

A Cadaveric Study of Splenic Fissures and Bilobed Spleen

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دراسة مجتئية للشقوق الطحالية والأطحة ثنائية الفصوص

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ABSTRACT: Objectives: Anatomical knowledge regarding the external morphology of the spleen is essential for surgical intervention and radiological diagnosis. A characteristic feature of the spleen is the presence of splenic notches at the superior border; however, such notches rarely extend deep enough to be considered fissures or to separate the spleen into multiple lobes. To date, there are very few cadaveric reports of splenic fissures. This study aimed to examine the anatomy and morphological structure of spleens collected from cadavers in order to identify the prevalence and clinical significance of splenic notches, fissures and lobation. **Methods:** This study was conducted at the Department of Anatomy, Katuri Medical College and Hospital, Guntur, Andhra Pradesh, India. A total of 50 spleens were collected from cadavers over a period of seven years from 2012–2019 and examined to determine the presence of splenic notches or fissures. **Results:** Of the 50 spleens, 40% had notches at the superior border, 10% had notches at the inferior border and 50% had no notches at either border. Fissures were present in five spleens (10%); of these, three showed incomplete fissures and the remaining two had complete fissures that divided the spleen into two lobes. **Conclusion:** The findings of this study provide valuable information regarding the anatomy and prevalence of splenic fissures and bilobed spleens. A bilobed spleen is a rare congenital malformation which should be considered distinct from other known splenic anomalies. The presence of splenic fissures in bilobed spleens can serve as a guide for surgeons during conservatory splenectomy procedures.

Keywords: Anatomic Variation; Spleen; Anatomy and Histology; Abnormalities; Congenital Abnormalities; Splenectomy; India.

المخلص: الهدف: المعرفة التشريحية المتعلقة بالشكل الخارجي للطحال أساسية للتدخل الجراحي والتشخيص الإشعاعي. السمة المميزة للطحال هي وجود ثلم طحالية على الحافة العلوية؛ غير أنه نادراً ما تمتد هذه الثلم بعمق كافٍ لاعتبارها شقوقاً أو لفصل الطحال إلى فصوص متعددة. إلى يومنا هذا هناك عدد قليل جداً من التقارير الجتئية عن الشقوق الطحالية. هدفت هذه الدراسة إلى فحص التشريح والبنية الشكلية للأطحة التي تم جمعها من الجثث من أجل التعرف على مدى انتشار الثلم والشقوق الطحالية والتفصيص الطحالي وأهميتها السريرية. الطريقة: أجريت هذه الدراسة في قسم التشريح بكلية ومستشفى كاتوري الطبي، جونتور، أندرا براديش، الهند. تم جمع ما مجموعه 50 طحالا من جثث على مدى سبع سنوات من 2012–2019 وفحصها لتحديد وجود الثلم أو الشقوق الطحالية. النتائج: من بين 50 طحالا، 40% كان لديها ثلما عند الحافة العلوية و 10% منها لديها ثلما عند الحافة السفلية و 50% منها ليس لديها ثلم عند أي من الحواف. كانت الشقوق موجودة في خمسة أطحة (10%). أظهر ثلاثة منها شقوقاً غير مكتملة وكان لدى الاثنان المتبقيان شقوقاً كاملة قسمت الطحال إلى فصين. الخلاصة: توفر نتائج هذه الدراسة معلومات قيمة فيما يتعلق بتشريح ومدى انتشار الشقوق الطحالية والأطحة ثنائية الفصوص. الطحال ثنائي الفصوص هو تشوه خلقي نادر يجب اعتباره متميزاً عن تشوهات الطحال المعروفة الأخرى. وجود شقوق الطحال في الأطحة ثنائية الفصوص قد يستخدم كمرشد للجراحين أثناء عمليات استئصال الطحال التحفظية.

الكلمات المفتاحية: الاختلاف التشريحي؛ طحال؛ علم التشريح وعلم الأنسجة؛ تشوهات؛ تشوهات خلقيّة؛ استئصال الطحال؛ الهند.

ADVANCES IN KNOWLEDGE

- The present study provides a complete anatomical description of splenic fissures and bilobed spleens collected over a seven-year period.
- Bilobed spleen is a rare congenital malformation which should be considered distinct from other known congenital defects of the spleen.

