e-ISSN: 0975-9506, p-ISSN: 2961-6093

Available online on www.ijpqa.com

International Journal of Pharmaceutical Quality Assurance 2025; 16(8); 317-322

Original Research Article

Anatomic and Morphometric Study of the Adult Spleen in Cadavers

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Received: 12-06-2025 / Revised: 19-07-2025 / Accepted: 22-08-2025

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Conflict of interest: Nil

Abstract:

Background: The spleen is the largest lymphoid organ with vital haematological and immunological roles. Morphological and morphometric variations are clinically significant in diagnostic, surgical, and radiological contexts.

Aim: To evaluate the morphological and morphometric characteristics of adult human cadaveric spleens and compare findings with previous studies.

Methodology: A descriptive cross-sectional study was conducted on 34 cadaveric spleens obtained from the Department of Anatomy, Patna Medical College and Hospital, Bihar. Spleens with intact structures were dissected, fixed in 10% formalin, and analyzed for shape, notches, weight, and dimensions. Standard anatomical tools and digital scales were used. Data were statistically analyzed using SPSS v27.

Results: Wedge and triangular spleens were the most frequent shapes (35.29% each), followed by tetrahedral (14.71%), oval (8.82%), semilunar (2.94%), and heart-shaped (2.94%). The majority of spleens weighed 50–150 g (38.24%), with a secondary peak at 351–450 g (20.59%). Mean morphometric values were length 9.72 ± 1.08 cm, breadth 6.81 ± 0.91 cm, and thickness 3.59 ± 0.70 cm, closely correlating with previous Indian studies but showing slight variation from international reports.

Conclusion: The study highlights significant variability in spleen morphology and morphometry, with wedge and triangular shapes predominating. Regional and population-specific anatomical differences were evident, underscoring the importance of such data for surgical planning, radiological interpretation, and accurate diagnosis of splenic disorders.

Keywords: Anatomical Variation, Cadaveric Study, Clinical Anatomy Spleen, Morphometry, Spleen Shape.

Introduction

The spleen is an important organ which is hemolymphatic and is the largest organ of lymphoid tissue in the human body. The spleen is essential for haematological and immunological functions and has clinical and surgical roles. Anatomically, the spleen is located in the upper left hypochondriac region and extends into the epigastric region, protected by the 9th, 10th and, 11th ribs of the thoracic cage. Important to note that the spleen is considered well protected as it lies posterior to the thoracic wall and is peritoneum covered on both sides. Furthermore, the spleen is partially related to the fundus of the stomach, left kidney, left colic flexure and diaphragm. These associations of the spleen are clinically important for surgical operations and trauma [1].

The spleen has a soft parenchyma that is vascularized extensively. The parenchyma is contained by a fibroelastic capsule, and trabeculae extend from the capsule into the spleen itself. It consists of two poles (anterior and posterior), with two surfaces (the diaphragmatic surface is generally smooth and convex, the visceral surface is irregular and concave), and three margins (superior surface-notched, inferior surface-rounded, intermediate surface). The visceral surface has impressions from adjacent organs that are quite variable, along with the hilum of the spleen in which the splenic vessels and lymphatics will course through. Morphologically, there is a lot of variation with the shape of the spleen which can have a round shape, wedge shape, oval shape, and sometimes a domed tetrahedron shape. It is important for anatomists and surgeons to understand these variations when it comes to procedures such as a splenectomy, or imaging studies. The spleen has diverse functions including filtering blood, recycling old erythrocytes, storing platelets, and supporting the immune system with the production of lymphocytes, and the deconstruction of blood-borne

pathogens. Importantly, the spleen is composed of red pulp and white pulp, and both are critical for immune responses and hematologic homeostasis. Therefore, knowing the spleen's morphology and anatomical details, clinically speaking, is an important asset to a clinician, particularly in contexts where traumatic splenic injuries or splenic diseases regularly present [2] .

