Abdominal Imaging

Abdom Imaging (2014)
DOI: 10.1007/s00261-014-0080-6

Multimodality imaging of splenic lesions and the role of non-vascular, image-guided intervention

Kara Gaetke-Udager,[1] Ashish P. Wasnik,[1] Ravi K. Kaza,[1] Mahmoud M. Al-Hawary,[1] Katherine E. Maturen,[1] Aaron M. Udager,[2] Shadi F. Azar,[1] Isaac R. Francis[1]

[1]Department of Radiology, Division of Abdominal Imaging, University of Michigan Health System, 1500 East Medical Center Drive Ann Arbor, Michigan 48109, USA
[2]Department of Pathology, University of Michigan Health System, 1500 East Medical Center Drive Ann Arbor, Michigan 48109, USA

Abstract

Splenic lesions are often incidentally detected on abdominal-computed tomography (CT), ultrasound, or magnetic resonance imaging (MRI), and these can pose a diagnostic challenge in patients with suspected or known malignancy. This review will discuss the multimodality imaging features of various benign and malignant splenic pathologies including trauma, infection, infarct, granulomatous disease, benign neoplasms such as hemangioma, hamartoma, and littoral cell angioma, cystic entities such as peliosis, splenic cysts, and pseudocysts, and malignant processes such as metastasis, lymphoma, angiosarcoma, and leiomyosarcoma. While several of these splenic pathologies have characteristic imaging features that are helpful in diagnosis, others have nonspecific findings. In such clinical dilemmas, image-guided intervention may be essential, and we therefore discuss the role of non-vascular, image-guided splenic interventions for diagnostic and therapeutic purposes. The radiologist can play a key part in the clinical diagnosis and management of splenic lesions, and therefore a thorough knowledge of the imaging features of splenic lesions and a thoughtful approach to their management is crucial.

Key words: Spleen—Benign—Malignant—Neoplasm—Intervention—Imaging

The spleen is the largest lymphatic organ in the body and serves a number of important functions, including phagocytosis of blood products, antibody production, hematopoiesis in anemic states, and sequestration of blood elements [1]. A wide spectrum of pathology can affect the spleen, including traumatic injury, infection, and neoplasm, both benign and malignant. The imaging appearances of splenic lesions can overlap significantly and therefore imaging alone will frequently fall short of truly categorizing a lesion. Splenic lesions in patients without a cancer history are likely to be benign, but there is little comprehensive data beyond case reports in the literature and no recognized consensus criteria at the time of this writing [2]. A diagnosis must be made from a combination of clinical, radiologic, and pathologic information. Traditionally the perceived risk of hemorrhage from percutaneous intervention led to a major role for splenectomy, but practice patterns have begun to shift [3]. This article reviews the imaging characteristics of a variety of splenic lesions. Several of these have specific features, while others are nonspecific and require definite characterization with tissue sampling. We will also review the role of percutaneous, image-guided intervention in the management of splenic lesions.

Normal appearance

The spleen is a highly vascular, lymphoid organ that varies in size with an individual's height and weight; it is largest in volume during young adulthood and then gradually decreases in size with increasing age. Splenic size is easily assessed, although there is some disagreement about the upper limit of normal size. One study showed that a single measurement of the craniocaudal dimension of greater than 9.76 cm on CT indicated splenomegaly [4]. Another study argued that on ultrasound, the upper limit of normal for splenic size is 11 cm [5]. Most resources, however, list 13 cm as the upper limits of normal size [6–9].

Correspondence to: Ashish P. Wasnik; *email:* ashishw@umich.edu

Published online: 14 February 2014

A fibrous capsule covers the spleen and helps maintain its shape. Generally speaking, the splenic parenchyma consists of red and white pulp. The red pulp is the larger of the two compartments and consists of splenic sinuses, cords, and small vessels. A single layer of cells, known as littoral cells, lines the sinuses, and cords of Billroth surround the sinuses to provide structure. Sinuses and cords contain red blood cells as well as histiocytes, which phagocytize the damaged red cells. White pulp contains the lymphoid component of the spleen and includes both B and T cells. Distinct zones of white pulp are seen histologically in children but not in adults [10].

The spleen can be evaluated by ultrasound, CT, MRI, and nuclear medicine studies. On ultrasound, the normal splenic parenchyma is homogeneous and more echogenic than normal liver parenchyma and renal cortex. On unenhanced CT, a normal spleen is slightly lower {5–15 Hounsfield Units (HU) less} in attenuation than the normal liver, ranging from 40–60 HU (Fig. 1). On unenhanced MR images, the normal spleen is lower in signal intensity than the liver on T1-weighted images and higher in signal than the liver on T2-weighted images (Fig. 2). During the arterial phase of imaging on CT or MRI, a normal spleen shows a heterogeneous, arciform pattern of enhancement, (Figs. 1, 2) presumably due to different rates of contrast flow through the different components of the splenic parenchyma. Approximately 1 min after IV contrast administration, the splenic parenchyma shows homogeneous enhancement (Fig. 1) [11, 12]. By scintigraphy, a normal spleen shows uptake of Tc-99m sulfur colloid but less than the liver; ^{18}fluorodeoxyglucose (FDG) positron emission tomography (PET)-CT shows homogeneous uptake in the spleen, equal to the liver [13](Fig. 3).

Trauma

A variety of mechanisms may cause splenic trauma, including blunt trauma, such as from motor vehicle accidents; penetrating trauma, such as from displaced rib fractures, gunshot, or stab wounds, and iatrogenic injuries. The parenchyma can be affected by contusion, laceration, subcapsular or intraparenchymal hematoma, or vascular injury. The spleen is the most commonly injured solid abdominal organ in blunt trauma [14]. The American Association for the Surgery of Trauma (AAST) has developed a grading scale including location, size, and severity of splenic parenchymal injuries (Table 1) [15]; this grading scale provides a useful method for communication with clinicians as to the severity of injury, especially as non-surgical management has become more common [16].

CT is generally the primary modality for imaging of abdominal trauma. Imaging findings of splenic trauma on contrast-enhanced CT include ill-defined or linear areas of low-attenuation within the parenchyma repre-

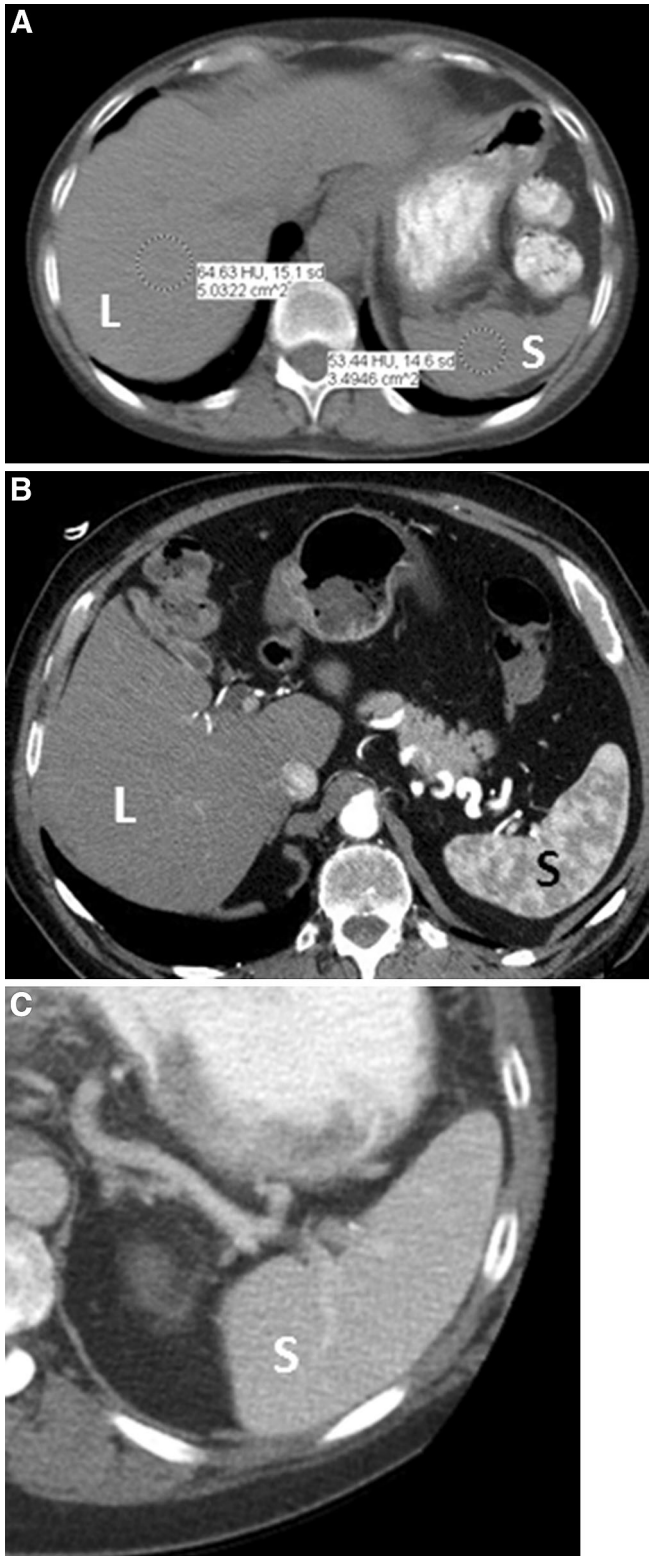

Fig. 1. Normal CT appearance of spleen. **A** Axial unenhanced CT shows the spleen (*S*), which is usually 40–60 HU in attenuation (53 HU in this case) and 5–10 HU less than the liver (*L*). **B** Axial contrast-enhanced CT in arterial phase (35–40 s) shows the arciform pattern of enhancement of the spleen (*S*). **C** Normal venous phase appearance of the spleen (*S*).

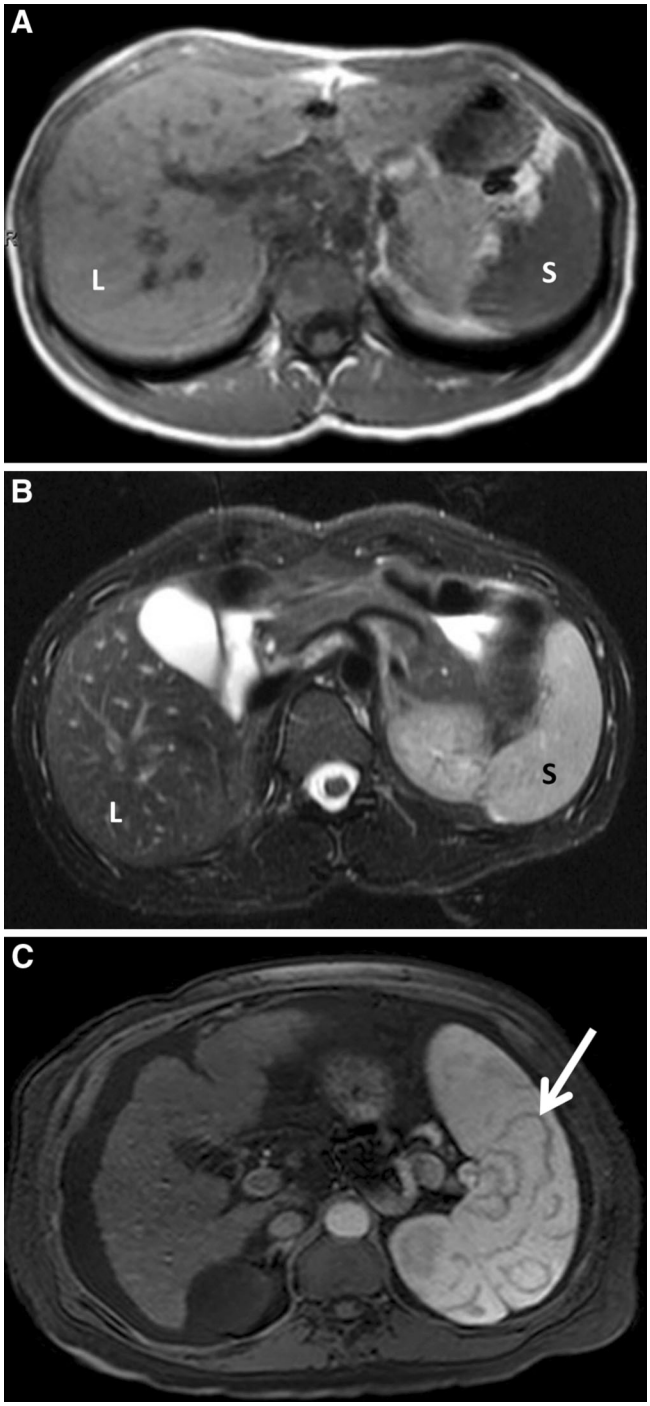

Fig. 2. Normal MRI appearance of spleen. **A** and **B** axial T1- and T2-weighted gradient echo images respectively, show the spleen (*S*) is lower in signal than the liver (*L*) on the T1-weighted image (**A**) and higher in signal than the liver on the T2-weighted image (**B**). **C** Axial gadolinium-enhanced arterial phase T1-weighted image shows arciform pattern of enhancement of an enlarged spleen (*arrow*).

