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Measurement of normal spleen volume and dimensions in all child age groups by abdominal computed tomography

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Abstract. – OBJECTIVE: This study aimed to calculate the spleen size and volume, portal vein diameter, splenic vein diameter, and accessory spleen presence in children aged 0–18 years in the Turkish population by computed tomography, according to age and gender.

MATERIALS AND METHODS: Abdominal computed tomography images of 406 children without systemic or organospecific disease were retrospectively analyzed in the study. Maximum interpolar length in axial and coronal sections in addition to maximum width at hilus level in axial sections of the spleen were measured in abdominal computed tomography. Luminal diameter measurements were obtained from axial sections at the level of the liver hilum of the portal vein and the hilus of the spleen of the splenic vein.

RESULTS: As age increases, the axial longest dimension (ALD), axial longest thickness (ALT) and coronal longest dimension (CLD) dimensions also increase, and this increase is statistically significant ($p<0.001$). The lowest splenic volume was measured in the 0-2 age group as 25.3 cm^3, and the highest splenic volume was 506.2 cm^3 in the 17-18 age group. Splenic vein diameter is between 1.9 mm and 11.0 mm, and the mean splenic vein diameter increases with increasing age. Portal vein diameter is between 4.1 mm and 14.9 mm, and the average portal vein diameter increases with age. The accessory spleen was seen in 22 (5.4%) children. Accessory spleen size ranged from 5 mm to 17 mm. There was a strong positive correlation between spleen volume and splenic vein diameter (r=0.696 $p<0.001$). Similarly, there was a strong positive correlation between spleen volume and portal vein diameter (r=0.704 $p<0.001$).

CONCLUSIONS: It may be helpful to know the normal spleen volume in healthy children according to age groups in making the correct diagnosis of splenomegaly. We assume that it will play an important role in the accurate diagnosis of portal hypertension to know the upper and lower limits of the portal vein and splenic vein diameters.

Key Words:
Spleen, Computed tomography, Pediatric age, Splenic vein, Portal vein.

Introduction

The spleen is located in the left upper quadrant of the abdominal cavity between the fundus of the stomach and the diaphragm. It is located intraperitoneally and is the largest organ in the reticuloendothelial system. Changes in the size and volume of organs can be associated with many diseases. For example, splenomegaly can be observed in some diseases that may include the liver, hematopoietic system, and immune system[1]. In addition, splenomegaly can be seen in infections, storage diseases, connective tissue diseases, and malignant diseases. Spleen atrophy is seen in celiac disease[2]. Therefore, the determination of normal values is important in the correct evaluation of these changes. Physical examination methods such as palpation and percussion may be insufficient to evaluate the size of the spleen[3].

Our study, on the other hand, included children aged 1 day to 18 years. Additionally, we conducted the study with a computerized tomography (CT) with the highest coverage as far as we could detect, it was. Our aim in this study is to help determine the normal values of spleen volume, portal vein, and splenic vein, and to reveal the incidence of the accessory spleen in the population.

Materials and Methods

In this study, we collected data from the retrospective review of abdominal CT scans of children (231 boys and 175 girls, aged 0 to 18) without underlying organic pathology. The children are selected from those who applied to the emergency

