Spleen anatomic variations in the context of morphology

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SUMMARY

The immune and hematopoietic systems in the human body depend on the spleen. The understanding of anatomical and morphological variations of the spleen and its arterial vascular segments (AVS) is crucial for performing whole or partial splenectomy in the treatment of splenomegaly and splenic rupture. The aim of this study was to compare the anatomical differences in the spleen and its AVS in Thai cadavers of both sexes. This cadaveric study was performed on 77 cadaveric spleens (males = 38 and females = 39) from the Gross Anatomy Laboratory at the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University. The average morphological measures of the observed spleens were 9.11±1.40 cm in length, 6.57±1.46 cm in width, 3.11±0.67 cm in thickness in male cadavers, and 8.77±1.87 cm in length, 5.91±1.35 cm in width, and 2.90±0.78 cm in thickness in female cadavers. The variations in spleen form were 7.79% oval, 16.88% tetrahedral, 28.57% triangular, and 46.75% wedge. The mean splenic hilum length was 5.14±1.10 cm in males and 5.12±1.22 cm in females. The mean lobar branch to hilum distance was 2.26±0.98 cm in males and 2.29±1.05 cm in females. Females were more likely than males to have two lobar arteries. Three lobar arteries, however, were more prevalent in males. The occurrence of accessory spleens was 2.63% for males and 7.50% for females. According to the data, there were significant differences in the number of lobar arteries and spleen size between male and female Thai cadavers.

Key words: Spleen – Anatomical Variation – Cadaver – Morphology

INTRODUCTION

The spleen is the largest organ in the lymphatic system. A soft dark purple in color, the spleen varies in shape and size and is located in the left upper quadrant of the abdomen. The mean average length, width, and thickness are 12, 7, and 3 centimeters, respectively, and spleens weigh approximately 150 grams. It has anterior and posterior extremities, as well as anterior and inferior borders and visceral and diaphragmatic surfaces (Cesta, 2006). The development of the spleen occurs during the fifth week of gestation by the aggregation of mesenchymal cells (Coetzee, 1982). Failure of splenic nodule fusion can lead to the development of the accessory spleen and the appearance of one or more notches on the border of the spleen. The spleen plays a crucial role in both the immune and hematopoietic systems, including filtration and regulation of erythrocytes,

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Submitted: June 2, 2023. **Accepted:** September 19, 2023

https://doi.org/10.52083/IXWW6102

production of lymphocytes, and prevention of infection from pathogens (Kapila et al., 2021). The blood supply of the spleen is from the splenic artery, where its terminal branch divides into lobar, segmental, and trabecular arteries. Due to the lack of anastomoses between the lobar arteries, the number of lobar arteries plays an important role in indicating the number of splenic segments (Sahni et al., 2003).

The major splenic disorders are splenomegaly, hypersplenism (hyperfunction), and splenic rupture. Splenomegaly, or spleen enlargement, is brought on by several potential causes, such as hematologic cancers, liver diseases, venous thrombosis, and infections from bacteria, parasites, and viruses. The spleen can be replaced by cancer cells, or it can be hyperactive. Hypersplenism is caused by an overactive spleen, which filters and destroys an excessive number of both healthy and damaged blood cells, resulting in anemia. The emergency condition known as splenic rupture is typically brought on by trauma or injury that results in severe internal bleeding in the upper left portion of the abdomen (Bowdler, 2002).

The spleen is the organ that is well-known for its variation in morphology and AVS which can potentially lead to complications. Therefore, the knowledge of the splenic variations is important for physicians, surgeons, and radiologists for precise diagnosis and potential preoperative planning for various upper abdominal surgeries and arterial intervention practices. In the case of severe splenic diseases, the spleen can be removed as a treatment option. Splenectomy can be divided into total splenectomy and partial splenectomy (Yi and Buicko, 2022). Both surgical procedures necessitate an understanding of anatomical variations and the arterial vascular segments (AVS), particularly to perform partial splenic removal effectively as an alternative treatment for some diseases. The aim of this study was to identify the anatomical variations of the spleen and AVS in the Thai population and compare the differences between males and females.

