (1): A photograph of the stomach (ST) and the spleen (SP) of a stillbirth. The splenic artery (S) divides into upper (U) and lower (L) divisions each of which divides into 3 terminal branches (T). The upper short gastric artery (G) gives medial polar artery (MP) to the medial end of the spleen. The left gastroepiploic artery (LG) gives lateral polar artery (LP) for the lateral end of the spleen.

Fig. (2): A photograph of an adult spleen (SP) and the fundus of the stomach (ST). Medial polar arteries (MP) arise from the upper short gastric artery (G) and from the arterial network at the fundus of the stomach. Medial polar arteries are accompanied with corresponding veins (V).

Fig. (3): A photograph of an adult spleen (SP) and the fundus of the stomach (ST). Medial polar arteries (MP) arise from the short gastric artery (G) and from the arterial network at the fundus of the stomach. They are accompanied with corresponding veins (V).

Fig. (4): A photograph of the stomach (ST), spleen (SP) and diaphragm (D) of a stillbirth. The splenic artery (S) is divided into 4 terminal branches (T) at the hilum of the spleen. The left gastroepiploic artery (LG) gives lateral polar artery (LP) and omental branch (O). The phrenic artery (P) gives 2 medial polar arteries (MP) for the medial end of the spleen which received another 2 branches from the upper short gastric artery (G).

Fig. (5): A photograph of an x-ray film showing the splenic artery (S) which ends by dividing into upper (U) and lower (L) divisions each of which divides into 2 terminal branches (T). The left gastroepiploic artery (LG) arises from the splenic artery at the junction of its middle and distal thirds and gives lateral polar artery (LP). A medial polar artery (MP) is seen arising from the aorta (A). Notice the communication between the polar arteries and the terminal splenic branches and the poor anastomosis at the capsular area.

Fig. (6): A photograph of an x-ray film of the splenic artery (S) which divides into upper (U) and lower (L) divisions each of which gives 3 terminal branches (T). The left gastroepiploic artery (LG) arises from the lower division and gives lateral polar artery (LP). A medial polar artery (MP) is seen arising from the upper short gastric artery (G). Notice the free intrasplenic anastomoses between the polar arteries and the terminal...
splenic branches. Notice also the rich anastomoses between the arteries of the stomach.

Fig. (7): A photograph of an x-ray film showing the splenic artery (S) dividing at the hilum of the spleen into 4 terminal branches (T). The left gastroepiploic artery (LG) arises from the splenic artery at the junction of its middle and distal thirds and gives lateral polar artery (LP). Another lateral polar artery is arising from the arterial network at the body of the stomach. The upper short gastric artery (G) gives medial polar artery (MP). Notice the rich anastomosis between the polar arteries and the terminal splenic branches. Notice also the rich anastomosis between the arteries of the stomach.

Fig. (8): A photograph of a plastic cast of the aorta (A), the splenic artery (S) & the left gastroepiploic artery (LG) which gives lateral polar artery (LP). The splenic artery ends by dividing into upper (U) and lower (L) divisions each of which gives 2 terminal branches (T). Notice the absence of avascular planes between the different segments of the spleen.

Fig. (9): A photograph of the spleen (SP), the liver (L) and the stomach (ST) of an albino rat 2 weeks after ligation of the splenic artery. Notice the infarction at the junction of the upper pole (U) and the rest of the spleen which appears normal.

Fig. (10): A photomicrograph of the site of infarction shown in fig. 9. Notice that the infarction is subcapsular and notice also the normal tissue deep to it. (Hx. & E: X 100).

Fig. (11): A photomicrograph of a spleen obtained 2 weeks after ligation of the splenic artery. Notice the normal tissues with absence of any necrosis or hemorrhage. The black deposits in macrophages are particles of India ink. (Hx. & E: X 400)

Fig. (12): A photograph of the liver (L), stomach (ST) and the spleen (SP) of an albino rat 2 weeks after ligation of the terminal splenic branches. Notice the dark color of the spleen & liver due to the uptake of India ink. The spleen shows no gross pathological changes. Polar arteries from the fundus...
of the stomach to the upper pole of the spleen are seen.

