The Spleen

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Introduction

Except when grossly enlarged, the spleen is usually non-accessible in the clinical examination. Ultrasound, however, offers a very sensitive and specific noninvasive imaging tool for a variety of pathological conditions in the pediatric population of every age group, from trauma to tumors. Hence, examination of the spleen should be an integral part of every standardized abdominal scan.

Obtaining high-quality sonographic images of the spleen is no easy task, due to its location high in the left upper quadrant under the ribs. This chapter offers hints to produce optimal ultrasound pictures of the most common pediatric splenic pathologies.

Scanning Techniques

Position of the Patient

Imaging of the spleen should be done with a curvilinear or linear transducer of lower frequency (2–5 MHz) capable of color-flow Doppler imaging. The spleen is best accessed through the 9th–11th intercostal space, between the anterior and posterior axillary lines. A first overview of the spleen can be obtained with the child in a supine position. Individual anatomical variation requires that the operator search for the best acoustic window in a dynamic, flexible fashion.

Often it is helpful to angle the patient left side up which facilitates a more posterior access. This can be accomplished by having the patient roll sideways actively, or by placing a roll or a pillow under the left flank.

Elevation of the left arm maximizes the intercostal space. If the patient can follow instructions, having the patient raise the arm behind their head is sufficient. In nonverbal patients, parents can manipulate the arm gently, according to the scanner's instructions.

Another point to remember is that the probe needs to be angled slightly along the intercostal spaces to prevent shadows of the ribs. Again, the amount of angulation is highly variable and patient dependent.

Patient Preparation and Coaching

It is helpful to have the patient inhale or exhale to provide different views of the spleen. Naturally, breathing is hard to control in young and nonverbal children, but an experienced sonographer will sense and benefit from their natural respiratory cycle. Older children should be appropriately coached to inhale or exhale in a way to offer a

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S. Scholz, M. D. Jarboe (eds.), *Diagnostic and Interventional Ultrasound in Pediatrics and Pediatric Surgery,* DOI 10.1007/978-3-319-21699-7_8

good view of the spleen. It can be helpful to show schoolchildren and teenagers a live image of their scan during the process as feedback, to let them participate actively in the process.

Normal Sonographic Findings

Age-dependent Splenic Size

Splenic length is measured as the largest diameter of the organ independent of hilum location with a convex transducer via an intercostal window (Fig. 8.1). Splenic width is measured perpendicular to this line at the level of the hilum.

Nomograms for splenic length as a function of age, height, weight, and body surface area have been published [1]. These show a complex, nonlinear relationship. Splenic dimensions are highly variable, but the average length ranges from 4.5 cm in 0–3-month-old to 10.5 cm in 14–17-year-old children (Table 8.1).

Echogenicity

In routine sonographic evaluation, healthy children demonstrate homogenous splenic echogenicity that is slightly lower than that of healthy liver tissue. Detailed discrimination between red and white splenic pulp can be accomplished by using a higher-frequency linear transducer (10–13 MHz). The white pulp is typically lower in echogenicity. It is important to remember that the lymphatic system and lymphatic follicles are not completely formed in newborns and infants, so the volume of the white pulp increases with age.

Table 8.1 Approximate age-dependent normal splenic lengths [1]

Age	Mean (cm)	Standard deviation
0–3 months	4.5	0.7
3–6 months	5.5	0.7
6–12 months	6.5	0.7
3 years	7.5	0.9
7 years	8.5	0.9
11 years	9.5	0.9
15 years	10.5	1.0

Blood Supply

A complete ultrasonographic evaluation of the spleen should always include Doppler flow studies of the surrounding and intraparenchymatous vessels. The architecture of the spleen is predominantly determined by the vascular structure. The

