

Morphological Analysis of the Spleen and its Vessels: A Cadaveric Study

Análisis Morfológico del Bazo y sus Vasos: Un Estudio Cadavérico

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SUMMARY: The spleen is a vital lymphatic organ found in the left hypochondriac region. A thorough understanding of the anatomy and anatomical variations of the spleen and its vessels plays a significant role in preventing iatrogenic injury during surgical procedures, improving diagnostic accuracy, informing treatment decisions, reducing the risk of surgical complications, and in treating various diseases related to the spleen. This study aimed to document the morphology of the spleen concerning its shape, poles, notches, margins, surfaces, and origin of its vessels. Observed anatomical variations were also noted. A sample of 32 cadavers, provided by the Discipline of Clinical Anatomy at the University of KwaZulu-Natal – Westville and Nelson R Mandela Medical School campuses were used in this study. The spleen and its associated vasculature were exposed following the dissection protocol according to Grant's Dissector. In the present study, the prevalent spleen shape was oval (40.6 %), followed by wedge (31.3 %), tetrahedral (18.8 %), and triangular (9.4 %) shapes. The highest number of notches recorded was 4 and notches were absent in 34.4 % of cases. Two surfaces, poles, and two margins were observed in all 32 (100 %) spleens. In 93.8 % cases, the splenic artery emerged from the celiac trunk, and it emerged from the abdominal aorta in 6.3 % cases. The findings of the current study conclude that there is no association between the shapes of the spleen, the presence of notches, and sex.

KEY WORDS: Spleen; Splenic Vessels; Cadavers; Morphology; Variations; Hypochondrium.

INTRODUCTION

The spleen has been a subject of significant scientific inquiry, despite its relatively modest dimensions, the precise role and function of this organ remains insufficiently comprehended, leading to its classification as an enigmatic organ (Srivani *et al.*, 2019). Nonetheless, recent studies on its structure and functionality have illuminated its vital significance within the human body (Srivani *et al.*, 2019). Its anatomical complexities, notably its vessels and potential variances, have piqued the interest of researchers seeking to understand the complexity of the human body. The spleen is the greatest lymphatic organ of the human body that is connected to the circulatory system and is made up of a sizable mass of vascular and lymphoid tissues (Chaudhry *et al.*, 2023). It is located between the fundus of the stomach and the diaphragm in the left hypochondrium and partly in the epigastrium (Chaudhry *et al.*, 2023). This organ comprises of two margins (anterior and superior) and two surfaces (visceral and diaphragmatic) (Srivani *et al.*, 2019). The shape of the spleen is variable, it is mostly determined by its association to adjacent structures during development

and typically giving it the appearance of a slightly curved wedge (Standing, 2015).

Studies by Kawamoto *et al.* (2012) and Chaudhari *et al.* (2014), reported of a presence of normal and fully functional collection of splenic tissue in ectopic locations known as auxiliary or accessory spleens. These can appear anywhere in the abdomen, including the gastrosplenic or splenorenal ligaments and the wall of the stomach or colon. The two most frequent places for accessory spleens are the splenic hilum (75 %) and the pancreatic tail (25 %) (Yildiz *et al.*, 2013). Although accessory spleens are distinct from the spleen's anatomical location, they are somewhat connected to it (Bajwa & Kasi, 2023). They are functionally and histologically alike to the average spleen and also receive arterial supply from the splenic artery (Bajwa & Kasi, 2023).

The average adult human spleen weighs approximately 150 g, with a thickness of 2.5 cm, a width of 7.5 cm, and a length of 12.5 cm (Tenaw & Muche, 2018). The spleen is a

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highly vascular organ with the splenic artery entering the splenic hilum close to the center of the visceral surface and this vessel predominantly supplies this organ (Drake *et al.*, 2015). The splenic artery originates from the celiac trunk and travels lateral to the superior aspect of the pancreas through the splenorenal ligament. This artery splits into gastric (left gastro-omental artery, short gastric arteries) and pancreatic (great, dorsal, and inferior pancreatic arteries) branches, before reaching the hilum of the spleen (Drake *et al.*, 2015). The gastrosplenic ligament, which houses the short gastric and gastro-omental vessels, connects the spleen to the stomach's greater curvature (Standring, 2015). The venous drainage of the spleen occurs through the splenic vein, which is a large vein that exits the spleen at its hilum to join with the superior mesenteric vein that forms the hepatic portal vein posterior to the neck of the pancreas, at the second lumbar vertebral level (Drake *et al.*, 2015).