APPLICATION TO PATIENT CARE

- These findings will help radiologists to differentiate bilobed spleens from other adjacent solid masses. Moreover, splenic fissures represent avascular planes which can act as a guide for surgeons performing conservatory splenectomies following injury.

THE SPLEEN IS THE LARGEST LYMPHOID ORGAN and is located in the left upper quadrant of the abdomen.^{1,2} Among adults, the spleen is wedge-shaped, approximately 3 × 12 × 7 cm in dimension and

150 g in weight and has a smooth serosal surface. The organ has two surfaces, the visceral and parietal surfaces, and three borders known as the superior, inferior and intermediate borders.^{1,2} In certain cases,

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the superior border can have between 2–4 notches which arise during embryological development.^{1–4} In contrast, notches do not typically occur on the intermediate or inferior borders.²

Splenic notches along the superior border are often used as a clinical guide to palpate an enlarged spleen.³ However, in some variant spleens, the notches extend as fissures on both the costal and visceral surfaces, dividing the spleen into two or more lobes.⁵ Moreover, the presence of notches along the inferior border can lead to complications in defining the borders of the spleen and adjacent structures such as the stomach and kidneys. In some cases, fluid can accumulate in splenic fissures due to their depth and be misdiagnosed as lacerations during radiological investigations.⁶

Blunt trauma of the abdomen most often involves the spleen and leads to intraabdominal complications such as haemorrhage and peritonitis. Although a complete splenectomy is the treatment of choice for splenic injuries, modern protocols advocate for a partial splenectomy in less severe cases with a view to preventing postoperative complications.² From this perspective, it is imperative that radiologists and surgeons understand the complete anatomy of the spleen—including the splenic artery, ligaments, segments and lobes—and its position relative to other surrounding structures.⁷ However, few cadaveric reports have been published describing splenic fissures and bilobed spleens. Hence, the present study was performed to identify and assess the clinical significance of splenic notches, fissures and lobation among spleens collected from cadavers over a seven-year period.

Methods

The present study was conducted with specimens collected between December 2012 and March 2019 at the Department of Anatomy of the Katuri Medical College and Hospital in Guntur, Andhra Pradesh, India. A total of 50 spleens were collected from cadavers of unknown medical history over the study period. The spleens were removed during routine dissection of the abdominal region by cutting the splenic vessels near the *hilum* and carefully detaching the organ from the peritoneum. Following removal, the spleens were preserved in 10% formalin.

Each spleen was carefully examined to determine the presence of splenic notches, fissures and lobation. Spleens possessing abnormal notches, fissures and more than one lobe were photographed. The data

were tabulated and subjected to further analysis using an Excel spreadsheet, Version 2016 (Microsoft Corp., Redmond, Washington, USA). Subsequently, findings were compared with those from previously reported studies in the literature.

This study received ethical approval from the College Ethics Committee of the Katuri Medical College and Hospital. All cadavers included in the study were unclaimed bodies issued by governmental tertiary care hospitals for use in teaching and research.

Results

Of the 50 spleens, 20 (40%) had notches at the superior border and five (10%) at the inferior border, while the remaining 25 spleens (50%) had no notches at either border. Fissures were observed in five spleens (10%). Among those with splenic notches, the number of notches varied from 2–4 at the superior border and 1–2 at the inferior border. Fissures were classified as either complete or incomplete based on the depth and extent of the opening. Complete and incomplete fissures were observed in two (4%) and three (6%) spleens, respectively.

In one spleen with a complete fissure, the cleft extended from the superior to the inferior border of the diaphragmatic surface, dividing it into two lobes (bilobed spleen) [Figure 1A]; moreover, each lobe had a separate *hilum*, as shown on the visceral surface [Figure 1B]. In another spleen, two notches were observed at the inferior border on the diaphragmatic surface [Figures 2A and B], one of which extended as a fissure from the inferior border to the *hilum*, dividing the spleen into two lobes that were visible only on the visceral surface [Figures 2C and D]. In the remaining three spleens, incomplete fissures of approximately 3–4 cm in length were visible on the diaphragmatic and visceral surfaces, extending to a depth of approximately

