Pictorial Essay

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Multimodality Imaging Features of Various Splenic Lesions: Clinical and Histopathologic Correlation

비장 병변의 다양한 영상 소견: 조직병리 소견과의 비교

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The spleen is occasionally referred to as the 'forgotten organ' because splenic lesions are less common and encountered rarely compared to pathologies of other abdominal solid organs. Therefore, although well-demonstrated using various abdominal imaging modalities, radiologists tend to be less familiar with splenic diseases, making interpretation challenging. This study aimed to review common and uncommon splenic diseases and illustrate the multimodal imaging (including ultrasonography, CT, MRI, and PET/CT) features of these lesions in correlation with their histopathology. Recognizing the radiological findings of various splenic lesions helps narrow down the differential diagnosis and guide appropriate clinical decision-making for radiologists.

Index terms Spleen; Multimodality Imaging; Histopathology; Splenic Lymphoma; Sclerosing Angiomatoid Nodular Transformation; Littoral Cell Angioma

INTRODUCTION

The spleen is the largest lymphoid organ that plays significant roles in the body (1). However, due to the rare and vague clinical symptoms of splenic diseases, the spleen is often overlooked during abdominal examinations, even though the organ can be visualized by various imaging modalities. Moreover, as image accessibility improves, an increased number of splenic lesions are being discovered, leading to a

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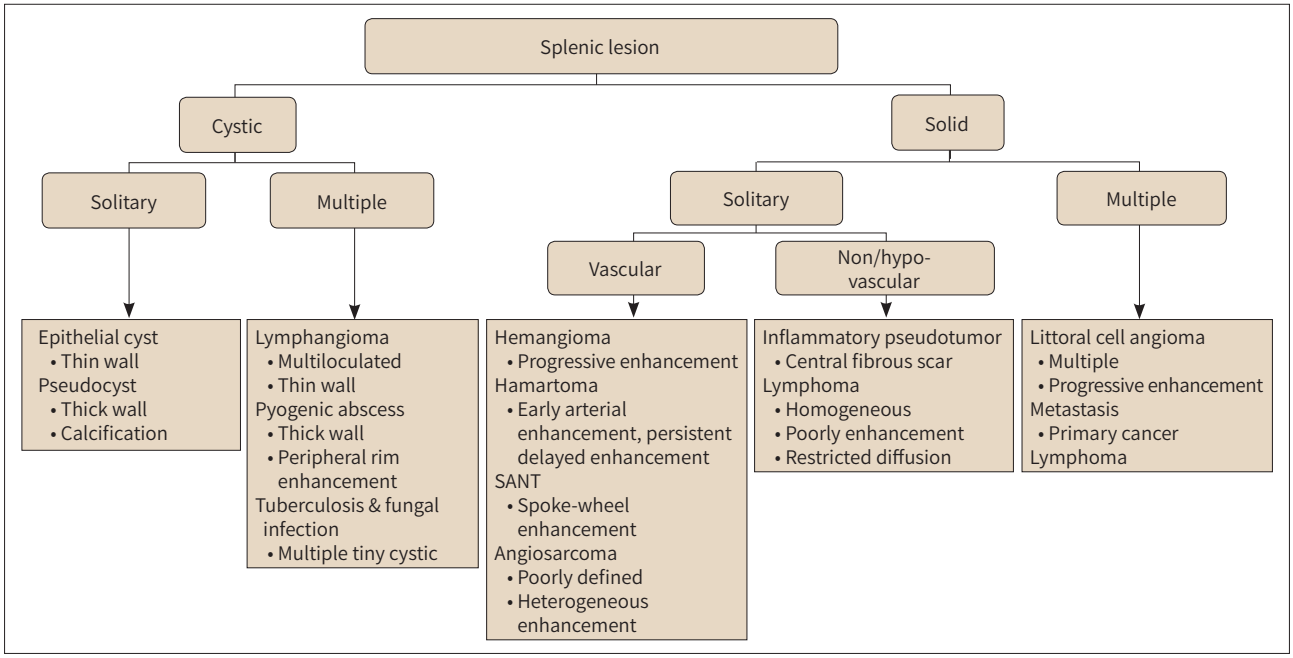
high demand for accurate differential diagnosis. In this pictorial essay, various splenic lesions are presented with typical and atypical imaging findings obtained through multimodal imaging using an image-based algorithm to differentiate splenic lesions (Fig. 1, Table 1). A brief comprehensive review of the clinical features and pathological findings is also presented. All cases were retrospectively reviewed using multimodal imaging, including ultrasonography (US), CT, MRI, and/or fluorodeoxyglucose (FDG)-PET/CT. All diagnoses were confirmed via histopathological examination.

NORMAL SPLEEN

The spleen, a lymphatic organ of mesodermal origin, comprises red and white pulp compartments. The red pulp, composed of vascular sinuses, and the white pulp, composed of lymphatic tissue cords, define its histological structure (Fig. 2) (2).

The spleen has two circulatory pathways: closed circulation, which rapidly directs blood into the venous sinusoids and eventually forms trabecular veins, and open circulation, where blood flows slowly through the reticular fibrous framework of the red pulp or the marginal zone of the lymphatic tissue before reaching the sinusoids (3, 4). These varying pathways within the spleen contribute to the distinct enhancement patterns observed during dynamic imaging. These patterns are characterized by heterogeneous enhancement in the arterial phase, often referred to as the 'zebra or psychedelic pattern,' and homogeneous enhancement in the portal venous phase (Fig. 3) (3, 4).

Fig. 1. The diagram demonstrates a pattern-based approach for various splenic lesions based on their consistency and number.



SANT = sclerosing angiomatoid nodular transformation

Table 1. Characteristic Findings of Splenic Lesions for Differential Diagnosis, Based on Consistency and Number

Lesion	Nature	Characteristic Imaging Findings
Solitary cystic lesions		
Epithelial cyst	Benign	Well-defined, unilocular Thin wall, non-enhancing Very high T2 SI, Low T1 SI
Pseudocyst	Benign	Well-defined, unilocular, non-enhancing Thick wall, wall calcification (50% of cases) Very high T2 SI, variable T1 SI (depending on contents [serous, hemorrhagic, proteinaceous])
Multiple cystic lesions		
Lymphangioma	Benign	Well-defined, multiloculated, thin-walled, subcapsular Intervening fibrous septa may have progressive enhancement and thin calcification
Infectious lesions	Benign	Pyogenic abscess: thick irregular wall, peripheral rim enhancement ± gas Mycobacterial or fungal: multiple tiny cystic or hypoechoic/hypoattenuating lesions
Solitary solid vascular lesions		
Hemangioma	Benign	M/C benign splenic lesion Peripheral nodular discontinuous early enhancement and progressive homogeneous enhancement Homogeneous T2 hyperintensity Doppler US: rarely shows flow No FDG PET-CT uptake Large: hemorrhage, cystic degeneration, fibrosis, infarction
Hamartoma	Benign	Early arterial enhancement, persistent delayed enhancement equilibrating with the background spleen Doppler US: increased vascularity (different from hemangioma)
SANT	Benign	Lobulated nodular margin Distinctive spoke-wheel enhancement pattern: early peripheral rim enhancement and radiating bands of progressive centripetal enhancement T2 hypointense radiating bands extending toward the center
Angiosarcoma	Malignant	Poorly defined nodular vascular masses Heterogeneous enhancement due to areas of hemorrhage, necrosis, or calcification Sometimes completely replaces most of the spleen
Solitary solid non-/hypovascular lesions		
Inflammatory pseudotumor	Benign	Iso- to hypoattenuating on non-contrast CT and delayed enhancement T1 iso-to hypointensity, T2 heterogeneous SI Central fibrous scar: T2 hypointensity and progressive enhancement Various calcification (rim-like or stippled shaped)
Lymphoma	Malignant	M/C malignant splenic tumor Variable appearance depending on type: splenomegaly without discrete lesion, solitary or multiple variable sized nodules (from miliary pattern to bulky mass) Homogeneous, hypoechoic/hypoattenuating, poorly enhancement Restricted diffusion
Multiple solid lesions		
Littoral cell angioma	Benign	Multiple small hypoechoic/hypoattenuating nodules Hypoenhancing in early and portal venous phases, with homogeneous iso-enhancement to background spleen on delayed phase images T1 hypointensity with progressive enhancement
Metastasis	Malignant	Detected in patients with primary cancer Primary: melanoma (M/C), ovarian, breast, lung, gastric cancer Variable appearance depending on primary cancer

FDG = fluorodeoxyglucose, M/C = most common, SANT = Sclerosing Angiomatoid Nodular Transformation, SI = signal intensity, ± = with or without

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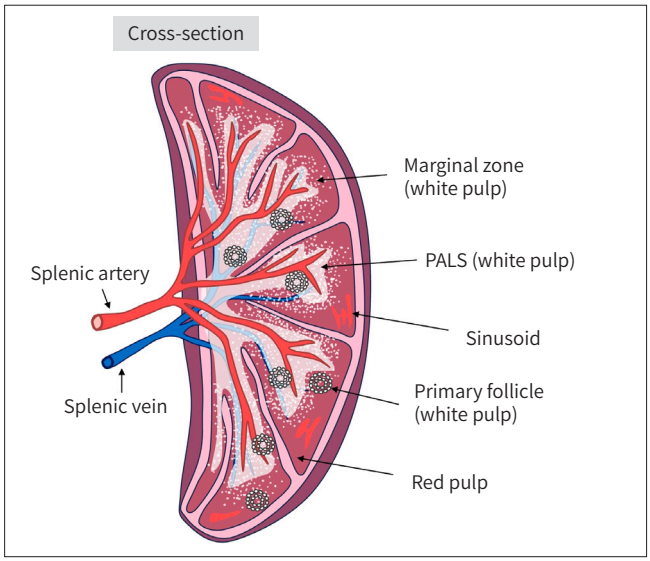
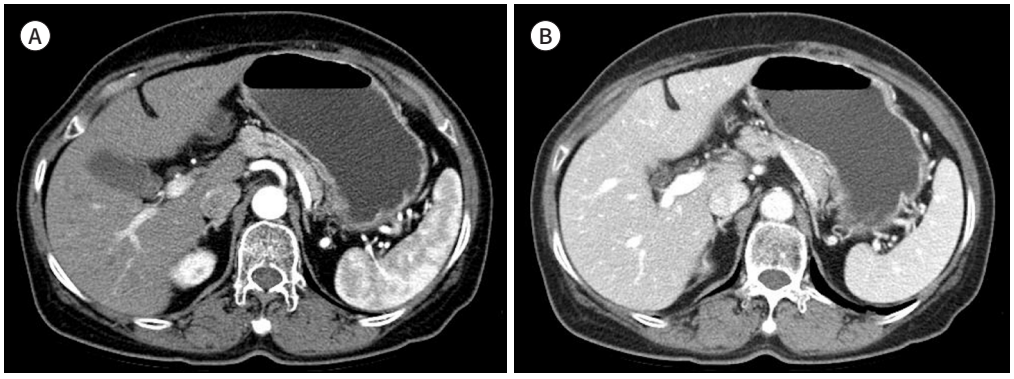


Fig. 2. Anatomical features of the spleen.
The spleen consists of two main compartments: white and red pulp. The white pulp contains immune cells organized into PALSs, primary follicles, and marginal zones. In contrast, the red pulp contains venous sinuses and splenic cords that are responsible for filtering and removing old red blood cells. This unique anatomy enables the spleen to perform essential immune and blood-filtration functions.
PALS = periarteriolar lymphoid sheath

Fig. 3. Dynamic CT of normal spleen.
A. Axial arterial phase CT image displays the characteristic heterogeneous enhancement pattern of the splenic parenchyma, called the 'zebra or psychedelic pattern.'
B. On the portal phase CT image, homogeneous enhancement is observed throughout the spleen.



SOLITARY CYSTIC LESIONS

EPITHELIAL CYST

Epithelial cysts, also known as primary cysts, are true cysts lined with epithelial membranes. They are a common benign lesion of the spleen (5, 6). Epithelial cysts are most commonly observed in the pediatric and young adult populations, with a predilection for females (7, 8). They grow slowly and are usually large at the time of their discovery. On US, the cyst appears as a well-defined, unilocular, and anechoic lesion with a thin wall. Furthermore, the cyst may demonstrate internal echoes due to cholesterol crystals or hemorrhages (Figs. 4, 5) (5). On CT scans, the cyst appears as a well-circumscribed, hypodense, non-enhancing lesion. On MRI, the cyst is hypointense on the T1-weighted image (T1-WI) and strongly hyperintense on the T2-WI. The signal intensity on T1-WI may increase due to proteinaceous or hemorrhagic content (6).

