The Spleen

Giovanna Bertolini

1 Introduction

The spleen is the largest single lymphatic organ in the body and is responsible for central immunological and hematological tasks. Consequently, it is involved primarily or secondarily in a wide range of pathological disorders. The spleen can be explored completely with CT and should be always assessed during abdominal examinations. CT evaluation of the spleen is indicated for the staging of splenic neoplasia and in cases of acute abdomen, hemoabdomen, and trauma (splenic trauma is treated in chapter "The Body Trauma").

The spleen is roughly tongue shaped in dogs and cats and is customarily divided into three segments: the head, body, and tail. Normal spleen size varies substantially among subjects and is influenced by several intrinsic (e.g., contraction) and extrinsic factors. Splenomegaly is a common finding in anesthetized dogs undergoing CT. Some anesthetic drugs used commonly in clinical practice, such as acepromazine, thiopental, and propofol, cause splenomegaly in normal dogs. Hence, the evaluation of spleen size using CT is difficult. Splenomegaly may be found in many benign and malignant conditions in dogs and cats, including non-neoplastic and neoplastic diseases (e.g., splenic congestion, splenic torsion, immune-mediated hemolytic anemia, inflammatory diseases, mastocytoma, lymphoma).

Accessory (or ectopic) spleens are rarely reported in small animals but are not so rarely encountered on whole-body MDCT examinations. They are foci of healthy splenic tissue separated from the main body of the spleen due to the failure of fusion of the initial clustering of embryonic cells from which the spleen develops. Accessory spleens are generally located along the spleno-pancreatic, gastrosplenic, or

G. Bertolini (✉)
San Marco Veterinary Clinic, Padua, Italy
e-mail: bertolini@sanmarcovet.it

G. Bertolini (ed.), *Body MDCT in Small Animals*, DOI 10.1007/978-3-319-46904-1_6

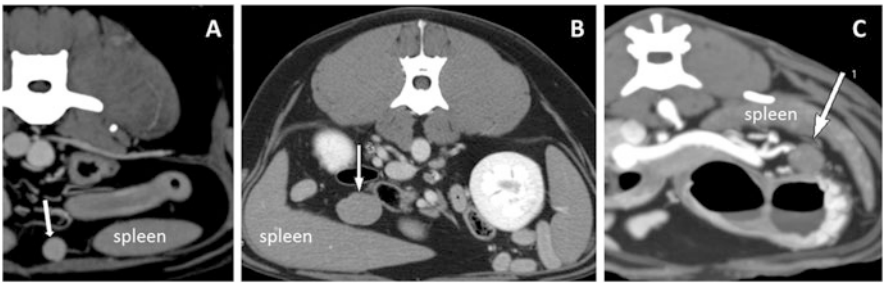

Fig. 1 Accessory spleen. (**a**) Transverse view of the abdomen in a dog, showing a small accessory spleen (*arrow*) supplied by a thin splenic vessel. (**b**) Transverse view from another dog, showing a large accessory spleen (*arrow*). (**c**) Accessory spleen in a cat (*arrow*) with blood supply and drainage by the splenic artery and vein branches

splenorenal ligaments and are supplied by a branch of the splenic artery (Fig. 1). They have same CT appearance as normal splenic tissue and are found most commonly in the proximity of the splenic hilum. These accessory spleens have no clinical significance and should not be removed in non-symptomatic patients. However, ectopic spleens are subject to the same diseases as is eutopic splenic tissue. The presence of ectopic splenic tissue in other organs, such as the liver and the pancreas, has been reported rarely. In the presence of primary splenic cancer, such as hemangiosarcoma, the pancreas should be assessed carefully for metastasis.

The splenic lymph nodes lie along the splenic vessels and are easily detected on thin-section MDCT images. They drain the spleen, as well as the pancreas, esophagus, stomach, and omentum. Thus, they may be enlarged in several pathological conditions.

2 MDCT Imaging Strategies

On pre-contrast CT images, the healthy spleen usually appears to be homogeneous in attenuation and has a density of about 50–60 HU, about 5–10 HU less than that of the liver (Fig. 2). Variations in splenic density can be observed in patients with focal or systemic diseases involving the spleen.