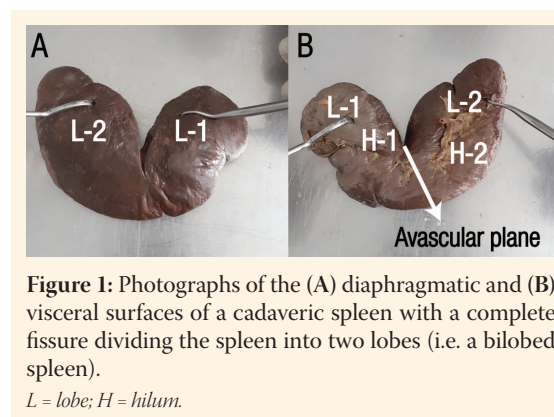


Figure 1: Photographs of the (A) diaphragmatic and (B) visceral surfaces of a cadaveric spleen with a complete fissure dividing the spleen into two lobes (i.e. a bilobed spleen).

L = lobe; H = hilum.

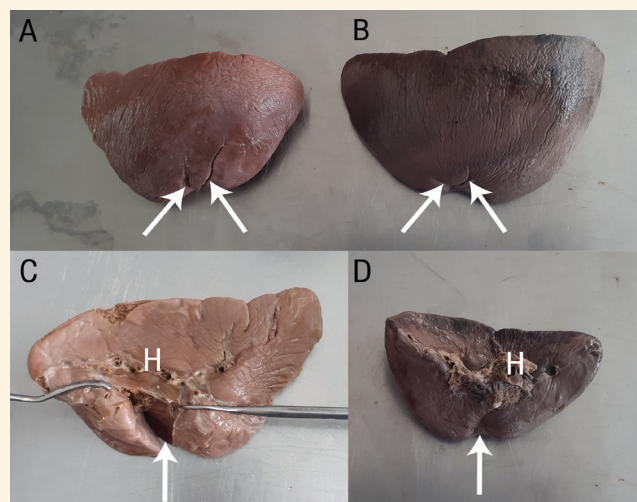


Figure 2: Photographs of the (A & B) diaphragmatic and (C & D) visceral surfaces of cadaveric spleens with notches (arrows) on the inferior border. Using a hook retractor, the notches were found to extend in the form of a fissure from the inferior border to the hilum.

H = hilum.

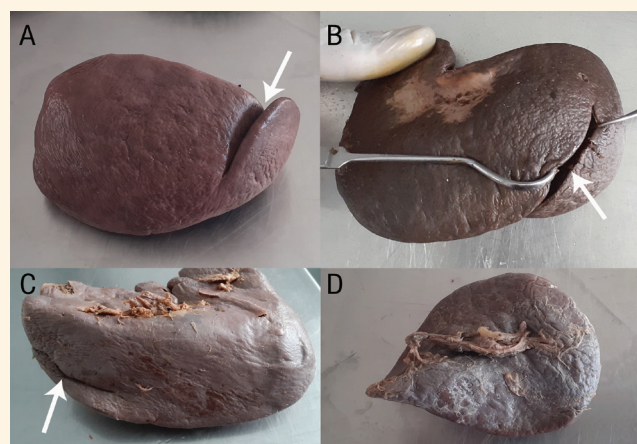


Figure 3: Photographs of the diaphragmatic surface of cadaveric spleens with incomplete fissures showing the fissures (arrows) extending from either the (A) superior border or (B & C) inferior border to the diaphragmatic surface and a (D) normal spleen without any notches or fissures.

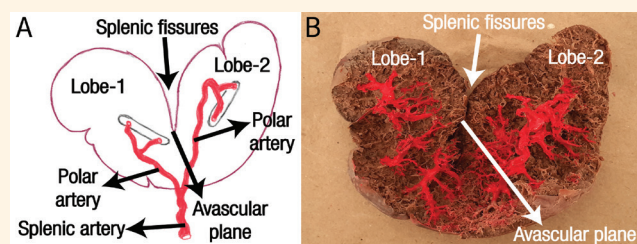


Figure 4: A: Schematic of a bilobed spleen with separate hila and polar artery branches. B: Model of a bilobed spleen showing the avascular plane between the two lobes.

Table 1: Literature review of studies assessing the topic of spleen segmentation^{20–24}

Author and year of publication	Number of segments
Redmond <i>et al.</i> ²⁴ (1989)	2
Gutierrez Cubillos ²⁰ (1969)	2–4
Gupta <i>et al.</i> ²¹ (1976)	2–4
Mikhail <i>et al.</i> ²² (1979)	5
Voboril ²³ (1982)	6
Present study (2020)	2

0.5–1 cm without lobation [Figure 3A–C]. A representative spleen with no fissures or notches at either border is shown in Figure 3D for comparative purposes.