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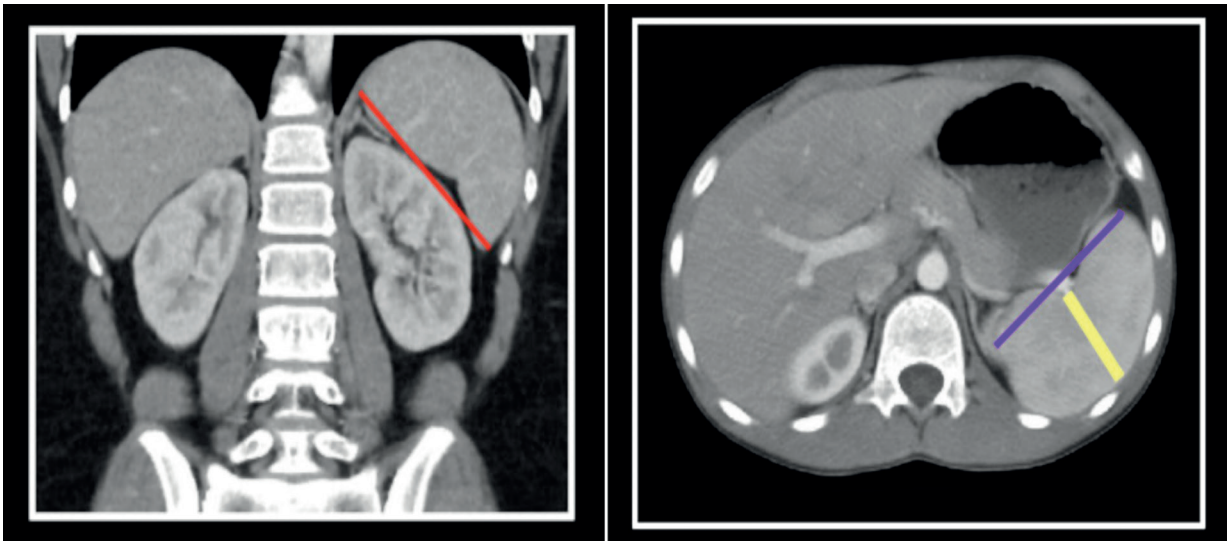

Figure 1. Measurement of maximal longitudinal spleen size between poles in the coronal plane (*red line*). Distance measurement between poles in axial images where the spleen hilum is visible (*purple line*). Measurement of maximal spleen thickness in axial images where the spleen hilum is visible (*yellow line*).

room between May 2019 and August 2021 with the complaint of abdominal pain or trauma. Patients with abnormal formations such as masses and patients with parenchymal damage such as laceration (30 patients) were excluded from the study. Spleen measurements were obtained from the images showing the maximal longitudinal spleen size between the poles in the coronal plane length (*red line*) (Figure 1), the distance between the poles in the axial images where the spleen hilum is visible width (*purple line*) (Figure 1), and the maximal spleen thickness perpendicular to it thickness (*yellow line*) (Figure 1). Spleen volume was calculated with the following formula: Spleen volume (cm^3) = 0.52 × length × thickness × width

The diameter of the portal vein (*blue line*) (Figure 2) was measured luminally from axial sections from the hilum of the liver and the diameter of the splenic vein (*green line)* (Figure 2) from the hilum of the spleen.