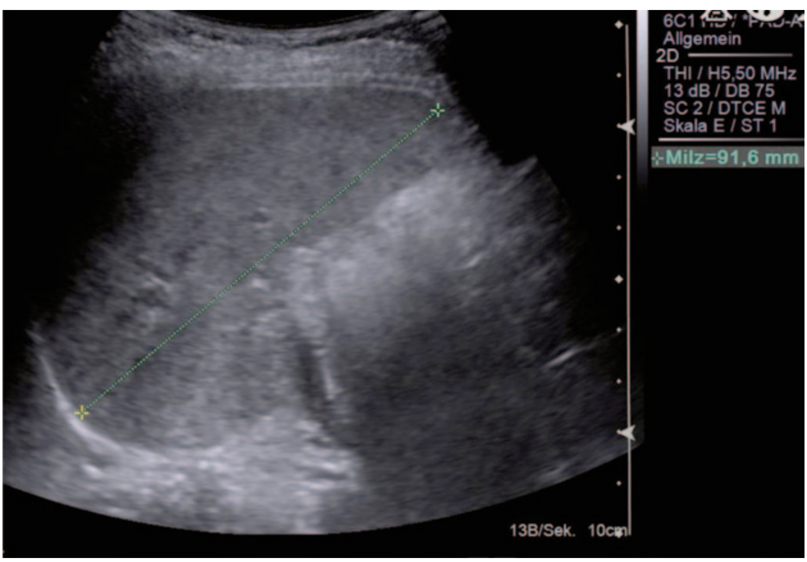

Fig. 8.1 Splenic length is measured as the maximal distance between the cranial and caudal poles of the spleen

Table 8.2 Common reasons for splenomegaly

Reason	Example
Increased hemolysis	Spherocytosis, thalassemia, sickle cell anemia
Cancer	Leukemia, lymphoma, histoplasmosis
Autoimmune diseases	Rheumatoid arthritis, lupus erythematosus, autoimmune hemolytic anemia, sarcoidosis
Infectious	Mononucleosis, leishmaniasis, malaria, tuberculosis, abscess, ehrlichiosis, echinococcosis
Portal hypertension	Liver cirrhosis, hepatic vein obstruction (Budd–Chiari syndrome), portal vein obstruction
Storage diseases	Gaucher, Hurler, Hunter, Niemann–Pick disease
Benign tumors	Hemangioma, hamartoma, epidermoid cyst

spleen is mainly supplied by the splenic artery, which arises from the celiac trunk and in most (80%) cases traverses along the upper border of the pancreas. Close to the hilum, it separates into two (80%) or three (20%) lobar arteries. These lobar arteries supply segments that typically do not form any collaterals between each other, which are important for spleen-preserving surgery. The spleen also obtains some blood from the short gastric vessels arising from the gastroepiploic artery.

Venous drainage is accomplished via the hilum into the splenic vein, which joins the mesenteric vein to form the portal vein. Therefore, splenomegaly may result from portal hypertension. Normal spleen size, however, does not rule out portal hypertension. Therefore, evaluation of the splenic drainage should always include a careful evaluation of the liver as well.

Contrast Enhanced Ultrasound

Contrast enhanced ultrasound for splenic indications has not been well studied in children. In a study that included some children, contrast enhancement increased the sensitivity for detection of splenic lacerations after blunt abdominal trauma from 59 to 96% [2]. The main disadvantage is that intravenous microbubbles of sulfur hexafluoride gas must be infused shortly before imaging.

Anomalies

Splenomegaly

In general, the spleen must increase in size at least twofold to be clinically palpable [3]. Clinical splenomegaly is defined by the organ being palpable under the left costal angle in the midclavicular line. However, the spleen may be palpable in healthy newborns in up to 17% of cases [4]. A good indicator for splenomegaly is the spleen–kidney ratio. The length of the spleen should not surpass the length of the kidney by 125% [5]. Another age-independent criterion for splenomegaly is caudal extension of the spleen beyond the lower pole of the kidney. The most common reasons for splenomegaly are listed in Table 8.2.

Asplenia, Polysplenia, and Topographic Anomalies

Asplenia/polysplenia, as well as the single right-sided spleen, belong to a very heterogeneous group of laterality defects including extreme variants such as total situs inversus. The exact cause remains widely unknown, but chromosomal aberrations are sometimes identified (i.e., Kartagener syndrome). Laterality defects are usually accompanied by congenital heart defects and major other anomalies such as biliary atresia, intestinal malrotation with microgastria, or isomerism of the lungs (bilateral left or right lung).