The splenic parenchyma consists of the red and white pulps that form a complex network within the organ. The red pulp is composed of erythrocytes and vascular structures, and the white pulp is formed by lymphatic tissue. With rapid CM injection, the spleen shows inhomogeneous enhancement with variable patterns, reflecting variable blood distribution between the red and white pulps (Fig. 3). These normal inhomogeneous patterns in early contrast-enhanced series vary substantially between dogs and cats and among subjects of the same species. In particular, cats may show a serpentine, cordlike, archiform distribution of splenic

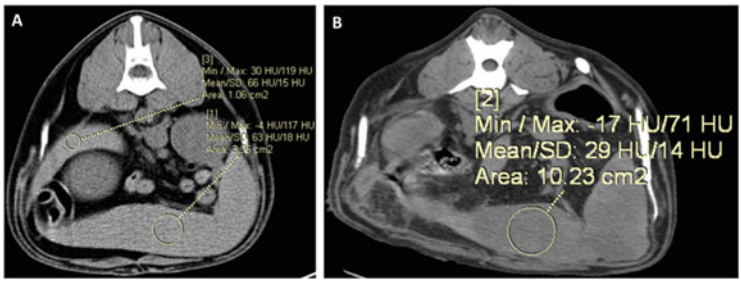

Fig. 2 Splenic attenuation values. (**a**) Non-contrast transverse view in a dog showing a comparison of splenic and hepatic attenuation values. In this patient, the liver has a mean attenuation of 66 HU and the spleen has a mean attenuation value of 63 HU. (**b**) Attenuation value of the spleen in a dog with splenic infarction. The mean value within the ROI at the tail of the spleen is 29 HU (suprafluid)

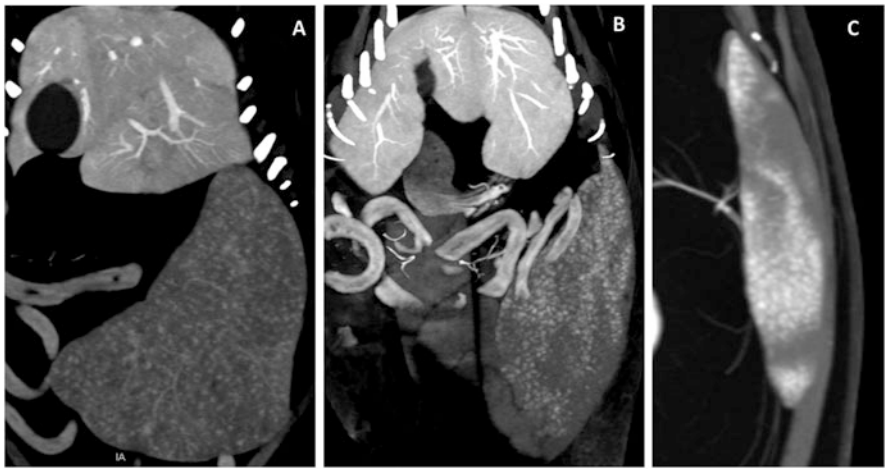

Fig. 3 Normal pattern of enhancement of the spleen in dogs and cats. (**a**) Dorsal MPR view in a dog. (**b**) Dorsal MPR view in a cat. (**c**) Normal pattern of enhancement of the spleen in another cat

parenchymal enhancement, similar to that described in humans. In the delayed phase, the normal spleen parenchyma shows homogeneous enhancement.

Multiphase CT imaging of the spleen is usually obtained during multiphase examination of the liver. Unlike the liver, the spleen has a unique arterial blood supply, from the splenic artery, a branch of the celiac artery. It is drained from the splenic vein, which receives the gastroepiploic and left gastric veins, before entering the portal vein. Thus, complete assessment of the spleen requires dual-phase examination (Fig. 4). The arterial phase provides information about the normal vascularization of the spleen and aids in the diagnosis of splenic torsion and infarction. It may reveal active bleeding (in cases of blunt trauma and benign and