MATERIALS AND METHODS

During the academic year 2021-2022, the anatomical variation of spleens and the AVS was evaluated at the Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand. The experiment was approved by the Siriraj Institutional Review Board, Mahidol University, Thailand (694/exemption). Exclusion criteria were splenic diseases such as splenomegaly of Thalassemia or tumor of the spleen.

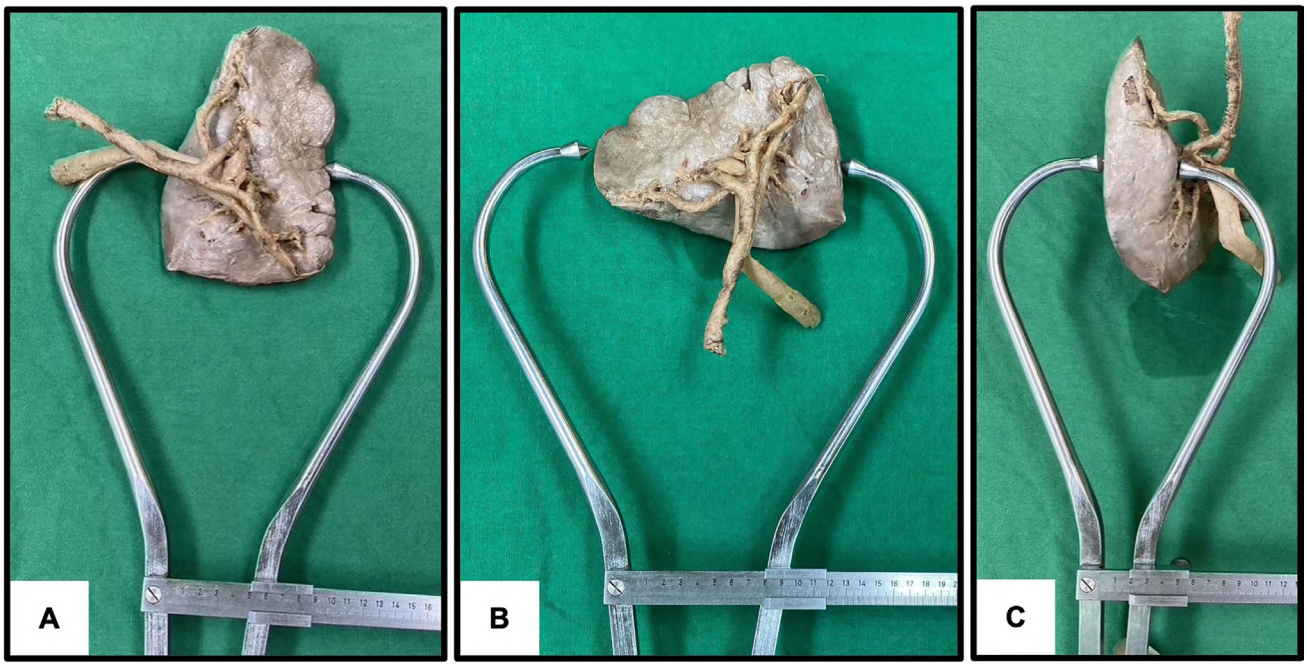

Fig. 1.- Measurement of the splenic size (width, length, and thickness) using the Vernier caliper. A: width; B: length; C: thickness.