Fig. 4. Epithelial cyst in a 25-year-old female with upper abdomen pain.
A. US reveals a large, thin-walled cystic lesion (*) with internal heterogeneous echogenic materials.
B. Axial contrast-enhanced CT image demonstrates an 11 cm-sized unilocular cystic lesion (*) in the spleen with no solid portion.
Considering these benign features on US and CT, the patient was suspected to have a benign splenic cyst. The internal heterogeneous materials observed on US were thought to be inner cholesterol crystals or debris. Histology confirmed the lesion as an epithelial cyst, as determined by splenectomy.

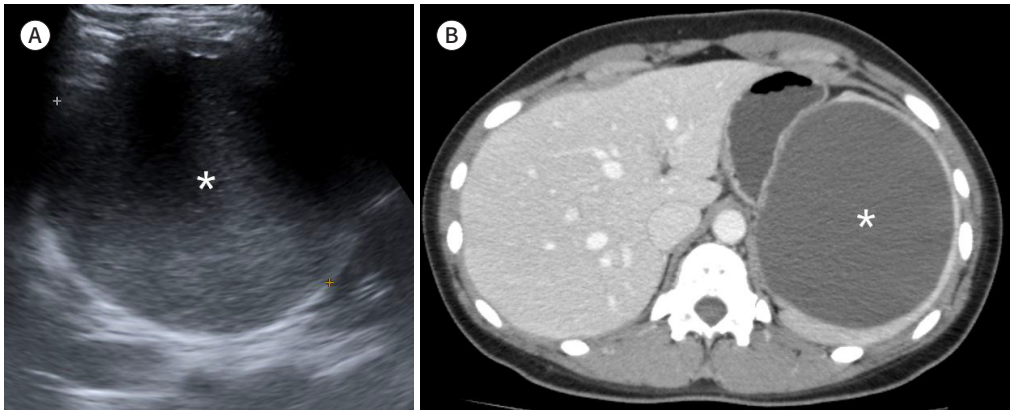
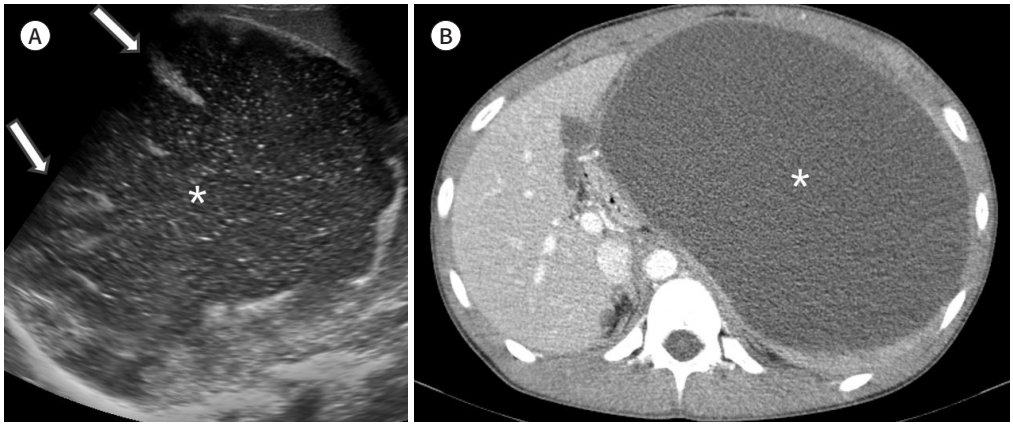


Fig. 5. Epithelial cyst in a 19-year-old male with upper abdomen discomfort.
A. US displays a large cystic lesion (*) with internal heterogeneous echogenic debris and septation (arrows).
B. Axial contrast-enhanced CT image displays a 21 cm-sized unilocular cystic lesion (*) in the spleen with no solid portion.
Histology confirmed the lesion as an epithelial cyst with old hemorrhage, as determined by splenectomy.



PSEUDOCYST

Pseudocysts, also known as secondary cysts, do not have an epithelial lining. The cyst wall is composed of dense fibrous tissues containing calcifications, hemosiderins, or cholesterol crystals. Pseudocysts can develop secondary to trauma or as sequelae of splenic infarctions and abscesses (8). On CT, wall calcification is observed in 50% of the cases (6). MRI typically demonstrates very high signal intensity on T2-WI and variable signal intensity on T1-WI, depending on the contents of the lesion (serous, hemorrhagic, proteinaceous, or necrotic) (6). However, as imaging findings of epithelial cysts and pseudocysts overlap, distinguishing between the two can be challenging (Fig. 6) (7).

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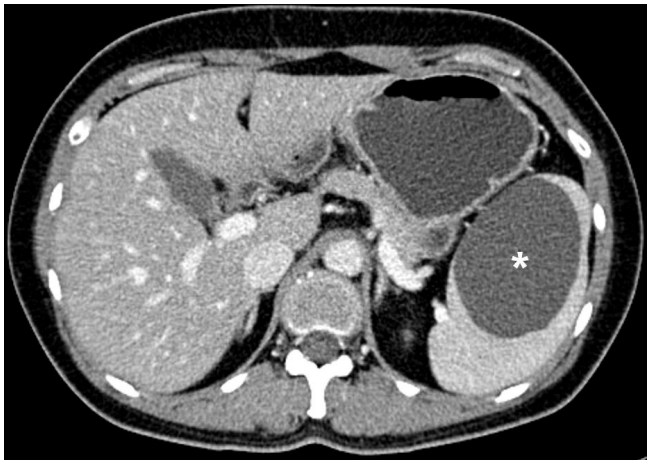


Fig. 6. A 45-year-old male with incidentally discovered pseudocyst.
Axial contrast-enhanced CT displays an 8 cm-sized unilocular cystic lesion (*) in the spleen without solid portion. Histology confirmed the lesion as a pseudocyst, as determined by splenectomy.

MULTIPLE CYSTIC LESIONS

LYMPHANGIOMA

Lymphangioma, a rare anomaly that manifests as dilated, interconnected cystic structures filled with fluid due to the abnormal development of lymphatic channels, is often attributed to congenital factors (8). They can be multifocal, diffuse, or solitary. Lymphangioma grossly appears as multiple variably sized thin-walled cysts separated by fibrous bands or residual splenic tissue (8). Most lymphangiomas are subcapsular because lymphatic vessels are primarily located in this region (8).

Patients may be asymptomatic or experience symptoms related to the pressure exerted by the mass, such as left upper quadrant pain and nausea. Potential complications include hemorrhage, rupture, splenomegaly, and portal hypertension (8, 9).

Multimodal imaging of lymphangioma reveals well-defined thin-walled lobulated or multiloculated cysts with intervening fibrous septa that may exhibit calcifications or progressive enhancement (Fig. 7) (9). Intracystic debris or hemorrhage can appear as echoes on the US or as an increased T1 signal intensity on MRI. Fibrous septa can appear hyperechoic on US and hypointense on both T1-WI and T2-WI MRI (10).

INFECTIOUS LESIONS

Infectious lesions of the spleen are rare due to its efficient reticuloendothelial phagocytic activity. Therefore, these lesions are more likely to develop in immunosuppressed individuals. The infectious lesions can be caused by bacteria, mycobacteria, fungi, or parasites (11, 12).

The appearance of infectious lesions varies depending on the stage. Typically, organized abscesses present as multiple cystic lesions that arise from necrotic inflammatory tissue caused by bacterial, fungal, or parasitic pathogens or from caseous necrosis associated with tuberculosis (12, 13).

However, cases of acute microabscesses at an early stage may present as hypodense nodular lesions without clear signs of fluid attenuation owing to incomplete necrosis. In these situations, a clinical correlation with symptoms such as fever and leukocytosis is essential, along with follow-up imaging studies to monitor changes over time (13).

Fig. 7. A 60-year-old female with incidentally identified lymphangioma.
A. Axial pre-contrast CT image displays multiple variable-sized low attenuating lesions in the spleen.
B. Axial contrast-enhanced CT image displays multiple variable-sized, multiloculated low attenuating lesions with intervening thin septa. No enhancing solid portion is observed. The largest one is about 3.6 cm in size.
Histology confirmed the lesion as lymphangioma undertaken by splenectomy.

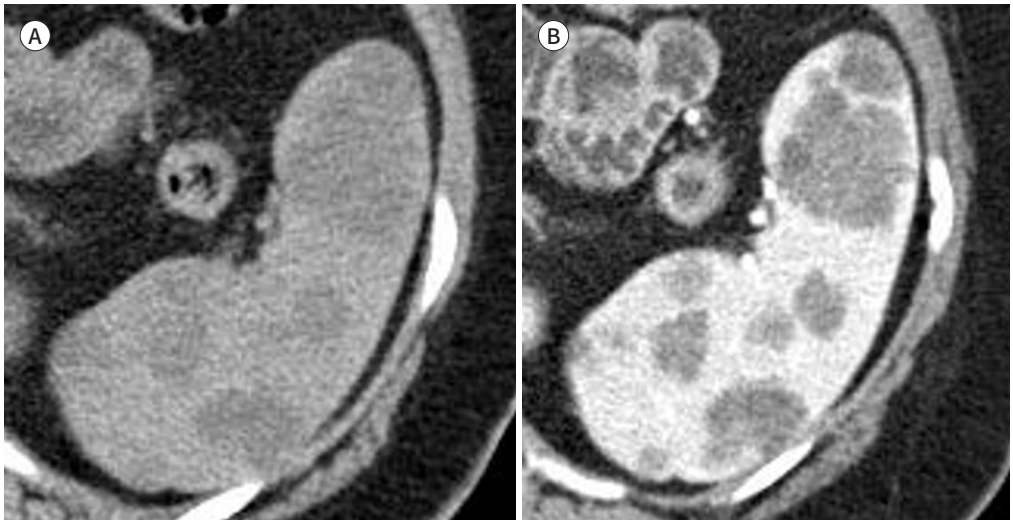
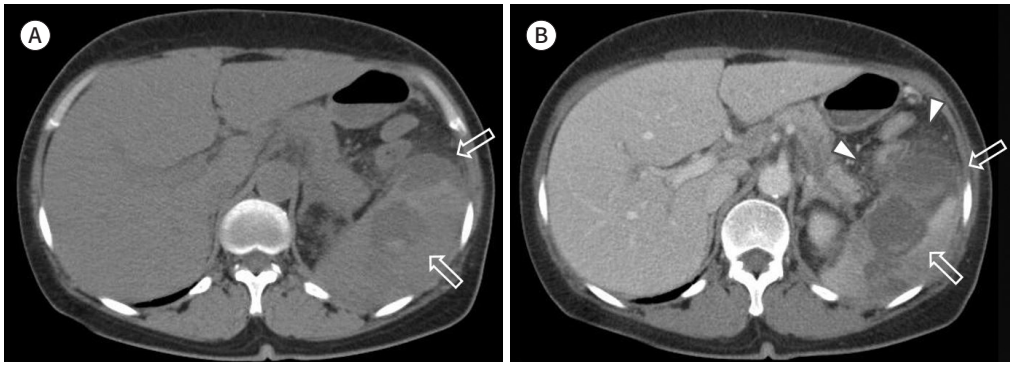


Fig. 8. Splenic pyogenic abscess in a 56-year-old female with fever and left upper abdomen tenderness.
A, B. Axial pre (A) and post (B) contrast-enhanced CT images display several variable-sized low attenuating lesions with central fluid attenuation and irregular peripheral rim contrast enhancement (arrows). Additionally, perisplenic fat stranding is noted (arrowheads).
Histology confirmed the lesion to be a splenic pyogenic abscess, as determined through splenectomy.



PYOGENIC ABSCESSES

Splenic pyogenic abscesses often arise from endocarditis, pneumonia, or gastrointestinal perforations (11, 12). *Escherichia coli*, *Staphylococcus*, *Streptococcus*, and *Salmonella* are the most common bacterial microbes in patients with pyogenic splenic abscesses (14).