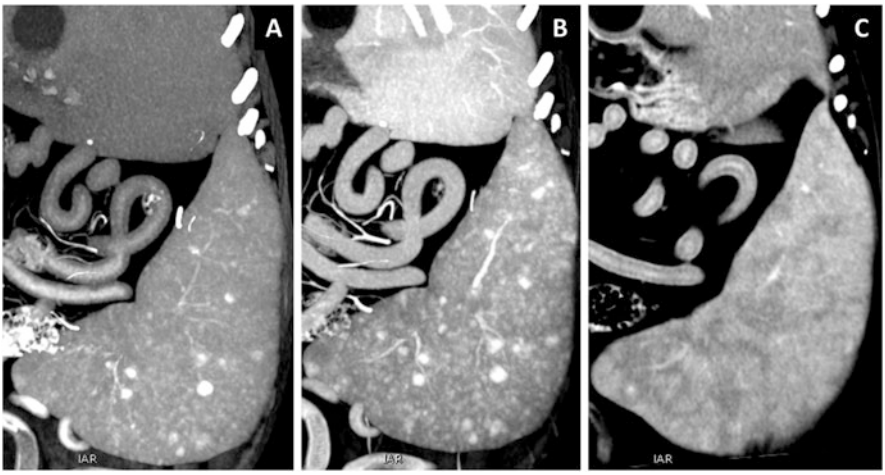

Fig. 4 Multiphasic examination of the abdomen. (**a**) Hepatic arterial phase (HAP). The spleen is enlarged and some hypervascular parenchymal nodules are present (extramedullary hyperplasia). (**b**) Portal venous phase (PVP). The spleen shows maximum parenchymal enhancement. (**c**) Interstitial phase or equilibrium phase (EP) of the liver. The spleen shows more homogeneous enhancement. Hematopoietic nodules are not visible

malignant masses) and may be useful for the detection of benign and malignant hypervascular lesions.

An adequate contrast-enhanced PVP is necessary for the assessment of splenic vein thrombosis and malignant vascular invasion (Fig. 5). Heterogeneous enhancement of the splenic vein is normally seen during the LAP (late arterial phase or inflow portal phase) and should not be confounded with true thrombosis. Multiplanar dorsal views are helpful to show the characteristic pattern of pseudothrombosis (Fig. 6). As it has less viscosity, non-contrasted blood adopts a central laminar flow that can be interpreted mistakenly as thrombosis. Artifactual filling defects of the splenic vein due to its partial opacification represent a time-dependent phenomenon that disappears in subsequent vascular phases. Thus, to avoid misdiagnosis, the examiner should check for complete opacification of the splenic vein in the PVP.

3 Hyperplastic, Reactive, and Inflammatory Splenic Conditions

Hyperattenuating/hypoattenuating lesions of the spleen need to be evaluated in the clinical context, because CT imaging appearances may overlap. Cytologic evaluation may provide a specific diagnosis in most instances.

Splenic extramedullary hematopoiesis (EMH), or the production of hematopoietic cells outside bone marrow, is common in our patients. This may be an

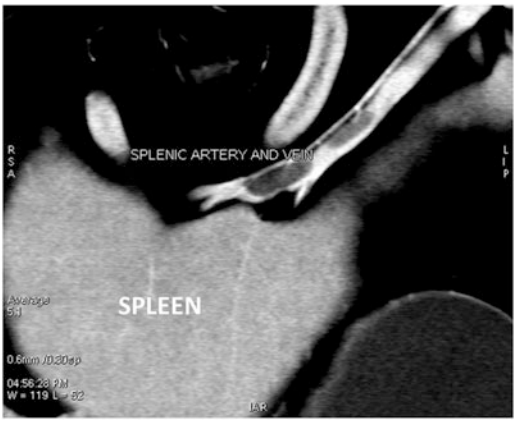

Fig. 5 Splenic vein thrombosis in a dog with lymphoma. Note the filling defects in the splenic vein