The cadavers were all Thai and fixed in a 10% solution of formaldehyde. 77 cadaveric spleens (38 males and 39 females) were excised and photographed. The spleens were examined for morphological characteristics, including shape and number of notches on all borders as well as accessory spleen. Variations in spleen shape were classified into four main shapes: wedge, triangular, tetrahedral, and oval. The size (length, width, and thickness) of the spleen was measured using the Vernier caliper (Fig. 1). The length was measured by the maximum distance between the posterior extremity and the anterior extremity. The width was measured by the maximum distance between the superior border and the inferior border. The thickness was measured at the midpoint between the visceral and the diaphragmatic surfaces. Furthermore, the splenic hilum area and the splenic vessels were cleaned for the investigation of the area. The length of the hilum was measured (Fig. 2.). The number of lobar arteries that branched from the splenic artery was identified and counted. Next, the distance from the beginning point of the lobar branches from the splenic artery to the point of the hilum was measured with the Vernier caliper (Fig. 2.). In cases where the lobar artery branched after the splenic hilum, the distance value was presented as negative. Last, the presence or absence of an accessory spleen within the hilum of the spleen was observed. The mean and standard deviation of the data were determined (SD). Using the independent t-test, differences between independent groups were examined (SPSS version 20.0 software, Inc., Chicago, IL, USA). A *p*-value of 0.05 was used to determine if the differences were significant.

RESULTS

According to the demographic characteristics of the cadavers, the total number of cadavers was 77 cadavers with 77 spleens, separating into 38 males and 39 females. All the cadavers were Thai, with an age range of 40-99 years old at the time of death, with a mean age of 74.49 years.

Shapes and dimensions of the spleen, including length, width, and thickness

There were four different shape variations of the spleen, including a wedge shape, a triangular shape, a tetrahedral shape, and an oval shape. Out of the 77 spleens studied, 36 (46.75%) had a wedge shape, followed by triangular, tetrahedral, and oval shapes, at 28.57%, 16.88%, and 7.79%, respectively (Fig. 3).

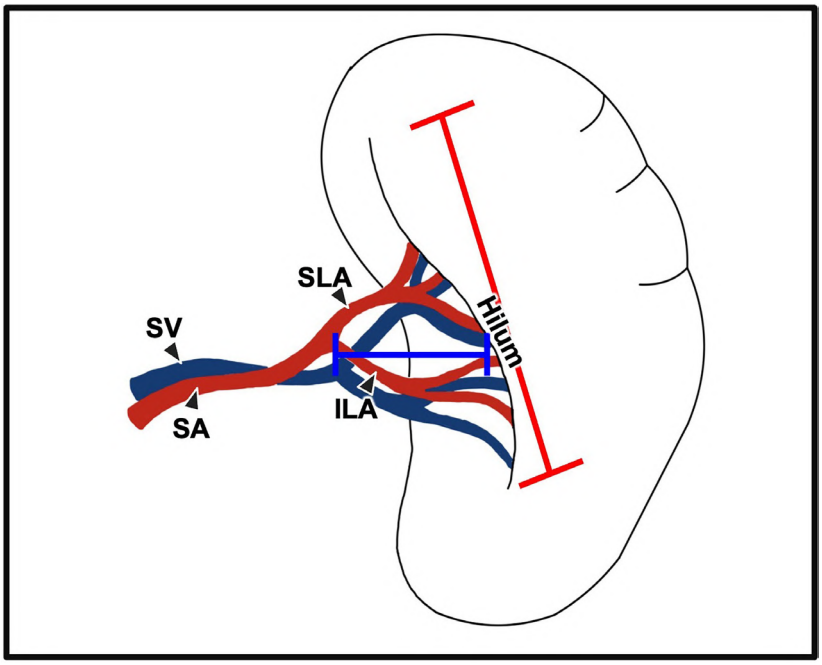

Fig. 2.- Schematic of spleen with blood vessels at the hilum. The length of the splenic hilum (red line); The distance from the beginning point of the lobar branches to the splenic hilum (blue line); Splenic artery (SA); Splenic vein (SV); Superior lobar artery (SLA); Inferior lobar artery (ILA).

Fig. 3.- The shape variations of the spleen. **A**: Wedge shape; **B**: Triangular shape; **C**: Tetrahedral shape; **D**: Oval shape.