Understanding the anatomy and possible anatomical variations of the spleen and its vessels can assist in preventing iatrogenic injury during surgical procedures. This knowledge can also be used to improve diagnostic accuracy, inform treatment decisions, reduce the risk of surgical complications, and treatment of various diseases related to the spleen such as splenomegaly, splenic abscess, splenic rupture, and tumors of the spleen. Thus, the current study aimed to document the morphology of the spleen and to note possible variations. It aimed to observe and document the shape, poles, notches, margins, surfaces, impressions, and the origin of the splenic vessels. This knowledge can aid in the accurate interpretation of imaging studies and planning of surgical procedures and contribute to the advancement of medical knowledge in the specialty of splenic anatomy and pathology.

MATERIAL AND METHOD

Sample. The study was performed on 32 cadavers of Caucasian descent which were evenly distributed according to sex and were provided by the discipline of Clinical Anatomy at the University of KwaZulu-Natal, Westville, and Nelson R. Mandela Medical School campuses. Ethical approval was obtained from the Biomedical Ethics Committee (BREC) at the University of KwaZulu-Natal (BREC/00020430/2023).

Dissection Procedure. The dissection was completed as per the Grant’s dissector’s manual 17th edition (Detton, 2020). A camera provided by the discipline of Clinical Anatomy was used to take the images presented in this manuscript. The superior portion of the rectus abdominis muscle was elevated. The abdominal wall was reflected inferiorly. The abdominal cavity was inspected by hand, and organs found within the abdomen, including the stomach and spleen, were

observed. The stomach was identified in the left upper quadrant, and the fundus of the stomach was located around the left side of the stomach. The spleen was observed in the left upper quadrant posterior to the stomach. The spleen was detached from its attachments and gently pulled anteriorly.

Morphological Analysis. The number of notches on the spleen's margins, shape, poles, surfaces, and margins were observed. The origin of the splenic vessels was also observed. The data was recorded and analysed accordingly and compared with that of previous studies.

Statistical analysis. Descriptive statistics was used to summarise the data. Frequencies and percentages were used to describe the shape, notches, poles, margins, and surfaces of the spleen. Stata v17 statistical software was used for the analysis. A p-value of < 0.05 was considered statistically significant.

RESULTS

Shape.The spleen was oval shaped in 40.6 % of cases (n=13/32). It was tetrahedral, wedge and triangular shaped in 18.8 % (n=6/32), 31.3 % (n=10/32) and 9.4 % (n=3/32) of cases, respectively (Table I) (Fig. 1).

Table I. Incidence of the splenic shapes

| Shapes | Female | | Male | | Total | p value |
|-------------|--------|------|------|-------|-------|---------|
| | n | % | n | % | | |
| Tetrahedral | 3 | 50.0 | 3 | 50.0 | 6 | 0.26 |
| Oval | 6 | 46.2 | 7 | 53.8 | 13 | |
| Wedge | 7 | 70.0 | 3 | 30.0 | 10 | |
| Triangular | 0 | 0.0 | 3 | 100.0 | 3 | |

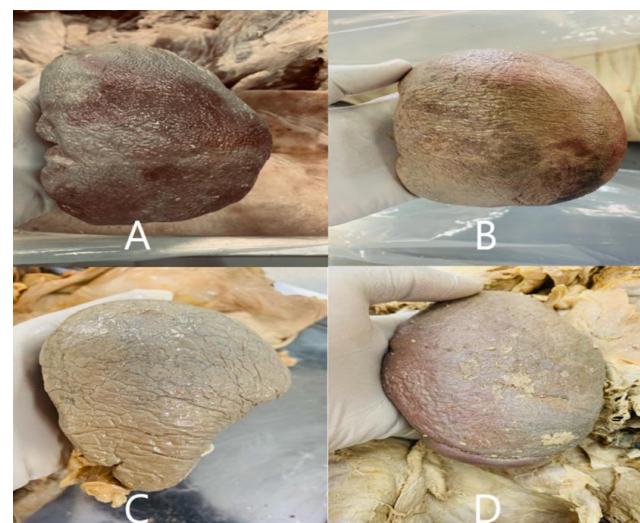


Fig. 1. Splenic shapes: Wedge-shaped (A); Tetrahedral (B); Triangular (C), and Oval (D).