On US, they typically appear cystic with a thick, irregular wall and may contain debris and septation (15). On CT, once a capsule is formed, the abscess typically appears as a low-attenuation lesion with central fluid attenuation and irregular peripheral wall contrast enhancement (Fig. 8). On MRI, the pyogenic abscess usually presents as a fluid signal depending on its size and maturation. Additionally, the lesion appears hypointense on T1-WI and hyperintense on T2-WI and demonstrates diffusion restriction related to the high viscosity and dense

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cellular composition of purulent content (12, 13, 16).

TUBERCULOSIS

Splenic tuberculosis usually occurs as part of miliary tuberculosis, and the spleen is the third most frequently affected site after the lungs and liver (17). Mycobacterial infection in the spleen typically manifests as splenomegaly and multiple small cystic or hypodense lesions with indistinct margins (Fig. 9) (17, 18). Additionally, splenic involvement is observed in widespread disease, often accompanied by enlarged lymph nodes with caseous necrosis, peritoneal involvement characterized by ascites and smooth peritoneal thickening, and adrenal involvement with hypoattenuating enlargement (12).

OTHER INFECTIOUS DISEASES

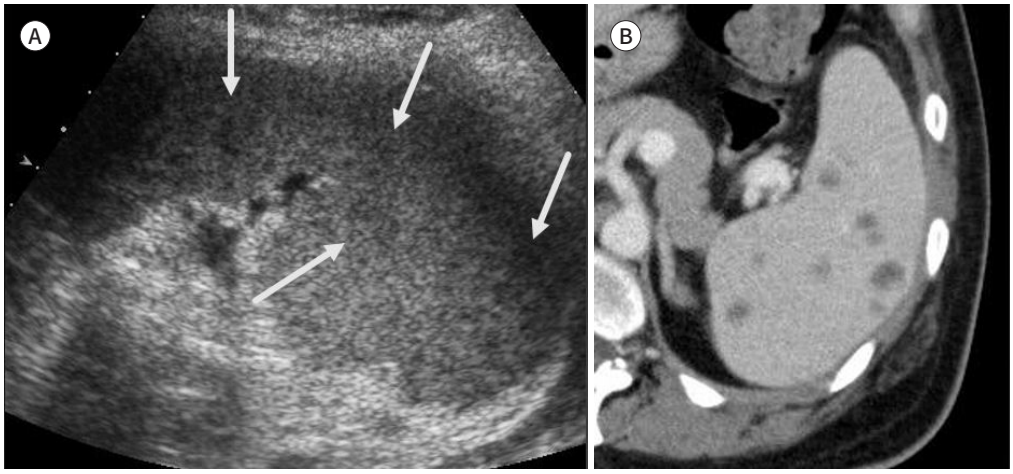
Although uncommon, other infectious diseases such as fungal or parasitic infections may also involve the spleen. Fungal infections primarily affect immunocompromised patients, with *Candida* being the most common. Additionally, other fungal infections such as aspergillosis and cryptococcosis can also lead to splenic infections (13, 19). These lesions frequently appear as multiple small abscesses characterized by numerous tiny cystic lesions with peripheral rim enhancement on CT. Moreover, splenic calcifications may develop in later stages (19). Parasitic infections such as echinococcosis can lead to hydatid cyst formation. The diagnosis of hydatid cysts is aided by the identification of daughter cysts which are characterized by circular, low-attenuation lesions within the main cyst (20).

SOLITARY SOLID VASCULAR LESIONS

HEMANGIOMA

Hemangiomas are the most common benign lesion of the spleen (5, 11). Most hemangiomas are incidentally detected in asymptomatic patients. Usually, solitary hemangiomas can

Fig. 9. Splenic tuberculosis in a 33-year-old female with fever and weight loss.
A. US demonstrates splenomegaly with multiple ill-marginated hypoechoic splenic lesions (arrows).
B. Axial contrast-enhanced CT image reveals multiple ill-marginated small low attenuating splenic lesions with splenomegaly.
Histology confirmed the diagnosis of tuberculosis, determined through splenectomy.



have multiple or diffuse splenic involvements, as observed in Kasaback-Merrit syndrome. This condition is also associated with abnormalities such as anemia, thrombocytopenia, and consumptive coagulopathy (21).

Histologically, hemangiomas are divided into capillary and cavernous types depending on the size of the vascular channels. The cystic space in hemangiomas can be small (capillary) but is more commonly large (cavernous) and filled with blood cells and proteinaceous fluid (8, 21).

On US, splenic hemangiomas can appear as well-defined hyperechoic masses without posterior acoustic shadowing. The lesions rarely demonstrate flow on color or power Doppler US (22). Dynamic contrast-enhanced CT and MRI revealed a well-circumscribed mass with peripheral nodular discontinuous early enhancement and homogeneous progressive enhancement. The mass may also present with homogeneous hyperintensity on T2-WI on MRI (23).

Large hemangiomas can undergo changes such as hemorrhage, cystic degeneration, fibrosis, infarction, or rupture, leading to variable appearances across different imaging modalities. Areas of fibrosis demonstrated progressive enhancement. However, areas of cystic degeneration did not display any enhancement (Fig. 10) (24). Additionally, hemangiomas can display variable dynamic contrast enhancement patterns, including immediate homogeneous enhancement that persists into the delayed phase, early peripheral enhancement with uniform delayed homogeneous enhancement, or peripheral enhancement with centripetal progression. The differentiation from malignant diseases may be difficult in cases with atypical features. In these cases, FDG PET/CT can help differentiate malignancy as hemangiomas do not demonstrate metabolic activity (24).

HAMARTOMA

Splenic hamartomas are rare benign lesions most often discovered incidentally in asymptomatic patients. No age- or sex-related predilection was observed. Moreover, splenic hamartomas can be associated with hamartomas in other parts of the body, particularly in connection with conditions such as tuberous sclerosis and Wiscott-Aldrich-like syndrome (21, 22).

Grossly, hamartoma is a well-circumscribed, unencapsulated, bulging, dark-red lesion. Fibrosis, hemorrhage, and calcification can also occur, particularly in long-standing lesions (25). Histologically, splenic hamartomas consist solely of red pulp which includes blood-filled cavities (venous sinuses) and splenic cords, but lacks normal white pulp elements (21).

On multimodal imaging, most hamartomas appear as solitary, well-circumscribed, solid hypervascular masses similar to the splenic red pulp. On US, splenic hamartoma typically appears as a homogeneous, well-demarcated mass that is hyperechoic to the surrounding normal spleen. Color Doppler imaging reveals increased blood flow within the mass (12). Identifying a splenic hamartoma on non-contrast CT is difficult because it demonstrates the isoattenuation of the adjacent splenic parenchyma. Additionally, large lesions may present with contour abnormalities as the only detectable finding on non-contrast CT (26). Dynamic contrast-enhanced CT and MRI demonstrate early arterial enhancement and persistent delayed enhancement that equilibrates with the background spleen (Fig. 11) (26). On MRI, splenic hamartomas typically appear isointense to the spleen on T1-WI and mildly hyperintense on T2-WI (26). Calcifications and cystic changes may also be present (24, 26).

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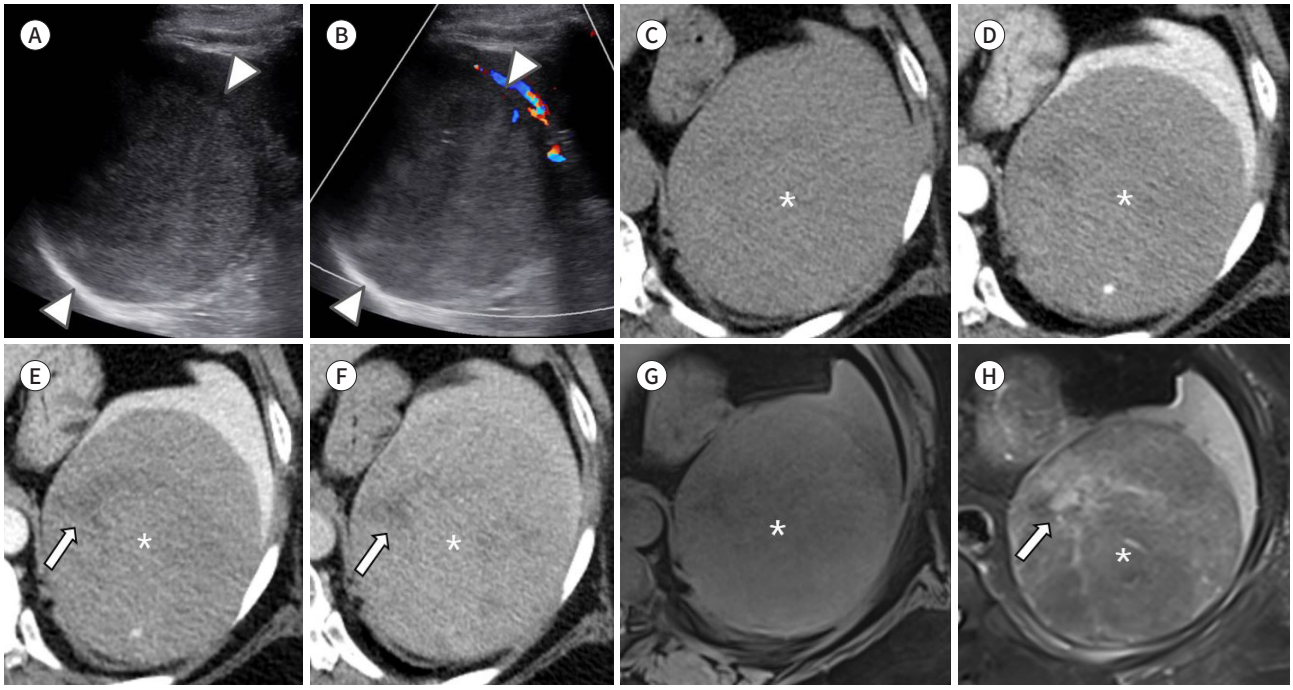
Fig. 10. Hemangioma in a 58-year-old female with epigastric discomfort.
A, B. US demonstrates an 11 cm-sized heterogeneous iso to hyperechoic solid mass (arrowheads) without increased internal vascularity on color Doppler US (B).
C-F. Axial dynamic contrast-enhanced CT images (pre-contrast (C), arterial (D), portal (E), venous (F) phase) demonstrate a well-defined hypoattenuating solid mass (*) with gradual enhancement. The region of interest within this mass demonstrates Hounsfield Unit values of 45 in the pre-contrast phase, 65 in the arterial phase, 72 in the portal phase, and 87 in the venous phase. A non-enhancing area is observed in the central portion of the mass (E, F, arrows).
G. Axial non-contrast T1-weighted image demonstrates that the mass (*) is isointense.
H. Axial fat-saturated T2-weighted image shows that the mass (*) is heterogeneously iso to slightly hyperintense. The non-enhancing area in the central portion of the mass on CT images (E, F, arrows) displays T2 hyperintensity (H, arrow), which is considered to be cystic or myxoid degeneration.
Histology confirmed the diagnosis of hemangioma as determined by splenectomy.



SCLEROSING ANGIOMATOID NODULAR TRANSFORMATION

Sclerosing angiomatoid nodular transformation (SANT) of the spleen is a rare benign vascular tumor-like lesion with unclear pathogenesis (21). The lesion is usually discovered incidentally in asymptomatic patients but can occasionally present with anemia, thrombocytopenia, or splenomegaly. Most affected patients are middle-aged adults, with a slight female predominance (27).

Histologically, SANT manifests as a well-circumscribed, non-encapsulated, solitary mass consisting of multiple red-brown nodules derived from the splenic red pulp. These multiple nodules are enveloped within a dense fibrous stroma, often with a central tan-white stellate scar (Fig. 12) (21, 28, 29).

On imaging, SANT typically presents as a solitary, lobulated, well-defined lesion with a distinctive spoke-wheel like enhancement pattern, characterized by early peripheral rim enhancement and radiating bands of progressive centripetal enhancement (28-30). On T2-WI, these lesions typically exhibit hyperintensity at the periphery, hypointensity at the center, and the presence of hypointense radiating bands extending toward the center of the lesion,

Fig. 11. Harmartoma in a 31-year-old male associated with left flank pain.
A. Axial arterial phase CT image displays a 4 cm-sized well-marginated early hyperenhancing mass (arrow).
B, C. Axial portal (B) and venous (C) phase CT images demonstrate persistent delayed enhancement of the mass (arrows), equilibrating with that of the spleen.
Histology confirmed the diagnosis as hamartoma, as determined by splenectomy.