In this study, male spleen lengths ranged from 6.90 cm to 13.90 cm, with an average of 9.11±1.40 cm, and female spleen lengths ranged from 4.80 cm to 13.50 cm, with an average of 8.77±1.87 cm. Male spleen widths ranged from 4.20 cm to 9.55 cm, with an average of 6.57±1.46 cm, and female spleen widths ranged from 3.20 cm to 9.30 cm, with an average of 5.91±1.35 cm. The thickness of the spleens ranged from 1.90 cm to 4.90 cm in males with an average of 3.11±0.67 cm and 1.70 cm to 5.20 cm in females with an average of 2.90±0.78 cm.

The notches of the splenic borders

The presence of notches on either border was also observed. Forty-four spleens (57.14%) presented with notches on the superior border only; 6 spleens (7.79%) had notches on the inferior border only; 21 spleens (27.27%) showed notches on both borders; and 6 spleens (7.79%) were found with the no notches on either border. The *p*-value was 0.001 for the location of notches between the superior and inferior borders.

The length of the splenic hilum

The length of the splenic hilum was measured. In male cadavers, the length of the hilum ranged from 3.25 cm to 9.10 cm, with a mean value of 5.14±1.10 cm. In female cadavers, the length of the hilum ranged from 2.70 cm to 9.10 cm, with a mean value of 5.12±1.22 cm. There was no statistically significant difference (p = 0.95) in the length of the splenic hilum between the sexes.

The distance from the beginning point of the lobar branch to the hilum

The distance from the beginning point of the lobar branch to the hilum varied from -0.20 cm to 4.10 cm in males and 0.70 cm to 5.40 cm in females (Table 1). There was no statistically significant difference (p = 0.91) between the sexes in the distance from the beginning point of the lobar branch to the hilum. There is 1.30% of a single branch of the splenic artery that directly terminates into the spleen without branching. However, the lobar arteries are presented after entering the hilum which results in a negative value by measuring from the hilum level the beginning point of the lobar branch.

Table 1. Distance from the beginning point of lobar branches to the splenic hilum.

Parameters	Minimum (cm)	Maximum (cm)	Mean ± SD (cm)
Males (n = 38)	-0.20	4.10	2.26 ± 0.98
Females (n = 39)	0.70	5.40	2.30 ± 1.05

*p<0.05; compared the distance from the beginning point of lobar branches to the splenic hilum between both sexes

The number and percentage of lobar artery branching types

The number of lobar arteries was found to be between two and three branches in this study, including the superior lobar artery, the middle lobar artery, and the inferior lobar artery (Fig. 4). There was a statistically significant difference (p = 0.048) in the number of lobar arteries between both sexes. Two lobar arteries were more common in females than in males. In contrast, three lobar arteries were more common in males, as exhibited in Table 2. However, in both sexes, there were more two-lobar arteries than three-lobar arteries.