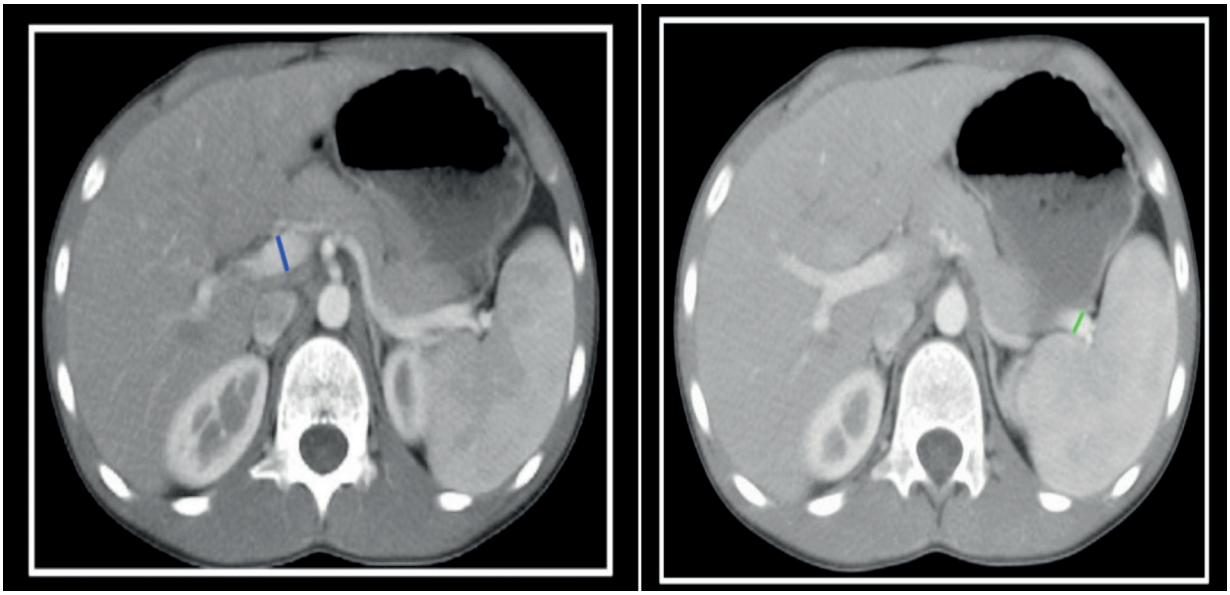

Figure 2. Luminal measurement of portal vein diameter from axial sections from the hilum of the liver (*blue line*). Luminal measurement of splenic vein diameter from axial sections from splenic hilum (*green line*).

Table I. Averages of spleen lengths by age and measurement method.

Age	N (%)	ALD ± SD	ALT ± SD	CLD ± SD
0-2	23 (5.7)	58.7 ± 8.1 mm	23.5 ± 4.5 mm	63.3 ± 11.8 mm
3-4	26 (6.4)	65.4 ± 8.3 mm	25.7 ± 3.3 mm	70.6 ± 8.1 mm
5-6	23 (5.7)	70.3 ± 10.7 mm	30.5 ± 5.9 mm	78.0 ± 9.0 mm
7-8	39 (9.6)	76.9 ± 12.0 mm	32.9 ± 6.0 mm	81.9 ± 13.4 mm
9-10	44 (10.8)	85.5 ± 12.4 mm	34.1 ± 6.2 mm	92.6 ± 13.8 mm
11-12	46 (11.3)	86.4 ± 13.7 mm	37.3 ± 5.4 mm	96.9 ± 16.7 mm
13-14	56 (13.8)	95.1 ± 14.7 mm	40.0 ± 6.9 mm	102.9 ± 15.5 mm
15-16	80 (19.7)	94.7 ± 13.7 mm	40.5 ± 6.9 mm	103.3 ± 16.2 mm
17-18	69 (17.0)	97.3 ± 11.8 mm	43.1 ± 6.7 mm	107.5 ± 15.8 mm
All	406 (100)	86.2 ± 17.1 mm	36.6 ± 8.4 mm	94.3 ± 19.7 mm
p		< 0.001	< 0.001	< 0.001

n: Number of children; ALD: Average of axial longest dimensions; ALT: average of longest thicknesses; CLD: Average of coronal longest dimensions; SD: standard deviation; *p* values were obtained by ANOVA test.

Children were divided into 9 groups according to their age (0-2 years, 3-4 years, […] and 17-18 years). The evaluation of the patients in terms of anemia was made according to the reference values of the World Health Organization[4]. The study was approved by the Clinical Research Ethics Committee of our hospital (ethical decision no: 2021/100).

Statistical Analysis

IBM SPSS Statistics for Windows 22.0 (IBM Corp., Armonk, NY, USA) was used to analyze the data. Children were divided into 9 groups according to their age. ANOVA test was used to determine the difference between the means of ALD, ALT, and CLD according to age groups. A *t*-test was used to evaluate the difference between spleen volume averages according to gender. Pearson correlation analysis was performed to evaluate the correlation between spleen volume and hemoglobin and hematocrit values and the direction of correlation, if any. The statistical significance level was taken as $p<0.05$. Mean values of organ sizes for all ages and 95% confidence limits were established.