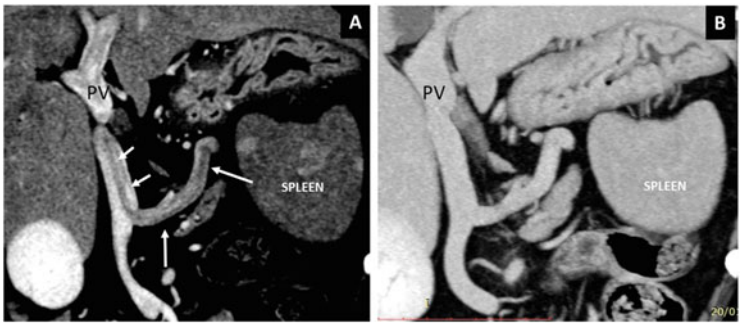

Fig. 6 Pseudothrombosis. (**a**) LAP. Non-contrasted blood of the splenic vein (*long arrows*) adopts a central laminar flow that propagates in the portal vein (*short arrows*). (**b**) In the PVP, the pseudothrombosis disappears, as all vessels are well enhanced

incidental finding, may be found in association with other splenic diseases, or may be a response to bone marrow failure. In personal experience, EMH represents the most common benign lesion of the spleen in dogs. In multiphasic CT examination, EMH appears as multiple hypervascular nodules of same or different sizes (Figs. 7 and 8). *Reactive splenic conditions* refer to generalized hyperplasia with lymphoid hyperplasia and increased hematopoietic precursors. In multiphase CT examination, splenic hyperplasia may have diffuse pattern (miliar or nodular) or may present as single nodule, mimicking a neoplasia (Fig. 9).

Hypoattenuating lesions of the spleen may be seen in case of septic and non-septic inflammatory conditions of the spleen (Fig. 10). These lesions may mimic splenic infarction and need to be evaluated in the clinical context.

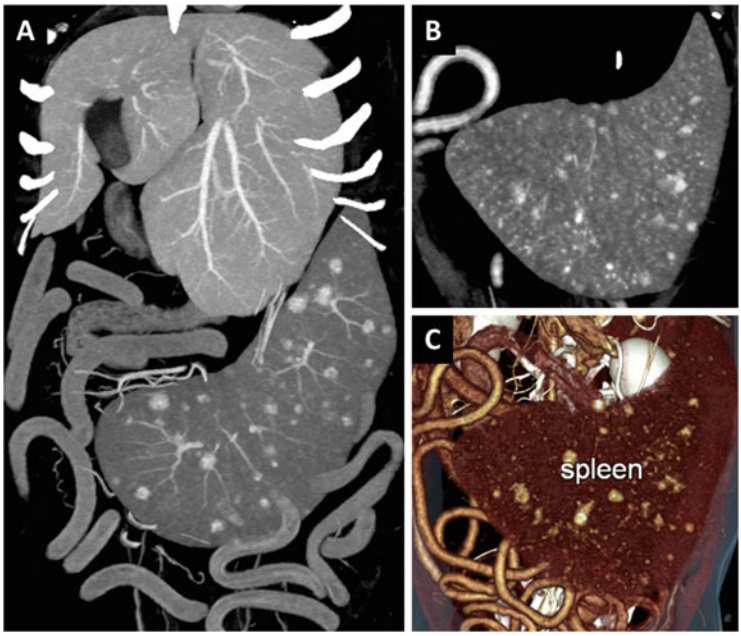

Fig. 7 Extramedullary hematopoiesis of the spleen in three different dogs (**a**–**c**), showing multiple hypervascular nodules

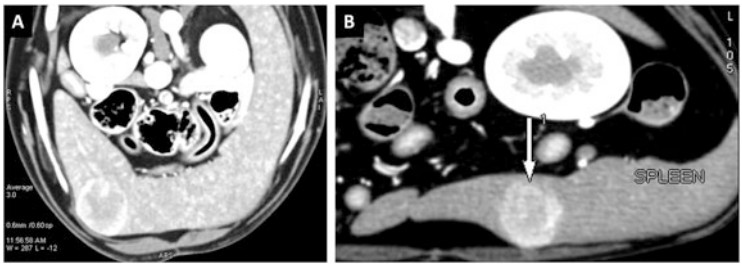

Fig. 8 Extramedullary hematopoiesis of the spleen in two different dogs (**a**, **b**). Extramedullary hematopoiesis presents as a single rounded hypervascular nodule