Fig. (13): A photomicrograph of the spleen obtained 2 weeks after ligation of the terminal splenic branches. Notice the black deposits of India ink especially at the marginal zone and the splenic cords. (Hx. & E: X 200)

arterial network at the fundus of the stomach (Figs. 2, 3). In 2 out of the 25 cases (8%), they arose from the splenic artery (Fig. 4), while on one out of the 25 cases (4%); it arose from the abdominal aorta (Fig. 5).

Lateral polar arteries

In all cases (100%), the lateral end of the spleen was found to receive a large artery which arose from the left gastroepiploic artery. The left gastroepiploic artery was found to arise from the splenic artery at the junction of its middle and distal thirds (92%) or from its lower division (8%). The artery to the lateral end of the spleen was called lateral polar artery (Figs. 1, 4, 5, 6, 7, and 8). In one out of the 25 cases (4%) there was an additional lateral polar artery arising from the arterial network at the body of the stomach (Fig. 7). The polar arteries were found to be followed by corresponding veins (Figs. 2, 3).

The mode of termination of the splenic artery:

In 16 out of 25 cases (64%), the splenic artery ended by dividing into upper and lower divisions, each of which further divided into 3 terminal branches in 10 cases (Figs. 1,6) or 2 terminal branches in 6 cases (Figs. 5,7,8). Thus, there were 6 terminal branches in 40% of the cases and 4 terminal branches in 24% of the cases. In 9 out of 25 cases (36%), the splenic artery ended at the hilum of the spleen by dividing directly into 4 terminal branches (Figs. 4, 7). The terminal branches, in addition to the lateral and medial polar arteries, were distributed to 6 or 8 segments (Figs. 1, 5, 6, 7, 8). The radiological study and plastic casts showed the free intrasplenic communication between the terminal splenic branches on one hand and the terminal splenic branches and the polar arteries on the other hand. No evident avascular planes were found separating the segments from each other (Figs. 5, 6, 7, 8). The subcapsular area showed absence of anastomoses between the arteries of the spleen (Figs. 5, 6, 7). The radiological study revealed rich anastomoses between all the arteries supplying the stomach (Figs. 6, 7).

EXPERIMENTAL AND HISTOLOGICAL STUDIES:

In the first group (4 rats), where the splenic artery was ligated, 3 cases revealed a normal spleen without evident pathological changes. Histological sections showed normal structure as well as persistent phagocytic activity to India ink. (Fig. 11). However, in one case the spleen showed an infarction at the junction of the upper pole while the rest of the spleen appeared normal (Fig. 9). Histological sections revealed that the infarction was superficial and subcapsular with normal deeper tissue (Fig. 10). In the second group (4 rats), where the terminal splenic branches were ligated, the spleen was without pathological changes (Fig. 12). Histological sections showed normal structure and maintained phagocytic activity to India ink (Fig. 13).

Discussion

The erroneous concept that considers splenectomy as the only legitimate operation of the spleen has been challenged by the marvelous results of splenic preservation in children. The growing knowledge about the vital activities of the spleen, the overwhelming postsplenectomy syndrome and the decreased immunity after splenectomy developed the enthusiasm for splenic salvage among clinicians. As a matter of fact, the conservation of the spleen, as any other organ, depends on the presence of adequate blood supply and/or collateral circulation.

Textbooks of anatomy and surgery describe the blood supply of the spleen in a consistent way. They usually specify five or more terminal branches of the splenic artery which supply the spleen. Daisy
Sahni et al. 17, reported that the splenic artery divided into two or three lobar arteries; each lobar artery subsequently divided into two to four lobular branches at the hilum of the spleen. However, many authors believe that the spleen is nourished via the short gastric arteries in addition to the main supply by the terminal splenic branches.12,18 Farag et al.12 found in 92% of their cases at least one artery arising from the upper short gastric artery or from the subserosal or submucous gastric plexus that supplies the upper pole (medial end) of the spleen. Nevertheless, Skandalakis et al.19 considered these arteries to be short gastric arising from the interior of the spleen. The present study proved the presence of medial polar arteries (so called in the present study) arising from the following sources: upper short gastric artery only (40%), both the upper short gastric artery and the arterial network at the fundus of the stomach (48%), the splenic artery (8%) or directly from the abdominal aorta (4%).