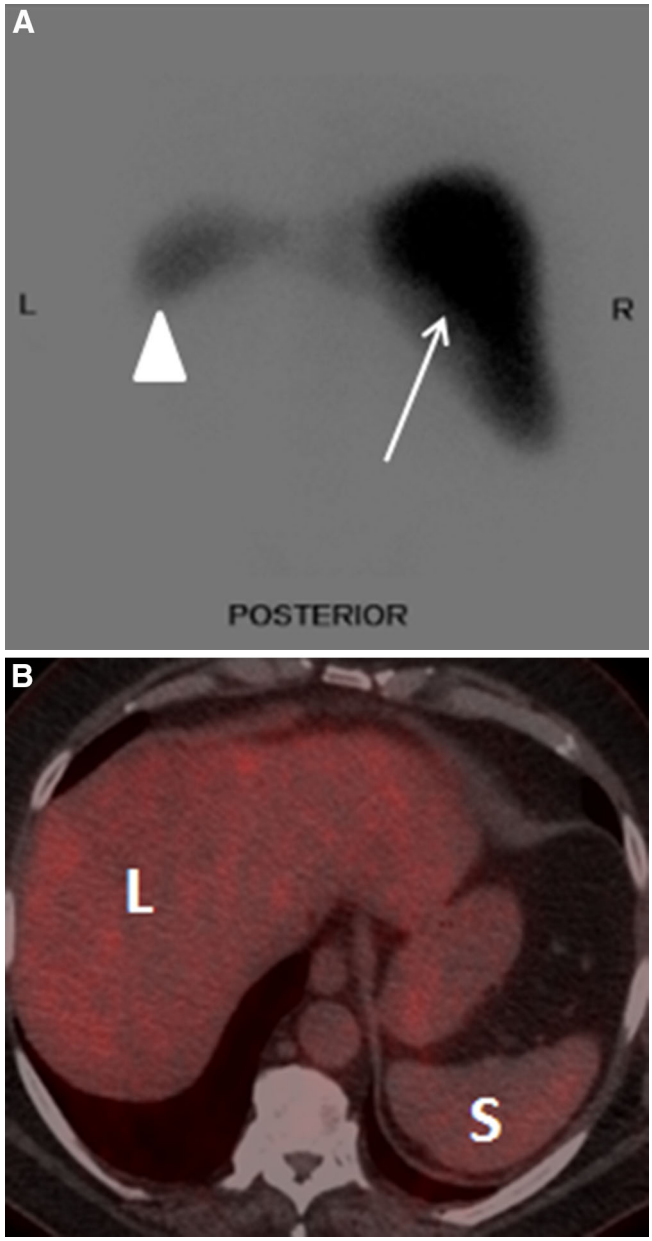

Fig. 3. Normal spleen on nuclear imaging. **A** Sulfur colloid scan. Normal liver-spleen nuclear scan using Tc-99m sulfur colloid shows homogeneous radiotracer uptake in the spleen (*arrowhead*), while the liver has more avid uptake (*arrow*). **B** ^{18}FDG (PET-CT. Axial image showing homogeneous uptake in the spleen (*S*) above normal blood pool but less than that of the liver (*L*).

senting contusions or lacerations, respectively. Low-attenuation material representing hematoma, either acute or chronic, may also be seen in a subcapsular or intraparenchymal location (Fig. 4). Very high attenuation (similar in density to that of injected contrast material in the arterial system) within or surrounding the spleen raises suspicion for an active bleed, and such cases would warrant evaluation with catheter angiography for possible embolization [14] (Fig. 5). Ultrasound may demonstrate ill-defined or linear areas of heterogenicity or hypoechogenicity with possible surrounding hypoechoic

Table 1. American association for the surgery of trauma: spleen injury scale

Grade[a]	Injury type	Description of injury
I	Hematoma	Subcapsular, <10% surface area
	Laceration	Capsular tear, <1 cm parenchymal depth
II	Hematoma	Subcapsular, 10–50% surface area; intraparenchymal, <5-cm diameter
	Laceration	Capsular tear, 1–3 cm parencymal depth, not involving a trabecular vessel
III	Hematoma	Subcapsular, >50% surface area or expanding; ruptured subcapsular or parenchymal hematoma; intraparencymal hematoma >5 cm or expanding
	Laceration	>3 cm parenchymal depth or involving trabecular vessels
IV	Laceration	Laceration involving segmental or hilar vessels producing major devascularization (>25% of spleen)
V	Laceration	Completely shattered spleen
	Vascular	Hilar vascular injury with devascularized spleen

[a] Advance one grade for multiple injuries up to Grade III. From Moore et al. [15]

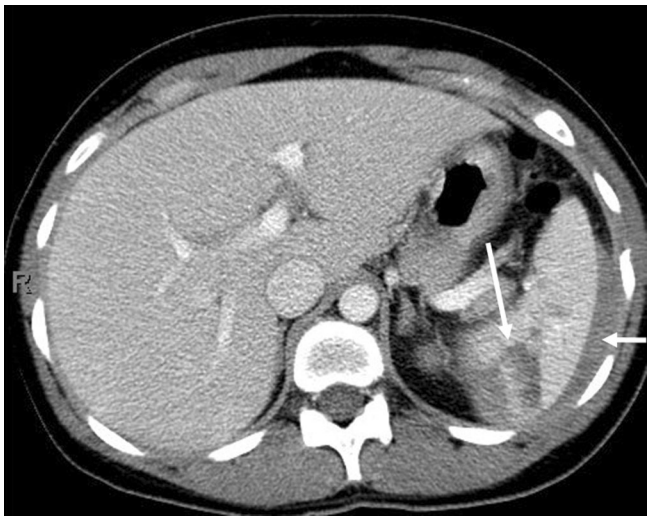

Fig. 4. Splenic trauma, laceration. 23-year-old male involved in motor vehicle accident. Axial contrast-enhanced CT demonstrates several low-attenuation areas in the spleen extending through the capsule (*long arrow*) with perisplenic hematoma (*short arrow*).

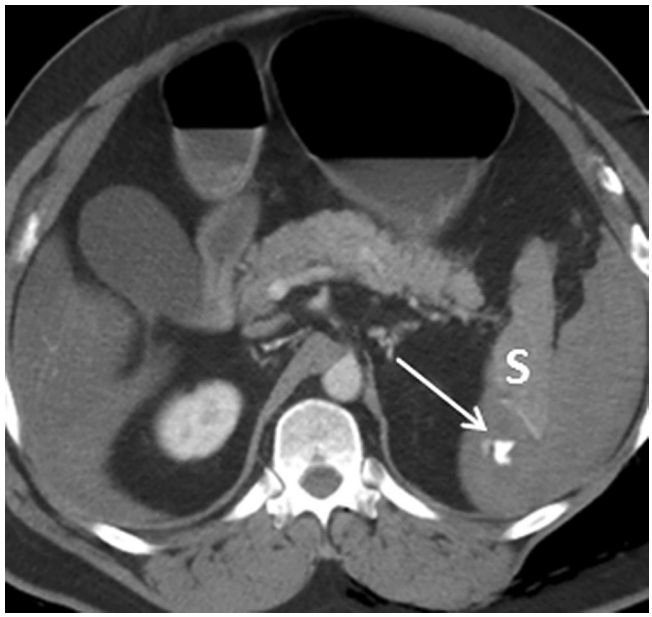

Fig. 5. Splenic trauma, active hemorrhage. 57-year-old male involved in motorcycle accident. Axial contrast-enhanced CT shows focus of very high attenuation (*arrow*) consistent with active extravasation of IV contrast with surrounding hematoma, displacing the spleen (*S*).

material representing hematoma, depending on maturity of hematoma. MR images will show intraparenchymal and/or perisplenic abnormalities that may follow the signal intensities of the hemorrhage as it evolves.

Infection

Splenic infection can manifest either as a dominant pyogenic abscess or as diffuse microabscesses. Mortality rates for splenic infection are significant, ranging from 20 to 60% [17]. In general, splenic pyogenic abscess is rare and is most often seen in patients with predisposing conditions (e.g., immune suppression) [18]. Affected patients generally present with nonspecific signs and symptoms such as fever and abdominal pain, with the abscess being discovered only on imaging. Microabscesses are often caused by fungal infection, although they can be caused by any infectious process. Likewise, these are typically seen in immunocompromised patients, such as patients with acute myelogenous leukemia (AML), including those on chemotherapy and with AIDS. The most common fungal agents causing splenic microabscesses are *Candida*, *Aspergillus*, and *Cryptococcus* [17].

Ultrasound and CT remain the primary methods of imaging in splenic infection [19]. Pyogenic abscess ranges from anechoic to complex heterogeneous lesions at ultrasound and can contain foci of hyperechoic gas (Fig. 6). On CT, splenic pyogenic abscess may appear as low attenuation lesions early in their evolution, but subsequently can progress to complex gas- and fluid-filled structures. Splenic pyogenic abscesses are seen on MR imaging as low signal on T1-weighted images and high signal on T2-weighted images with peripheral rim enhancement on post-contrast images. Microabscesses

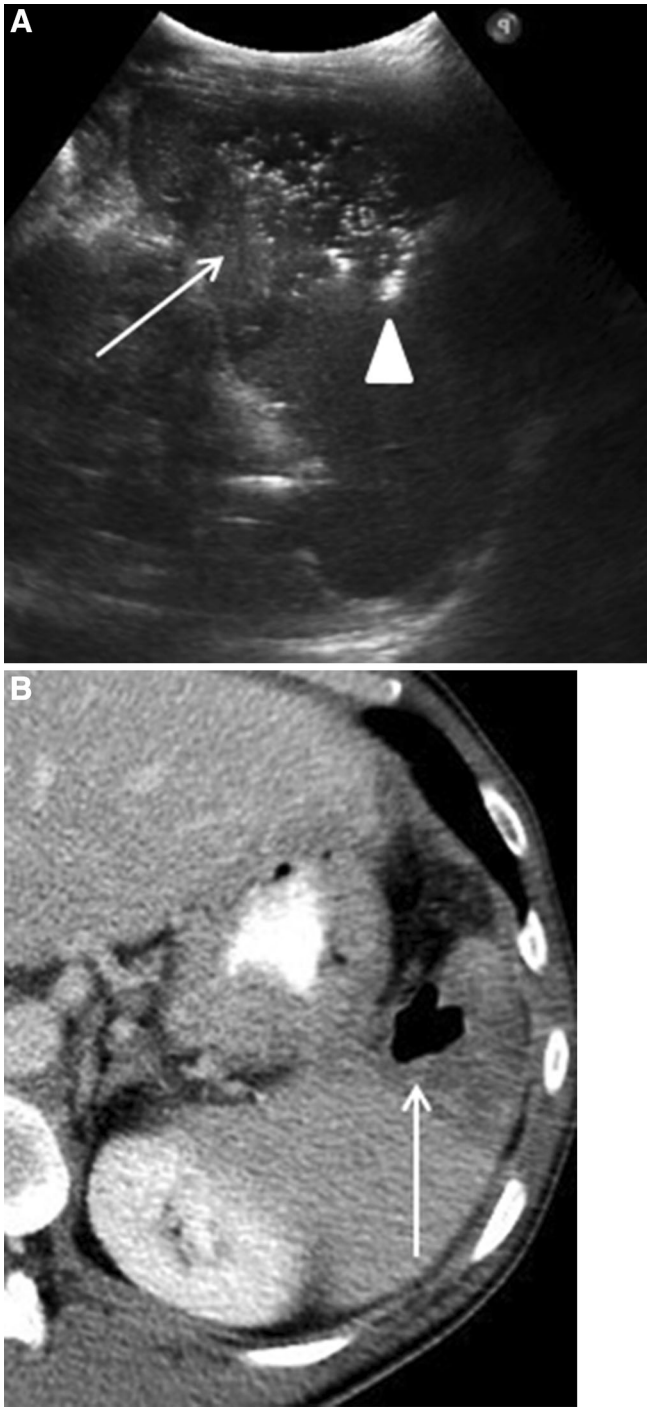

Fig. 6. Pyogenic abscess of spleen. 65-year-old woman with fever and abdominal pain. **A** Longitudinal ultrasound image of the *left upper* quadrant shows a complex fluid collection (*arrow*) in the spleen with hyperechoic gas foci (*arrowhead*) consistent with abscess. **B** Axial contrast-enhanced CT confirms the sonographic findings of splenic abscess with a complex area of fluid attenuation and internal gas (*arrow*).