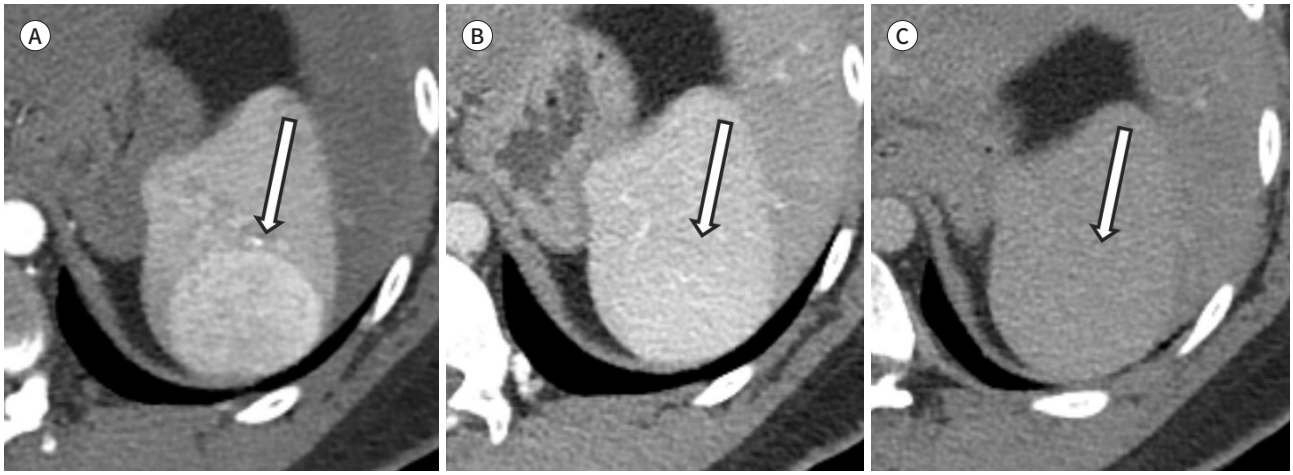
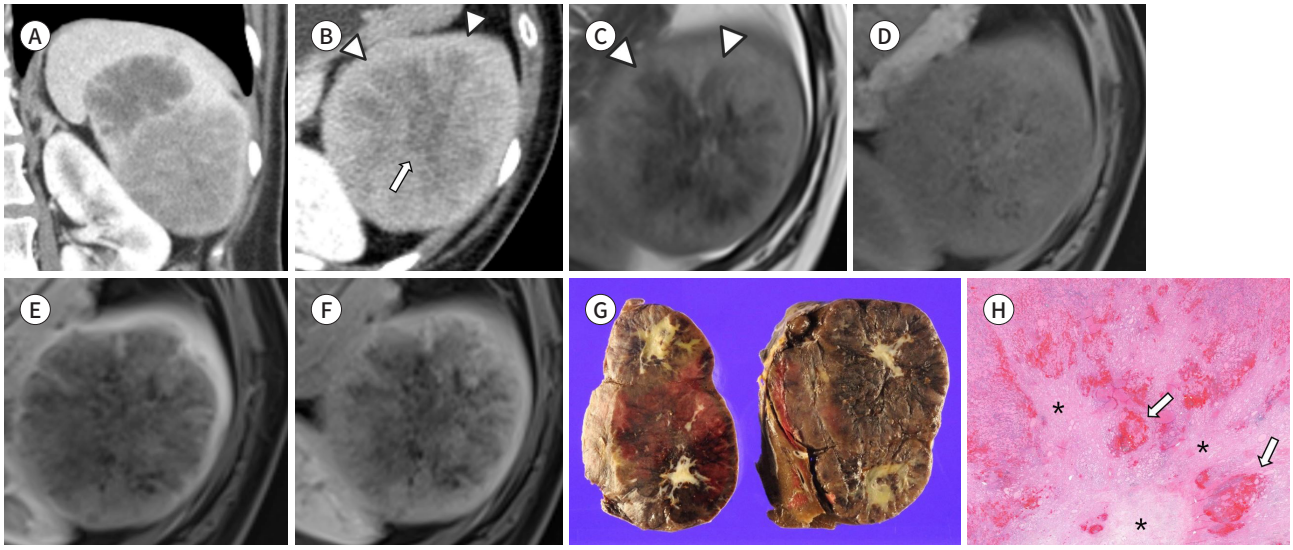


Fig. 12. A 47-year-old female with incidentally found SANT.
A. Coronal contrast-enhanced CT image displays two conglomerated hypodense splenic masses with lobulated contours.
B. On axial contrast-enhanced CT image, the largest mass displays a central hypodense scar (arrow) with a radiating hypodense band penetrating from the periphery toward the center of the mass (arrowheads).
C. T2-weighted MR image exhibits a spoke-wheel pattern of the mass that is predominantly hyperintense at the periphery and has hypointense radiating bands extending toward the center of the mass (arrowheads).
D-F. Axial dynamic contrast-enhanced T1-weighted MR images (pre-contrast (D), arterial (E), venous (F) phase) demonstrate progressive centripetal enhancement, described as a spoke-wheel pattern.
G. The gross specimen displays two conglomerated, well-circumscribed firm multinodular masses, each composed of blood-filled red-brown nodules with a central stellate tan-white fibrous scar.
H. Histopathological image displays multiple angiomatoid nodules filled with red blood cells (arrows) and internodular band-like fibrous stroma (*) (hematoxylin and eosin staining, ×20).
Histology confirmed the diagnosis as SANT undertaken by splenectomy.
SANT = sclerosing angiomatoid nodular transformation



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which correspond to fibrous stroma (Fig. 12). Furthermore, hypointensity on both T2-WI and diffusion-weighted images suggests the presence of hemosiderin deposition and fibrous tissues (28).

ANGIOSARCOMA

Splenic angiosarcomas are the most common primary malignant vascular neoplasm of the spleen. They arise from the endothelial lining of splenic blood vessels (31).

Symptoms include weight loss, abdominal pain, malaise, fever, a palpable abdominal mass, and hypovolemic shock due to splenic rupture (12). Angiosarcomas are highly aggressive lesions with a high mortality rate, and metastases are frequently observed at the time of diagnosis (32-34).

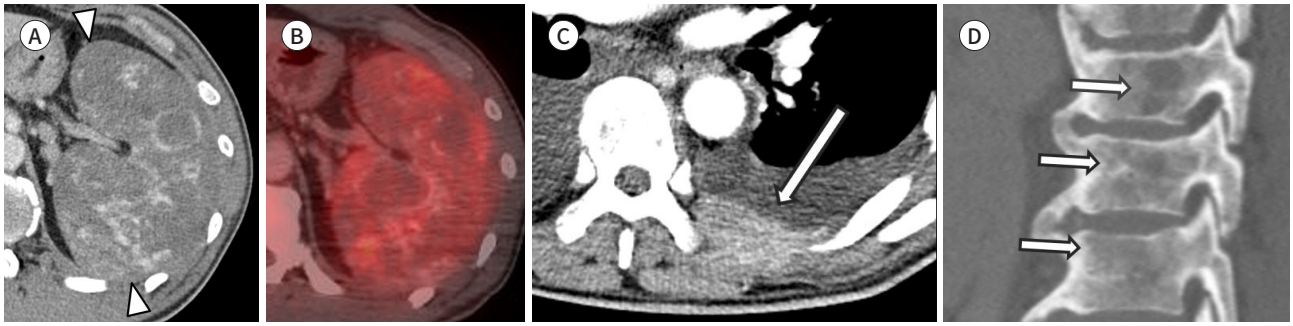
On imaging, angiosarcomas can appear as solitary or multiple, poorly defined, heterogeneous nodular masses owing to the presence of both solid components and areas of hemorrhage, necrosis, or calcification. Additionally, angiosarcoma can sometimes appear as a large heterogeneous lesion that completely replaces most of the splenic parenchyma. (Fig. 13) (8, 12). The US typically displays splenomegaly with heterogeneous echogenic masses. Increased flow in bizarre and dilated vascular channels can be observed on color Doppler US. Contrast enhancement and MRI signal intensity vary depending on the presence of blood products and the degree of tumor necrosis (34).

SOLITARY SOLID NON-/HYPOVASCULAR LESIONS

INFLAMMATORY PSEUDOTUMOR

Inflammatory pseudotumor (IPT) is rare benign entities with a diverse spectrum of biological behaviors and are composed of a mixture of inflammatory, myofibroblastic spindle, and plasma cells. Grossly, IPT is a well-circumscribed yellow-white or tan mass, with areas of necrosis, hemorrhage, and fibrosis (35, 36).

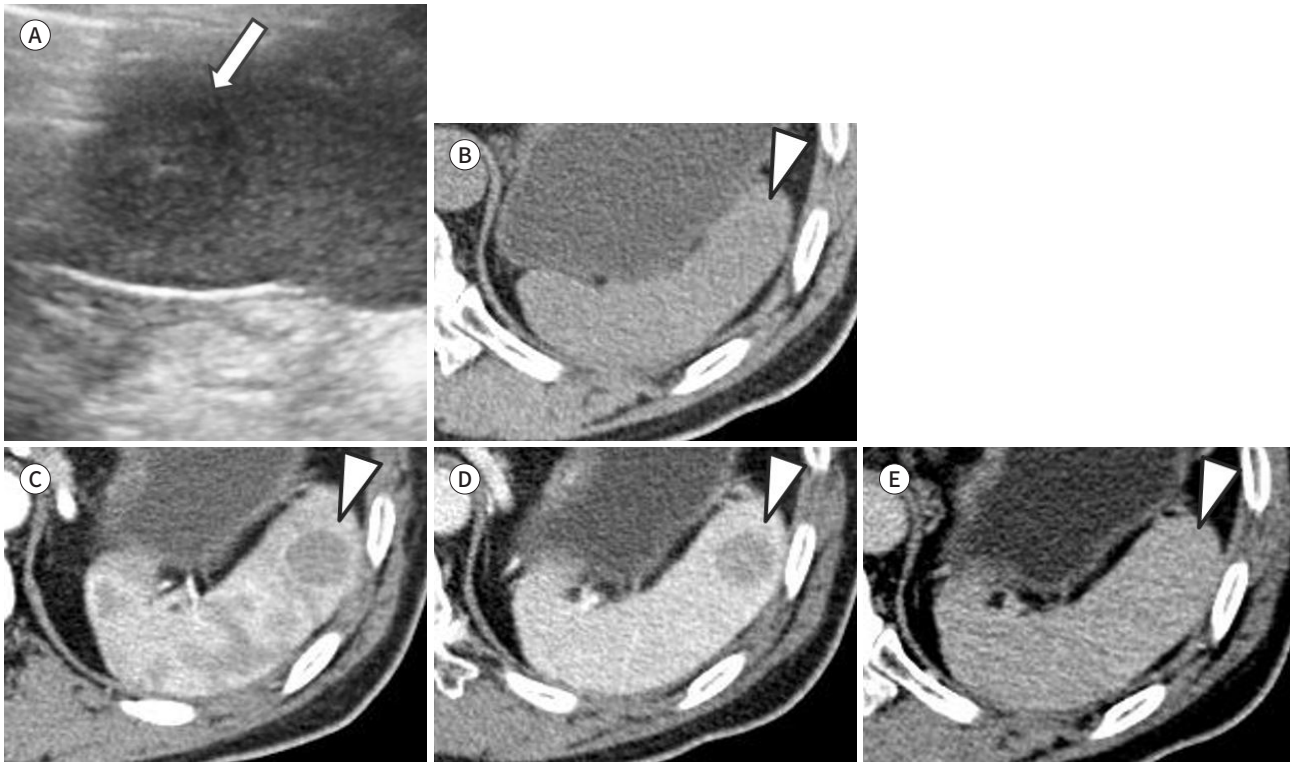
Fig. 13. Littoral cell angiosarcoma in a 54-year-old male, who presented with pathologic fracture of T-spine.
A. Axial contrast-enhanced CT image displays multiple conglomerated peripheral enhancing splenic masses (arrowheads) throughout the enlarged spleen.
B. Fluorodeoxyglucose-PET/CT image exhibits multiple hypermetabolic splenic masses (up to SUVmax 6.3).
C, D. In addition, an enhancing soft tissue mass (C, arrow) can be observed on the inner aspect of the left seventh proximal rib. Multiple osteolytic lesions are visible on the spine (D, arrows).
Histology confirmed the diagnosis of metastatic littoral cell angiosarcoma of the spleen, which was undertaken by needle biopsy of a soft tissue mass at the inner aspect of the left seventh proximal rib.
SUVmax = maximum standardized uptake value



Although the exact etiology is unknown, infection, infarction, and radiation exposure have been linked to IPT as potential contributing factors (35, 37). Although uncommon in the spleen, they can occur throughout the body. Splenic IPT is most often observed in middle-aged and older patients. The lesion is strongly associated with Epstein-Barr virus (EBV) infections (35, 36). The clinical presentation of IPT varies, ranging from asymptomatic to symptoms such as abdominal pain, weight loss, fever, splenomegaly, anemia, and elevated levels of inflammatory markers (21, 38).