4 Splenic Infarction and Splenic Vein Thrombosis

Splenic infarction refers to acute occlusion of the arterial blood supply to the spleen, which leads to parenchymal ischemia and subsequent tissue necrosis. Blood enters the spleen at the hilus by way of up to approximately 25 arterial branches. Therefore, small focal splenic infarctions remain generally asymptomatic and can be encountered incidentally during CT examination. In dogs, massive splenic infarction involving the arterial blood supply of the spleen can be observed

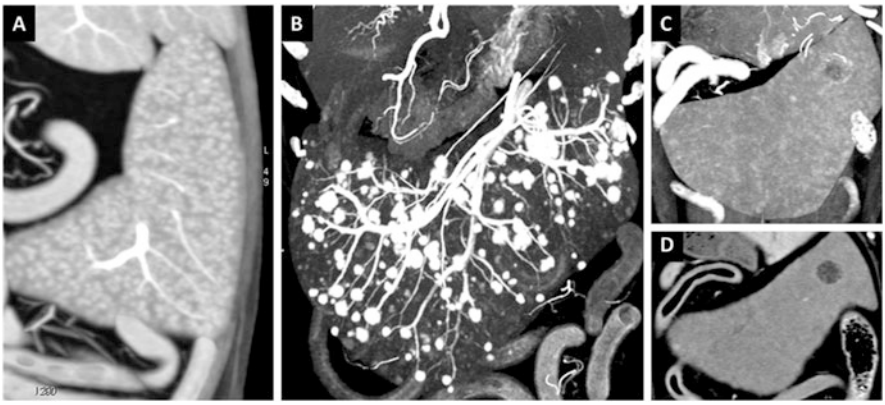

Fig. 9 Splenic hyperplasia in dogs. (**a**, **b**) Diffuse miliary and nodular hypervascular pattern of splenic hyperplasia (PVP and HAP). (**c**, **d**) HAP and PVP in a dog with a single hyperplastic nodule of the spleen

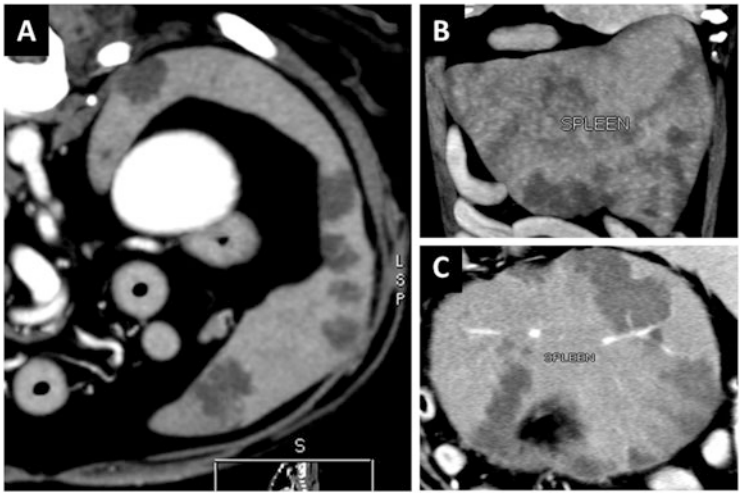

Fig. 10 Splenitis in three different dogs with systemic diseases. (**a**) Multiple hypovascular splenic lesions in a dog with bacterial splenitis and spondylodiscitis (Klebsiella). (**b**) Hypoattenuating/hypovascular lesions in the spleen (suppurative splenitis) of a dog with immunomediated polyarthritis. (**c**) Splenitis in a dog with systemic infection (Mycobacterium avium)

in splenic torsion with or without gastric volvulus, leading to temporary or permanent splenic artery thrombosis. Splenic infarction due to arterial occlusion may have other severe causes, including cardiac diseases and infiltrative hematological tumors. Imaging features of splenic infarction may vary with the cause and stage of the infarct. In splenic torsion, the whole spleen is hypoattenuating and enlarged. Acute infarction with causes other than torsion may present as a typical peripheral,