Accessory Spleen

Accessory spleens can be found in 7–20% of patients at autopsy or in computed tomography series [6, 7]. The most common location is the splenic hilum (75%; Fig. 8.2) and pancreatic tail but accessory tissue can be found anywhere in the abdomen. Ultrasound usually shows an oval mass of the same parenchymal structure and

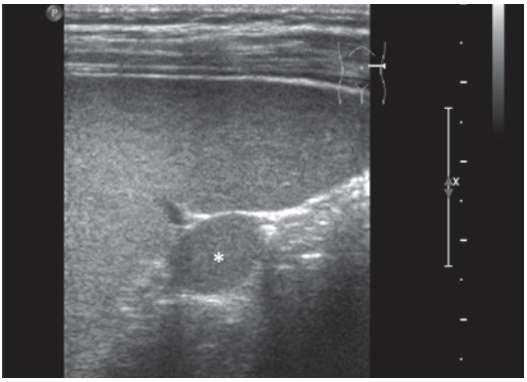

Fig. 8.2 An accessory spleen is identified at the splenic hilum (*). The mass has an oval shape and is similar in echotexture to the spleen itself

echogenicity as the spleen, sometimes with a visible feeding artery from the splenic arteria. In cases of torsion, the ultrasound shows a homogeneous hypoechoic mass without evidence of perfusion or, in cases of recurrent torsion, signs of infarction with inhomogenic parenchyma. Free intra-abdominal fluid can be a sign of rupture.

Wandering Spleen

The ectopic location of the spleen occurs either in missing ligamental fixation, laxity, or maldevelopment of the splenic ligaments. In very rare cases, the absent ligamental fixation can lead to torsion of the wandering spleen. This may manifest as an acute abdomen with no detectable spleen in the typical location, and an abdominal mass with spleen-like echostructure on the initial ultrasound instead. Lack of perfusion of the abdominal mass in Doppler imaging, as well as an elevated resistive index in the proximal splenic artery is highly suspicious for torsion of the wandering spleen.

In all cases of splenic ectopia, ultrasound remains a noninvasive, easily accessible imaging method. In symptomatic unclear cases, however, further imaging with magnetic resonance imaging or computed tomography should be considered before surgical exploration.

Diffuse Changes of the Splenic Parenchyma

Diffuse parenchymal changes (Fig. 8.3) may be a sign of hematopoietic diseases, storage disorders, infections, autoimmune disorders, sequellae of trauma, or portal hypertension (Table 8.2). Further investigation with cross-sectional radiographic or nuclear scans may be indicated in these cases.

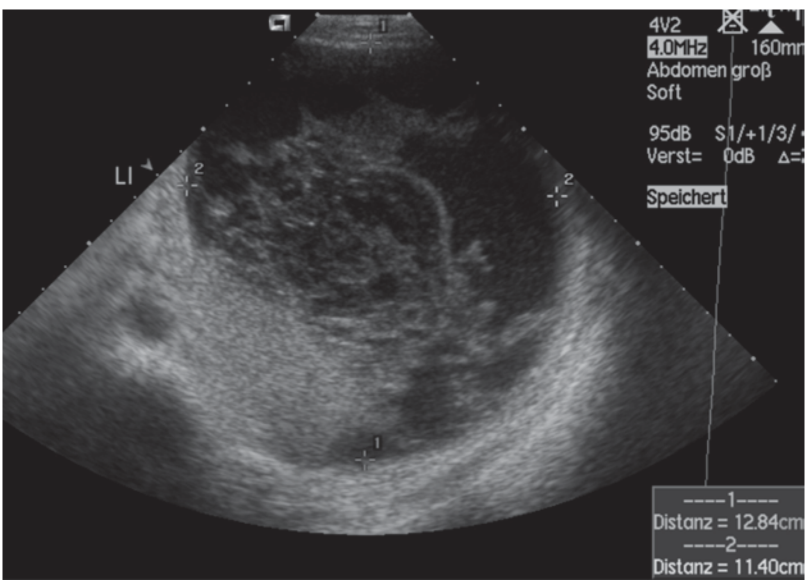

Fig. 8.3 Diffuse complex parenchymatous changes may result from a variety of disorders. They can also appear as sequellae to trauma, as in this case