Splenic IPT exhibits nonspecific and diverse radiological findings. Size and enhancement patterns may demonstrate chronological changes depending on the dynamic course of the inflammatory process (39, 40). On US, IPT usually appears as a solitary, well-circumscribed, hypoechoic, solid mass (Figs. 14, 15) (41, 42). The lesion is usually isoattenuated on non-contrast CT and demonstrates delayed enhancement (Fig. 14). Varying patterns of calcification such as rim-like or stippled shapes may be present (42, 43). On MRI, IPT may appear isointense to hypointense on T1-WI, with heterogeneous signal intensity on T2-WI and delayed enhancement. Moreover, IPTs can have a central fibrous scar, which appears as central low attenuation on CT and T2 hypointense area on MRI. The scar also demonstrates central de-

Fig. 14. A 63-year-old female with an inflammatory pseudotumor and a history of liver cirrhosis.
A. US displays a 2 cm-sized heterogeneously iso- to hypoechoic solid lesion (arrow).
B-E. Axial dynamic contrast-enhanced CT images (pre-contrast (B), arterial (C), portal (D), venous (E) phase) display a 2 cm-sized well-defined round homogeneous hypoattenuating lesion (arrowheads) with gradual enhancement. The region of interest within this mass demonstrates Hounsfield Unit values of 42 in the pre-contrast phase, 75 in the arterial phase, 90 in the portal phase, and 112 in the venous phase.
As this was a newly developed solid mass, malignant or inflammatory lesions were initially suspected.
Histology confirmed the lesion as an inflammatory pseudotumor, based on the results of the needle biopsy.



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layed enhancement (43, 44).

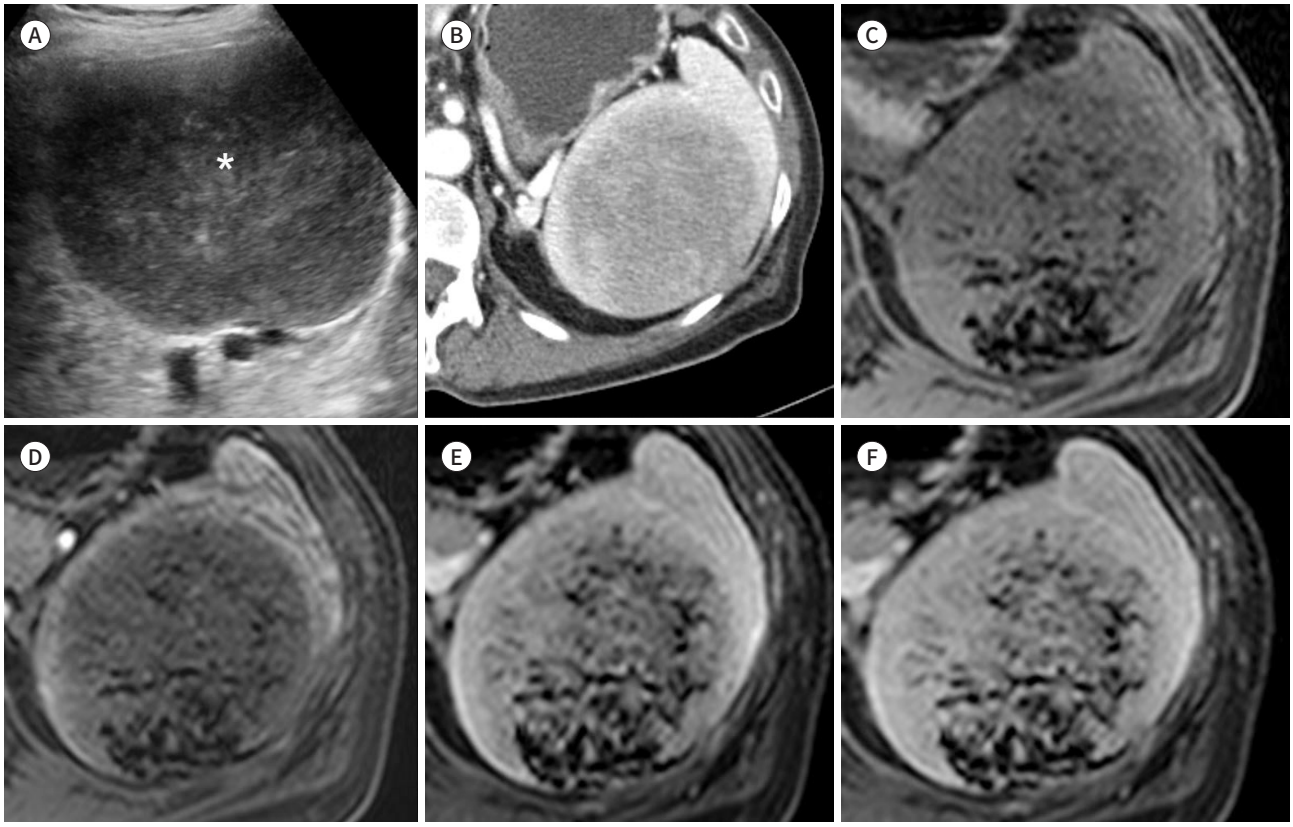
Although IPT is a benign entity with a favorable prognosis, it tends to mimic malignancies clinically and radiologically. IPT may exhibit local recurrence, and in rare cases, distant metastases. Therefore, careful follow-ups are required (37, 45).

LYMPHOMA

Lymphoma is the most common malignant tumor of the spleen. Secondary involvement is much more common, with approximately 30%–40% of patients with lymphoma demonstrating splenic involvement. Primary splenic lymphoma, defined as lymphoma confined to the spleen and perisplenic lymph nodes, is rare (<1%) (8, 11).

Splenic lymphoma has a variety of imaging features, ranging from a normal appearance with only microscopic lesions, diffuse infiltration with homogeneous or heterogeneous splenomegaly without discrete lesions (Fig. 16), to solitary or multiple variable-sized nodules (from miliary patterns to bulky masses) (Figs. 17-19) (46). These diverse imaging features are influenced by distinct growth patterns that vary according to the type of lymphoma. For instance, in small B-cell lymphomas such as splenic marginal zone B-cell lymphoma, small

Fig. 15. A 78-year-old female with incidentally identified inflammatory pseudotumor.
A. US displays an 8 cm-sized heterogeneously iso- to hypoechoic solid mass (*).
B. Axial contrast-enhanced CT image reveals an 8 cm-sized well-defined round heterogeneous hypoattenuating mass.
C-F. Axial dynamic contrast-enhanced T1-weighted MRI (pre-contrast (C), arterial (D), portal (E), venous (F) phase) displays gradual enhancement of mass with internal amorphic low signal intensity.
Histology confirmed the lesion as an inflammatory pseudotumor undertaken by needle biopsy.



lymphocytes disseminate through the tissue in a miliary pattern that replaces the white pulp or shows diffuse proliferation of the marginal zone of the white pulp, resulting in splenomegaly without discrete nodules (Fig. 16). In contrast, large B-cell lymphomas and Hodgkin's lymphomas frequently involve the white pulp and typically lead to the formation of single or multiple discrete masses in the spleen (Figs. 17-19) (47-50).

Discrete lesions typically appear hypoechoic on US and exhibit low attenuation on CT with poor enhancement, which is best observed during portal venous-phase imaging. On MRI, discrete lesions demonstrate low-to-intermediate signal intensity on T1-WI and mild-to-moderate signal intensity on T2-WI. Furthermore, lymphomas present with elevated restricted diffusion compared to that of the surrounding normal splenic tissue. Although calcification is uncommon, it might be seen after treatment. Lymphomas exhibit mild to marked FDG avidity on FDG PET/CT (Figs. 16, 19) (7).

MULTIPLE SOLID LESIONS

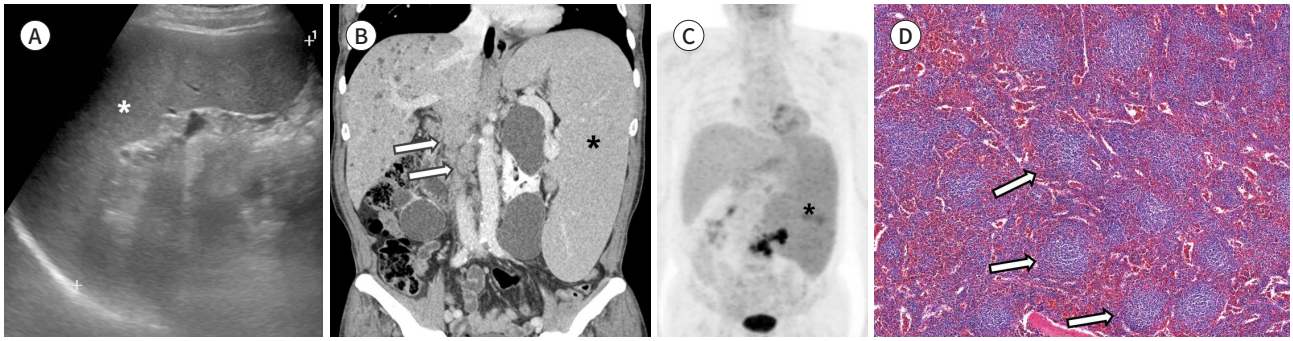
LITTORAL CELL ANGIOMA

Littoral cell angioma is a rare benign vascular neoplasm that arises from the littoral cells lining the sinus channels of the splenic red pulp (21). The lesion occurs mainly in adults without sex preference. Littoral cell angioma is most often discovered incidentally in asymptomatic individuals. However, in some cases, signs of hypersplenism, such as splenomegaly, anemia, or thrombocytopenia, may be present (21). The lesion is usually benign, although variants with malignant histology have been described (12).

Histologically, littoral cell angiomas present as multiple spongy and cystic nodules that are distinguishable from the background splenic tissue. These nodules consist of multiple irregular cystic vascular channels lined with tall endothelial cells (Fig. 20) (21).

Littoral cell angiomas manifest as multiple nodules on imaging studies due to the tumor's

Fig. 16. Lymphoma in a 65-year-old male with incidentally discovered lymphoma splenomegaly on routine US.
A. US displays severe splenomegaly (*) without focal splenic lesion.
B. Coronal contrast-enhanced CT image displays severe splenomegaly (*) with multiple variable-sized intraabdominal lymph nodes (arrows).
C. Maximum intensity projection FDG-PET image demonstrates mild increased FDG uptake in the splenic parenchyma with splenomegaly (*).
D. Histopathology displaying proliferation of small lymphocytes that predominantly surround and replace the splenic white pulp (arrows). Some sinusoidal infiltration of the red pulp is also evident (hematoxylin and eosin staining, ×100).
Histology confirmed the diagnosis as marginal zone B-cell lymphoma, as determined by splenectomy.
FDG = fluorodeoxyglucose



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diffuse involvement of the spleen, comprising nodular masses of red pulp elements (12). On US, the appearance of lesions can vary, ranging from splenomegaly with a mottled echotexture to multiple solid hypo-, iso-, or hyperechoic nodules (6). On CT scans, littoral cell angiomas present as multiple low-attenuating lesions that appear hypoenhanced during the arte-

Fig. 17. Lymphoma in a 54-year-old male with a newly developed splenic lesion on follow-up CT for stomach cancer.
A. US displays a 2 cm-sized hypoechoic nodule in the spleen (arrow).
B. Axial contrast-enhanced CT image displays a 2 cm-sized ill-marginated hypoattenuating nodule (arrow) in the spleen and splenomegaly with heterogeneous parenchymal enhancement. Considering these imaging features and the clinical history of stomach cancer, metastasis or lymphoproliferative diseases such as lymphoma were initially suspected.
Histological examination confirmed classical Hodgkin lymphoma after splenectomy.