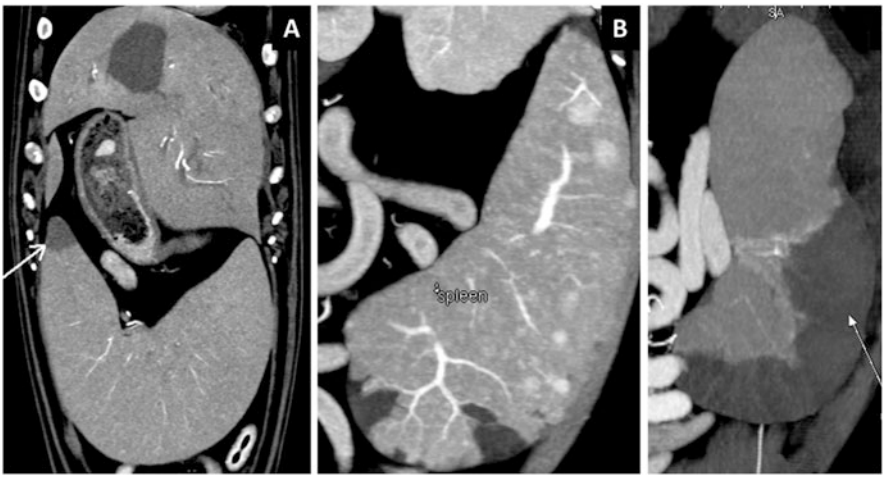

Fig. 11 Splenic infarction. (**a**) Small infarcted marginal areas discovered incidentally in a dog. (**b**) Multiple splenic infarctions in a dog with metastatic lung neoplasia. (**c**) Large chronic infarction in a dog

wedge-shaped hypoenhancing region or multiple, heterogeneous areas of patchy enhancement (Fig. 11). A "rim sign" of high density relative to the parenchyma can be noted on the splenic capsule. In the chronic phase, an infarction may be not detected or may result in progressive volume loss caused by fibrotic contraction, with secondary hypertrophy of the surrounding normal splenic parenchyma.

Splenic vein thrombosis can also result in venous infarction. Local factors, such as splenic masses or infiltration, can cause portal vein occlusion. In addition, systemic risk factors may be involved in the pathogenesis of splenic thrombosis. A hypercoagulable state is the main disorder causing splenic infarction, and it has been associated with a variety of non-neoplastic and neoplastic conditions, including myeloproliferative disorders and prothrombotic conditions, such as pancreatitis, immune-mediated hemolytic anemia, disseminated intravascular coagulation, conditions caused by corticosteroid exposure due to hyperadrenocorticism or exogenous steroid administration, and renal failure with proteinuria (Figs. 5, 12, and 13).

5 Splenic Torsion

Splenic torsion is a relatively uncommon occurrence, and it is usually considered to be secondary to the complex of gastric dilatation and volvulus. Primary or isolated splenic torsion is an uncommon splenic disease, generally occurring in large- or giant-breed, deep-chested dogs, such as Great Danes. Its pathogenesis is not completely clear.

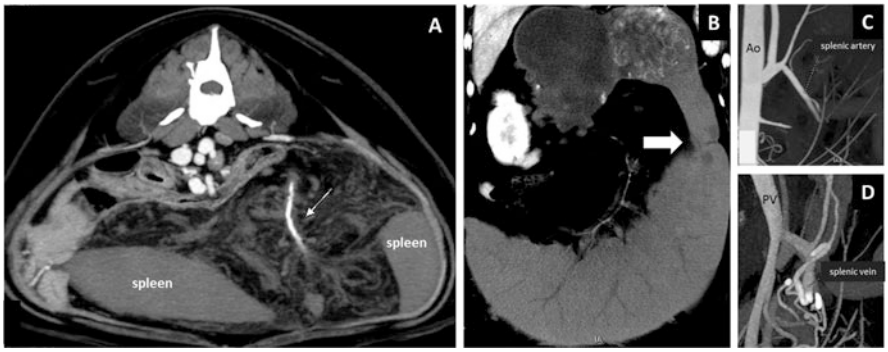

Fig. 12 Splenic infarction in torsion. (**a**) Transverse view in a dog with splenic torsion. The splenic artery (*arrow*) is interrupted and the spleen is not perfused. (**b**) Splenic enlargement and hypoperfusion in a dog with splenic hemangiosarcoma. The dog was referred for suspected splenic torsion. At the time of CT examination, the dog showed a normally positioned spleen, with narrowing at the body (*arrow*) and absent blood flow. (**c**) Interrupted splenic artery. (**d**) Tilted splenic vein (consistent with partial omental torsion)