often appear on ultrasound as numerous tiny hypoechoic foci throughout parenchyma, and similarly are seen on CT as scattered, tiny (<1 cm) low attenuation

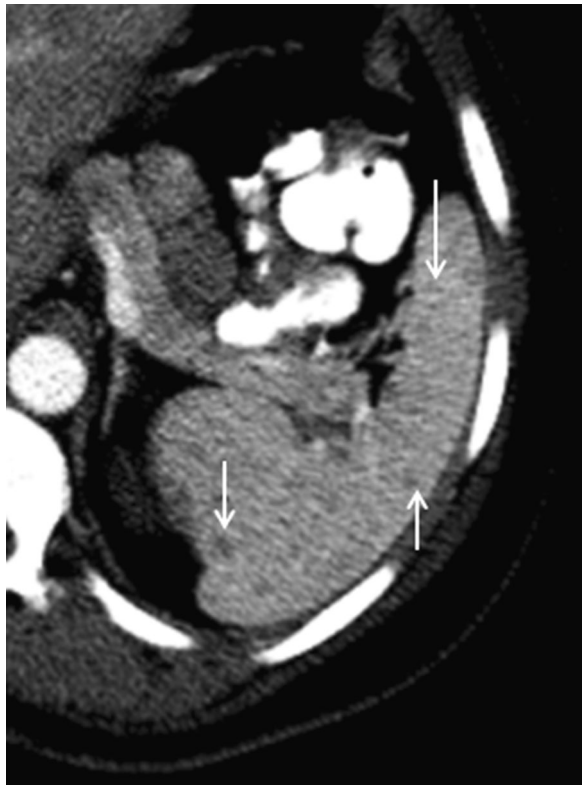

Fig. 7. Splenic microabscess. 30-year-old woman with history of renal transplant on immunosuppressive medication, presenting with nausea, vomiting, and leukocytosis. Axial contrast-enhanced CT image shows numerous small, low attenuation lesions throughout the spleen (*arrows*). These were presumed to be microabscesses given the history; the patient's symptoms improved with antibiotics and antifungal medications.

parenchymal foci (Fig. 7); these can be associated with splenomegaly. MR imaging of microabscesses shows numerous small lesions with low signal on T1-weighted images and high signal on T2-weighted images in both the acute and subacute phase.

Vascular

Infarct. Splenic infarcts are relatively common. Patients with hematologic or thromboembolic disorders can present with fever and left upper quadrant pain, although a significant percentage of patients with splenic infarcts will remain asymptomatic with incidental discovery [20]. Often the clinical setting suggests the possibility of an infarct, and patients with portal hypertension, atrial fibrillation, endocarditis, collagen vascular disease, and sickle cell anemia are at increased risk for developing splenic infarcts [13]. The presence of multiple splenic infarcts or infarcts in other organs suggests an embolic process.

Infarcts typically appear as peripheral wedge shaped hypoechoic areas within the splenic parenchyma on ultrasound with a coarsened appearance. Sometimes the

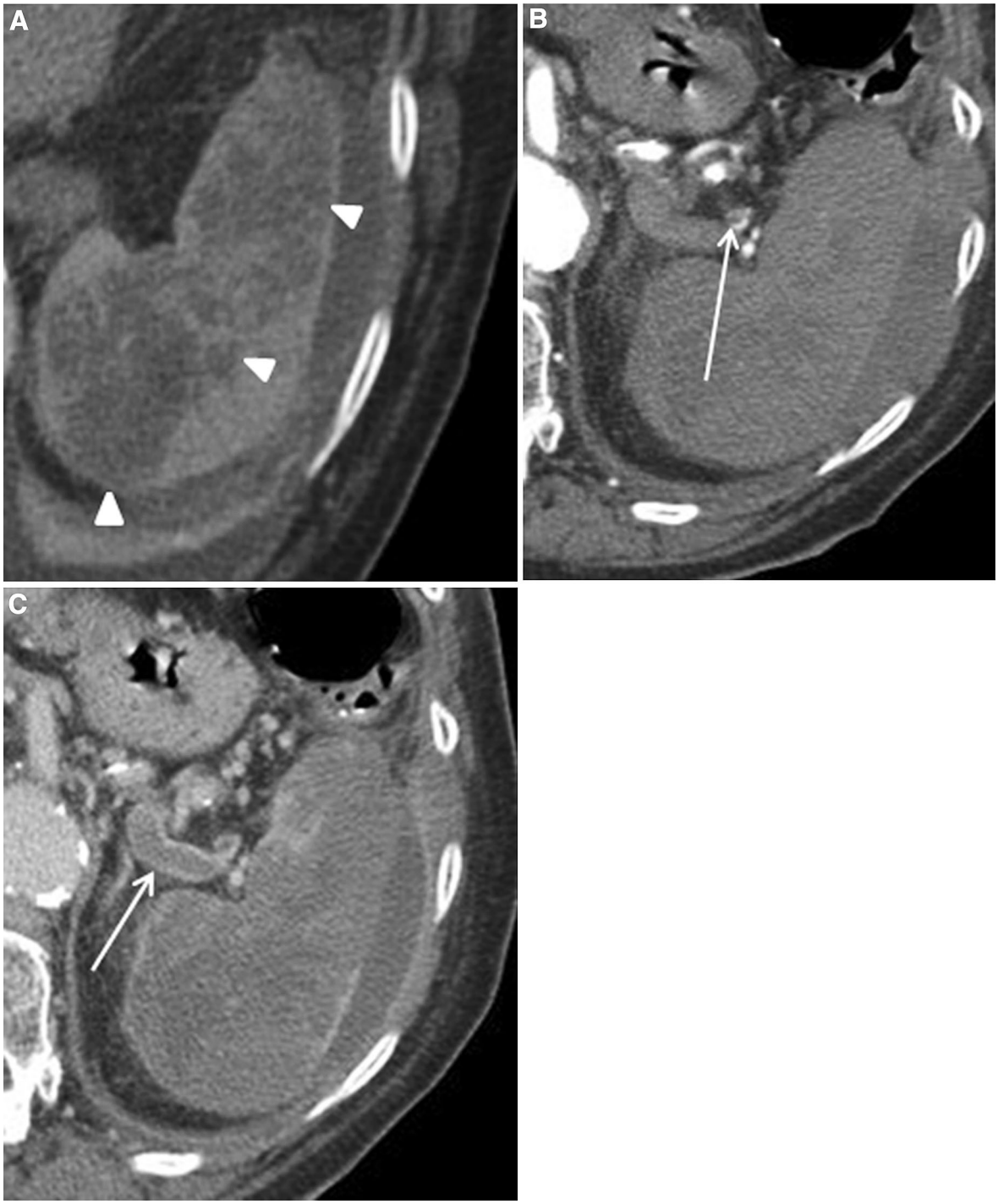

Fig. 8. Splenic infarct. 58-year-old hospitalized man with abdominal pain. **A** Axial unenhanced CT shows low-attenuation areas in the splenic parenchyma (*arrowheads*). **B** Arterial and **C** portal venous phase contrast-enhanced axial CT images show a low-attenuation filling defect in the splenic artery (*arrow* in **B**), and complete occlusion of the splenic vein (*arrow* in **C**).

infarct will be irregular, multifocal, or replace most of the splenic parenchyma (Fig. 8). On CT and MR imaging, infarcts also appear as irregular or wedge-shaped areas that do not enhance with contrast. Infarcts are low attenuation on CT and show low signal intensity on both T1- and T2-weighted images [21]. Complications include abscess formation, hemorrhage, and rarely splenic rupture in the case of massive infarcts.

Auto-splenectomy. Another closely related ischemic abnormality is auto-splenectomy. This process is often seen in the setting of sickle cell disease in which hemolytic anemia and vaso-occlusive crises cause multiorgan infarction. The natural progression seen on imaging is splenomegaly before the age of 10, recurrent splenic infarcts with increasing atrophy, splenic hemosiderosis, and eventually an atrophied, calcified spleen [22] (Fig. 9). Hemosiderosis is seen on MR imaging as low signal on T1- and T2-weighted images due to iron deposition, although in- and opposed-phase gradient echo T1-weighted sequences are the most sensitive for detecting this abnormality. CT is the best modality for showing calcification.

Siderotic nodules

Siderotic nodules, also known as Gamna-Gandy bodies, are small, granuloma-like nodules composed of hemosiderin, calcium, and fibrous tissue and typically occur within the splenic parenchyma, most often in patients with portal hypertension [23]. Gradient-echo (GRE) MRI with in- and opposed-phase sequences is the most sensitive imaging modality for these nodules, given the hemosiderin and resulting small foci of susceptibility artifact [24]. CT can show faint, high attenuation foci in the splenic parenchyma, but these can often go unnoticed [24]. Ultrasound shows multiple tiny, hyperechoic foci in the spleen, with one study showing a sensitivity of approximately 70%, compared to GRE MRI as a standard [25]. These nodules are of no known clinical significance, except for their correlation with portal hypertension.

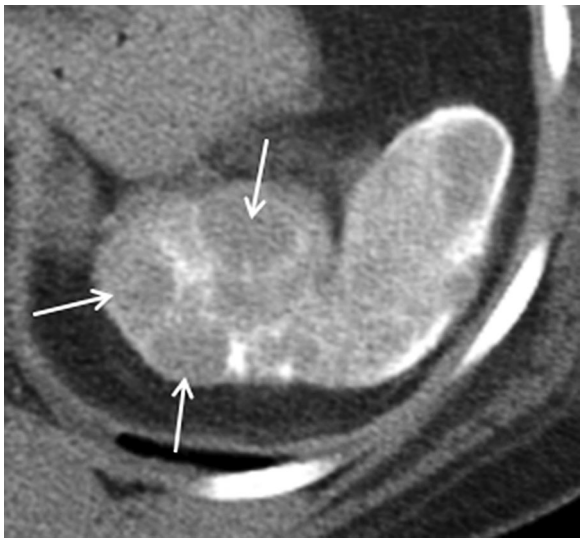

Fig. 9. Chronic splenic infarct and autosplenectomy. 19-year-old male with sickle cell anemia. Axial unenhanced CT shows a shrunken and lobulated contour of spleen, with diffuse calcification of the parenchyma, due to multiple chronic infarcts; there are several lobular-appearing, low-attenuation areas within the spleen (*arrow*), which represent the remaining splenic parenchyma.

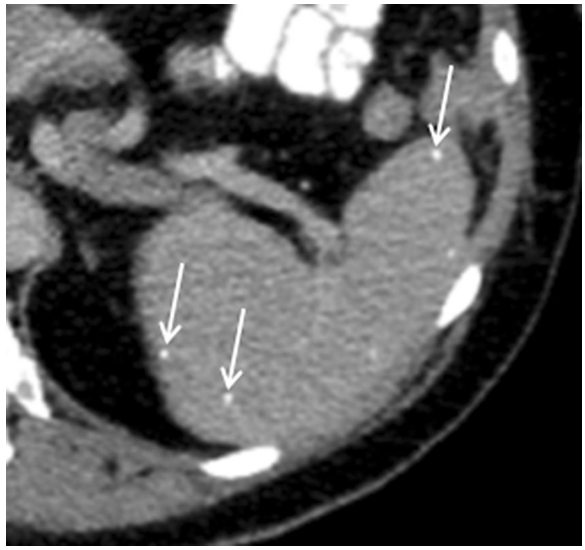

Fig. 10. Old granulomatous disease. Axial CT image shows multiple small, high attenuation foci (*short arrows*) in the splenic parenchyma. This is typical of calcified granulomas.