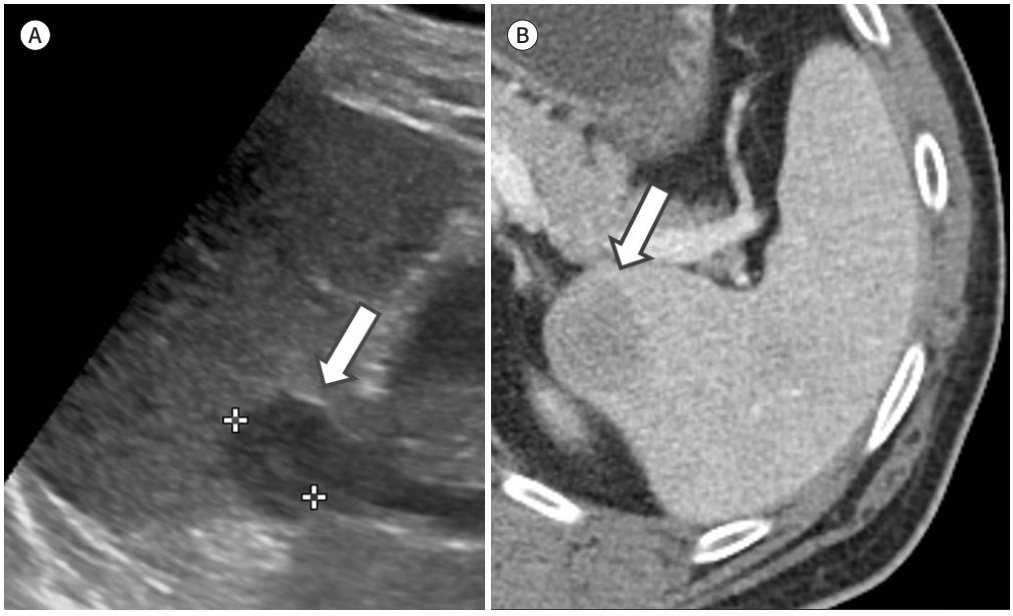


Fig. 18. Lymphoma in a 54-year-old female who presented with weight loss and fatigue.
A. US displays multiple small hypoechoic nodules (arrows) in the spleen, less than 1.3 cm in size.
B, C. Axial contrast-enhanced CT image displays multiple small hypoenhancing splenic nodules (arrows).
D. Axial T2-weighted MRI displays multiple hyperintense splenic lesions (arrows).
Considering the multifocal splenic lesions, lymphoma, metastases, and granulomatous disease were initially suspected.
Histology confirmed a diffuse large B-cell lymphoma on core needle biopsy.

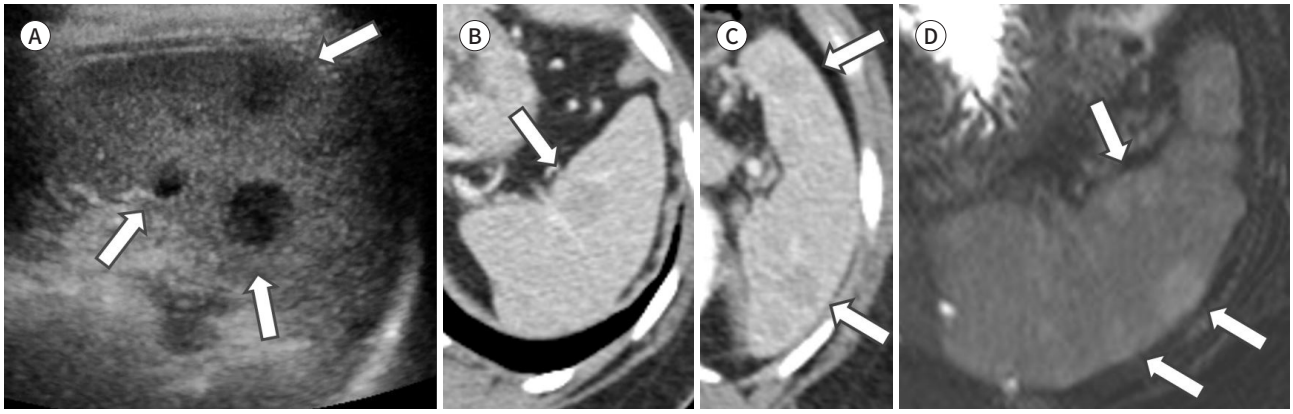


Fig. 19. Lymphoma in a 65-year-old male who presented with abdominal discomfort.
A. US displays a huge heterogeneous hypoechoic lesion (arrowheads) with splenomegaly.
B. Axial contrast-enhanced CT image displays hypoattenuating splenic lesion larger than 15 cm (arrowheads) with splenomegaly and multiple enlarged intraabdominal lymph nodes (arrow).
C. Fluorodeoxyglucose-PET/CT displays a large hypermetabolic splenic mass (SUVmax 29.0) (arrowheads) with splenomegaly and multiple enlarged hypermetabolic lymph nodes (arrow).
Histology confirmed the diagnosis as a diffuse large B-cell lymphoma on core needle biopsy.
SUVmax = maximum standardized uptake value

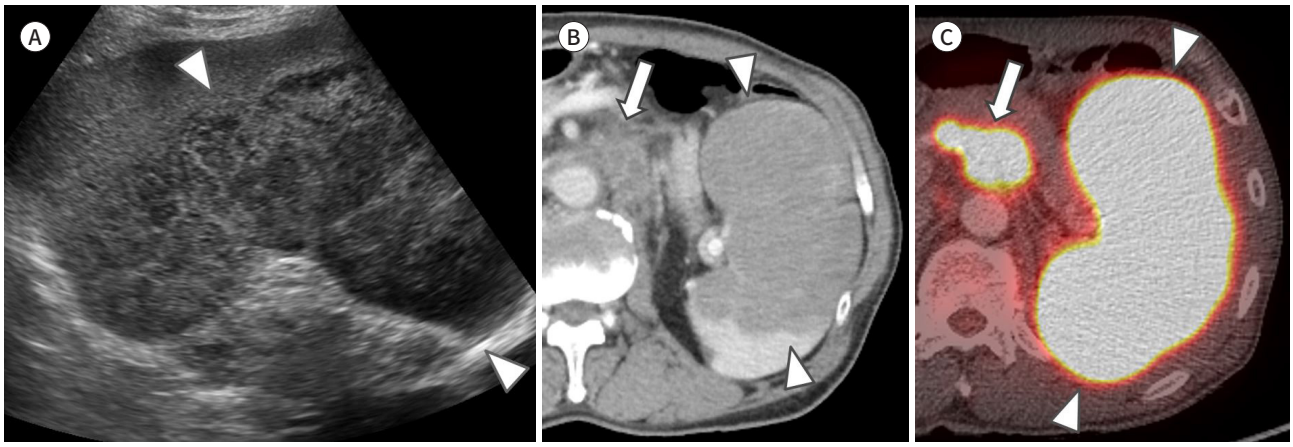
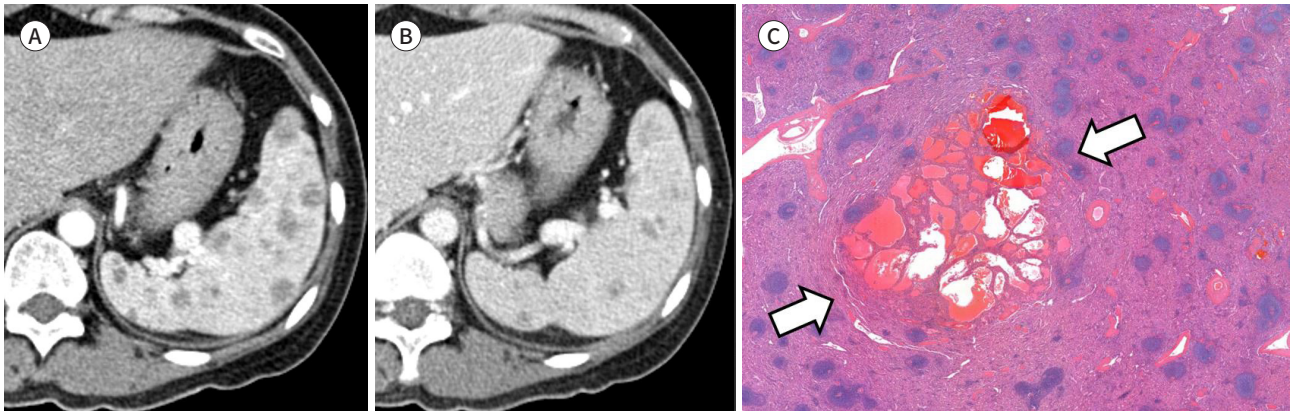


Fig. 20. A 40-year-old female was incidentally found to female with incidentally found littoral cell angioma.
A, B. Axial contrast-enhanced CT image on arterial phase (A) displays multiple variable-sized ill-marginated low attenuating lesions in the spleen. As these lesions gradually enhance, they exhibit iso to hypoattenuation relative to normal parenchyma during the portal phase (B).
C. Histopathology demonstrates ill-defined nodules (arrows) composed of irregular cystic vascular channels filled with red blood cells. (hematoxylin and eosin staining, ×10).
Histology confirmed the diagnosis as littoral cell angioma, as determined by partial splenectomy.



rial and portal venous phases. On delayed-phase images, the lesions display homogeneous isoenhancement compared to the surrounding spleen (Fig. 20) (51). MRI may demonstrate T1 hypointensities with progressive enhancement. The T2 signal intensity varies from low, probably due to hemosiderin accumulation, to high, reflecting its cellularity (12, 52).

METASTASIS

Splenic metastasis is a relatively rare finding in imaging studies and is more commonly discovered during autopsy. Furthermore, splenic metastasis is usually part of a widespread meta-

static disease. The condition can present as single or multiple solid or cystic masses and may rarely be infiltrative. The most common primary sources of splenic metastasis are melanoma, and ovarian, breast, lung, and gastric cancers (16, 53).

On US, splenic metastasis typically presents as one or more well-defined hypoechoic masses. On CT, it appears as a hypodense mass which may include a cystic component (Fig. 21). On MRI, splenic metastasis appears as a hypointense mass on T1-WI and a hyperintense mass on T2-WI, with a varying contrast enhancement pattern depending on the primary tumor (16, 53).

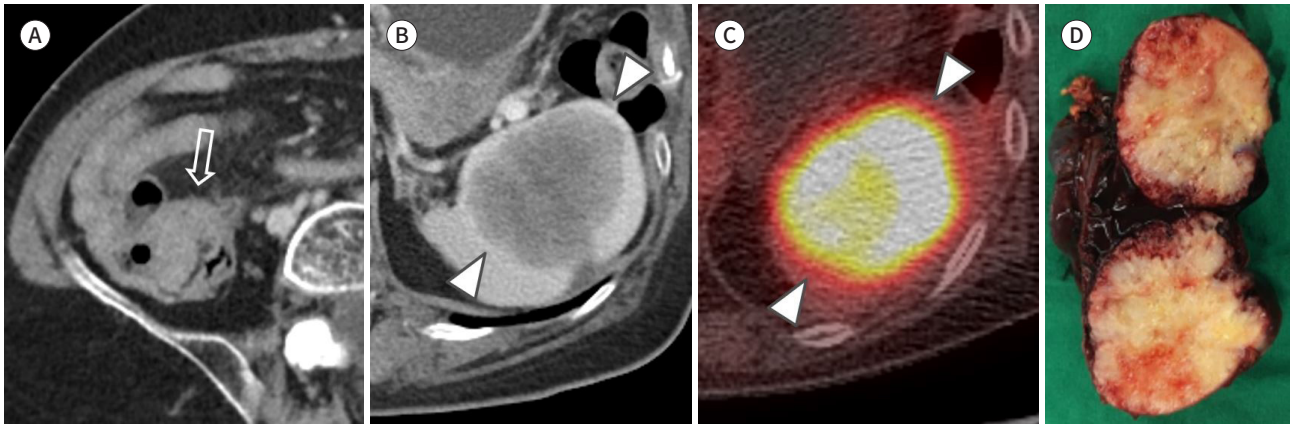
RARE DISEASE

EXTRAPLEURAL SOLITARY FIBROUS TUMOR

Extrapleural solitary fibrous tumor, formerly referred to as "hemangiopericytoma," is a rare soft tissue vascular tumor arising from capillary pericytes. Although mostly benign, these tumors have malignant potential (54-56). Tumors can occur throughout the body, including within the capillaries, with a notable prevalence in the pelvic retroperitoneum, excluding the pleura. Although tumors can originate in the spleen, such cases are extremely rare (57). The extrapleural solitary fibrous tumor occurs mainly in adults aged 20–70 years without a gender preference. Patients with extrapleural solitary fibrous tumors present with various clinical signs, such as pain, lump, rupture, and hemorrhage (31, 58, 59, 60).