There was not statistical significance for the association between shape and sex was ($p = 0.26$). The Fisher's test was used to determine the probability for this association.

Notches. Notches were absent in 34.4 % ($n=11/32$) of cases. The number of notches varied from zero to three, but in most cases, there were only one or two notches (Table II, Fig. 2) The calculated p-value for the association between notches and sex was $p = 0.90$.

Table II. Incidence of the splenic notches.

| Number of notches | Female | | Male | | Total | p value |
|-------------------|--------|------|------|------|-------|---------|
| | n | % | n | % | | |
| 0 | 5 | 45.5 | 6 | 54.5 | 11 | 0.90 |
| 1 | 3 | 33.3 | 6 | 66.7 | 9 | |
| 2 | 5 | 83.3 | 1 | 16.7 | 6 | |
| 3 | 3 | 50.0 | 3 | 50.0 | 6 | |

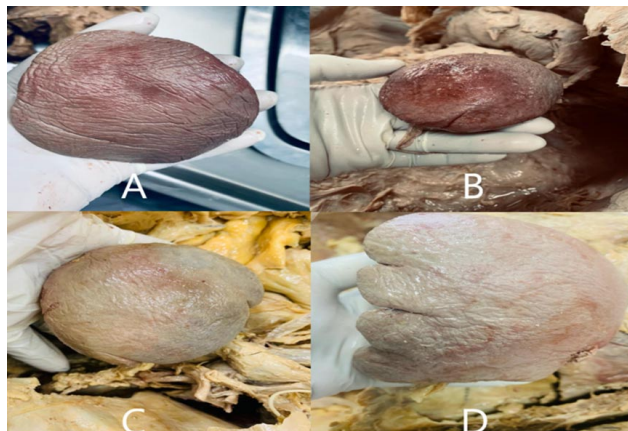


Fig. 2. Splenic notches, A: Spleen with zero notches; B: One notch; C: Two notches; D: Three notches.

Surfaces and margins. In all 100 % ($n=32/32$) of cases, the spleen comprised two surfaces, two poles, and two margins.

Origin of splenic artery. The splenic artery predominantly emerged from the celiac trunk in 93.8 % ($n=30/32$) of cases and from the abdominal aorta in 6.3 % ($n=2/32$) of cases, (Fig. 3).

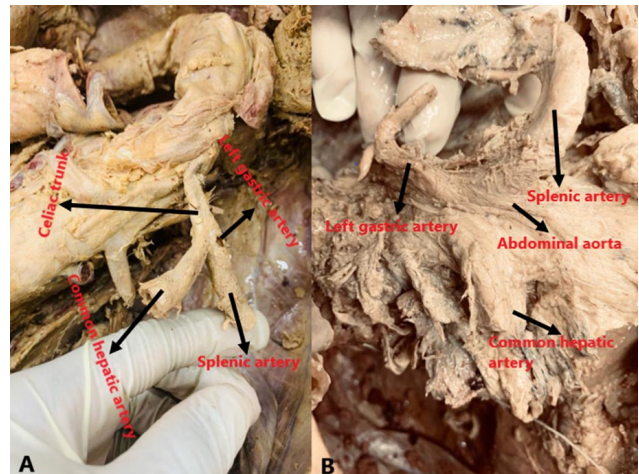


Fig. 3. Origin of the splenic artery, A - normal (celiac trunk); B - variation (Abdominal aorta)

DISCUSSION

Shape. The spleen is an organ of many shapes, and those shapes can vary between individuals (Covantev *et al.*, 2021). Splenic variations and anomalies must be considered to avoid diagnostic errors. The hypothesis tested was that there may be differences in spleen morphology and vascular supply between males and females, and individuals. The results aligned with the hypothesis for this study, leading to its acceptance. However, certain aspects of the hypothesis were not attained, and these additional findings related to the accepted hypothesis are discussed below. (Table III).