Granulomatous disease

Granulomatous diseases including sarcoidosis, histoplasmosis, and tuberculosis can involve the spleen, usually when there is diffuse systemic involvement. The patient can be asymptomatic. Marked splenomegaly occurs about one third of the time, and the patient can present with hypersplenism, anemia, thrombocytopenia, and leukopenia [26]. Granulomas typically occur in the white pulp in association with the arterial circulation. Old granulomatous disease, in which there are numerous, small, calcified nodules in the splenic parenchyma, is a common imaging finding (Fig. 10).

Sarcoidosis of the spleen manifests as multifocal or solitary avascular hypoechoic masses on ultrasound. CT imaging shows multiple low-attenuation, non-enhancing lesions (Fig. 11). On MR imaging, the lesions have low signal on T1- and T2-weighted imaging with no definite post-gadolinium enhancement [27]. Similar imaging appearances are found in splenic tuberculosis [28] (Fig. 12). Isolated involvement of spleen in tuberculosis is rare and the majority of cases are seen in the context of miliary spread. History of exposure to tuberculosis or residence in an endemic region may be of help. As the imaging characteristics are similar to those of infectious foci or infiltrative neoplasm, image-guided biopsy of the spleen or liver is often necessary to confirm the diagnosis.

Benign masses

Cyst/pseudocyst. Splenic cysts can be divided into two categories: true (primary) splenic cysts and false (secondary) cysts, otherwise known as pseudocysts. True cysts are epithelial-cell-lined and generally either congenital or parasitic (echinococcal) in origin. True

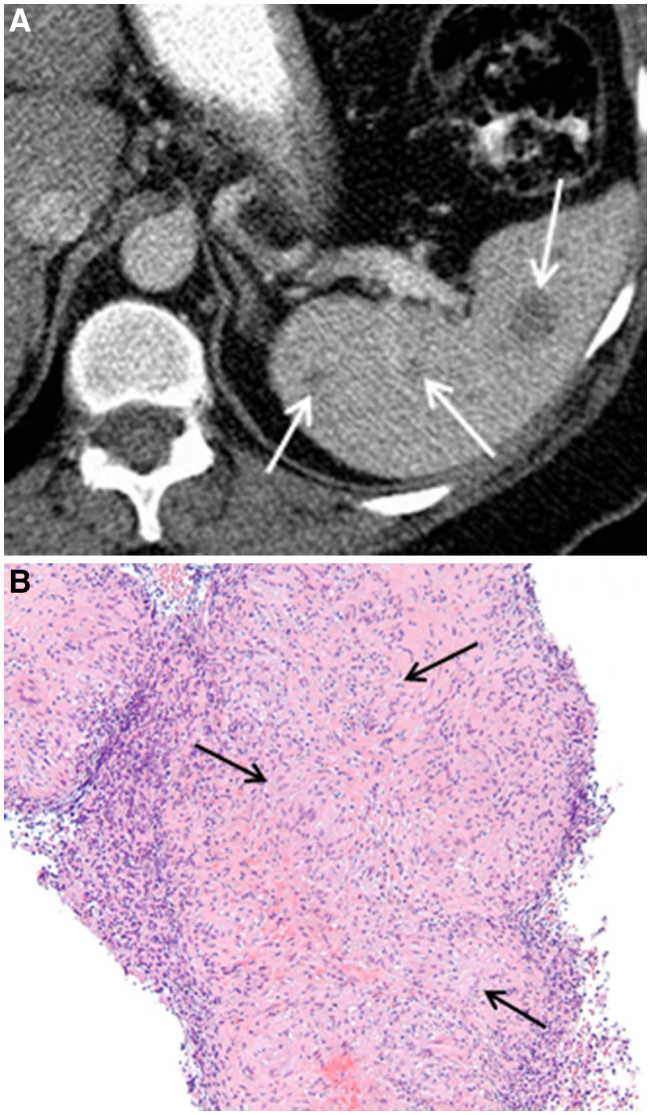

Fig. 11. Splenic sarcoidosis. 54-year-old woman with history of retroperitoneal hemangiopericytoma and new splenic lesions. **A** Contrast-enhanced axial CT image shows multiple discrete hypodense foci (*arrows*) relative to the background spleen and range in size from 1–2 mm to 2 cm. Ultrasound guided biopsy confirmed sarcoidosis. **B** Sarcoidosis involving the spleen. A core biopsy demonstrates numerous non-caseating epithelioid granulomas (*arrows*), consistent with sarcoidosis; hematoxylin and eosin, ×100 magnification. Special stains for fungal and acid-fast organisms were negative (not shown).

congenital splenic cysts are more often seen in women than men and typically form in childhood or adolescence. Pseudocysts have no epithelial lining and are usually post-traumatic; these are thought to represent the end-stage of splenic hematoma [26].

Imaging appearances of true splenic cysts and pseudocysts are similar, with anechoic to hypoechoic appearance on ultrasound, fluid-density on CT without intralesional enhancement (Fig. 13), and fluid signal intensity (low on T1- and high in T2-weighted images) on MR imaging. Splenic cysts and pseudocysts can be difficult to distinguish on imaging, but certain characteristics may be helpful. Ultrasound can show internal echoes and debris in pseudocysts, and similarly T1-weighted MR images can show variable signal depending on the amount of internal proteinaceous material. On CT, cyst wall calcification is more common in pseudocysts than in true cysts. True cysts can show wall trabeculation or peripheral septation, but these features are less common in pseudocysts.

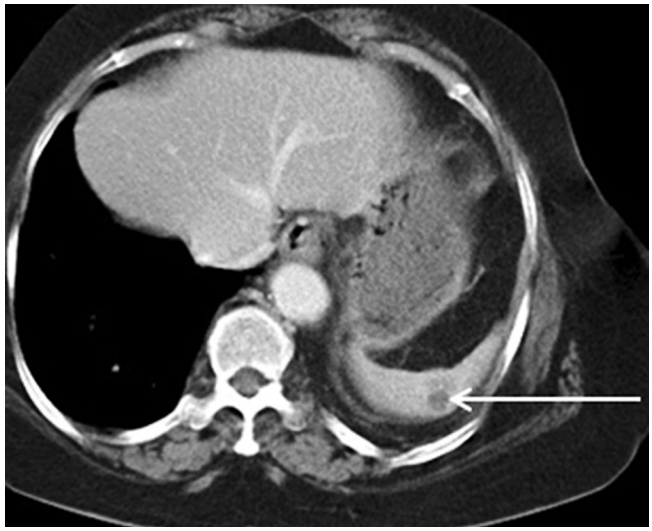

Fig. 12. Splenic tuberculosis. 67-year-old man with abdominal pain. Axial, contrast-enhanced CT image shows a low attenuation splenic lesion (*arrow*); there were multiple similar, smaller lesions in other areas of the spleen. The patient had known tuberculosis, and the lesions improved after therapy. Image courtesy of Nilesh Gupta, MBBS, DNB, (Raipur, India).

Peliosis. Peliosis is a rare disorder of the reticuloendothelial system, which can involve the liver, spleen, and sometimes bone marrow. Isolated splenic peliosis is particularly uncommon [29]. Epithelial breakdown results in multiple blood filled cystic spaces within these organs. Peliosis is associated with oral contraceptives, steroids, HIV/AIDS, and hematologic malignancy and is usually found incidentally, although the cysts can rupture and cause hemoperitoneum [30].

Imaging of peliosis shows hypoechoic lesions throughout spleen on ultrasound. CT images show non-enhancing or mildly enhancing hypodense lesions (Fig. 14), which can be difficult to characterize. MR imaging shows multiple foci with variable signal on both T1- and T2-weighted images, depending on the age of the blood content of the cysts.

Hemangioma. Hemangiomas are the most common benign neoplasm of the spleen. These tumors are often found incidentally, as symptoms are rare unless the

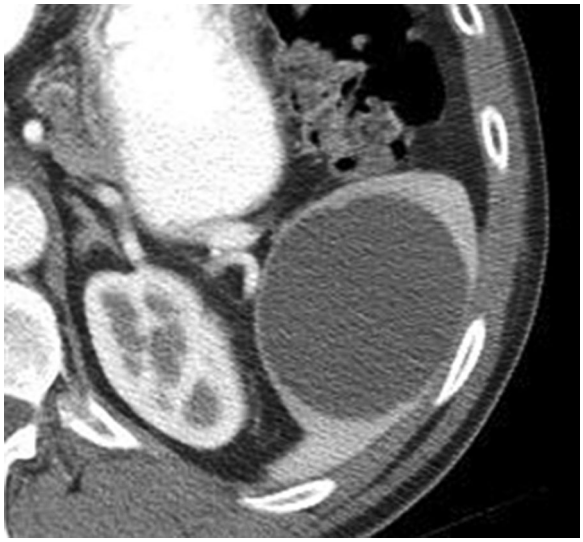

Fig. 13. Congenital epithelial cyst of the spleen. 34-year-old woman with intermittent left upper quadrant pain for a few months. Axial contrast-enhanced CT images show a large, fluid-attenuation, unilocular, ovoid lesion. The patient elected to undergo laparoscopic splenectomy. On histology, epithelial lining was present on biopsy consistent with congenital epithelial true cyst, but pseudocyst would have the same CT appearance.

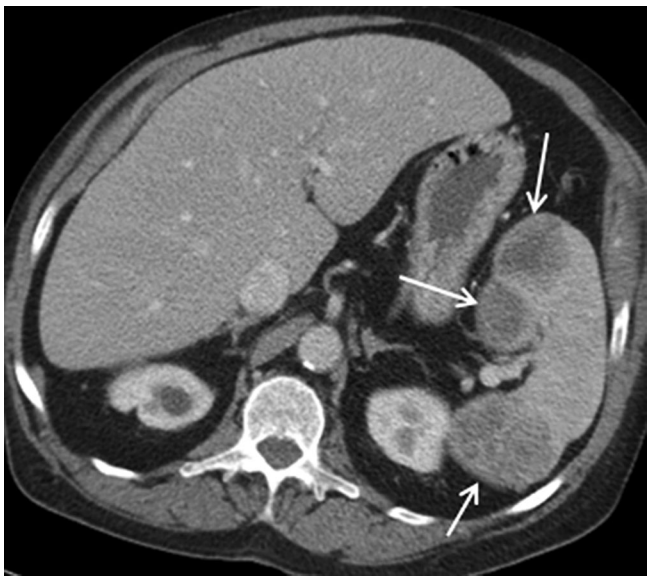

Fig. 14. Peliosis of the spleen. 66-year-old man with COPD and incidental splenic lesions seen on chest CT. Axial contrast-enhanced CT image show *multiple round*, low-attenuation lesions of various sizes (*arrows*) throughout the spleen and with minimal internal enhancement; these were histologically proven peliosis on splenectomy.

lesion is very large. Hemangiomas of the spleen have been reported in up to 14% of patients undergoing autopsy, although they are much less common than hepatic hemangiomas [31].The natural course of hemangiomas is one of slow growth, and some lesions may become large enough to rupture [30]. Diffuse splenic hemangiomatosis can also occur, in which the splenic tissue is replaced by multiple hemangiomas [32].

Like liver hemangiomas, splenic hemangiomas exhibit early peripheral enhancement with delayed fill-in of contrast. However, their peripheral enhancement is more often concentric as opposed to nodular and discontinuous as seen in the typical hepatic cavernous hemangioma. MR imaging shows iso- to hypo-intense signal on T1-weighted imaging, hyperintense signal on T2-weighted imaging, and subtle peripheral arterial enhancement and delayed central filling (Fig. 15). Hemangiomas have a variable appearance on ultrasound and can range from hyperechoic to heterogeneous lesions.

Hamartoma. Hamartomas of the spleen are rare, benign lesions composed of malformed splenic red pulp elements. Because imaging features overlap with other lesions, definitive diagnosis is often only made following splenectomy. Hamartomas may occur at any age with equal gender predilection and in most cases the discovery is incidental [33]. These tumors are associated with hamartomas elsewhere in the body and have also been reported in cases of tuberous sclerosis. The importance of imaging splenic hamartomas lies in the need to differentiate them from malignant lesions of the spleen such as lymphoma, sarcomas, and metastasis.