Imaging reveals a large, well-defined, multilobulated mass that is highly vascularized (31). The presence of large collateral feeding vessels is a key feature that can help distinguish a solitary fibrous tumor (61). Necrosis, calcification, common in large tumors (Fig. 22), and invasion of adjacent structures are suggestive of malignancy (62).

Fig. 21. Splenic metastasis in a 68-year-old female with cecal cancer.
A. Axial contrast-enhanced CT image displays a soft tissue mass (arrow) in the cecum. She underwent a right hemicolectomy and was diagnosed with cecal adenocarcinoma.
B. A follow-up axial contrast-enhanced CT image acquired 2 years later displays a poorly enhancing splenic mass 6 cm in size (arrowheads).
C. Fluorodeoxyglucose-PET/CT image displays a large hypermetabolic splenic mass (SUVmax 12.7) (arrowheads).
D. The gross specimen demonstrates a well-demarcated solid whitish splenic mass.
Histology confirmed the diagnosis as metastatic adenocarcinoma from cecal cancer, as determined by splenectomy.
SUVmax = maximum standardized uptake value



HISTIOCYTIC SARCOMA

Histiocytic sarcomas are rare hematopoietic tumors characterized by morphological and immunophenotypic features of mature histiocytic cells (63-65). The sarcoma commonly affects the intestinal tract but can also occur in the lymph nodes, skin, and other extranodal sites. The clinical presentation of histocytic sarcoma varies from localized to widespread dissemination. Additionally, the sarcoma is potentially lethal with a poor prognosis.

Imaging features of histiocytic sarcomas have been described in a limited number of case reports. This type of sarcoma may demonstrate splenomegaly with normal parenchymal texture or diffuse patchy parenchymal infiltration. These tumors may appear as solitary or multiple hypodense masses (Fig. 23) and can also exhibit multiple hepatic infiltrations (63-65).

FOLLICULAR DENDRITIC SARCOMA

Follicular dendritic sarcoma is a rare, low-grade sarcoma that is primarily identified in the lymph nodes, although the sarcoma can also occur in other parts of the body, such as the head and neck, spleen, liver, gastrointestinal tract, mediastinum, and breasts. Splenic involvement is often associated with EBV infection and has an IPT-like form. Tumors in the abdominal cavity, including those in the spleen, tend to be aggressive and prone to distant metastasis.

Fig. 22. Extrapleural solitary fibrous tumor in a 35-year-old female presenting with nausea and malaise.
A-D. Axial dynamic contrast-enhanced CT images (pre-contrast (A), arterial (B), portal (C), venous (D) phase) display a 7.8 cm-sized multilobulated splenic mass with large irregularly shaped dense calcification (arrowheads). The mass exhibits intense enhancement in the central portion (black arrows) and faint enhancement in the peripheral portion (white arrows) across different phases.
E. The gross specimen displays a well-circumscribed, non-encapsulated mass, demonstrating extensive hyalinization, dystrophic calcification, and hemorrhage.
Histology confirmed the diagnosis as an extrapleural solid fibrous tumor, as determined by splenectomy.

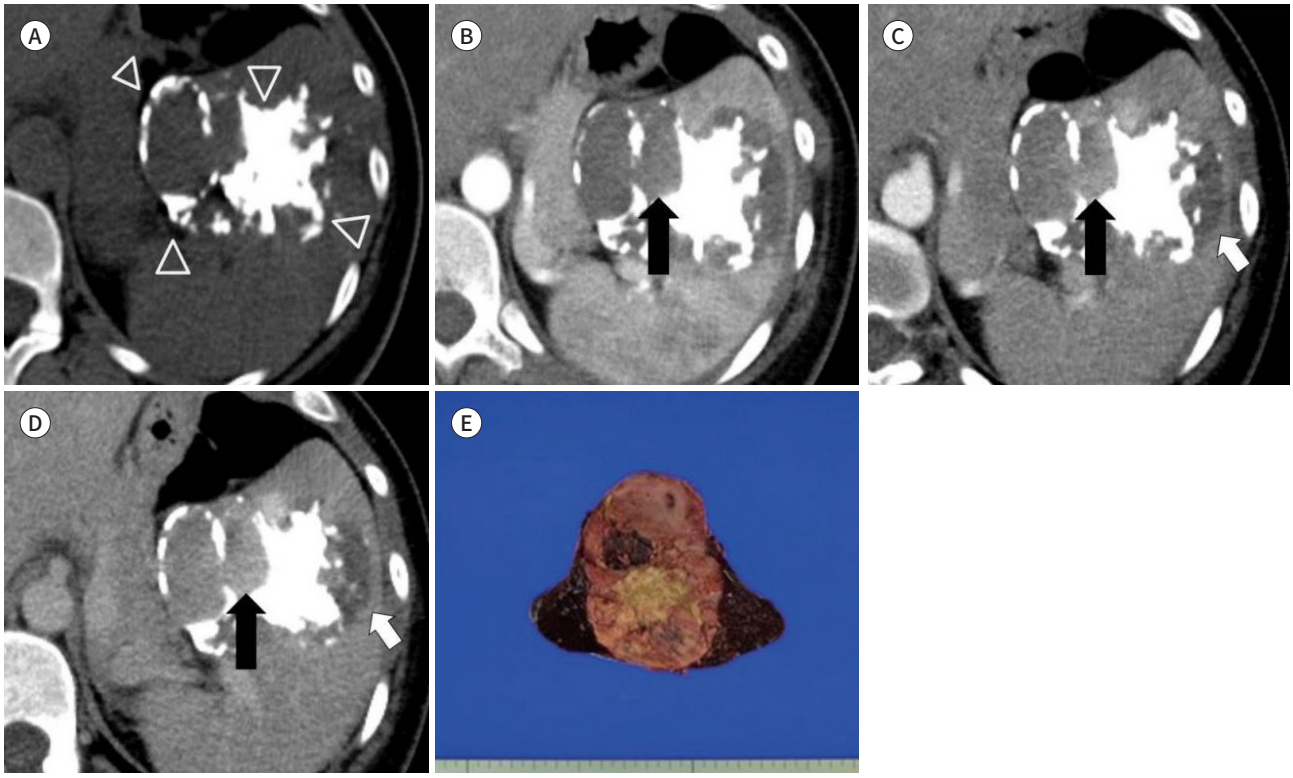


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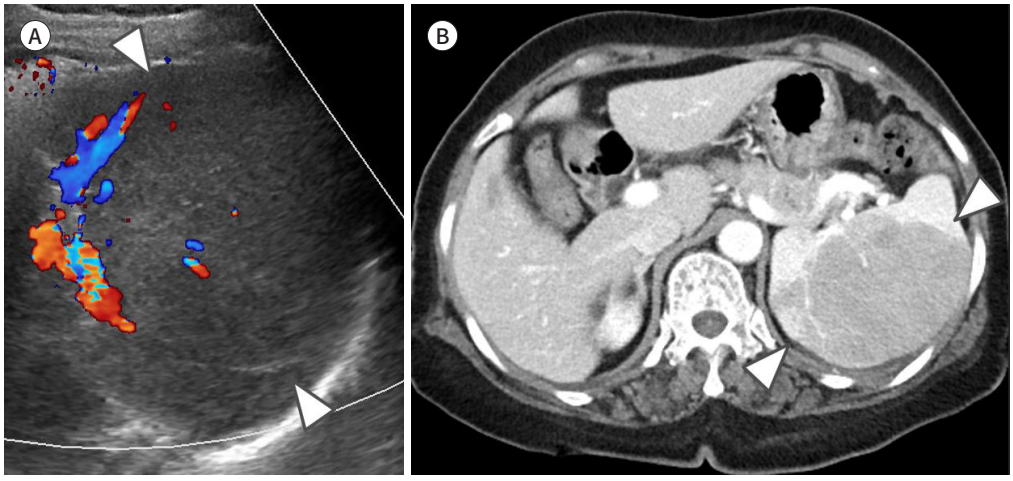
Fig. 23. Histiocytic sarcoma in an 83-year-old female with weight loss and bicytopenia.
A. US displays a huge ill-defined isoechoic lesion (arrowheads) with splenomegaly.
B. Axial contrast-enhanced CT image displays a heterogeneously hypoattenuating splenic lesion more than 10 cm in size (arrowheads) that replaces almost the entire spleen.
Histology confirmed the diagnosis as histiocytic sarcoma, as determined by splenectomy.



However, patients are often asymptomatic (40, 66).

Imaging features of follicular dendritic sarcomas are not well established. On CT, the sarcoma may appear as a well-circumscribed, hypodense mass with internal calcification and relatively homogeneous enhancement, except for necrotic areas (Fig. 24). On MRI, follicular dendritic sarcoma can appear as an isointense mass on T1-WI and as a hypointense mass on T2-WI (66).

GRANULOCYTIC SARCOMA

Granulocytic sarcoma, also known as myeloid sarcoma, chloroma, or extramedullary myeloid tumor, is a rare type of extramedullary mass composed of myeloid precursor cells. Moreover, granulocytic sarcoma is most observed in myelogenous leukemia, with up to 21% of patients presenting with this type of sarcoma after allogeneic bone marrow transplantation. Granulocytic sarcoma is more frequently observed in children, with 60% of cases occurring in children aged <15 years. This particular sarcoma can involve any part of the body, with the most common sites being the breasts, subcutaneous tissues, and bones (67, 68).

Imaging features of granulocytic sarcoma typically appear as a soft-tissue nodule or mass, or as a diffuse infiltrative process (Fig. 25). The appearance of granulocytic sarcomas on US, CT, and MRI is often similar to that of lymphomas (67, 68). The prognosis varies depending on the underlying condition. In patients with acute leukemia, the prognosis was not significantly impacted. However, the prognosis is poor in patients with chronic leukemia or myeloproliferative disorders. On the other hand, granulocytic sarcoma is very sensitive to focal radiation therapy or chemotherapy and can resolve completely in less than 3 months. However, recurrence has been reported in 23% of the patients (67, 68).