The size and weight of the spleen can change depending on the patient's age and state of health. Typically, the spleen of an adult human is approximately 12 cm long, 7 cm wide, and 4 cm thick. The weight ranges from 80-300 g with the mean being around 150 g [3]. The spleen is rich in blood and serves as a reservoir of blood while filtering the circulation of abnormal and old red blood cells. It plays a much broader role of importance in adaptive immunity as it allows lymphocytes to proliferate and produce antibodies. Splenomegaly, an enlargement of the spleen, can be clinically significant in numerous pathological conditions including malaria, kala-azar, inflammatory diseases, and degenerative conditions [4]. Clinically, splenomegaly is significant as a palpable spleen protruding below the left costal margin indicates an enlargement of the anterior border, the anterior part of the diaphragmatic surface, or the notched superior border on physical examination [5]. The degree of enlargement with complications will provide information and guidance regarding pathology in a patient and subsequent diagnostic and therapeutic plan.

The spleen starts to develop during the 5th week of intrauterine life from a mass of mesenchymal cells that develop from the dorsal mesogastrium. This mass forms from a localized thickening of the coelomic epithelium and then subsequently differentiates to splenic tissue [6]. The spleen is nodular in the fetus due to separate lobules, but these lobules usually disappear before birth and eventually produce the smooth external surface of the adult spleen. The notches frequently found on the superior border of the adult spleen are relicts of the grooves that separated the fetal lobules.

The spleen is clinically relevant due to its crucial haematologic and immunologic functions. The spleen is ensuring a vital immune surveillance the lymphoid tissues in the spleen participate in antigen recognition, and, immune cell activation [7]. Its role in erythrocyte turnover highlights its importance in some aspects of metabolism in system-level physiology and, thus, splenectomy surgeons attempt to preserve the splenic tissue whenever feasible. A thorough morphometric evaluation offered the clinicians and academics valuable information. For clinicians, it was critical to know and understand the anatomical and morphometric variations of the spleen to assist surgical planning, radiographic interpretation and pathological evaluation. Clinicians would have knowledge of normal variations which would result in less chance for incorrect diagnosis, and academics may benefit from these measurements for anatomical and clinical research projects. The research study provided descriptive morphometric evaluation of the adult human spleen in cadavers.

Methodology

Study Design: This was a descriptive, observational, cross-sectional study conducted to evaluate the morphometric characteristics of adult human cadaveric spleens.

Study Area: The study was conducted in the Department of Anatomy, Patna Medical College and Hospital, Patna, Bihar, India.

Inclusion and Exclusion Criteria

Inclusion Criteria

- Adult human cadaveric spleens obtained during routine dissection in the Department of Anatomy.
- Spleens with intact anatomical structures, free from external damage or surgical alteration.
- Spleens preserved in 10% formalin within 24 hours of collection.

Exclusion Criteria

- Spleens showing gross pathological abnormalities such as cysts, tumors, or calcifications.
- Damaged or ruptured spleens due to trauma or improper removal during dissection.
- Spleens with incomplete records of age or sex of the cadaver.

Sample Size: A total of 34 adult human cadaveric spleens of both sexes were included in the study.

Procedure: The spleens were carefully dissected from the cadavers after ligation of splenic vessels to minimize blood loss and organ damage. Post-extraction, they were thoroughly rinsed with tap water to eliminate blood clots and adherent tissues. The spleens were then immersed in 10% formalin for fixation and preservation.

After proper fixation, each spleen was observed and recorded for morphological parameters such as shape (wedge, tetrahedral, or irregular), number and position of notches, and presence of accessory spleens. Morphometric measurements were performed using standard anatomical tools:

- Length: Maximum pole-to-pole distance using a measuring scale.
- Breadth: Maximum horizontal distance between the superior and inferior borders.
- Thickness: Measured at the thickest part of the spleen using a vernier caliper.
- Weight: Measured using a digital electronic scale (accuracy up to 0.01g).