Ultrasound of a splenic hamartoma usually shows a solid, homogeneous mass, which is often relatively hypoechoic. CT imaging shows a well marginated lesion which is iso-attenuating prior to and following IV contrast administration; a contour abnormality may be the only clue to the lesion's presence. Hamartomas are isointense on T1-weighted MR images and heterogeneously hyperintense on T2-weighted images. The lesion will show heterogeneous enhancement on early post-contrast and more uniform homogeneous enhancement on delayed images (Fig. 16).

Littoral cell angioma. Littoral cell angioma of the spleen is a rare tumor that arises from the littoral cells that normally line the splenic red pulp sinuses. There are a few reports of littoral cell angioma with malignant features, but generally these tumors are benign [34]. Patients often present with splenomegaly due to the multifocal lesions, although rarely these tumors are solitary. Imaging findings of littoral cell angioma are non specific, and therefore tissue sampling and immunohistochemical staining is necessary to make the diagnosis [33, 35].

Ultrasound shows multiple ill-defined, hypoechoic masses. On CT, the lesions are iso- or low attenuation on non-contrast CT, hypodense on arterial phase imaging, and isodense to spleen on the delayed phase On MR

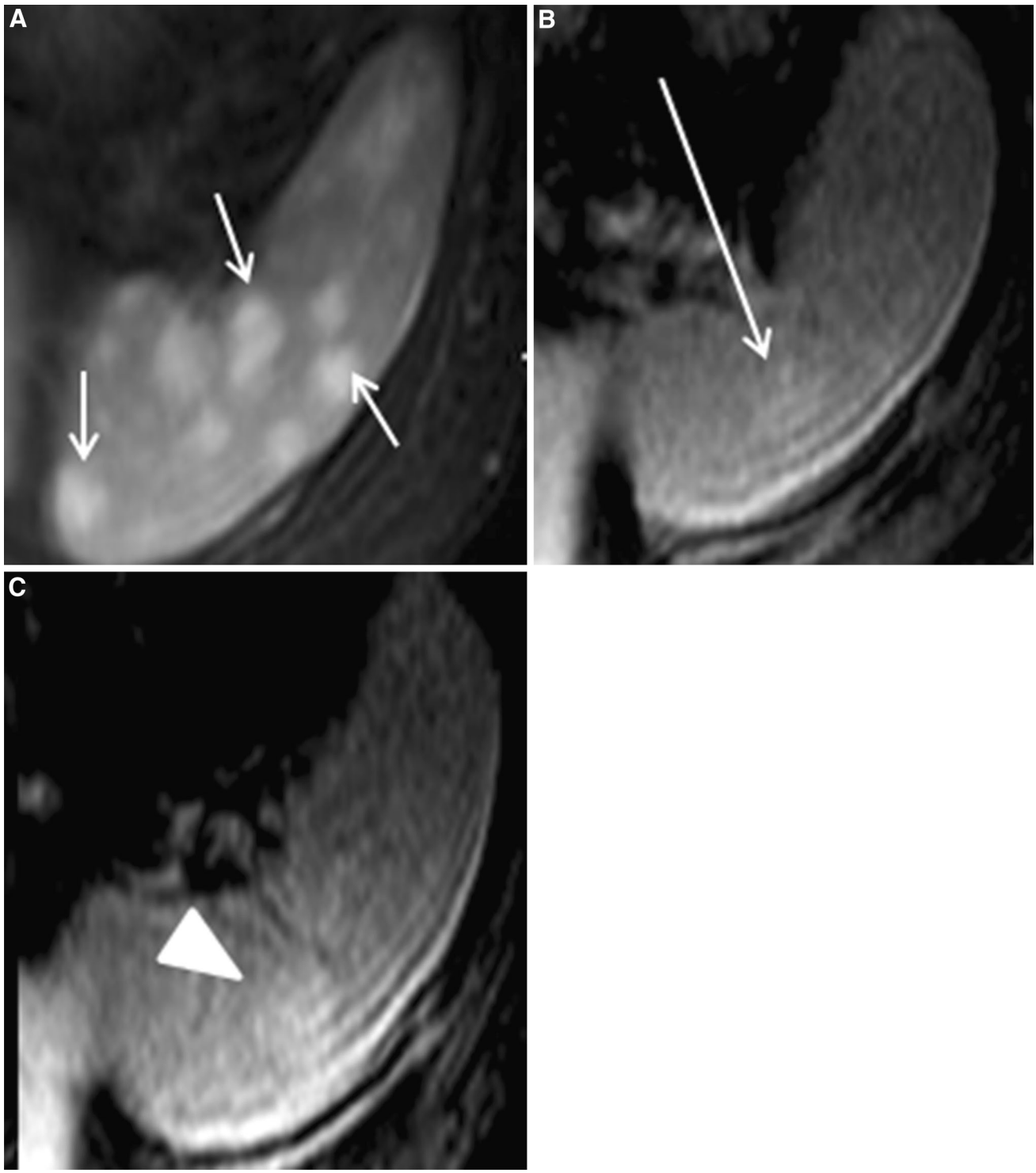

Fig. 15. Splenic hemangiomas. 63-year-old woman with incidental finding on liver MRI. **A** Axial T2-weighted image shows multiple high signal intensity foci (*short arrows*) in the spleen. **B** Arterial and **C** delayed post-gadolinium-enhanced axial T1-weighted image shows minimal early post-contrast enhancement peripherally (*long arrow*) with subtle fill-in on the delayed images (*arrowhead*).

imaging, the lesions are low signal on T1-weighted sequences, variable signal on T2-weighted sequences, and show heterogeneous peripheral arterial enhancement with delayed centripetal filling [35] (Fig. 17).

Malignant neoplasms

Lymphoma. Lymphoma is the most common malignancy affecting the spleen and can be either primary or sec-

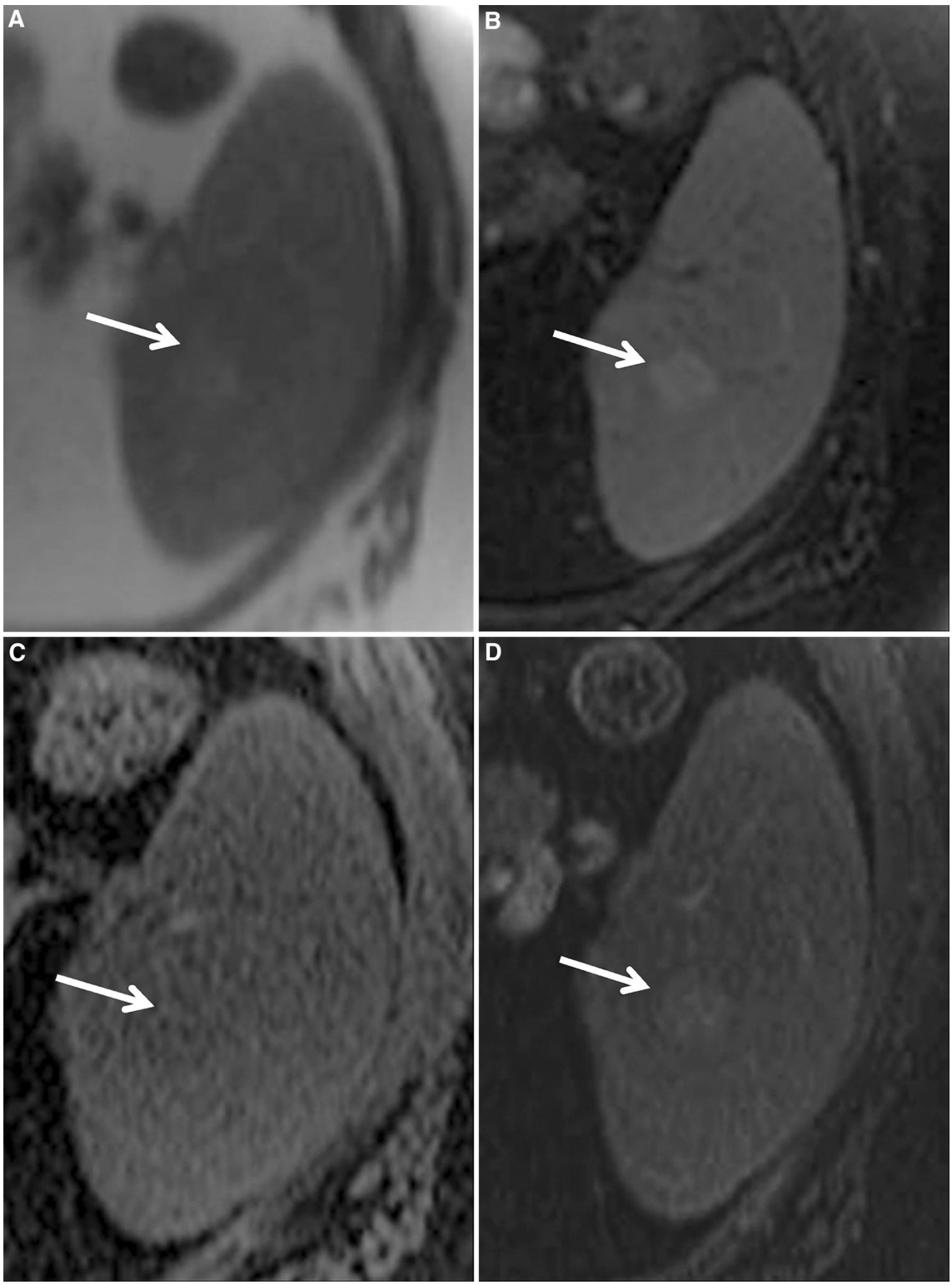

Fig. 16. Splenic hamartoma. 60-year-old woman with incidental finding on MRI. Axial MR images illustrate a rounded lesion (*arrow*), relatively iso-intense to the splenic parenchyma on T1-weighted image (**A**) and hyper-intense signal on T2-weighted imaging (**B**). **C** Arterial and **D** delayed post-gadolinium-enhanced T1-weighted gradient echo images show no significant enhancement initially (**C**) but persistent mild enhancement relative to splenic parenchyma on delayed post-gadolinium images (**D**).

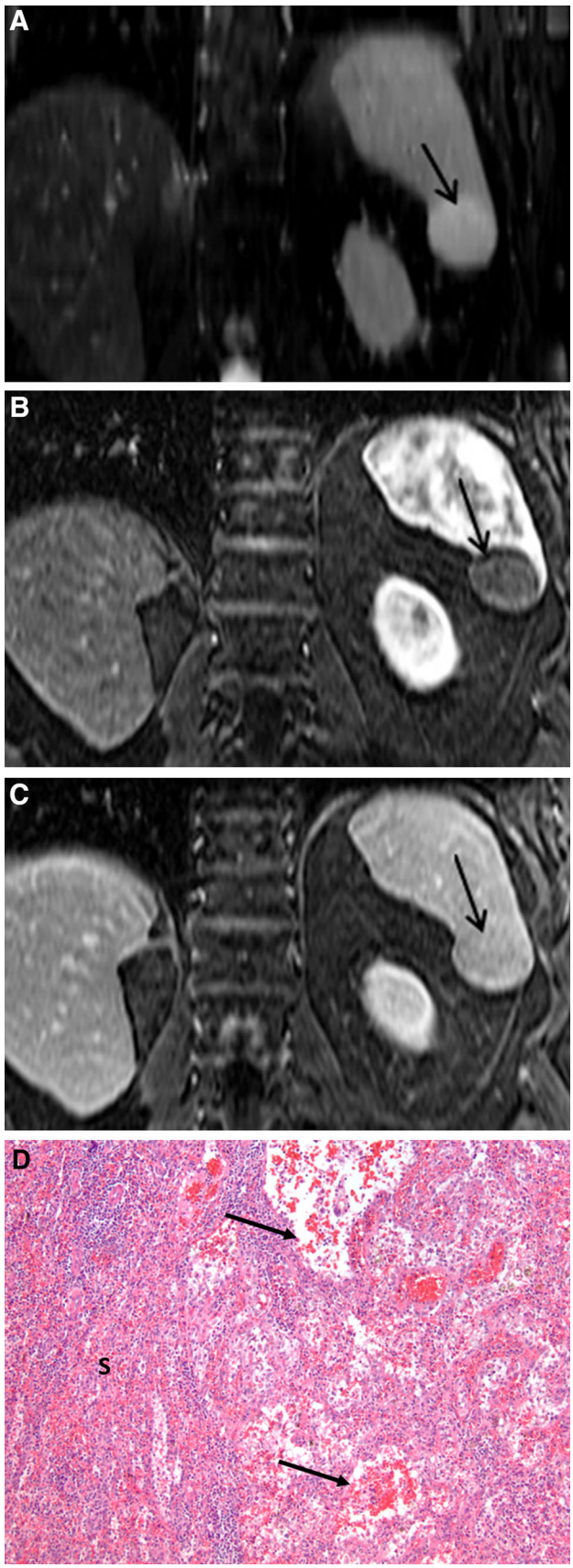

Fig. 17. Splenic littoral cell angioma. 78-year-old man with history of nephrectomy for RCC. **A** Coronal T2-weighted gradient echo image, **B** post-gadolinium arterial phase, and **C** equilibrium phase coronal T1-weighted gradient echo image show a lesion in the inferior aspect of the spleen (*arrows*), which is of high signal intensity on T2-weighted image and shows mild peripheral enhancement on the arterial phase (**B**) with centripetal filling, becoming almost isointense to spleen on equilibrium phase (**C**). This was confirmed biopsy-proven littoral cell angioma. **D** A representative histopathology specimen shows the interface between normal spleen (*S*) and a collection of dilated vascular spaces (*arrows*) lined by plump endothelial cells with occasional papillary projections and frequent sloughing into the lumen, consistent with a littoral cell angioma; hematoxylin and eosin, ×100 magnification.