These common shapes were, triangular, wedge, tetrahedral, and oval. The most common shape in this study was noted to be oval-shaped spleens. This showed that an oval-shaped spleen was more common in males independently and as compared to the females, but there was no significant discrepancy as the values of difference were close. A comparison of shape within sexes produced a statistical analysis with a value of 0.26 which is greater than 0.05 and suggests that it is not significant, this means there is no evidence in this study of an association of shape and sex and that the values presented in (Table I) could have occurred by chance. This study's sample size, which included

Table III. Comparison of variations in the morphology of the spleen (shapes).

| Shapes of | Charware <i>et al.</i> , 2012 (India) | Chaudhari <i>et al.</i> , 2014 | Swargam <i>et al.</i> , 2019 | Present study |
|-------------|---------------------------------------|--------------------------------|------------------------------|---------------|
| Tetrahedral | 21.62 % | 32.25 % | 15 % | 18. 8% |
| Oval | 3.60 % | 8.06 % | 30 % | 40. 6% |
| Wedge | 61.26 % | 33.87 % | 15 % | 31.3 % |
| Irregular | 0.90 % | 6.45 % | 0 % | 0% |
| Triangular | 12.61 % | 19.35 % | 40 % | 9.4 % |

32 cadavers, is also smaller than some previous studies, which may contribute to the differences in findings. Therefore, we cannot conclude that there were morphological differences in terms of shape in males and females.

The literature on the shapes of the spleen includes several studies that have investigated the prevalence of different spleen shapes in various populations. Swargam *et al.* (2019) reported that the most prevalent shape was the triangular spleen, in 40 % of cases. Charware *et al.* (2012) found that a wedge-shaped spleen was the most prevalent shape, with 61.26 % of cases reported. A study by Chaudhari *et al.* (2014) also reported a wedge-shaped spleen as most prevalent in 33.87 % of cases. The indicated studies involve a representation of the most common shapes reported in each study. The present investigation found that 18.8 % of spleens were tetrahedral, 40.6 % were oval, 31.3 % were wedge-shaped, and 9.4 % were triangular. The present study reported that the most common shape of the spleen was oval-shaped, and there was no significant variance in the shape of the spleen between females and males. This is similar to the findings of other studies by Charware *et al.* (2012), Chaudhari *et al.* (2014), and Swargam *et al.* (2019), that have reported various shapes of the spleen, including wedge, tetrahedral, triangular, and oval. However, the most common shape of the spleen varies between studies, with studies by Chaudhari *et al.* (2014) reporting wedge shaped spleen as the most common shape, and Swargam *et al.* (2019) reported a triangular shape as most common. These studies suggest that the spleen can have a variety of shapes, including tetrahedral, oval, wedge-shaped, triangular, and irregular. The shape of the spleen has no significant correlation with age, gender, or population group. The chances of observing a particular shape are influenced by the sample size. There is no shape that can be considered as the most common shape of the spleen as shapes vary vastly between individuals and all these studies present different shapes as most frequently noted among their studies. The shape of the spleen can also be influenced by the surrounding organs, such as the stomach and the left kidney, and the development of the spleen during embryonic development. Understanding the shapes of the spleen and their prevalence is important in the diagnosis and treatment of diseases and disorders related to the spleen.

Notches, poles and surfaces. The table provided below presents a comparison of a range in the presence of splenic notches in different studies.

In 100 % of cases, the spleens showed constant morphology in terms of poles (anterior and posterior), margins (inferior and superior), and surfaces mainly diaphragmatic and visceral (colic, renal, and gastric impressions). The spleen's location, margins and surfaces characteristics were consistent with the findings documented in existing literature and standard anatomy textbooks (Standring, 2015).