Similarly, the lateral end of the spleen was found, in all cases of the studied specimens, to receive a large lateral polar artery (so called in the present study) which arose from the left gastroepiploic artery. In one case, there was an additional lateral polar artery arising from the arterial network on the body of the stomach. In accordance with these results, Skandalakis et al.19 and Buyukunal et al. 20 mentioned that the spleen receives branches from the left gastroepiploic artery. The polar arteries, described herein, were accompanied with corresponding veins. The presence of these polar arteries, supplying the ends of the spleen, was not mentioned in any of the known textbooks of anatomy or surgery.

Contrary to the description of the origin of the left gastroepiploic artery in the textbooks of anatomy as one of the terminal branches of the splenic artery, the present study showed that it arises from the splenic artery at the junction of its middle and distal thirds (2%) or from its lower division (8%). The knowledge of the exact site of origin of the left gastroepiploic artery is important, from the surgical point of view, for its exposure at operations.

Partial splenectomy is another option for conservative management of the spleen that depends on its segmental nature. Christo 14 reported successful partial splenectomy in eight patients with traumatic injury using avascular planes. These results encouraged surgeons and there developed a growing interest in subtotal splenectomy.13,21-23

In spite of the success in partial splenectomy few contradictory reports were found in the literature dealing with the segmental nature of the spleen. Gupta et al. 24 used corrosion technique and showed that the spleen is divided into two (84%) or three (16%) arterial segments separated by avascular planes. Mc Minn 25 mentioned that the branches of the splenic artery give rise to 4 segments (perhaps 2 or 3) and those intersegmental vessels were small and scanty. Nyhus and Baker 10 reported that as many as 5 lobes may be present in the spleen. Jamieson 4 mentioned that in addition to the upper and lower polar segments there are 5 central segments. Actually, the number of the splenic segments is variable. The results presented herein showed that there were 4 or 6 hilar segments formed by the terminal branches of the splenic artery in addition to 2 polar segments formed by the polar arteries. Thus, a total of 6 or 8 segments may be present in the spleen.

The present study showed that there are free intrasplenic anastomosis between the terminal splenic branches and the polar arteries. Likewise, Sahni et al. 17 found anastomosis between the arteries of splenic lobules. The presence of such anastomosis contradicts the presence of avascular planes mentioned by other authors. The intrasplenic anastomosis proved to be adequate to maintain a viable and functioning spleen as evidenced, herein, by persistent phagocytic activity after ligation of the splenic artery or its terminal branches. This view is supported by the belief of most authors that in most injuries of the spleen, ligation of the splenic artery leaving the spleen in situ, may occasionally be successful. Buyukunal et al. 20 mentioned that no complications or side effects were encountered after ligation of the splenic artery in 20 patients. Similarly, Cooper and Williamson 18 reported that ligation of the segmental arteries in partial splenectomy allows compensatory hypertrophy of the splenic remnants and a return to normal function.

The present work confirmed the presence of adequate collateral blood supply to the spleen represented by the polar arteries and their accompanying veins with their intrasplenic communications with other splenic vessels. The enjoyment of the spleen with dual polar supply, in addition to the main supply by the splenic artery, leads to the conclusion that the spleen should not be sacrificed easily after trauma or during the removal of other organs. In cases of splenic trauma or hilar avulsion, partial splenectomy would be satisfactory and feasible. In the meantime, the removal of the stomach or the pancreas, for example, does not necessitate splenectomy as was commonly believed before. In gastrectomy, the spleen can depend on the
splenic artery, while in pancreatectomy; it can depend on the polar arteries.

It is recommended that in obligatory splenectomy, care should be taken to avoid injury of the polar vessels which may be overlooked due to the lack of information about them among surgeons. Lesions of these polar vessels will result in severe intraoperative bleeding. Moreover, in pancreatectomy the gastroepiploic artery should be ligated proximal to the spleen through the rich gastric anastomosis between the arteries of the stomach with the left gastroepiploic artery as shown in the present work.

In conclusion, the presence of collateral blood supply via the polar vessels to either end of the spleen was confirmed through this study. The free intrasplenic communication of these polar arteries with the terminal splenic branches presents a firm base for splenic preservation or partial splenectomy.

References