ondary, although secondary involvement is much more common. Primary splenic lymphoma usually is due to non-Hodgkin type lymphoma [36]. The spleen is involved in up to 40% of patients with either Hodgkin disease or non-Hodgkin lymphoma [37]. In Hodgkin disease, the spleen is the abdominal organ most commonly involved, and the presence of splenic disease results in up-staging. In non-Hodgkin lymphoma, most patients present with disseminated disease and the spleen is not as crucial a factor in staging; however, if the spleen is the predominant site of involvement, therapeutic approach might be altered. Therefore, for either type of lymphoma, degree of splenic involvement with disease can influence treatment options and determine the overall prognosis [37].

Imaging findings can range from an enlarged spleen without discrete mass, to a single lesion, multiple lesions, or diffuse involvement. Splenomegaly is the most common imaging finding. Up to 70% of cases with splenic involvement manifest as diffuse infiltration or lesions smaller than 1 cm [30]. On CT they appear as areas of low-attenuation in the splenic parenchyma, which may be confluent mass(es) with heterogeneous enhancement (Fig. 18). On MR imaging, diagnosis is less reliable than CT, as lymphoma has similar signal on T1- and T2-weighted imaging compared to normal splenic parenchyma. PET-FDG imaging shows regions of increased radiotracer uptake in the spleen (Fig. 18).

Metastasis. Splenic metastases are found with a frequency varying from 2 to 7% at autopsy of cancer patients [36]. The most common primary malignancies are breast, lung, pancreas, ovary, and melanoma, and splenic metastases are usually a part of widespread metastatic disease late in the course of the illness [38]. Metastatic lesions are typically either solitary or diffuse rather than having only a few lesions. The majority of

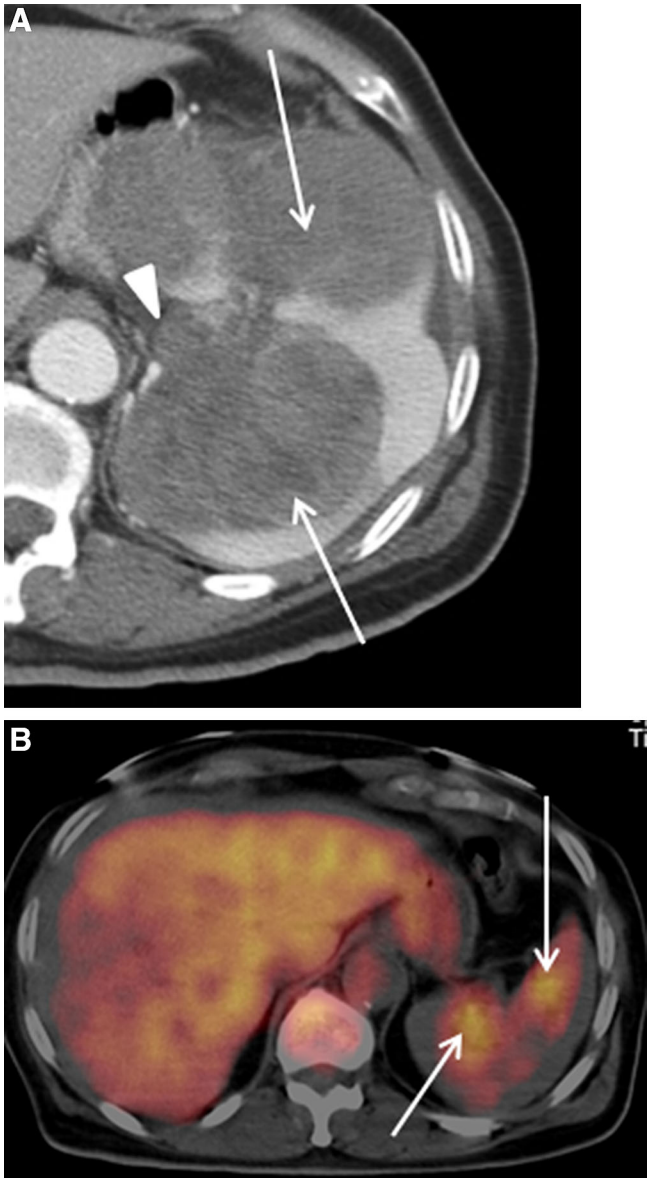

Fig. 18. Splenic lymphoma. 68-year-old with splenic lymphoma. **A** Axial contrast-enhanced CT image shows large, lobulated, heterogeneous hypodense masses (*arrows*) in the spleen. Apart from a few enlarged perisplenic hilar lymph nodes (*arrowhead*), no other enlarged distal thoraco-abdominal nodes were seen. Ultrasound guided biopsy-confirmed primary splenic lymphoma. **B** Axial ^{18}FDG PET/CT at 6-month post chemotherapy follow up confirms treatment response, but with residual disease in the spleen manifesting as areas of increased ^{18}FDG uptake (*arrows*).

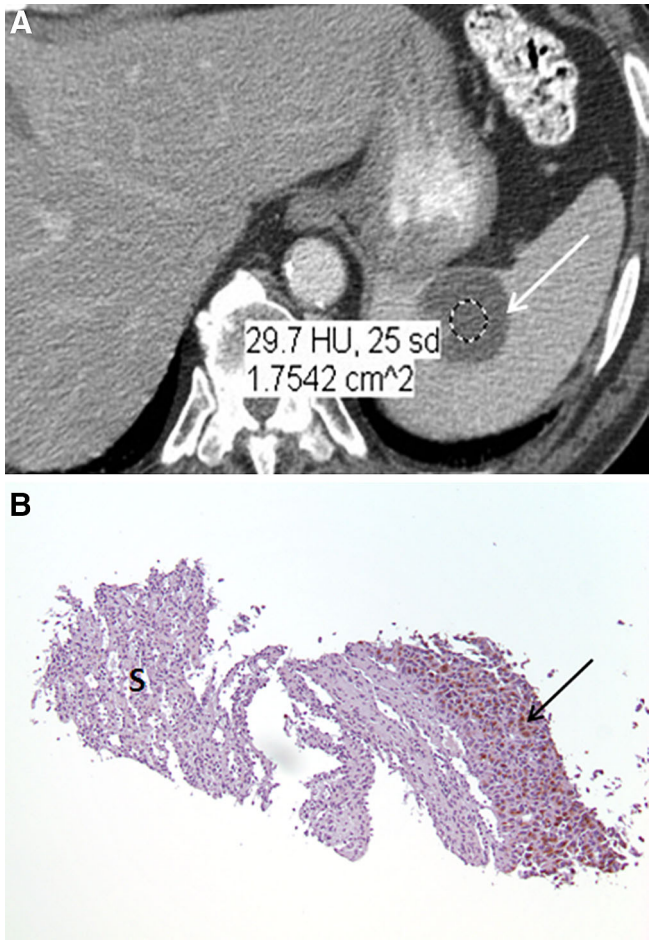

Fig. 19. Splenic metastasis. 45-year-old man with history of melanoma. **A** Axial contrast-enhanced CT image shows an irregularly marginated low-attenuation lesion (*arrow*) in the spleen. **B** Percutaneous biopsy demonstrated metastatic melanoma. Core specimen shows interface between normal spleen (S) and a mass of pleomorphic, spindled to epithelioid malignant cells that robustly express the melanocytic marker HMB-45 (brown stain, *arrow*), consistent with metastatic melanoma; HMB-45 immunohistochemistry, ×100 magnification.

splenic lesions are small and asymptomatic; large splenic deposits can undergo hemorrhage, necrosis, and potentially rupture.

Imaging findings of splenic metastases on CT are varied and include lesions with solid, heterogeneous, or cystic low attenuation (Fig. 19). There is no specific pattern of post-contrast enhancement, although there is usually minimal to heterogeneous centripetal enhancement, depending on the primary neoplasm. MR imaging shows low or intermediate signal on T1-weighted images, heterogeneous or high signal on T2-weighted images, and variable post-contrast enhancement.

Angiosarcoma. Angiosarcoma of the spleen is an aggressive malignant neoplasm arising from splenic sinusoidal vascular endothelium. Secondary spread to the spleen from the liver can also occur; some of these

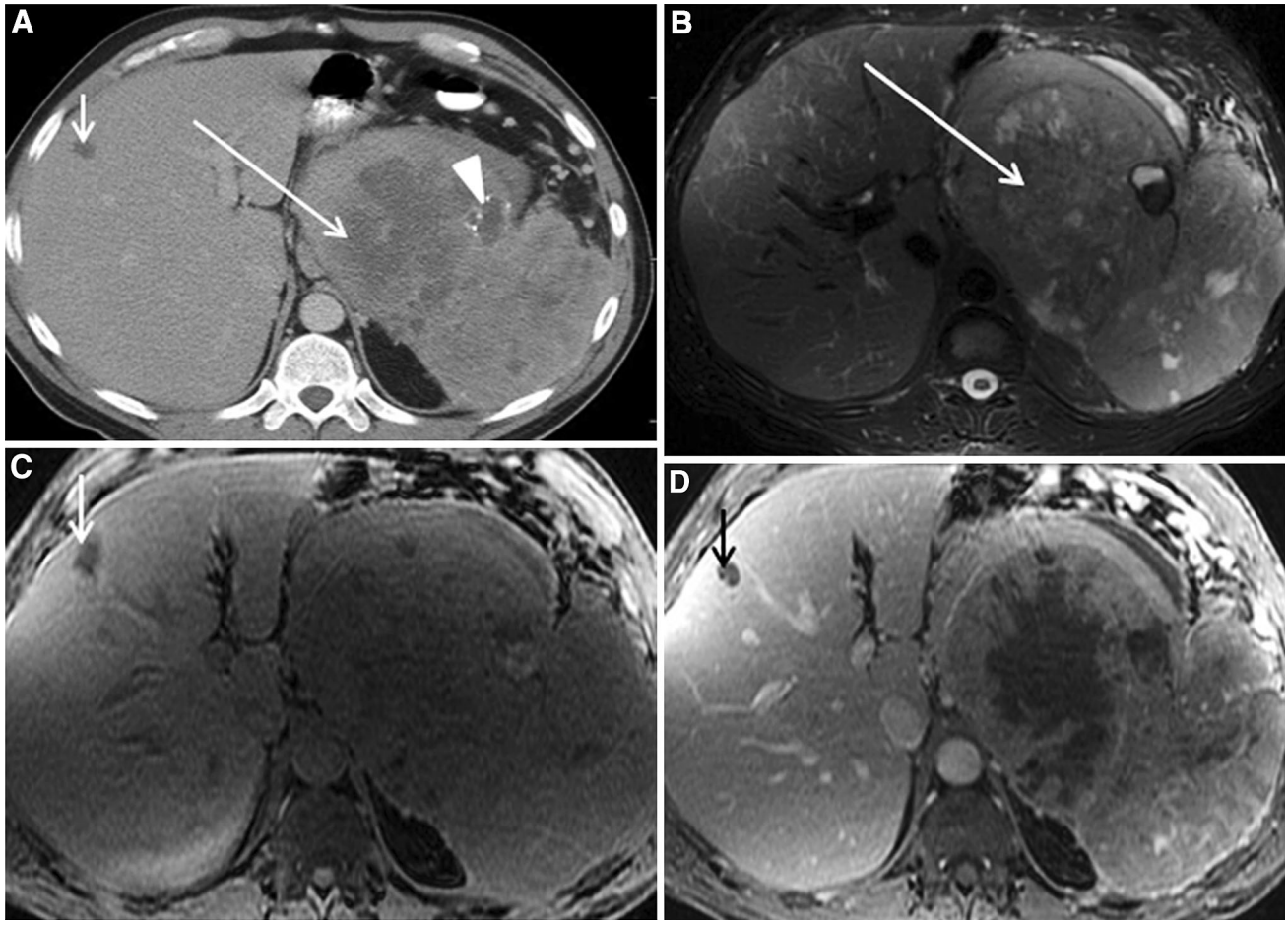

Fig. 20. Angiosarcoma. 53-year-old man with abdominal fullness, nausea, and vomiting. **A** Axial contrast enhanced CT shows a large, heterogeneous mass (*long arrow*) arising from the spleen with internal low attenuation foci (likely representing necrosis and/or hemorrhage) and calcifications (*arrowhead*). **B** Axial T2-weighted gradient echo image shows a corresponding heterogeneous mass (*long arrow*) with areas of high signal. **C** Unenhanced axial T1-weighted image shows heterogeneous but relatively iso- to hypointense signal of the mass to the rest of splenic parenchyma. **D** Axial gadolinium-enhanced axial T1-weighted gradient echo image shows heterogeneous enhancement. *Short arrows* (**A**, **C**, **D**) indicate a suspected hepatic metastasis.

cases are related to administration of toxic substances such as thorium dioxide (Thorotrast) and vinyl chloride [30]. Widespread disease and/or splenic rupture often occur before diagnosis. Splenectomy can result in long-term survival, whereas radiation and chemotherapy frequently do not prevent disease spread.

