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Ultrasound of the spleen

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Anatomic remarks

The spleen is an intraperitoneal organ located in the left-lateral upper quadrant, underneath the diaphragm and abutting ribs. It is attached to the retroperitoneum by fatty ligaments that also contain its vascular supply. The spleen is located close to the stomach, the left kidney, the splenic flexure of the colon and the tail of the pancreas. The splenic artery has a tortuous course and enters the hilum on the medial surface through the splenorenal ligament. The splenic vein drains through the central hilum and courses along the antero-superior part of the pancreas to its confluence with the superior mesenteric vein to form the portal vein.

The spleen consists of two parts: macroscopically, the red pulp can be differentiated from very small grey spots of 0.2-0.7 mm called the white pulp, which are both separated by the marginal zone. The white pulp consists of T and B lymphocytes. The red pulp forms a spongy reticular network that surrounds the blood sinusoids. The red colour is caused by the large number of erythrocytes in the sinuses. The sinusoids are the sites of cellular exchange located between the spleen and circulatory system. The splenic arteries enter the pulp within the trabeculae. From these trabecular arteries, the central arteries extend into white and then the red pulp. The arteries branch into the white pulp and are surrounded by a sheath of lymphocytes, mainly T cells, called periarterial lymphatic sheath or PALS. From the central arteries, small branches enter the red pulp or are connected directly to the sinusoids at the end of the arterioles. These sinusoids are part of the marginal zone. Blood from the sinusoids are collected in the pulp and trabecular veins. These trabecular veins merge to form the splenic vein leaving the spleen through the hilum.

Thus, an open circulation (mainly open-ended arterioles in the red pulp) can be differentiated from a closed circulation in which arterioles are directly connected to the sinusoids. The open circulation functions as a filter for red blood cells because only flexible (and younger) red blood cells can pass through the slits of the sinusoids and re-enter systemic circulation; older and worn-out red blood cells are destroyed and dissolved by phagocytosis. Open circulation is a relatively slow process and allows blood cells to be filtered when entering the sinusoids. In comparison, the closed circulation is rapid; blood cells traverse the sinusoids and are drained into the splenic veins.

Imaging the normal spleen

The spleen can be imaged from a left intercostal coronal approach in either a supine or right lateral decubital position. The probe should be placed between the ribs at the level of the ninth intercostal space.

To detect small intrasplenic lesions it is important to image the spleen completely. For the examination of the spleen a wideband 2-5MHz convex probe is usually used. In the case of lymphatic diseases a high-frequency linear probe is recommended.

Measurements should be taken from a longitudinal and transverse plane. A normal spleen weighs 150 g and is approximately 11-12 cm in craniocaudal length and is 3-4 cm thick. A normal-sized spleen is not usually palpable. But, that does not necessarily mean a clinically palpable spleen is pathological. An enlarged spleen is usually caused by extrasplenic diseases. The spleen length in children correlates with age, weight, body surface area and length of a patient [(1)]. There is a wide range of normal spleen sizes, from very small to large organs. A normal spleen decreases in size and weight with increasing age. It also slightly increases during digestion and can vary in size depending on the nutritional status of the body [(2)]. As splenomegaly normally develops secondary to systemic or liver disease, it is important to know at which splenic size the organ is considered enlarged. Spielman reported that splenic length and width in young athletes correlates with length and gender [(3)]. Male athletes taller than 2 m had a mean spleen length of 13.2 cm (maximum 16.2 cm) and in females approximately 2 m in height had a mean spleen length of 11.2 cm (maximum 14.0 cm). A good correlation (r=0.86) between splenic length measured in the right lateral decubitus position and CT volume has been described by Lamb [(4)].

**Figure 1   Measuring the splenic size.**

In routine clinical practice, most radiologists and sonographers perform measurements on longitudinal scans only. Lamb's study concluded that the measurement of splenic length in routine clinical practice is a very good indicator of actual splenic size [Figure 1] [(4)]. As well as measuring diameter, it has been suggested that the largest area should also be calculated. A study describing portal hypertension in cirrhotic patients defined a normal sized spleen as having an area of <45 cm^2, a moderately enlarged spleen of 45-65 cm^2 and a marked splenomegaly having an area of > 65 cm^2 [(5)] [Figure 2].