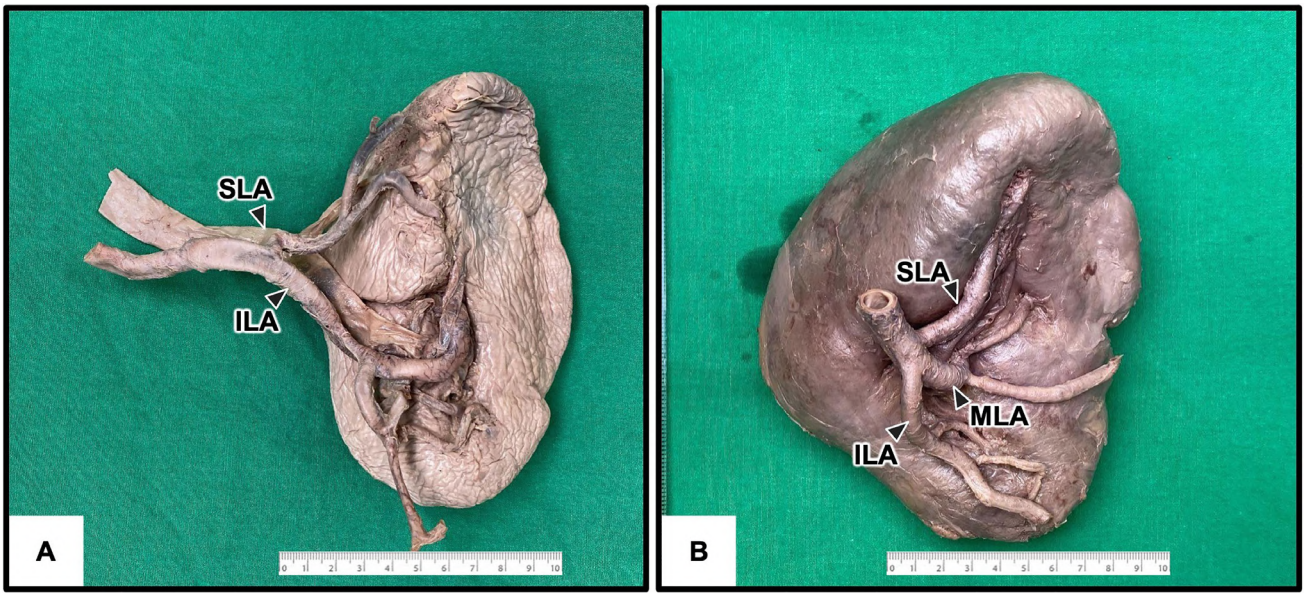

Fig. 4.- The medial view of the branches of the lobar arteries (**A-B**). Superior lobar artery (SLA); Inferior lobar artery (ILA); Middle lobar artery (MLA).

Table 2. Presence of number and percentage (%) of lobar artery branching types of the splenic arteries.

Parameters	Number and percentage (%) of lobar artery branching types	
Males (n = 38)	2 branches (superior and inferior)	3 branches (superior, middle, and inferior)
	Mean ± SD = 2.16 ± 0.37 br.	
	n = 32 (84.21%)	n = 6* (15.79%)*
Females (n = 39)	2 branches (superior and inferior)	3 branches (superior, middle, and inferior)
	Mean ± SD = 2.03 ± 0.16 br.	
	n = 38* (97.44%)*	n = 1 (2.56%)

*p<0.05; compared the number and percentage of lobar artery branching types between both sexes

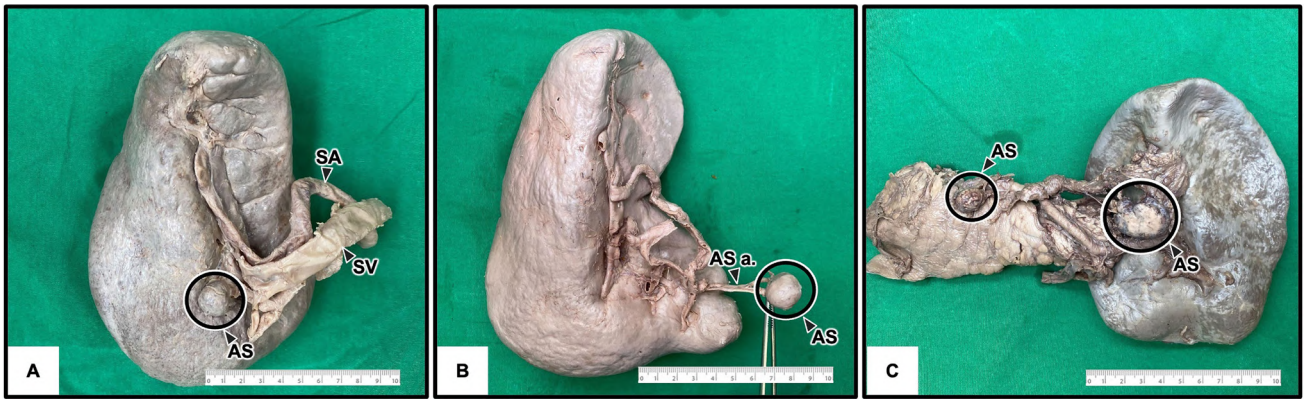

Fig. 5.- Variation of locations of accessory spleen. **A**: Accessory spleen at the splenic hilum. **B**: Accessory spleen at the splenic hilum with its arterial supply. **C**: Accessory spleens at the tail of pancreas and splenic hilum. Accessory spleen (AS); Splenic artery (SA); Splenic vein (SV); artery of accessory spleen (AS a.).