The observations made from this study regarding the absence of notches and a range of observable notches on the spleens were so much analogous to those made by Srivani *et al.* (2019).

A test for the association between notches and sex was done. The statistical analysis showed a p value of 0.90. The study found that the number of notches in the spleen did not differ significantly between males and females. The p-value for the association between notches and sex was found to be not significant (p = 0.90). This meant that there is no association between the availability and unavailability of notches between males and females as the statistical analysis regards it as not significant.

The presence of notches on the superior margin is useful for palpation of the spleen during enlargement of the spleen (D'sa *et al.*, 2020). These notches serve as palpation landmarks, aiding in locating and assessing the spleen during examinations. The presence or no presence of notches does not constitute to any medical condition, as notches are a result of embryological development for the fusion of splenic tissue which may persist until adulthood (D'sa *et al.*, 2020). (Table IV).

Origin of splenic artery. Findings of the current study indicate that, in 93.8 % cases, the splenic artery emerged from the celiac trunk, and another site of origin was the abdominal aorta. In terms of the course of the splenic artery, it followed the supra-pancreatic course in 100 % of cases. Variations in the anatomy of the splenic artery are frequently observed (Krishna *et al.*, 2017). Understanding

Table IV. Comparison of variations in the number of splenic notches.

| Author | Maximum number of notches | Spleens without notches (%) |
|--------------------------------------|---------------------------|-----------------------------|
| Agarwal <i>et al.</i> , 2018 (India) | 6 | 5 |
| Swargam, 2019 (India) | 4 | 0 |
| Sofia <i>et al.</i> , 2019 (India) | 6 | 40 |
| Present study | 3 | 34.4 |

Table V. Comparison of the origin of splenic artery with other studies.

| | STUDIES | SOURCES OF ORIGIN | | | | |
|---|---|-------------------|-------|-----------------|-----------------------|-------------|
| | | Celiac trunk | SMA | Abdominal aorta | Common hepatic artery | Other sites |
| 1 | Prakash <i>et al.</i> , 2011 (India) | 86 % | --- | --- | 4 % | 10 % |
| 2 | Kumar <i>et al.</i> , 2014 (India) | 90.6 % | --- | 8.1 % | --- | 1.3 % |
| 3 | Jyothi <i>et al.</i> , 2015 (India) | 98 % | --- | --- | 2 % | --- |
| 4 | Krishna <i>et al.</i> , 2017 (India) | 100 % | --- | --- | --- | --- |
| 5 | Manatakis <i>et al.</i> , 2021 (Greece) | 97.2 % | < 1 % | 2.1 % | < 1 % | --- |
| 6 | Present study | 93.8 % | --- | 6.3 % | --- | --- |

these variations is crucial for patients who undergo diagnostic laparoscopic procedures, upper abdominal surgeries, and radiological investigations to avoid inadvertent surgical complications.

In a study conducted by Prakash *et al.* (2011), it was found that the splenic artery originated from the celiac trunk in 86 % of cases. In 4 % of cases, the splenic artery arose from the hepato-splenic trunk. In 2 % of cases, the splenic artery originated directly from the abdominal aorta. Kumar *et al.* (2014), reported that the splenic artery originated from the celiac trunk in 90.6 % of cases, originated from the abdominal aorta in 8.1 % of cases. Jyothi *et al.* (2015) found that the splenic artery originated from the celiac trunk in 98 % of 49 cadavers, and in 2 % of cases, it arose along with the common hepatic artery as the hepato-splenic trunk from the celiac trunk. In a study by Krishna *et al.* (2017) to investigate the origin and course of the splenic artery in the population of Jharkhand, the splenic artery was reported to be originating from the coeliac trunk in 100 % of cases. Manatakis *et al.* (2021) reported that the origin of the splenic artery was from the celiac trunk in 97.2 % of cases, from the abdominal aorta in 2.1 % of cases, and from the superior mesenteric artery or common hepatic artery in < 1 % of cases. In the present study, the splenic artery's source of origin was observed to be the celiac trunk in 93.8 % of cases, and from the abdominal aorta in 6.3 % of cases.