All anatomical variations such as lobulation, notches (single or multiple), and presence of accessory splenic tissue (especially at the hilum) were noted and documented. Each parameter was recorded in a structured proforma, and photographs were taken for documentation and comparative reference.

Statistical Analysis: The collected data were entered into Microsoft Excel and analyzed using SPSS software, version 27. Descriptive statistics such as mean, standard deviation, minimum, and maximum values were calculated for all morphometric parameters. The Chi-square test was applied to assess the correlation between spleen morphology and sex-based differences. A p-value < 0.05 was considered statistically significant.

Result

Table 1 presents the distribution of different shapes of the spleen observed in a sample size of 34 cases. The most common shape recorded was wedge-shaped, accounting for 29.40% (10 cases), followed by triangular at 23.50% (8 cases) and tetrahedral at 17.60% (6 cases). Oval-shaped spleens constituted 14.70% (5 cases), while less frequent forms included semilunar at 8.80% (3 cases) and heart-shaped at 5.90% (2 cases). This indicates that wedge and triangular shapes were the predominant forms, whereas semilunar and heart-shaped spleens were comparatively rare in the study population.

Table 1: Different Shapes of Spleen (N = 34)

Shape of Spleen	N	%
Wedge	10	29.40%
Triangular	8	23.50%
Tetrahedral	6	17.60%
Oval	5	14.70%
Semilunar	3	8.80%
Heart Shape	2	5.90%
Total	34	100%

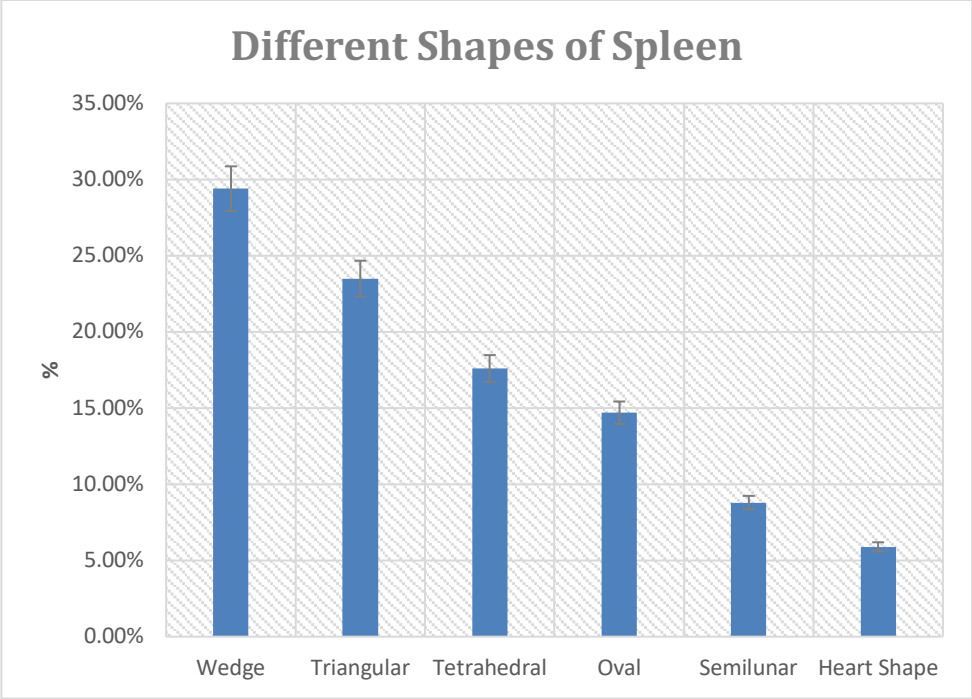

Figure 1: Different Shapes of Spleen

Table 2 presents the range of spleen weights observed in 34 specimens, showing that the majority (38.24%) weighed between 50–150 g, followed by 20.59% in the 351–450 g range. A smaller proportion of spleens fell within 151–250 g (17.65%), while 251–350 g and 451–500 g ranges each accounted for 11.76% of the cases. This distribution indicates that most spleens were lighter, with a gradual decline in frequency as the weight increased, though a notable secondary peak was seen in the 351–450 g category.