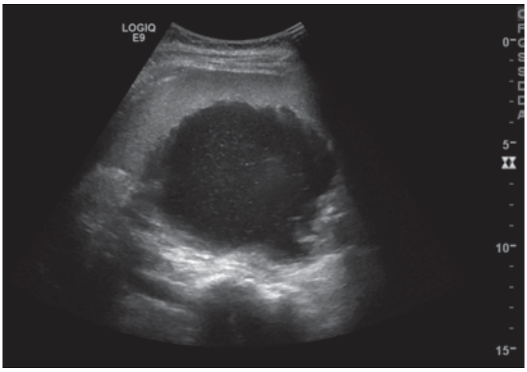

Fig. 8.4 Splenic cysts may be congenital or acquired. Epidermoid splenic cysts have typical trabeculation in the cyst wall

Cysts, Abscesses, Tumors

Fluid-filled anomalies are readily visible on ultrasound examination. They include cysts (Fig. 8.4), abscesses (Fig. 8.5), and post-traumatic pseudocysts (Fig. 8.6). Solid and mixed tumors are also easily picked up because their structural appearance contrasts sharply to the even echogenicity of the spleen in most of the cases (Fig. 8.7). If indicated, cysts and masses can be accessed percutaneously under sonographic guidance to aid in diagnosis [8], but simple percutaneous drainage of most cysts almost always results in recurrence [9].

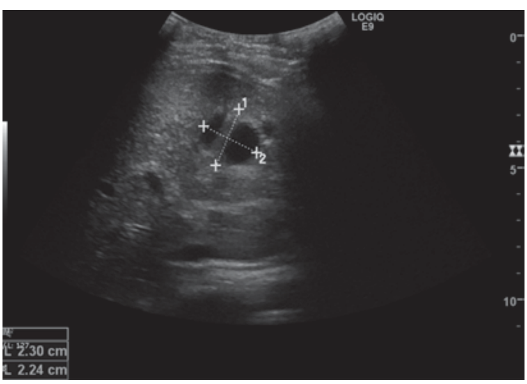

Fig. 8.5 Abscesses are usually smaller than primary splenic cysts and may be loculated. They also may contain echogenic debris

Traumatic Injury

Focused assessment with sonography in trauma (FAST) has become a standard practice in the adult setting and is increasingly used in children as well. It comprises taking standardized ultrasound images of the hepatorenal recess, the bladder, the pericardium, and the perisplenic space (Fig. 8.8). A positive FAST implies the detection of free peritoneal or pericardial fluid or obvious solid organ injury, but is not used for solid organ injury staging. The sensitivity and specificity of FAST in children ranges from 33 to 93 % and 85 to 97 %, respectively [10–12]. In cases of known splenic laceration or avulsion, ultrasound in general is a very good diagnostic tool for further monitoring, especially in the pediatric population, because there is no need for sedation and no exposure to ionizing radiation.

Splenic Laceration and Avulsion

Splenic laceration is the second most common solid organ injury in blunt pediatric trauma. Careful scanning of the spleen is quite sensitive to pick up splenic lacerations (Fig. 8.9), although sonography has never been validated for grading the injury. Besides splenic morphology, indirect signs of trauma such as perisplenic or free intraperitoneal fluid, as well as focal pain during the examination itself should be taken into consideration. It is also mandatory to perform a color Doppler examination of the organ (Fig. 8.10), since avulsion of the spleen can be picked up by the lack of perfusion.