The findings of this study aligned with studies by Prakash *et al.* (2011), Krishna *et al.* (2017) and Manatakis *et al.* (2021) on the origin of the splenic artery, noting the celiac trunk as the most common area of origin for the splenic artery. Any variations on the origin of the splenic artery may not have a significant impact on the spleen's functionality because of the spleen's capability to adapt to changes in blood supply. Variations on the origin of the splenic artery do not indicate any medical or anatomical pathology and there is no association regarding differences on the origin of the splenic artery. These differences are likely to occur by chance, as noted in the literature and this study that there are insignificantly rare cases of the splenic artery originating elsewhere other

than from the celiac trunk. Rather these differences are influenced by the sample size, as previous studies had access to larger sample sizes, greater variations were observed. None of these demographics seem to be having any impact as variations in shapes and blood supply are conserved. These variations are likely to occur by chance, the only factor is the sample size, with a larger sample size, the probability of encountering variations increases. (Table V).

Limitations. The main limitation of this study was the unavailability of cadavers from different population groups in cadavers provided by the discipline of Clinical Anatomy at the University of KwaZulu-Natal, Westville, and Nelson R. Mandela Medical School campuses. The current study was conducted using cadavers from only one population group (Caucasians), which may not be representative of other population groups.

CONCLUSION

The literature on the morphological differences in spleen shape and vascular supply between males and females and different population groups is very limited. The available literature suggests that there is no clear evidence of significant differences in the morphology or vascular supply of the spleen between different population groups. The findings of the current study conclude that there is no association between the shapes of the spleen, availability of notches, and sex. The morphology of the spleen in terms of shape, notches, margins, and surfaces can vastly differ from person to person, the findings of this study outlined common shapes of the spleen variations in terms of the origin of the splenic artery, therefore answering the research question for this study. All these shapes do not constitute a pathological discovery, but in some cases, depending on the imaging technique and the physician's experience, they may require more examination and interpretation. These findings contribute to the advancement of medical knowledge in the field of splenic anatomy and pathology and can also be used as a reference for future research on the anatomy and vasculature of the spleen.

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GUMEDE, S. V.; NGUBANE, N. P & NDLAZI, Z. M. Análisis morfológico del bazo y sus vasos: un estudio cadavérico. *Int. J. Morphol.*, 43(2):511-516, 2025.

RESUMEN. El bazo es un órgano linfático vital que se encuentra en la región del hipocondrio izquierdo. Una comprensión profunda de la anatomía y las variaciones anatómicas del bazo y sus vasos desempeña un papel importante en la prevención de lesiones iatrogénicas durante los procedimientos quirúrgicos, la mejora de la precisión diagnóstica, la información para las decisiones de tratamiento, la reducción del riesgo de complicaciones quirúrgicas y el tratamiento de diversas enfermedades relacionadas con este órgano. Este estudio tuvo como objetivo documentar la morfología del bazo en relación con su forma, polos, muescas, márgenes, superficies y origen de sus vasos. Se observaron además las variaciones anatómicas. Se utilizó una muestra de 32 cadáveres, proporcionados por la Disciplina de Anatomía Clínica de la Universidad de KwaZulu-Natal, campus de Westville y Nelson R. Mandela Medical School. Se analizaron el bazo y su sistema vascular siguiendo el protocolo de disección según el libro de disección de Grant. La forma predominante del bazo era ovalada (40,6 %), seguida de la forma en cuña (31,3 %), tetraédrica (18,8 %) y triangular (9,4 %). El mayor número de muescas registradas fue 4 y las muescas estaban ausentes en el 34,4 % de los casos. Se observaron dos superficies, polos y dos márgenes en los 32 bazos (100 %). En el 93,8 % de los casos, la arteria esplénica emergió del tronco celíaco y en el 6,3 % de los casos emergía directamente de la aorta abdominal. Los hallazgos del presente estudio concluyen que no existe asociación entre las formas del bazo, la presencia de muescas y el sexo.

PALABRAS CLAVE: Bazo; Vasos esplénicos; Cadáveres; Morfología; Variaciones; Hipocondrio.

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