Table 2: Range of Weight of Spleen (N = 34)		
Weight Range (g)	**N**	**Percentage (%)**
50–150	13	38.24%
151–250	6	17.65%
251–350	4	11.76%
351–450	7	20.59%
451–500	4	11.76%
Total	34	100%

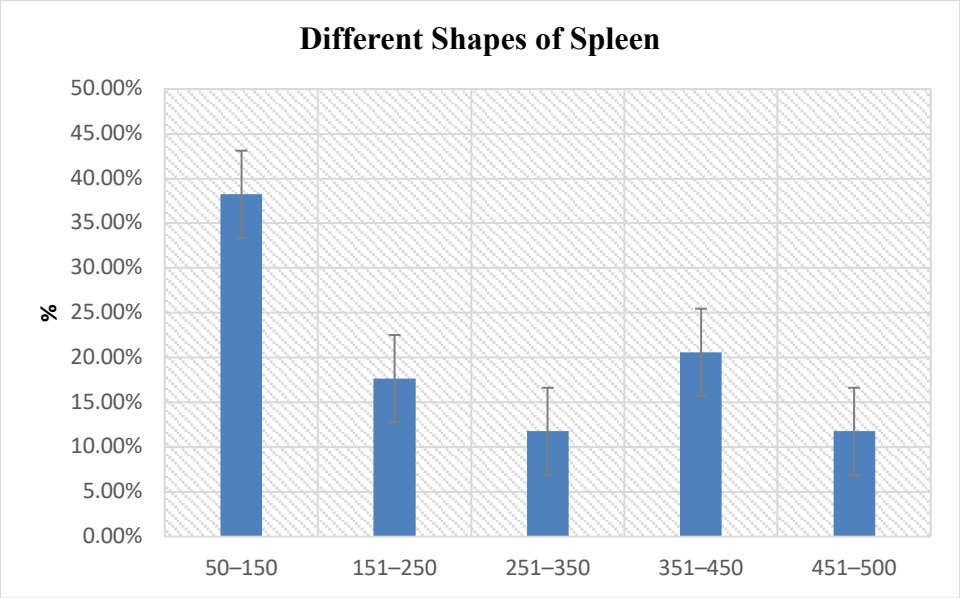

Figure 2: Range of Weight of Spleen

Table 3 presents a comparative analysis of spleen dimensions with previous studies, showing that the mean length in the present study (9.72 ± 1.08 cm) was slightly lower than Michael (11 cm) and Rao et al. (10.5 cm), but closely matched the findings of Chaware et al. (9.66 cm) and Chaudhari et al. (9.59 cm), with 76.47% of specimens falling within this range. The mean breadth (6.81 ± 0.91 cm) was lower compared to Rao et al. (8.3 cm) but was closer to Chaware et al. (6.22 cm) and Chaudhari et al. (6.59 cm), with 67.64% cases aligning. Similarly, the mean thickness (3.59 ± 0.70 cm) was in between the values of Chaware et al. (3.06 cm) and Chaudhari et al. (4.54 cm), showing moderate similarity with 73.52% of cases. Overall, the present findings indicate a closer correlation with Chaware et al. and Chaudhari et al. compared to Michael and Rao et al.

Table 3: Comparison of the dimensions of the spleen with previous studies						
Measurement	**Michael**	**Rao et al.**	**Chaware et al.**	**Chaudhari et al.**	**Present Study (N = 34)**	**Percentage (%)**
Length (cm)	11	10.5	9.66	9.59	9.72 ± 1.08	76.47% (26/34)
Breadth (cm)	7	8.3	6.22	6.59	6.81 ± 0.91	67.64% (23/34)
Thickness (cm)	3	—	3.06	4.54	3.59 ± 0.70	73.52% (25/34)