Discussion

In humans, the spleen begins to develop during the fourth week of gestation during mesenchymal condensation in the dorsal *mesogastrium* of the lesser

sac. Later, these mesenchymal cells differentiate to form lobules which subsequently fuse together to form a lymphatic organ, the spleen.^{3,4} The fusion of multiple lobules leads to the formation of notches on the superior border of the spleen.^{8,9} While the fetal spleen is typically lobulated, the majority of these lobules disappear before birth; however, some can persist and be seen at the *hilum* as an accessory spleen. Accessory spleens are one of the most frequent congenital splenic anomalies and are sometimes located on the upper pole of the kidney, thereby leading to misdiagnosis as a renal mass or tumour.¹⁰

Splenomegaly is a symptom of various haematological, immunological and infectious diseases. Clinically, enlarged spleen is identified during palpation due to the presence of notches on its superior border.³ Radiologically, splenic notches also help to differentiate the spleen from other *viscera* in the left hypochondriac region.¹⁰ Humans typically possess 4–5 notches along the superior border of the spleen, with the presence of a greater number of notches indicating its embryological persistence.^{1,3} However, as reported by Gandhi *et al.*, some variant spleens can possess as many as seven notches on the superior border.¹¹ In the present study, the maximum number of notches on the superior border was four. Previous studies have shown variations in the percentage of spleens possessing notches along the superior border (50–98%).^{2,5,8,10} However, in the present study, the prevalence of splenic notches was much lower (40%). Skandalakis *et al.* reported that splenic notches indicate the entrance of multiple arteries to the organ; as such, special care should be taken to ligate these arteries during surgical procedures involving the spleen.²

The presence of notches along the inferior border is a rare occurrence, with previous studies reporting the incidence of this feature to be very low (4–8%).^{8,12} In the current study, five spleens (10%) possessed notches on the inferior border; in fact, in one case, two notches were seen on the inferior border, one of which extended as a fissure up to the *hilum*, dividing the spleen into two lobes on the visceral surface with a single *hilum*. This abnormal fissure could result from a developmental defect during fusion of the splenic lobules or due to the compression effect of adjacent organs.⁸ Such fissures may mimic a splenic tear or laceration in cases of abdominal trauma, potentially leading to diagnostic pitfalls. No notches were visible on either border among the remaining spleens in the current study (50%). The absence of notches has no clinical relevance; from an embryological perspective, this simply suggests the complete fusion of the splenic lobules during fetal development.⁴

Splenic fissures are notches that extend to a depth of 2–3 cm and can be seen on both the diaphragmatic and visceral surfaces of the spleen.^{8,13} The occurrence of deep fissures on the diaphragmatic surface is uncommon.^{8,13} In the present study, only one spleen showed a complete fissure extending from the superior to the inferior border of the diaphragmatic surface, dividing the spleen into two lobes. Similarly, Das *et al.* observed this feature in only 2% of cases.⁸ Nayak *et al.* reported a case in which a bilobed spleen was divided by a single fissure on the costal/diaphragmatic surface, with the presence of multiple *hila*.¹⁴ It would seem that the occurrence of a complete fissure dividing the spleen into two lobes is very rare.¹⁵

Ultrasonography and computed tomography (CT)—the modalities most commonly used for imaging the spleen—typically show a homogenous pattern.¹⁶ However, bilobed spleens may show a mottled heterogeneous enhancement pattern (i.e. a zebra-like pattern) during arterial-phase CT due to variable blood flow rates through the sinuses of the red pulp.¹⁷ This is a significant finding which can help to distinguish normal and bilobed spleens. Furthermore, bilobed spleens should be differentiated from a wide variety of other congenital splenic anomalies such as accessory spleens, *splenunculi* and other adjacent solid masses. The medial lobe of a bilobed spleen is most often misdiagnosed as a solid mass arising from the gastric *fundus*, left adrenal gland, upper pole of the left kidney or the body or tail of the pancreas; moreover, it often displaces the left kidney to a lower position.⁹ Hence, clinicians should be aware of the possibility of fissures dividing the spleen into two lobes, in addition to other congenital anomalies, in order to successfully differentiate bilobed spleens from the adjacent *viscera*.