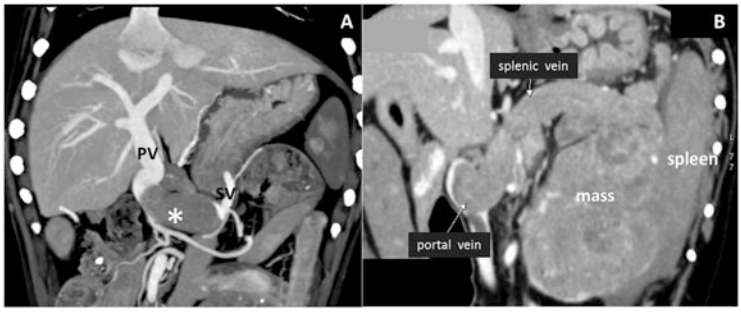

Fig. 13 Splenic vein thrombosis. (**a**) Dorsal MPR view in a dog with a hypercoagulable state and large benign splenic vein thrombosis (*asterisk*). *PV* portal vein, *SV* splenic vein. (**b**) Dorsal MPR view in a dog with a splenic mass (neuroendocrine carcinoma) and tumoral invasion of the splenic vein

Patients with torsion are often evaluated in an emergency setting, where imaging, usually by ultrasonography and CT, plays an important role. MDCT features of splenic torsion include displacement and enlargement of the organ, which shows considerably decreased or heterogeneous attenuation on pre-contrast images (due to infarction). The twisted splenic pedicle containing splenic vessels and surrounding fat produces the "whirl sign," confirming splenic torsion (Figs. 14 and 15). Post-contrast images may show interruption of the vascular blood supply to the spleen. As stated previously, the rim sign (relative capsular hyperdensity) may be noted in cases of massive splenic infarction. Adjacent inflammatory changes and free fluid are generally present.

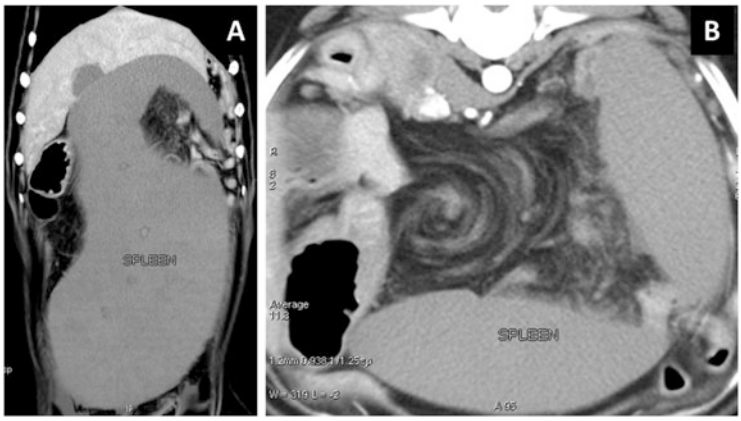

Fig. 14 Splenic torsion. (**a**) Dorsal MPR views from a Great Dane. The spleen is enlarged and avascular. (**b**) Transverse view of the same dog showing a twisted splenic pedicle containing unperfused splenic vessels (*whirl* sign)

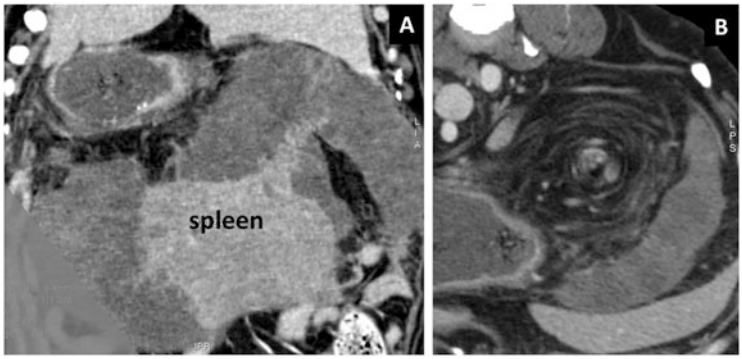

Fig. 15 Splenic torsion and infarction in a Caucasian Mountain dog. (**a**) The spleen is enlarged and some areas of the splenic parenchyma are infarcted. (**b**) *Whirl* sign at the splenic vascular pedicle