Table 3. The number and percentage of absence and presence of accessory spleens.

Parameters	**Accessory spleen (Number and percentage (%))**	
Males (n= 38)	**Absence**	**Presence**
	n = 37	n = 1
	97.37 %	2.63 %
Females (n = 39)	**Absence**	**Presence**
	n = 36	n = 3
	92.31 %	7.69 %

*p<0.05; compared the number and percentage of absence and presence of accessory spleens between both sexes

The number and percentage of accessory spleens and their locations

The presence of an accessory spleen was found in four cases in this study: one spleen (2.63%) in males and three spleens (7.69%) in females (Table 3).

The accessory spleen was found in various locations, including at the splenic hilum and at the tail of the pancreas. Some accessory spleens had their own artery, which independently supplied the accessory spleen body directly (Fig. 5).

DISCUSSION

In the present study, the anatomical variations of the spleen and its AVS were observed in 77 spleens, with an average dimension of 9.11 cm in length, 6.57 cm in width, and 3.11 cm in thickness in male cadavers and 8.77 cm in length, 5.91 cm in width, and 2.90 cm in thickness in female cadavers. The average length, width, and thickness in the previous studies by Mohammadi et al. (2016) report the male average as 11.50 cm, 8.20 cm, and 2.06 cm, respectively and the female average as 10.67 cm, 7.51 cm, 1.86 cm, respectively. The findings on the size of the spleen were closely consistent in both studies. Moreover, the comparison of the spleen dimension in both genders indicates a larger spleen size among males than in females. Therefore, the spleen size is significantly correlated with gender which can potentially apply as a reference for spleen-related surgeries.

The shape variations of the spleen appeared in this study. The most prevalent splenic shape was a wedge shape, followed by a triangular shape, a tetrahedral shape, and finally an oval shape with the same order in both genders. When compared with the previous studies, all the reported results appeared to align with the present study in terms of variations in splenic shape. Setty and Katikireddi (2013) reported the percentage of each shape of the spleen as 40% wedge, 32% triangular, 20% tetrahedral, and 8% oval. Chidambaram et al. (2015) reported 73.33%, 13.33%, 6.67%, and 6.67%, respectively. The findings showed a strong

variation of splenic shapes in the overall population without notable differences in shape variations between sexes.

Splenic notches are caused by the improper lobulation of splenic nodules during the embryonic stage (Gandhi et al., 2013). It was observed mostly on the superior border (57.14%) and only 7.79% on the inferior border. The greater proportion of notches on the superior versus inferior border (p = 0.001) found in the present study also correlated with previous studies, as 63.33% versus 10.00% were noted by Chidambaram et al. (2015) and 70% versus 14% were noted by Setty and Katikireddi (2013). Therefore, this supports the statistically higher chance of finding notches on the superior border compared to the inferior border. In some cases, abnormal deep fissures might be present which could lead to the misinterpretation of splenic hematoma by radiologists (Nayak et al., 2014; Smidt, 1967). However, the appearance of splenic fissures was absent in the present study. The presence of notches is essential for physicians as a clinical landmark for distinguishing splenomegaly and differentiating it from the tumor of the left kidney since splenic notches are more exaggerated and palpable (Gandhi et al., 2013; Nayak et al., 2011; Coetzee, 1982).

The *p-value* for the length of the splenic hilum was 0.95, indicating that no statistically significant difference existed between the sexes. The distance between the starting point of lobar branches and the splenic hilum had a *p-value* of 0.91. Therefore, there was no statistically significant difference in the distance from the beginning of lobar branches to the hilum between both sexes. To perform partial splenectomy, investigation of the distance between the splenic AVS and the length of the splenic hilum is crucial in terms of surgical planning since the terminal branches of the splenic artery need to be differentiated and incised to separate the segments of the spleen body. There is no significant variation between the sexes in the length of the splenic hilum and the distance of the terminal branches of the splenic arteries, so these measurements might not essentially affect the performance of a partial splenectomy.