Post-traumatic Arteriovenous Fistula

Splenic lacerations close to the hilum may result in a post-traumatic arteriovenous fistula (Fig. 8.11). These usually heal spontaneously, but in some refractory cases with pronounced blood flow, transarterial embolization may be indicated. Ultrasound is an ideal method to follow such changes over time.

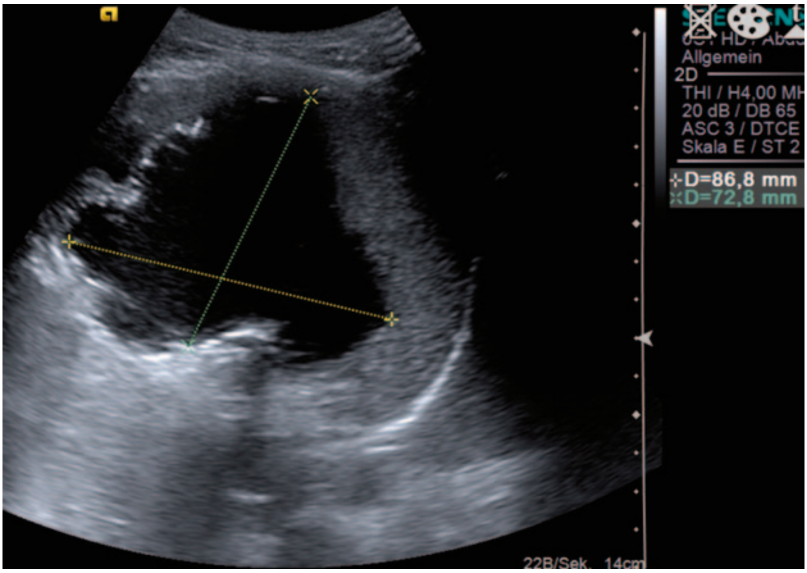

Fig. 8.6 Post-traumatic splenic cysts are common. Most of them can be observed, but persistent ones may require resection

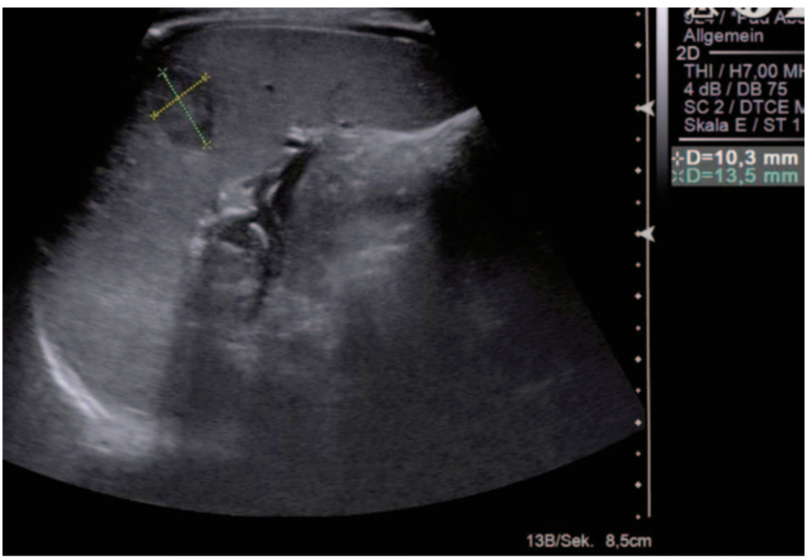

Fig. 8.7 Solid and mixed tumors of the spleen include hemangiomas and vascular malformations. Doppler studies may be useful to differentiate them from malignancies such as lymphoma

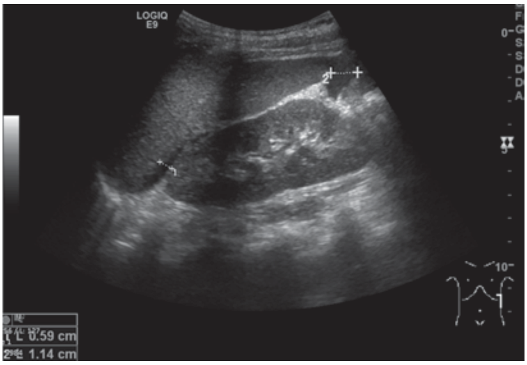

Fig. 8.8 Positive FAST scan with fluid in the splenorenal fossa (1) and around the lower pole of the spleen (2)