Results

A total of 406 patients, including 231 (56.9%) boys and 175 (43.1%) girls, were included in the study. The mean age of the patients in our study was 11.57±4.92 years. Children were divided into 9 groups according to their age. The number of children by age group is presented in Table I. As the age increases, the axial longest dimension (ALD), axial longest thickness (ALT) and coronal longest dimension (CLD) dimensions also increase, and this increase is statistically significant ($p<0.001$). The ALD, ALT, and CLD dimensions of the children by age are presented in Table I.

Similarly, splenic volume (SV) increases with increasing age (Figure 3). The lowest splenic volume was measured at 25.3 cm^3 in the 0-2 age group, and the highest splenic volume was measured at 506.2 cm^3 in the 17-18 age group. In the 7-8, 13-14, 15-16, and 17-18 age groups, the mean spleen volume of boys was found to be significantly higher than that of girls ($p=0.009$, $p=0.041$, $p=0.007$, $p<0.001$, respectively). There was no difference between the mean spleen volume of girls and boys in other age groups. Spleen volume averages and *p*-values by gender are presented in Table II.

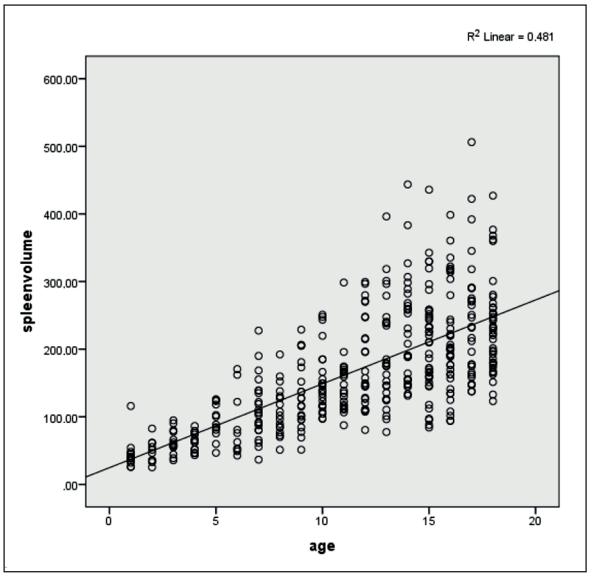

Figure 3. Correlation graph between age and spleen volume.

Table II. Average of spleen volume by age and gender.

Age	Girls n (%)	MSV ± SD cm³	Boys n (%)	MSV ± SD cm³	All MSV ± SD cm³	*p*
0-2	6 (26.1)	40.8 ± 10.9	17 (73.9)	48.7 ± 22.5	46.7 ± 20.2	0.421
3-4	5 (19.2)	61.4 ± 18.3	21 (80.8)	62.7 ± 16.0	62.5 ± 16.0	0.873
5-6	12 (52.2)	79.1 ± 27.2	11 (47.8)	103.3 ± 41.0	90.6 ± 35.8	0.107
7-8	17 (43.6)	91.5 ± 25.2	22 (56.4)	125.7 ± 46.1	110.8 ± 41.6	0.009
9-10	22 (50.0)	135.4 ± 45.6	22 (50.0)	151.2 ± 53.2	143.3 ± 49.6	0.295
11-12	16 (34.8)	182.7 ± 61.9	30 (65.2)	157.3 ± 58.6	166.1 ± 60.3	0.176
13-14	22 (39.3)	186.0 ± 49.5	34 (60.7)	225.6 ± 91.3	210.0 ± 79.5	0.041
15-16	48 (60.0)	193.8 ± 70.6	32 (40.0)	240.9 ± 79.6	212.7 ± 77.4	0.007
17-18	27 (39.1)	190.4 ± 41.5	42 (60.9)	270.3 ± 80.8	239.0 ± 78.3	< 0.001

MSV: Mean spleen volume; SD: Standard deviation; *p* values were obtained by *t* test.