On ultrasound, angiosarcoma appears as a heterogeneous, complex mass. CT also shows an ill-defined mass with heterogeneous contrast enhancement, areas of necrosis, and possibly scattered calcifications (sometimes in a radial pattern if there is massive calcification). MR images show increased or decreased signal on T1- and T2-weighted images and heterogeneous post-gadolinium enhancement. Sometimes the neoplasm presents as multiple lesions within the spleen, and metastatic disease is common at presentation (Fig. 20).

Leiomyosarcoma. Leiomyosarcomas can occur in any organ containing smooth muscle cells. Metastatic leiomyosarcoma is much more common than a primary splenic leiomyosarcoma. The tumor is aggressive with poor prognosis. Other sites of tumor spread include pulmonary metastases, mesenteric or omental metastases causing ascites, retroperitoneal lymphadenopathy, and bone metastases [39]. CT imaging of leiomyosarcoma shows a mass or multiple masses with heterogeneous

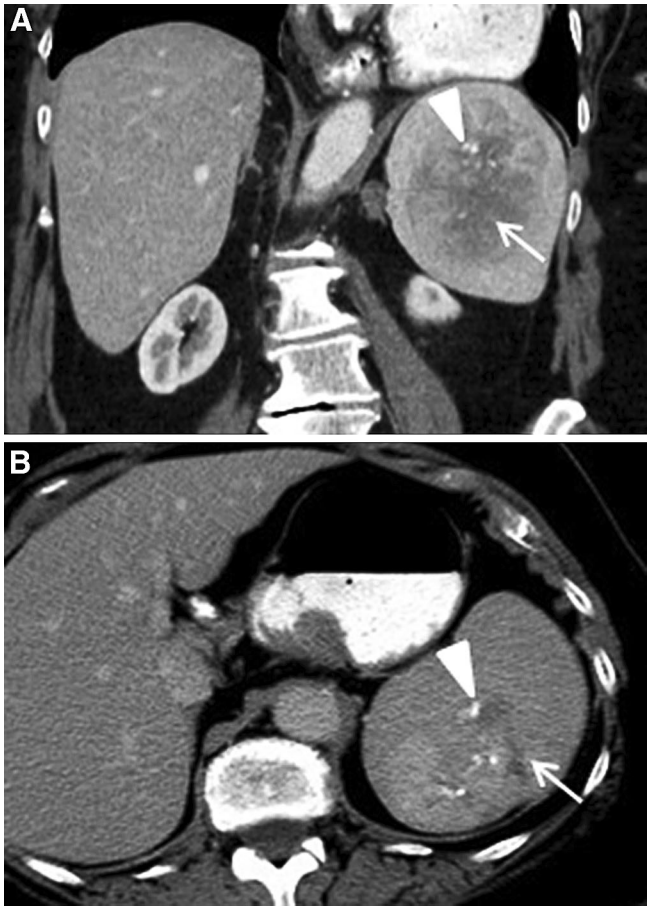

Fig. 21. Splenic leiomyosarcoma. 44-year-old man with left upper quadrant pain **A** coronal reformatted and **B** axial contrast-enhanced CT images demonstrate a large, heterogeneous mass in the spleen with internal low-attenuation areas (*arrows*, representing necrosis and/or hemorrhage) and several internal calcifications (*arrowheads*). The mass does not extend through the splenic capsule. Splenectomy was performed, and the pathology showed leiomyosarcoma.

contrast enhancement and central areas of necrosis and calcification (Fig. 21). On MR imaging, the lesion is typically isointense to skeletal muscle on T1-weighted sequences and hyperintense on T2-weighted sequences. Other MR imaging features include avid enhancement with gadolinium and calcific foci of low signal intensity on T1- and T2-weighted sequences.

Non-vascular Splenic Intervention

Infectious, traumatic, or neoplastic splenic disease may necessitate intervention. Because patients can lead relatively normal lives without their spleens, and because percutaneous splenic intervention historically was

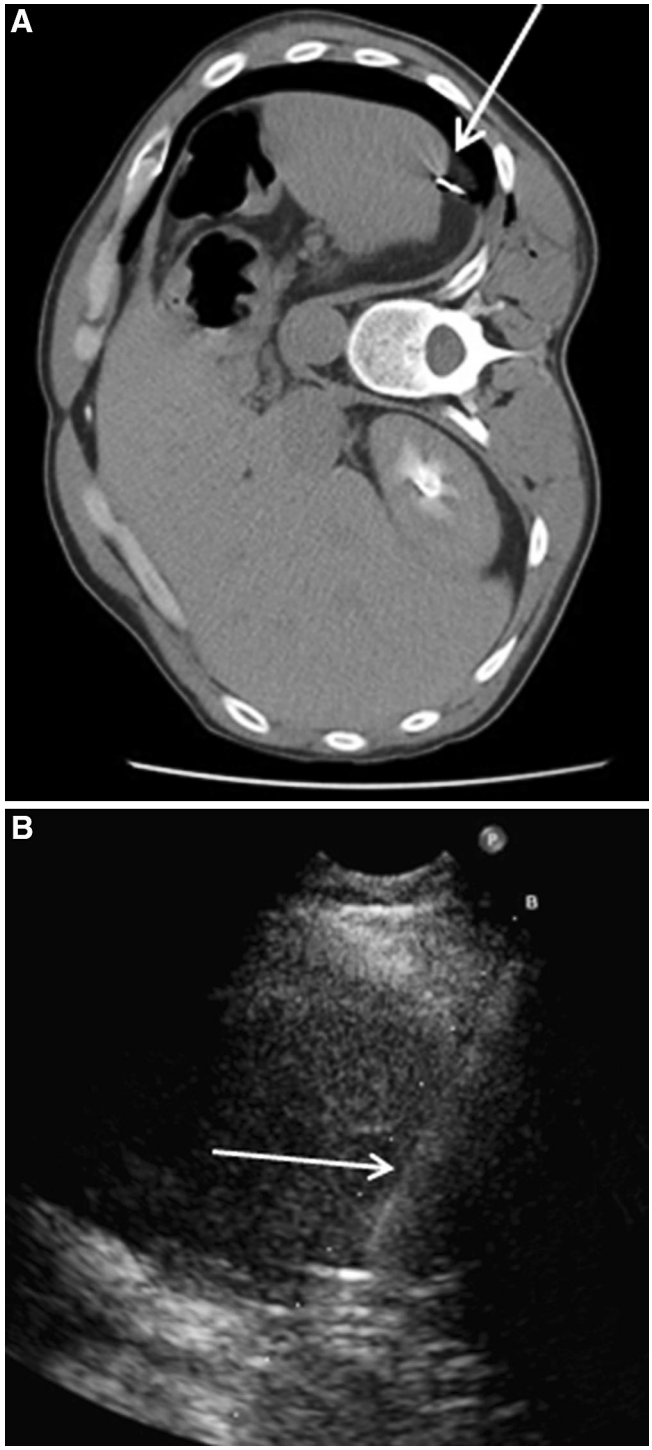

Fig. 22. Image-guided splenic biopsies. **A** 59-year-old man with splenic lesion. Axial CT image shows a portion of the biopsy needle in the spleen (*arrow*); this was proven to be littoral cell angioma. **B** 54-year-old woman with incidental splenic lesion on CT. Ultrasound-guided biopsy was performed, with the needle (*arrow*) seen within the lesion.

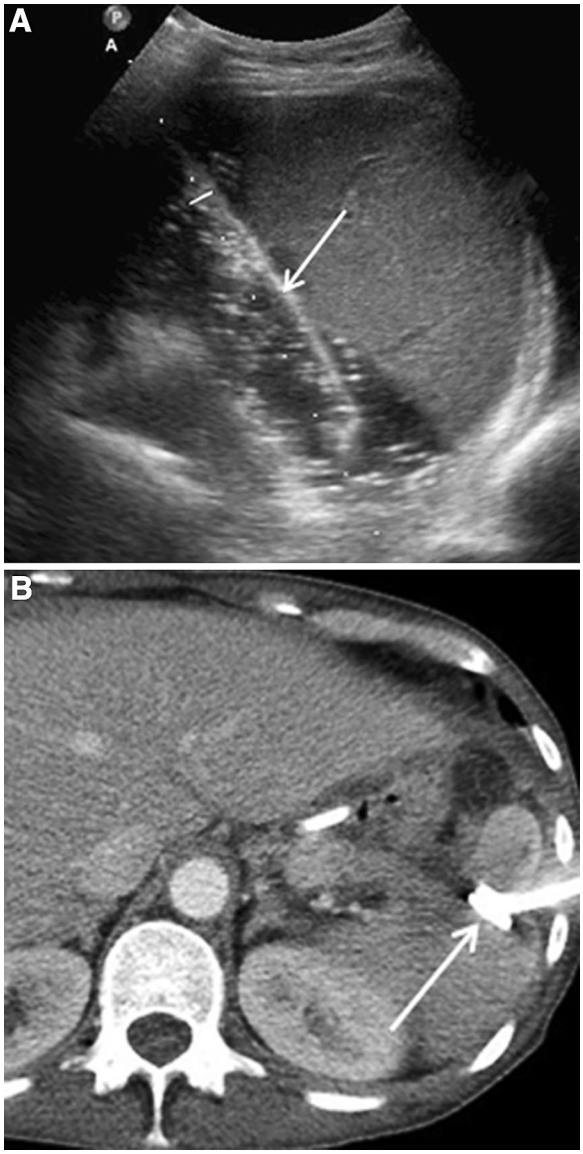

Fig. 23. Ultrasound-guided splenic abscess drainage. 65-year-old woman with fever and abdominal pain, same patient as Fig. 6. **A** Ultrasound image during percutaneous drain placement. The echogenic, linear structure (*arrow*) is the needle passing into the abscess cavity. The drain was subsequently placed via the trocar technique, and is seen on follow-up CT imaging (**B**, *arrow*).

thought difficult and risky, splenectomy was more widely used in the past for management. The risk of immune deficiency and of the surgery itself, however, warrants judicious use of percutaneous splenic intervention when possible. Imaging plays a major role in such interventions.

Biopsy. Given the wide range of splenic pathology with similar imaging characteristics, a pathologic diagnosis is often required for clinical decision making. Image-guided splenic biopsy has historically been viewed with some apprehension, likely because of early reports of major complications, primarily hemorrhage [40]. However, recent studies have focused on the use of smaller needle gauges, which result in lower complication rates. A recent review of percutaneous image-guided splenic biopsy found a pooled sensitivity of 87.0% and a pooled specificity of 96.4%. The pooled major complication rate was 2.2%, which dropped to 1.3% with the use of 18-gauge or smaller needles [3]. Other complications include pneumothorax, pleural effusion, and colonic injury [41].