The number of lobar branches of the splenic artery was found to be significantly different between sexes at a *p-value* of 0.048. According to Table 2, the presence of three lobar arteries was more common in males (15.79%) than in females (2.56%). Therefore, it could possibly be said that there is a significantly higher chance of finding three lobar arteries in males than in females. In the present study, 89.74% of the cases had two branches, while 8.97% had three branches of lobar arteries. In comparison, Gupta et al. (1967) reported 84% with two branches and 16% with three branches. Likewise, Katritsis et al. (1982) found 85.7% with two branches and 14.3% with three branches. Moreover, Alim et al. (2014) stated that 70% of the cases had two lobar arteries, 23% had three lobar arteries, and they even found 7% with four branches of lobar arteries. The number of lobar arteries varies from two to more than four, which would indicate the number of AVS (superior, middle, and inferior segments) of the splenic body. This also directly has a significant association with the performance of partial splenectomy due to the diversity of a number of AVS in different patients (Sahni et al., 2003).

The presence of a small nodule formed by splenic tissue located outside of the main spleen is known as the accessory spleen. The accessory spleen is a benign mesenchymal remnant from the embryonic period. In cases where an accessory splenic artery was present, similar physiology was seen in the accessory spleen as the normal spleen body (Bajwa and Kasi, 2018; Kumar et al., 2014). This study also discovered the presence of accessory spleens in various locations. A slightly higher number of accessory spleens was observed in females (7.69%) versus male cadavers (2.63%). The location of the accessory spleen varies from the splenic hilum to any area in the abdominal cavity which sometimes causes complications of misdiagnosis due to the mimicry of the accessory spleen to tumors or lymphadenopathy for the radiologists (Nivargi et al., 2014). Therefore, the possibility of an accessory spleen is important to consider when reviewing a CT scan before performing abdominal surgeries. Since the accessory spleen can function as a normal spleen, the removal of the accessory spleen is also necessary while performing the splenectomy to treat vascular disorders such as hypersplenism to entirely recover. (Bajwa and Kasi, 2018).

The overall findings suggest that there is prevalent variation in the spleen main body and its AVS. The investigation obtained a statistically significant value for the presence of the lobar artery. The variation of the aforementioned findings including the information on the length of the hilum and the distance between the hilum beginning of lobar arteries are significantly correlated with the performance of splenic arterial interventions to treat traumatic injuries and other complications. The knowledge is also important for physicians and radiologists in order to apply to other interventional radiology practices (Madoff et al., 2005). The data pool of the present studies confirmed the anatomical variations of the spleen that would be associated with the performance of upper abdominal surgeries, especially partial splenectomy. Due to possible complications and the diminished hematologic and immunologic function of the spleen from total splenectomy, partial removal might be more suitable for some cases. To preserve the spleen function, the variation of splenic terminal branches and AVS advocates partial splenectomy as an alternative to treat splenomegaly, hypersplenism, or splenic rupture. Therefore, physicians must acknowledge and understand the variation of the spleen and its artery including any potential rare conditions such as accessory spleen for accurate diagnosis and successful treatments.

CONCLUSION

The characteristics of splenic architectures and their AVS were found because of the high recognition of morphological variations. The prevalence of the lobar artery and the number of notches between both borders in the cadavers under study varies statistically significantly between males and females. Moreover, the findings of the length of the hilum and the distance between the beginning of the splenic branch of the hilum indicate significant clinical implications for physicians. Regarding anatomical variances, the study can be utilized as a guide for diagnosis and surgeries including a whole splenectomy and particularly a partial splenectomy.

ACKNOWLEDGEMENTS

This research was supported by Chalermphrakiat Grant, Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand. The authors express their sincere gratitude to those who donated their bodies to science so that anatomical research and teaching could be performed. Results from such research can potentially increase scientific knowledge and enhance patient care. Therefore, these donors and their families deserve our highest respect.

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