Anemia is observed in 47 children (11.6%). A significant and moderate correlation was found between spleen volume and hemoglobin and hematocrit values only in the 15-16 and 16-17 age groups. Correlation r values and *p*-values are presented in Table III.

Splenic vein diameters are measured between 1.9 mm and 11.0 mm, and the mean splenic vein diameter has a linear correlation with age. The correlation between age and splenic vein diameter is presented in Figure 4. Portal vein diameter is found to be between 4.1 mm and 14.9 mm, and the average portal vein diameter increases with age. The minimum and maximum values and averages of the splenic and portal vein diameters of the children are presented in Table IV.

There was a strong positive correlation between spleen volume and splenic vein diameter (r=0.696 $p<0.001$). Similarly, there was a strong positive correlation between spleen volume and portal vein diameter (r=0.704 $p<0.001$).

The accessory spleen was observed in 22 (5.4%) children. Accessory spleen size ranged from 5 mm to 17 mm. The accessory spleen was observed as localized in hilar and perisplenic areas.

Discussion

The spleen is the largest organ of the lymphoid system. It is also the most connected organ to the blood circulation unlike other lymphoid tissues in the immune system. Its main function is filtering microorganisms, proteins, and excessively aged or pathological blood cells, and is also involved in the establishment of humoral and cellular immune responses[5]. Primary disease of the spleen is rare but is usually affected by systemic disease processes[6]. Splenomegaly may be due to infectious agents, congestion, excessive antigenic stimulation, or may occur as a clinical manifestation of various etiologies, including the destruction of

Table III. Correlation analysis between spleen volume and hemoglobin level, spleen volume and hematocrit level.

Age	Spleen volume-Hb		Spleen volume-Htc	
	r	*p*	*r*	*p*
0-2	0.118	0.593	0.277	0.200
3-4	-0.105	0.610	-0.157	0.444
5-6	0.120	0.586	0.024	0.912
7-8	-0.200	0.223	-0.137	0.406
9-10	0.109	0.480	0.226	0.141
11-12	-0.057	0.707	-0.030	0.841
13-14	0.083	0.545	0.157	0.248
15-16	0.295	0.008	0.266	0.017
17-18	0.309	0.010	0.262	0.030

Hb: Hemoglobin; Htc: Hematocrit; The r and p values were calculated with the Pearson correlation test.

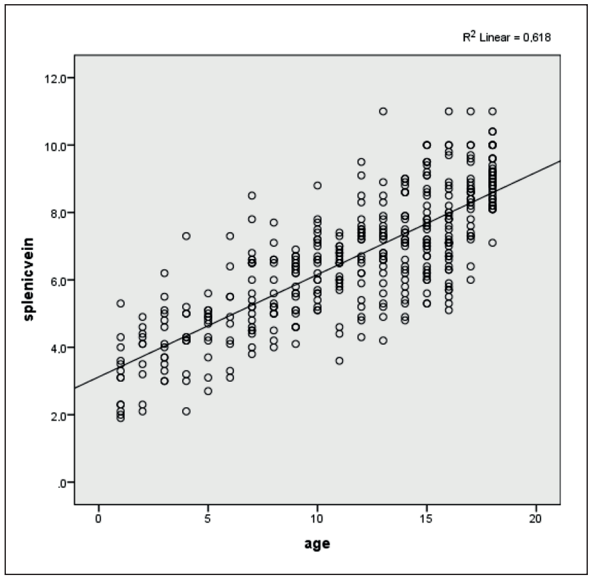

Figure 4. Correlation graph between age and splenic vein diameter.

abnormal blood cells and neoplastic infiltration. It can be detected in symptomatic or incidentally asymptomatic patients. Therefore, an appropriate evaluation of spleen size is required to initiate the diagnostic process, make appropriate therapeutic decisions, and monitor treatment effects[7,8]. In our study, we aim to find the normal spleen sizes of children according to their age groups and to use them in diagnosis and treatment follow-up.