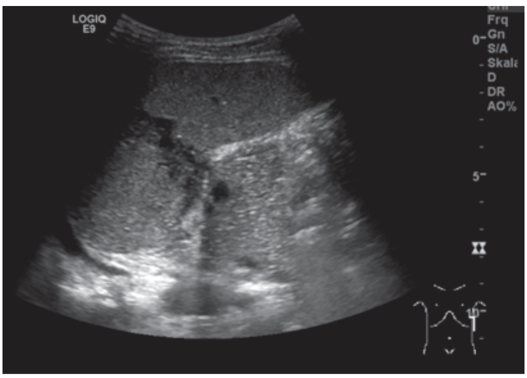

Fig. 8.9 B-mode ultrasound of the spleen after blunt abdominal trauma. The laceration in this case is hypoechoic and extends from the hilum to the periphery

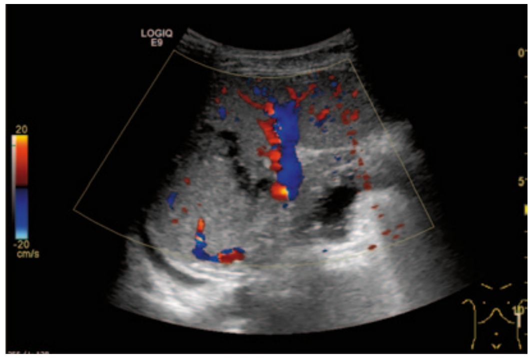

Fig. 8.10 Doppler imaging of the same patient as in Fig. 8.9 shows the relationship of the laceration *(dark line)* to the left of the vessels. Free fluid is also seen at the hilum, and below the diaphragm *(lentiform dark line in the lower left corner of the scan)*

Summary

Ultrasound is an ideal modality to image the pediatric spleen, although obtaining high-quality images can be challenging due to location and lack of patient cooperation. Splenomegaly is easily picked up on ultrasound, as are cystic and solid lesions, as well as trauma. Comprehensive imaging of the spleen should always include color Doppler studies.

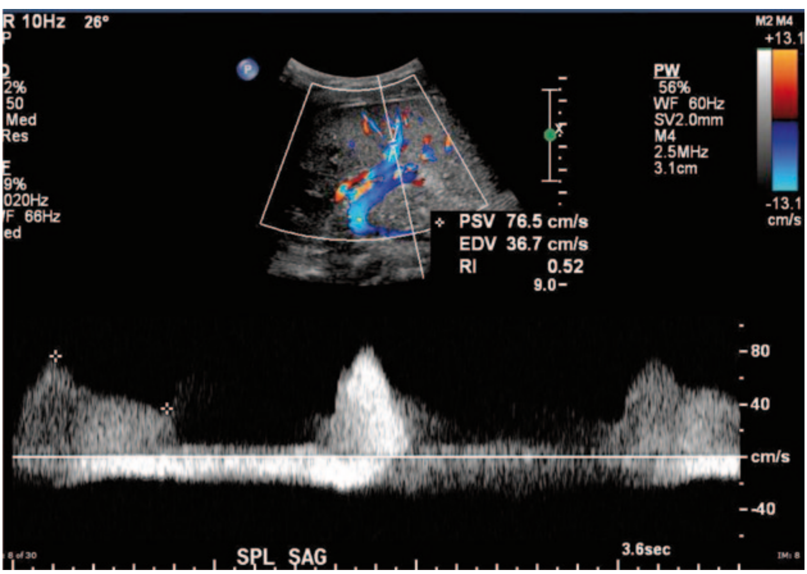

Fig. 8.11 This Doppler study shows a large, hemodynamically important post-traumatic arteriovenous fistula that did not improve with time. It was eventually coiled by interventional radiology

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