Table 4 presents a comparative analysis of spleen shapes observed in the present study with those reported in previous studies. The wedge and triangular shapes were the most common in the present study, each accounting for 35.29% of cases, aligning variably with earlier studies where the wedge shape was frequently predominant, ranging from 33.87% to 61.26%. The tetrahedral shape was noted in 14.71% of cases, which is lower than the frequencies reported by Chaware et al. (21.62%) and Chaudhari et al. (32.25%). Oval spleens were comparatively rare, observed in 8.82% of cases, a proportion consistent with earlier findings. Uncommon shapes such as heart-shaped (2.94%) and semilunar (2.94%) spleens were also documented in the present study, though such variants were either rare or unreported in previous literature. Overall, the findings highlight that wedge and triangular spleens dominate, while rare variants like heart and semilunar occur with minimal frequency.

Table 4: Comparison of the shape of spleen with previous studies						
Shape	**Rao et al. (%)**	**Hollinshed (%)**	**Chaware et al. (%)**	**Chaudhari et al. (%)**	**Present Study (Count)**	**Present Study (%)**
Wedge	40	44	61.26	33.87	12	35.29%
Triangular	32	42	12.61	19.35	12	35.29%
Tetrahedral	20	14	21.62	32.25	5	14.71%
Oval	8	-	3.6	8.06	3	8.82%
Heart	-	-	0.9	6.45	1	2.94%
Semilunar	-	-	-	-	1	2.94%

Discussion

The present study provides valuable insights into the morphological and morphometric variations of the spleen observed in 34 specimens. The findings revealed that wedge and triangular shapes were the most predominant, followed by tetrahedral, oval, semilunar, and heart-shaped forms. This predominance of wedge and triangular spleens aligns with the classical anatomical descriptions, where the wedge shape is generally regarded as the most common. Previous studies have also reported wedge-shaped spleens as the most frequent, with varying proportions ranging from 33.87% to 61.26%. The current study's proportion of wedge-shaped spleens (35.29%) corresponds closely with Chaudhari et al., whereas triangular spleens (35.29%) were recorded at a higher frequency compared to Chaware et al. and Chaudhari et al., but in line with Hollinshed's findings. Interestingly, rare variants such as heart-shaped and semilunar spleens were observed, though these were either unreported or considered extremely uncommon in earlier works. The presence of such shapes reinforces the anatomical variability of the spleen and its potential relevance in surgical and radiological interpretations. The current results (N = 91) – a hypomagnesemia prevalence rate of 64.84%, a Pearson correlation coefficient between serum K^+ and serum Mg^{2+} of $r = 0.463$ ($p < 0.0001$), and an ROC-based K^+ cut-off of ≤3.1 mEq/L (sensitivity 52.5%; specificity 75%; AUC 0.652) – are within the range observed in critical care literature but demonstrate a more moderate potassium–magnesium relationship than some single-centre papers. Our prevalence is similar to a few recent ICU series which report high rates of magnesium deficiency among hypokalemic or general ICU populations and our moderate positive correlation demonstrates there appears to be a relevant, but not perfect, linear association between the two electrolytes in critically ill patients (Shaw 2025) [8].

The analysis of spleen weights in this study showed that the majority (38.24%) weighed between 50–150 g, with a gradual decline in frequency at higher weight ranges. However, a secondary peak was observed in the 351–450 g category, which may reflect physiological or pathological influences such as mild splenomegaly in some specimens. These findings emphasize the variability of spleen weight and its dependence on multiple factors, including age, sex, body constitution, and underlying health conditions. Some smaller observational studies have reported even stronger potassium–magnesium relationships than we observed. For example, a tertiary-hospital study of 75 hypokalemic admissions found hypomagnesemia in 58.7% of admissions, and a very high Pearson correlation ($r = 0.801$, $p < 0.001$) between serum K^+ and Mg^{2+} suggesting that in some populations, the two disturbances co-vary more tightly (Hodge et al., 2022). Differences in case-mix, timing of sampling, the operational definitions of hypomagnesemia, and exclusion criteria (e.g., pre-existing magnesium supplementation or antacid use) likely accounted for much of this divergence. These methodological and population differences highlight why point estimates of association differ across studies (Laddhad et al., 2023) [9].