The use of imaging techniques has recently been accepted as the most accurate method in both diagnosis and follow-up in the case of splenomegaly. Computed tomography (CT) shows spleen volume with the highest sensitivity and specificity[9]. To detect changes in the size and volume of an organ, normal anatomical values must be known. Comparing these values across organs produces data that can be used to diagnose specific diseases. These data help the clinician diagnose atrophy or hypertrophy of an organ. Detailed knowledge of age-related structural changes in the spleen is necessary for the diagnosis of pathological processes and for distinguishing them from normal variants[10]. One of our aims in our study was to find the normal values and volume of the spleen in pediatric age groups to assist radiologists in the diagnosis of diseases related to splenomegaly and atrophy, which are also used by hematologists and immunologists in the diagnosis of various gastrointestinal and hematological diseases. In addition, our study revealed that spleen size increases may have differences in three measurement directions. Thus, we find it more accurate to use volume measurement for the diagnosis of splenomegaly. We think that an increase in only one direction of spleen may cause a false diagnosis of splenomegaly.

The portal vein (PV) is formed by the union of the superior mesenteric vein and the splenic vein at the level of the lumbar second vertebra behind the pancreas[11]. In most studies on portal vein diameter performed with ultrasound, the main portal vein diameter values in healthy individuals are between 9.6 and 12.5 mm[12-14]. In addition, it is commonly accepted upper limit value of the main portal vein diameter is 13 mm[15]. CT is a widely used method in abdominal imaging. We revealed the normal values for each age group by evaluating the mean portal vein diameter in the healthy child population. The smallest portal vein diameter was 4.1 mm in the 0-2 age group and the largest portal vein diameter was 14.9 mm in the 17-18 age group.

Table IV. Minimum-maximum values and averages of splenic vein and portal vein diameters by age.

Age	Splenic vein diameter		Portal vein diameter	
	Min-Max mm	Mean ± SD mm	Min-Max mm	Mean ± SD mm
0-2	1.9-5.3	3.4 ± 1.0	4.1-10.0	6.0 ± 1.4
3-4	2.1-7.3	4.3 ± 1.1	3.6-9.3	7.2 ± 1.1
5-6	2.7-7.3	4.7 ± 1.1	6.4-9.9	7.9 ± 0.9
7-8	3.8-8.5	5.6 ± 1.1	4.1-10.8	8.9 ± 1.1
9-10	4.1-8.8	6.1 ± 1.0	7.0-11.9	9.7 ± 1.1
11-12	3.6-9.5	6.6 ± 1.2	7.7-12.4	10.1 ± 1.1
13-14	4.2-11.0	7.0 ± 1.3	7.2-14.4	10.9 ± 1.3
15-16	5.1-11.0	7.5 ± 1.4	9.0-14.3	11.6 ± 1.2
17-18	6.0-11.0	8.8 ± 1.0	10.2-14.9	12.5 ± 1.0

Min: Minimum; Max: Maximum; SD: Standard deviation

In a study, the mean normal portal vein diameter measured in CT was found to be 15.05 mm[15]. An increase in portal vein diameter indicates portal hypertension. Portal hypertension is one of the most important complications of cirrhosis. Studies have shown that the frequency of esophageal varices increases as the diameter of the portal vein increases[16]. Splenomegaly can be seen in hypersplenism. Hypersplenism is a common finding in patients with portal hypertension[17]. It is accepted that knowing the normal values of the portal vein diameter is important for the correct diagnosis of portal hypertension. In our study, we found the upper limit value of portal vein to be approximately 15 mm in CT in the 17-18 age group. The lower and upper limits of the portal vein, which change according to the age groups, are not known. In our study, each age's lower and upper limit reference range has been revealed (Table IV).

Zaman et al[18] studies with ultrasound revealed that portal vein diameter is directly related to spleen caudocranial length. In our study with tomography, we found that the portal vein diameter increased as the spleen volume increased.