The existence of splenic notches has long raised questions regarding segmentation of the spleen. In 1870, researchers observed that the human spleen consists of segments divided by fibrous *septa*, similar to that seen in animals such as cats, dogs and horses.¹⁸ Subsequently, in 1956, Braithwaite and Adams injected radiopaque media into the spleens or tributaries of the portal venous system of rats which confirmed that the spleen consists of distinct segments, each of which has its own dedicated arterial supply and venous drainage.¹⁹ Despite multiple studies on this topic, there is as yet no consensus regarding the precise number of spleen segments in humans [Table 1].^{20–24} Both Gutierrez Cubillos and Gupta *et al.* reported the presence of 2–4 segments, while Mikhail *et al.* revealed up to five individual lobes.^{20–22} Voboril found as many as 10 distinct segments with a mean of six.²³ Using a combination of gross dissection, casting and

radiological methods, Redmond *et al.* claimed that the spleen had three segments, consisting of one central segment and one at each pole.²⁴

Anatomical knowledge regarding splenic vasculature is vital during surgeries involving the spleen. In general, splenic vessels do not anastomose, resulting in several vascular segments separated by avascular planes.²⁵ During splenic lobectomies or segmentectomies, the first step involves the ligation of vessels in the injured lobe or segment.^{26,27} In the current study, the bilobed spleen had a single fissure resulting in two lobes, both of which were equal in size and of a similar shape. The splenic artery arises almost invariably from the coeliac axis along with the left gastric and hepatic arteries.¹ In contrast, the authors hypothesise that bilobed spleens have two polar branches arising from the splenic artery, with the single fissure representing the avascular plane of division [Figure 4]. These avascular planes between segments can be used to minimise blood loss during subtotal splenectomies.²⁸ Moreover, splenic fissures in bilobed spleens can serve as a guide to assist surgeons in the ligation of vessels during partial splenectomies.

Conclusion

In cases of blunt abdominal trauma, knowledge of the complete morphology and anatomy of abdominal organs such as the liver, spleen, pancreas and kidneys is vital. The present study describes the incidence of notches, fissures and lobation in spleens collected from cadavers over a seven-year period. Gross variations in the presence of notches and fissures were observed on both the visceral and diaphragmatic surfaces and extending to various depths, sometimes dividing the spleen into two separate lobes. Bilobed spleens are one of the rarest types of congenital splenic anomalies. These findings are valuable for distinguishing splenic variations from other visceral abnormalities in abdominal imaging and during conservatory splenectomies.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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References

1. Standring S, Ed. Gray's Anatomy: The anatomical basis of clinical practice, 39th ed. London, UK: Churchill Livingstone, 2005. Pp. 1239–44.