Fig. 24. A 76-year-old female with incidentally identified follicular dendritic sarcoma.
A. Axial contrast-enhanced CT image displays a 10 cm-sized heterogeneously enhancing mass (arrowheads) with internal calcification (arrow) and central non-enhancing portion suggesting necrosis.
B. Fluorodeoxyglucose-PET/CT image displays a large hypermetabolic splenic mass (SUVmax 8.2) (arrowheads).
Histology confirmed the diagnosis as follicular dendritic sarcoma, as determined by splenectomy.
SUVmax = maximum standardized uptake value

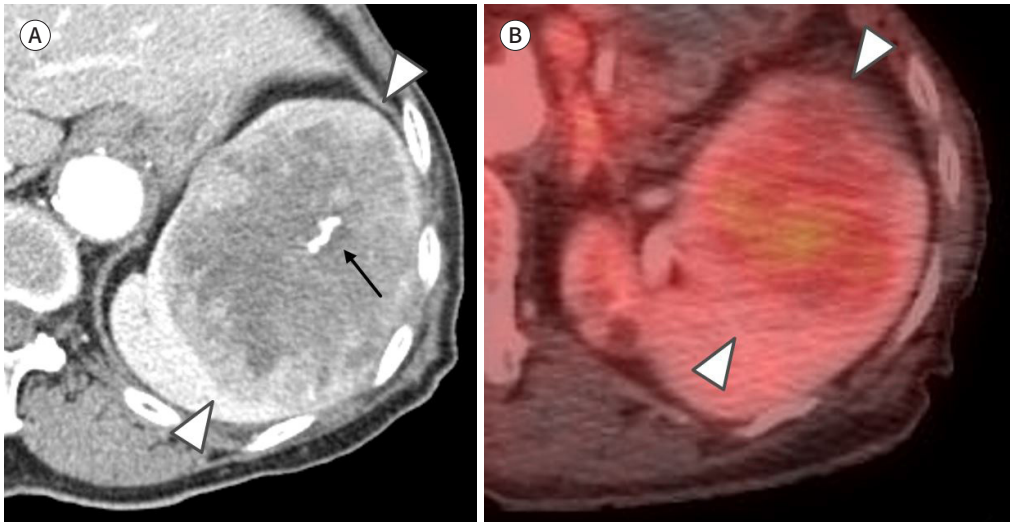
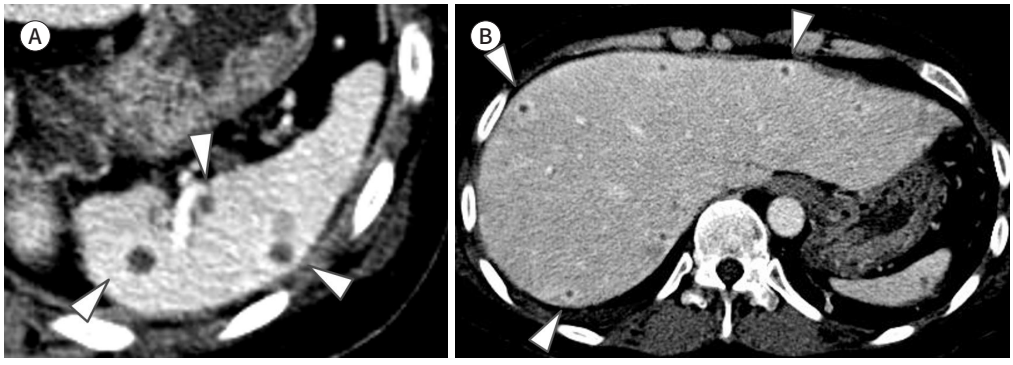


Fig. 25. Granulocytic sarcoma in an 83-year-old female with abdominal pain and a history of leukemia.
A. Axial contrast-enhanced CT image displays multiple small low attenuating lesions in the spleen with rim enhancement (arrowheads). These lesions are new and were not present previously.
B. In addition, multiple low attenuating lesions with rim enhancement (arrowheads) are observed in the liver in the axial contrast-enhanced CT image.
Histology confirmed granulocytic sarcoma on a liver biopsy. Therefore, the splenic lesions were also considered to be granulocytic sarcomas.



MANAGEMENT

Integrating imaging findings with clinical information can assist in formulating a pertinent differential diagnosis and can guide suitable treatment. The proposed algorithm, which is derived from imaging features and clinical symptoms, is illustrated in Fig. 26. Initially, patients were categorized into three groups: asymptomatic, symptomatic with pain related to the splenic lesion, or symptomatic with systemic symptoms or manifestations (69).

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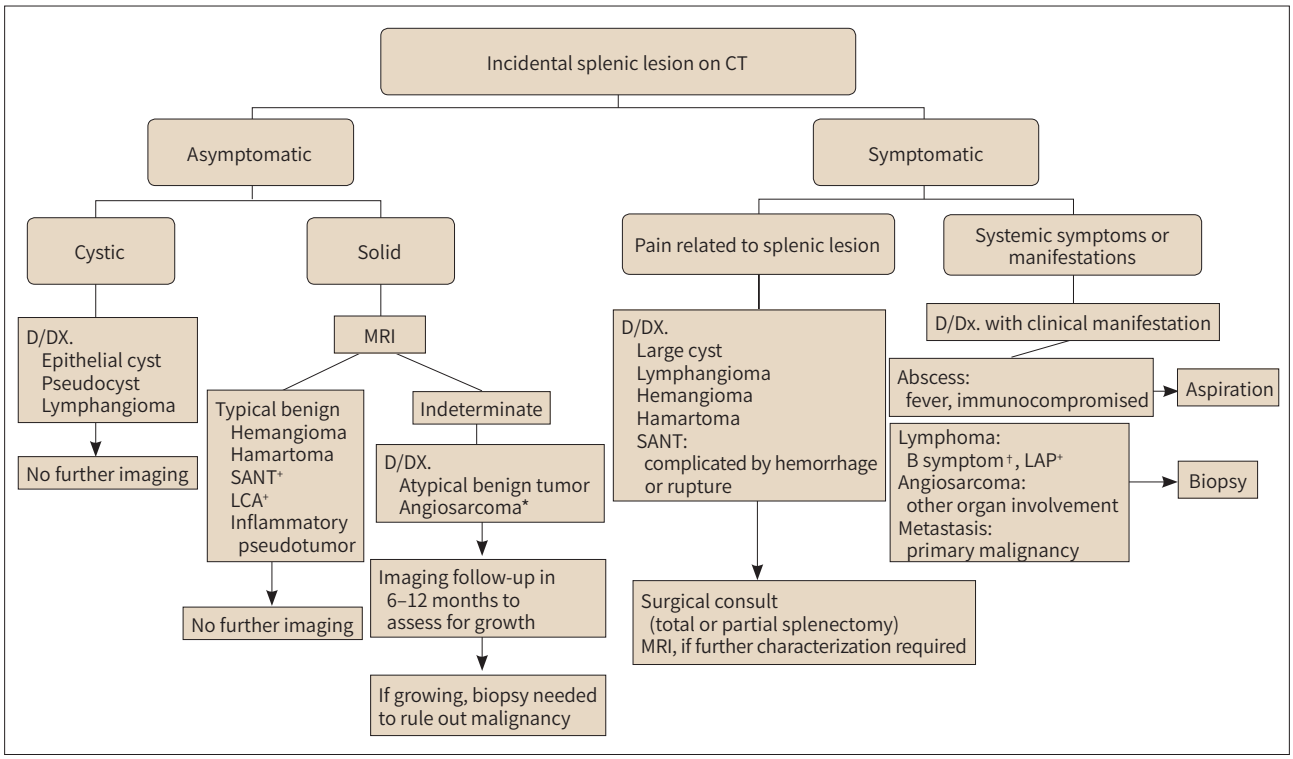
Fig. 26. The diagram illustrates an algorithmic approach to managing an incidental splenic lesion on CT, which incorporates imaging findings and clinical symptoms.



*The incidence of asymptomatic angiosarcoma is exceedingly rare.
†Fever, night sweats, and unintentional weight loss.
D/Dx = differential diagnosis, LAP = lymphadenopathy, LCA = littoral cell angioma, SANT = sclerosing angiomatoid nodular transformation

For asymptomatic patients, the proposed algorithm distinguishes between cystic and solid lesions. Cystic lesions were differentially diagnosed as epithelial cysts, pseudocysts, or lymphangiomas. Typically, benign cystic lesions do not require further evaluation or follow-up imaging (70).

In contrast, contrast-enhanced MRI may be necessary for further characterization of asymptomatic patients with solid lesions. If a lesion exhibits typical imaging features of a benign lesion on MRI, follow-up imaging is usually unnecessary. Possible diagnoses for solid lesions include hemangioma, hamartoma, SANT, littoral cell angioma, and IPTs. However, if MRI findings are inconclusive, such as in cases of atypical benign lesions (e.g., atypical large hemangioma or IPT) or suspected angiosarcoma, follow-up imaging at 6–12 months is recommended for growth assessment (69). If a lesion grows, a biopsy is necessary to rule out malignancy. However, most patients with angiosarcomas present with systemic symptoms and involvement of additional organs (69).

In symptomatic patients with pain related to splenic lesions, left upper quadrant pain is often observed due to the mass effect and stretching of the splenic capsule (69). Large cysts, pseudocysts, and lymphangiomas can result in symptoms or complications, such as intracystic hemorrhage or rupture, hemangioma, hamartoma, and SANT may cause hypersplenism or increase the risk of splenic hemorrhage or rupture. Surgical consultation is recommended when splenic lesions are suspected to be associated causing abdominal pain. Minimally in-

vasive surgical techniques, including marsupialization or partial cystectomy, have demonstrated positive outcomes in preserving splenic function for patients with symptomatic cysts or pseudocysts (70, 71). For symptomatic cases of hemangioma, hamartoma, and SANT, partial or total splenectomy is a viable surgical option (72, 73).

Additionally, if clinically indicated, further characterization using MRI may be beneficial for refining the differential diagnosis or evaluating aggressive imaging features that could influence management decisions.

For symptomatic patients with systemic symptoms or manifestations, specific clinical and laboratory findings can help narrow down the differential diagnosis of splenic lesions.

Patients with infectious conditions affecting the spleen, including bacterial, fungal, and parasitic abscesses, often experience symptoms such as fever and are typically immunocompromised. Percutaneous aspiration can confirm the diagnosis and direct treatment (74).

Patients with lymphomas may manifest B symptoms (night sweats, fever, and unintentional weight loss) or they present with lymphadenopathy. If lesions are identified in organs other than the spleen, it may suggest malignancy such as metastases or a metastatic primary splenic angiosarcoma, based on their frequency (69). In such cases, obtaining tissue confirmation through image-guided percutaneous splenic biopsy is crucial for making treatment decisions. Lymphoma treatment varies by stage but generally includes chemotherapy as a key component. Angiosarcoma, an aggressive tumor, generally has a poor prognosis, with the majority of patients dying within 12 months of diagnosis, regardless of treatment (32, 33). Splenectomy is considered a viable treatment option for isolated splenic metastasis. However, in the context of widespread metastatic disease, surgery may not be appropriate to address splenic metastasis (75, 76).

ROLE OF SPLENIC BIOPSY

When the diagnosis remains uncertain despite imaging findings, a biopsy is essential, particularly when dealing with unknown primary diagnoses or when the imaging findings are unusual or ambiguous. In the past, percutaneous splenic biopsy was questioned due to concerns about hemorrhage and perceived low diagnostic accuracy. As a result, total or partial splenectomy has historically been the primary diagnostic and treatment method (21, 77). However, recent studies have demonstrated that percutaneous splenic biopsy carries a low risk of major complications and has high diagnostic accuracy (77). Specifically, a core needle biopsy can aid in diagnosing benign entities such as IPTs, SANT, and littoral cell angiomas, where prospective imaging diagnosis is challenging, thereby avoiding unnecessary splenectomy (78-80).

CONCLUSIONS

In this pictorial essay, various splenic lesions are discussed using typical and atypical images obtained from multimodality imaging. A brief comprehensive review of their clinical features and pathological findings is also presented. Radiological findings such as multiplicity, margins, and specific imaging findings can help differentiate various splenic lesions. Knowl-

edge of the radiological findings of various splenic lesions is helpful for radiologists to correctly narrow down the differential diagnosis, guide clinical strategies to minimize unnecessary invasive diagnostic procedures, and provide appropriate treatment.

Author Contributions

Conceptualization, S,K.S.; data curation, O.Y.J.; investigation, O.Y.J.; supervision, S,K.S.; writing—original draft, O.Y.J.; and writing—review & editing, L.J.E., Y.S.K., O.J.Y., H.H.Y., K.J.M., S.K.S.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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비장 병변의 다양한 영상 소견: 조직병리 소견과의 비교

오유진[1] · 이정은[1] · 유선경[1] · 엄준영[1] · 한현영[2] · 김진만[3] · 신경숙[1]*

비장은 다른 복부 장기에 비해 병변이 드물게 발생하기 때문에, 때때로 '잊혀진 장기'라고 불린다. 비장 병변은 다양한 복부 영상에서 잘 보임에도 불구하고 영상의학과 의사들에게 덜 친숙하여 감별 진단하기에 어려운 경향이 있다. 저자들은 비장 병변의 다양한 증례들을 제시하고, 이에 대해 초음파(ultrasonography), 컴퓨터단층촬영(CT), 자기공명영상(MRI), 양전자단층촬영(PET/CT)을 포함한 다양한 영상 소견과 조직 병리학적 소견을 비교하여 설명하고자 한다. 다양한 비장 병변의 영상 소견을 인지하는 것은 감별 진단을 좁히고 적절한 임상적 의사결정을 안내하는 데에 도움이 될 것이다.

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