Figure 2   Area calculation in a moderately enlarged spleen, with a longest diameter of 16.7 cm and a width of 5.5 cm, representing an area of 82.7 cm^2.

a

b
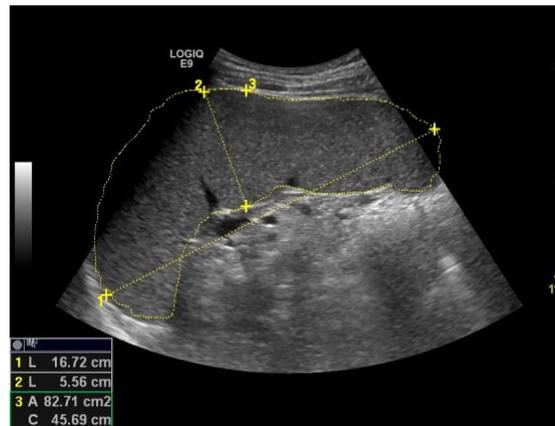
Several techniques are used to image the spleen by ultrasound: B-mode ultrasound, Colour, duplex and Power Doppler, as well as contrast-enhanced ultrasound (CEUS). The behaviour of the spleen at CEUS examination is similar to other imaging modalities such as contrast-enhanced CT or contrast-enhanced MRI and correlates with the anatomic particularities of the organ.

Imaging modalities such as contrast-enhanced CT or contrast-enhanced MRI shows heterogenous contrast filling during the arterial phase; after approximately 1 min the spleen shows a homogeneous enhancement. The same is true on contrast-enhanced ultrasound examinations during the first minute of contrast bolus injection. In contrast to the liver, the arterial phase of the spleen is not suited for the detection and characterization of splenic lesions.

MRI examination demonstrates different splenic circulations immediately after gadolinium breath-hold Tl weighted spoiled gradient echo (SGE) sequences. The most common pattern (79%) is arciform. This appears as a serpiginous pattern of high signal (closed circulation) and low signal (open circulation) stroma. This pattern becomes homogeneous and high in signal within 1 min post-contrast [(6-9)]. It has been observed in all healthy spleens and in some spleens of patients with inflammatory or neoplastic diseases. Two other different splenic enhancement patterns have been described on immediate post-gadolinium images. The second most common pattern (16%) is homogeneous high signal intensity enhancement. This was identified in patients with inflammatory or neoplastic disease, focal fatty liver infiltration or hepatic enzyme abnormalities. It is thought that a non-specific immune response could be

responsible for this pattern of enhancement. The third pattern is uniform low-signal intensity (5%). This was found in all patients who had undergone multiple recent blood transfusions. The T2 shortening effects from haemosiderin deposition in the reticuloendothelial system replace the Tl shortening effects of gadolinium [(6-9)]. Similar images are seen on contrast-enhanced CT.
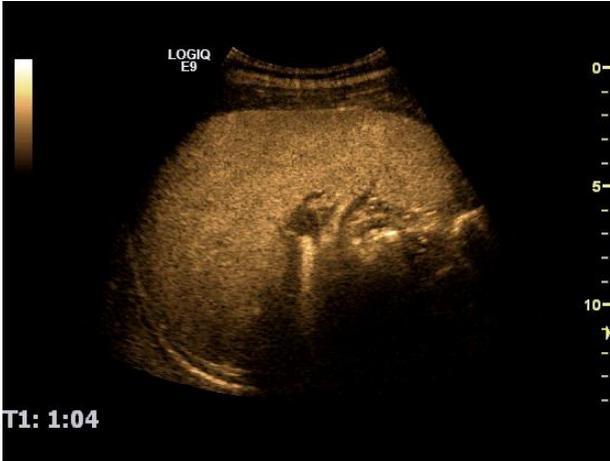
Data have shown that a normal vascular pattern of spleen enhancement on contrast-enhanced ultrasound is close to contrast-enhanced-CT [Figure 3c] or contrast-enhanced-MRI. The splenic artery starts to become opaque at about 12 seconds after sulphur-hexafluoride filled phospholipid stabilized microbubbles (SonoVue™, Bracco, Italy) bolus injection. Heterogenous enhancement of splenic parenchyma occurs in the arterial phase, which resembles the well-known zebra-striped pattern seen on dynamic CT or MRI [(10)]. During the first minute following injection, small arteries are seen radiating from the splenic artery. Approximately 1 min after the injection, the splenic parenchyma becomes homogeneously enhanced and shows a dense persistent enhancement for at least 7-10 min [Figure 3 a,b]. It is thought that closed circulation is enhanced much faster than the open circulation. But, this assumption has not been proven. It is important to note that SonoVue produces spleen-specific enhancement longer than the blood pool phase due to parenchymal uptake [(11)]. In comparison with the contiguous left kidney that shows intense but transient enhancement, the spleen appears as hypoechoic during the early opaque phase and hyperechoic during the late phase [(12)]. The other two enhancement patterns described before at MRI examination can also be found on CEUS. Although there are no studies, homogenous enhancement has been found in some cases of liver diseases and inflammatory disorders [Figure 4].

Figure 3   **Contrast images of the spleen 18 (a) and 64 (b) seconds after bolus injection of Sonovue. An arciform-like enhancement pattern of the normal spleen quickly develops during the arterial phase with the closed circulation enhancing later. After one minute the spleen is homogeneously enhanced. Contrast images of the spleen during arterial and venous phase on CE-CT. Images are similar to CEUS (c,d).**

a

b

c

d