2. Skandalakis JE. Skandalaki's Surgical Anatomy: The embryologic and anatomic basis of modern surgery. Nicosia, Cyprus: Broken Hill Publishers Ltd., 2004. Pp. 1231–77.
3. Moore KL, Persaud TV. The Developing Human: Clinically oriented embryology, 6th ed. Philadelphia, Pennsylvania, USA: Saunders, 1998. Pp. 271–302.
4. Larsen WJ, Ed. Human Embryology, 2nd ed. Philadelphia, Pennsylvania, USA: Saunders, 1997. Pp. 229–59.
5. Nayak BS, Somayaji SN, Soumya KV. A study on the variations of size, shape and external features of the spleen in south Indian population. *Int J Morphol* 2011; 29:675–77. <https://doi.org/10.4067/S0717-95022011000300001>.
6. Dodds WJ, Taylor AJ, Erickson SJ, Stewart ET, Lawson TL. Radiologic imaging of splenic anomalies. *AJR Am J Roentgenol* 1990; 155:805–10. <https://doi.org/10.2214/ajr.155.4.2119113>.
7. Zarzaur BL, Rozycki GS. An update on nonoperative management of the spleen in adults. *Trauma Surg Acute Care Open* 2017; 2: e000075. <https://doi.org/10.1136/tsaco-2017-000075>.
8. Das S, Abd Latiff A, Suhaimi FH, Ghazalli H, Othman F. Anomalous splenic notches: A cadaveric study with clinical importance. *Bratisl Lek Listy* 2008; 109:513–16.
9. Gayer G, Hertz M, Strauss S, Zissin R. Congenital anomalies of the spleen. *Semin Ultrasound CT* 2006; 27:358–69. <https://doi.org/10.1053/j.sult.2006.06.002>.
10. Ungör B, Malas MA, Sulak O, Albay S. Development of spleen during the fetal period. *Surg Radiol Anat* 2007; 29:543–50. <https://doi.org/10.1007/s00276-007-0240-2>.
11. Gandhi KR, Chavan SK, Oommen SA. Spleen with multiple notches: A rare anatomical variant with its clinical significance. *Int J Stud Res* 2013; 3:24–5. <https://doi.org/10.4103/2230-7095.113829>.
12. Parsons FG. Notches and fissures of the spleen. *J Anat Physiol* 1901; 35:416–27.
13. Nayak SB, Kumar V, Kumar N, Jetti R. Unusual fissure on the diaphragmatic surface of the spleen: A case report. *Int J Anat Var* 2012; 5:96–8.
14. Nayak SB, Shetty P, Deepthinath R, Sirasanagandla SR, Shetty SD. A lobulated spleen with multiple fissures and hila. *J Clin Diagn Res* 2014; 8:AD01–2. <https://doi.org/10.7860/JCDR/2014/8996.4774>.
15. Yildiz AE, Ariyurek MO, Karcaaltincaba M. Splenic anomalies of shape, size, and location: Pictorial essay. *ScientificWorldJournal* 2013; 2013:321810. <https://doi.org/10.1155/2013/321810>.
16. Vancauwenberghe T, Snoeckx A, Vanbeckevoort D, Dymarkowski S, Vanhoenacker FM. Imaging of the spleen: What the clinician needs to know. *Singapore Med J* 2015; 56:133–44. <https://doi.org/10.11622/smedj.2015040>.
17. Ali HM. Bilobed spleen: An extremely rare imaging finding. *BJR Case Rep* 2017; 3:20170021. <https://doi.org/10.1259/bjrcr.20170021>.
18. Kyber E. Über die Milz des Menschen und einiger Säugetiere [Concerning the spleen of humans and some other mammals]. *Arch Mikrosk Anat* 1870; 6: 540–80.
19. Braithwaite JL, Adams DJ. Vascular compartments in the rat spleen. *Nature* 1956; 178:1178–9. <https://doi.org/10.1038/1781178a0>.
20. Gutierrez Cubillos C. Segmentación esplénica [Splenic segmentation]. *Rev Esp Enferm Apar Dig* 1969; 29:341–50.
21. Gupta CD, Gupta SC, Arora AK, Singh PJ. Vascular segments in the human spleen. *J Anat* 1976; 121:613–16.
22. Mikhail Y, Kamel R, Nawar NN, Rafla ME. Observations on the mode of termination and parenchymal distribution of the splenic artery with evidence of splenic lobation and segmentation. *J Anat* 1979; 128:253–8.

23. Voboril Z. On the question of segmentation of the human spleen. *Folia Morphol (Praha)* 1982; 30:295–314.
24. Redmond HP, Redmond JM, Rooney BP, Duignan JP, Bouchier-Hayes DJ. Surgical anatomy of the human spleen. *Br J Surg* 1989; 76:198–201. <https://doi.org/10.1002/bjs.1800760230>.
25. García-Porrero JA, Lemes A. Arterial segmentation and subsegmentation in the human spleen. *Acta Anat (Basel)* 1988; 131:276–83. <https://doi.org/10.1159/000146529>.
26. Liu DL, Xia S, Xu W, Ye Q, Gao Y, Qian J. Anatomy of vasculature of 850 spleen specimens and its application in partial splenectomy. *Surgery* 1996; 119:27–33. [https://doi.org/10.1016/s0039-6060\(96\)80209-1](https://doi.org/10.1016/s0039-6060(96)80209-1).
27. Vanhoenacker FM, Op de Beeck B, De Schepper AM, Salgado R, Snoeckx A, Parizel PM. Vascular disease of the spleen. *Semin Ultrasound CT MR* 2007; 28:35–51. <https://doi.org/10.1053/j.sult.2006.10.006>.
28. Uy PPD, Francisco DM, Trivedi A, O'Loughlin M, Wu GY. Vascular diseases of the spleen: A review. *J Clin Transl Hepatol* 2017; 5:152–64. <https://doi.org/10.14218/JCTH.2016.00062>.