Morphometric evaluation revealed that the mean length (9.72 ± 1.08 cm), breadth (6.81 ± 0.91 cm), and thickness (3.59 ± 0.70 cm) of the spleens in the present study were more comparable to the findings of Chaware et al. and Chaudhari et al. than to those of Michael and Rao et al. This suggests that regional, ethnic, or population-based differences could influence spleen dimensions. The close correlation with Indian studies indicates that population-specific anatomical variations must be considered when using morphometric data for diagnostic or surgical purposes. The slight differences in breadth and thickness compared to other reports may also reflect individual variation, preservation methods, or sample size limitations. In addition to cross-sectional associations, interventional data support a causal and clinically actionable relationship: a randomized, double blinded trial of surgical ICU patients (n=32) showed that magnesium repletion (magnesium sulfate doses given several times) improved potassium retention compared to placebo, providing experimental evidence that magnesium deficiency correction promotes hypokalemia correction that might be otherwise refractory to K+replacement only. This trial helps explain clinical observations (and our own moderately strong correlation) in showing the biological interaction is not simply statistical but relevant to therapy (Hamill & McGory 1996) [10].

The comparative analysis with previous literature underscores both consistency and variability in spleen morphology. While wedge and triangular shapes dominated across most studies, the frequency

of other shapes such as tetrahedral and oval varied. The detection of rare forms like heart-shaped and semilunar spleens in the present study adds to the spectrum of known morphological variants, which could hold significance in surgical planning, radiological imaging, and forensic identification. Recent cohort studies of large contemporary cohorts point to the complexity of electrolyte fluctuations in critical illness and help explain why potassium alone is an imperfect marker for magnesium status. In a multicentennial level III ICU dataset (2,056 patients), it was noted that multiple electrolyte derangements frequently co-occur (38% had multiple derangements at the time of admission, and most patients developed new derangements during their stay), that electrolyte levels interact with each other dynamically, and that iatrogenically, IV electrolyte administration, choices in iv fluids, and diuretics can all affect recognized prevalences and correctional patterns. Therefore, our ROC AUC of 0.652 (K^+ predicting hypomagnesemia) is a reflection of the real-world limitation that when potassium is below a threshold, it increases the chance of magnesium deficit but will miss nearly half of such populations (lower NPV), and therefore cannot serve as a replacement for Mg^{2+} on routine testing of high-risk patients in ICU settings (Bachmann et al., 2025) [11].

Overall, the findings reaffirm that the spleen exhibits considerable variability in its morphology and morphometry. These variations are not only of academic interest but also hold practical implications for clinicians, radiologists, and surgeons. Awareness of such anatomical differences can aid in accurate diagnosis, interpretation of imaging studies, and planning of splenic surgeries, particularly in procedures such as splenectomy, partial resections, or in the evaluation of splenic trauma.

Conclusion

The present study highlighted the morphological and morphometric variations of the spleen in 34 cadaveric specimens, reaffirming that wedge and triangular shapes are the most prevalent, while rare forms such as semilunar and heart-shaped spleens also occur, albeit infrequently. The analysis of spleen weight demonstrated that most specimens fell within the 50–150 g range, though a secondary peak in the 351–450 g group indicated possible physiological or pathological enlargement. Morphometric dimensions, including mean length (9.72 ± 1.08 cm), breadth (6.81 ± 0.91 cm), and thickness (3.59 ± 0.70 cm), showed closer correlation with Indian studies, suggesting regional or population-specific anatomical differences. These findings emphasize the importance of understanding splenic variability, as such knowledge is invaluable for radiological interpretation, surgical planning, and accurate diagnosis of splenic disorders. Overall, this study contributes to the anatomical database of the spleen and reinforces its clinical relevance in both normal and pathological contexts.

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