The splenic vein is formed by the fusion of several veins in the splenic hilum. The splenic vein runs along the posteromedial border of the pancreas. It joins with the superior mesenteric vein behind the pancreatic neck to form the portal vein[19]. Diseases such as splenic vein thrombosis, splenic vein aneurysm, splenic arteriovenous malformations, and spontaneous splenorenal shunt affect the splenic vein. It is known that splenic vein aneurysms are mostly connected with portal hypertension[20]. We think that it would be helpful for radiologists evaluating these diseases to know the normal splenic vein diameters in pediatric age groups. In our study, the smallest splenic vein diameter was found to be 1.9 mm in the 0-2 age group and the highest splenic diameter was 11mm in the 17-18 age group (Table IV).

A splenic vein diameter greater than 8 mm in patients undergoing splenectomy is considered risky for the development of portal vein thrombosis after splenectomy[21]. It is a method used in the treatment of partial splenic artery embolization, splenic injury, pancytopenia, ascites, esophagogastric varices, and portal hypertensive gastric disease. However, this procedure may cause complications such as portal venous system thrombosis. The maximum diameter of the splenic vein greater than 17 mm before partial splenic artery embolization is reported to be risky for the development of thrombus in the portal venous system[22]. We think that the knowledge of normal values of splenic vein diameters may help prevent complications that may occur in interventional procedures for the splenic vein. In our study, normal values of splenic vein diameter were found according to child age groups (Table IV).

Accessory Spleen (AS) is a congenital ectopic spleen tissue that arises during embryological development, most of which remains asymptomatic and is discovered incidentally. It is usually located near the hilum of the spleen[23]. In our study, we observed the AS either in the spleen hilum or in the perisplenic area.

AS may also be found in atypical localizations such as the intrapancreatic area (24), greater omentum[25], the tail of the pancreas[26], and scrotum[27]. In a study conducted with CT, the rate of accessory - spleen was seen in 11% of the patients who participated in the study[28]. In our study, we found the accessory - spleen rate to be 5.4%.

AS or splenosis is an important cause of recurrence in diseases where splenectomy is curative, such as chronic immune thrombocytopenic purpura and hereditary spherocytosis[29]. Removal of AS or spleen fragments is therapeutic for these diseases[30]. AS may be mistakenly confused with adrenal tumors in patients who have undergone splenectomy[31]. AS is also located in the intrinsic mucosa of the stomach and may be mistakenly diagnosed as a gastrointestinal stromal tumor[32]. It has been reported that the accessory spleen can sometimes become symptomatic due to torsion, spontaneous rupture, bleeding, and cyst formation[33,34]. In our study, no symptomatic case was observed, and all of them were asymptomatic. However, we think that even if the location of the accessory spleen is not symptomatic, it can be ensured that possible curative treatments can be fully implemented, and misdiagnosis can be prevented by specifying the location of the AS in the report by the radiologists.

Conclusions

The knowledge of the normal spleen volume in healthy children according to age groups will enable the correct diagnosis of splenomegaly. Thus, while the correct diagnosis rate increases, it can decrease the false diagnosis of splenomegaly. The knowledge of lower and upper limits of the portal vein and splenic vein diameters contributes to

the accurate diagnosis of portal hypertension. In addition, it allows the interventional procedures for portal vein and splenic vein to be performed more safely.

Conflict of Interest
The Authors declare that they have no conflict of interests.

Informed Consent
Informed consent was obtained from all the participants of this study.

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Authors' Contribution
The authors confirm contribution to the paper as follows: study conception and design: Mehtap Ilgar, Serkan Ünlü; data collection: Mehtap Ilgar, Serkan Ünlü; analysis and interpretation of results: Mehtap Ilgar, Serkan Ünlü; draft manuscript preparation: Mehtap Ilgar, Serkan Ünlü. All authors reviewed the results and approved the final version of the manuscript.

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Ethical Approval
This retrospective study recieved approval from Malatya Turgut Özal University Clinic Ethics Committee. Prothocol number is 2021/100.

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