Ultrasound or CT-guidance can be used for the biopsy. Ultrasound allows real-time guidance and feedback during the procedure (Fig. 22). Doppler imaging can help localize and avoid nearby blood vessels. CT can sometimes provide better quality images when the lesion is difficult to see on ultrasound, but this comes at the cost of radiation dose and the need for scanner time.

Aspiration and catheter drainage. Antibiotics are the mainstay of treatment of splenic infections, but aspiration and/or drain placement can sometimes help in management. CT-guided splenic drain placements have been shown to be a safe and effective alternative to surgical intervention [42]. Compared with an open procedure, placement of a percutaneous catheter can help avoid intraperitoneal spillage of abscess contents. Patients with co-morbidities or contraindications to surgery may be particularly good candidates for this procedure.

Ultrasound or CT guidance can be utilized for percutaneous drain placement (Fig. 23). Usually a 7–12 French pigtail catheter is used for drainage. The drain can be placed by either Seldinger technique, using a guidewire and co-axial dilation, or trocar technique, using direct needle puncture of the fluid collection and inserting a catheter. The Seldinger technique is more accurate and theoretically has a lower risk of damage to adjacent structures, but the trocar technique is more time-efficient [42]. Unilocular or bilocular abscess cavities without septations tend to be easier to drain. Hemorrhage is the most common complication of drain placement [41]. Patients are usually simultaneously treated with IV antibiotics.

Conclusion

A wide variety of incidental splenic lesions can be encountered on imaging studies (Table 2). These lesions can represent either primary benign or malignant lesions or indicate systemic disease with secondary involvement of the spleen. Many splenic lesions have overlapping imaging features, which can pose a diagnostic challenge, and image-guided biopsy can prove useful in sampling lesions for pathologic diagnosis. In some instances splenectomy is performed for both diagnosis and treatment, especially when a malignancy is suspected.

Table 2. Imaging features of splenic lesions

	Non-enhanced CT	Contrast-enhanced CT	T1-WI MRI	T2-WI MRI	Post-gadolinium T1-WIMRI
Trauma	Ill-defined or linear low attenuation	No enhancement in lesion itself	Variable, follows hemorrhage	Variable, follows hemorrhage	No enhancement
Abscess	Ill-defined low attenuation +/− gas bubbles	None/rim enhancing	Low/intermediate	High	Low signal with peripheral rim enhancement
Infarct	May see low attenuation, wedge-shaped areas	No enhancement	Low	Low	No enhancement
Hemangioma	Low solid/ multicystic mass +/-calcification	Early peripheral; Late central	Low	High	Peripheral enhancement, then fills in
Hamartoma	Small-iso/hypo; Large- central scar/necrosis	Variable, uniform on delayed	Low	Heterogeneous /high	Variable/uniform on delayed
Littoral cell angioma	Low attenuation	Early no enhancement; Late isodense	Low	Low or high	Peripheral enhancement, then fills in
Peliosis	Low attenuation	No or mild enhancement	High	High	No enhancement
Cyst/Pseudocyst	Fluid attenuation	No enhancement	Low	High	No enhancement
Sarcoid	Multifocal low	No enhancement	Low (Best seen on T2 fat sat and early post contrast phase)		Minimal on delayed
Lymphoma	Splenomegaly; solitary (AIDS), multifocal/diffuse: low attenuation	Minimal to no enhancement	Isointense to splenic parenchyma		Low signal relative to enhancing spleen
Angiosarcoma	Solitary, multiple: low attenuation, +/−calcifications	Heterogenous/variable	Variable: hemorrhage, necrosis, calcification		Variable or ring-like
Leiomyosarcoma	Low attenuation	Heterogeneous	Low or iso-intense	High	Avid enhancement
Metastases (melanoma, breast, lung)	Solid/cystic: low attenuation	Central/peripheral enhancement	Isointense/low	High	Depends on primary

Acknowledgments. The authors acknowledge Nilesh Gupta, MBBS, DNB (Raipur, India) for providing CT image in Fig. 12.

Conflicts of interest. The authors declare that they have no conflicts of interest.

References

1. Perkins JA (2010) Diseases of the white blood cells, lymph nodes, spleen and thymus. In: Kumar V, Abbas AK, Fausto N, Aster AC (eds) *Robbins and cotran pathologic basis of disease*, 8th edn. Philadelphia, PA: Saunders/Elsevier, pp 589–638
2. Berland LL (2013) Overview of white papers of the ACR incidental findings committee II on adnexal, vascular, splenic, nodal, gallbladder, and biliary findings. J Am Coll Radiol 10(9):672–674
3. McInnes MD, Kielar AZ, Macdonald DB (2011) Percutaneous image-guided biopsy of the spleen: systematic review and meta-analysis of the complication rate and diagnostic accuracy. Radiology 260(3):699–708
4. Bezerra AS, D'Ippolito G, Faintuch S, Szejnfeld J, Ahmed M (2005) Determination of splenomegaly by CT: is there a place for a single measurement? AJR Am J Roentgenol 184(5):1510–1513
5. Frank K, Linhart P, Kortsik C, Wohlenberg H (1986) Sonographic determination of spleen size: normal dimensions in adults with a healthy spleen. Ultraschall Med 7(3):134–137
6. Robertson F, Leander P, Ekberg O (2001) Radiology of the spleen. Eur Radiol 11(1):80–95
7. Pozo AL, Godfrey EM, Bowles KM (2009) Splenomegaly: investigation, diagnosis and management. Blood Rev 23(3):105–111
8. Spielmann AL, DeLong DM, Kliewer MA (2005) Sonographic evaluation of spleen size in tall healthy athletes. AJR Am J Roentgenol 184(1):45–49
9. Webb WR, Brant WE, Helms CA (1998) *Fundamentals of body CT*, 2nd edn. Philadelphia, PA: Saunders
10. Arber DA (2009) The spleen. In: Weidner N, Cote R, Suster S, Weiss L (eds) *Modern surgical pathology*, 2nd edn. Philadelphia, PA: Saunders/Elsevier, p 1513
11. Wasnik AP, Mazza MB, Lalchandani UR, Liu PS (2011) Normal and variant abdominal anatomy on magnetic resonance imaging. Magn Reson Imaging Clin N Am 19(3):521–545
12. Ito K, Mitchell DG, Honjo K, et al. (1996) Gadolinium-enhanced MR imaging of the spleen: artifacts and potential pitfalls. AJR Am J Roentgenol 167(5):1147–1151
13. Positron Clark P, Tomography Emission (2009) In: Dalrymple N, Leyendecker J, Oliphant M (eds) *Problem solving in abdominal imaging*. St.Louis, MO: Mosby/Elsevier, pp 81–84
14. Boscak A, Shanmuganathan K (2012) Splenic trauma: what is new? Radiol Clin North Am 50(1):105–122
15. Moore EE, Cogbill TH, Jurkovich GJ, et al. (1995) Organ injury scaling: spleen and liver (1994 revision). J Trauma 38(3):323–324
16. Clark TJ, Cardoza S, Kanth N (2011) Splenic trauma: pictorial review of contrast-enhanced CT findings. Emerg Radiol 18(3):227–234
17. Kamaya A, Weinstein S, Desser TS (2006) Multiple lesions of the spleen: differential diagnosis of cystic and solid lesions. Semin Ultrasound CT MR 27(5):389–403
18. Faught WE, Gilbertson JJ, Nelson EW (1989) Splenic abscess: presentation, treatment options, and results. Am J Surg 158(6):612–614
19. Rabushka LS, Kawashima A, Fishman EK (1994) Imaging of the spleen: CT with supplemental MR examination. Radiographics 14(2):307–332
20. Anderson SW, Lucey BC, Soto JA (2009) Nontrauma abdomen. In: Soto JA, Lucey BC (eds) *Emergency radiology: the requisites*, 1st edn. Philadelphia, PA: Mosby/Elsevier, pp 303–304
21. Elsayes KM, Narra VR, Mukundan G, et al. (2005) MR imaging of the spleen: spectrum of abnormalities. Radiographics 25(4):967–982
22. Al-Salem AH (2011) Splenic complications of sickle cell anemia and the role of splenectomy. ISRN Hematol 2011:864257

23. Ouyang HQ, Gong ZJ, Zha YF, Liu CS, Yang ZH (2013) Splenic siderotic nodules in patients with liver cirrhosis. Exp Ther Med 6(2):445–450
24. Selcuk D, Demirel K, Kantarci F, Mihmanli I, Ogut G (2005) Gamna-Gandy bodies: a sign of portal hypertension. Turk J Gastroenterol 16(3):150–152
25. Chan YL, Yang WT, Sung JJ, Lee YT, Chung SS (2000) Diagnostic accuracy of abdominal ultrasonography compared to magnetic resonance imaging in siderosis of the spleen. J Ultrasound Med 19(8):543–547
26. Aslam S, Sohaib S, Reznek RH (2008) Reticuloendothelial disorders: the spleen. In: Adam A, Dixon A, Grainger R, Allison D (eds) *Grainger & Allison's diagnostic radiology*, 5th edn. Philadelphia, PA: Churchill Livingstone, pp 1759–1770
27. Siegelman ES (2004) MRI of the spleen. In: Siegelman ES (ed) *Body MRI*, 1st edn. Philadelphia, PA: Saunders, p 197
28. Sharma SK, Smith-Rohrberg D, Tahir M, Mohan A, Seith A (2007) Radiological manifestations of splenic tuberculosis: a 23-patient case series from India. Indian J Med Res 125(5):669–678
29. Adachi K (2011) Isolated splenic peliosis presenting with giant splenomegaly and severe coagulopathy. Am J Surg 202(2):e17–e19
30. Nakamoto DA (2008) Spleen. In: Haaga J, Dogra V, Forsting M, Gilkeson R, Ha H, Sundaram M (eds) *CT and MRI of the whole body*, 5th edn. Philadelphia, PA: Mosby/Elsevier, pp 1771–1803
31. Mathieson JR, Cooperberg PL (1998) The spleen. In: Rumack CM, Wilson SR, Charboneau JW (eds) *Diagnostic ultrasound*, 2nd edn. St. Louis: Mosby, pp 155–174
32. Cheuk W, Chan JKC (2007) Tumors of the lymphoreticular system: part B, the spleen. In: Fletcher C (ed) *Diagnostic histopathology of the spleen*, 3rd edn. Philadelphia, PA: Churchill Livingstone, pp 1304–1309
33. Abbott RM, Levy AD, Aguilera NS, Gorospe L, Thompson WM (2004) From the archives of the AFIP: primary vascular neoplasms of the spleen: radiologic–pathologic correlation. Radiographics 24(4):1137–1163
34. Ben-Izhak O, Bejar J, Ben-Eliezer S, Vlodavsky E (2001) Splenic littoral cell hemangioendothelioma: a new low-grade variant of malignant littoral cell tumour. Histopathology 39(5):469–475
35. Shah S, Wasnik A, Pandya A, Bude RO (2011) Multimodality imaging findings in image-guided biopsy proven splenic littoral cell angioma: series of three cases. Abdom Imaging 36(6):735–738
36. Kaza RK, Azar S, Al-Hawary MM, Francis IR (2010) Primary and secondary neoplasms of the spleen. Cancer Imaging 10:173–182
37. Bhatia K, Sahdev A, Reznek RH (2007) Lymphoma of the spleen. Semin Ultrasound CT MR 28(1):12–20
38. Lam KY, Tang V (2000) Metastatic tumors to the spleen: a 25-year clinicopathologic study. Arch Pathol Lab Med 124(4):526–530
39. Davies CE, Davies AM, Kindblom LG, James SL (2010) Soft tissue tumors with muscle differentiation. Semin Musculoskelet Radiol 14(2):245–256
40. Keogan MT, Freed KS, Paulson EK, Nelson RC, Dodd LG (1999) Imaging-guided percutaneous biopsy of focal splenic lesions: update on safety and effectiveness. AJR Am J Roentgenol 172(4):933–937
41. Singh AK, Shankar S, Gervais DA, Hahn PF, Mueller PR (2012) Image-guided percutaneous splenic interventions. Radiographics 32(2):523–534
42. Thanos L, Dailiana T, Papaioannou G, et al. (2002) Percutaneous CT-guided drainage of splenic abscess. AJR Am J Roentgenol 179(3):629–632