6 Splenic Neoplasia

Focal lesions of the spleen are encountered commonly during MDCT examination for various reasons and should be assessed carefully. Although nonmalignant masses have been reported to account for the majority of focal splenic masses in dogs, a recent study of a wide population of dogs showed nearly equal distributions of malignant (53%) and nonmalignant (47%) tumors. Benign lesions encountered commonly on multiphasic MDCT examination of the abdomen include nodular hyperplasia, splenic hematoma, extramedullary hematopoiesis, hemangioma, and myelolipoma (Figs. 8 and 16). Some of these benign lesions can reach considerable

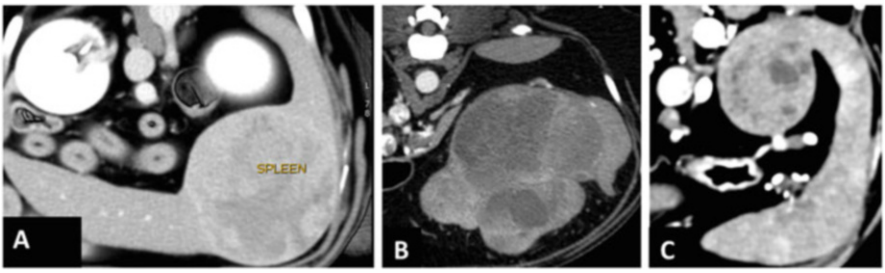

Fig. 16 Benign splenic masses in three different dogs. (**a**) Sagittal thin-MIP image showing a large splenic mass (hematoma). (**b**) Large inhomogeneous mass (hematoma). (**c**) Transverse view of the spleen in a dog with splenic myelolipoma

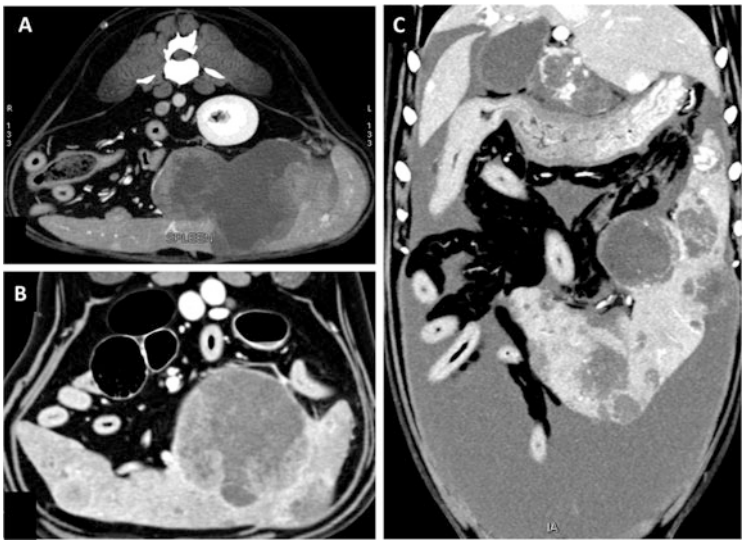

Fig. 17 Splenic hemangiosarcoma in dogs. (**a**, **b**) Transverse view in two dogs with primary splenic hemangiosarcoma. (**c**) Dorsal MPR view in another dog, with hemoabdomen due to ruptured metastatic hemangiosarcoma

dimensions and may be confounded with malignant splenic tumors. Hemangiosarcoma is the most common malignant tumor in the canine spleen, and it is almost indistinguishable from splenic hematoma. In addition, cytology is not always accurate in this case and the two conditions can coexist. Several other histology tumor types are possible in the spleen, such as fibrosarcoma, leiomyosarcoma, undifferentiated sarcoma, osteosarcoma, and histiocytic sarcoma (Figs. 17 and 18).

To ensure accurate interpretation, splenic lesions should be evaluated in the clinical context of the patient's history, as the CT imaging appearances of certain entities overlap and cannot be used to distinguish benign and malignant lesions.

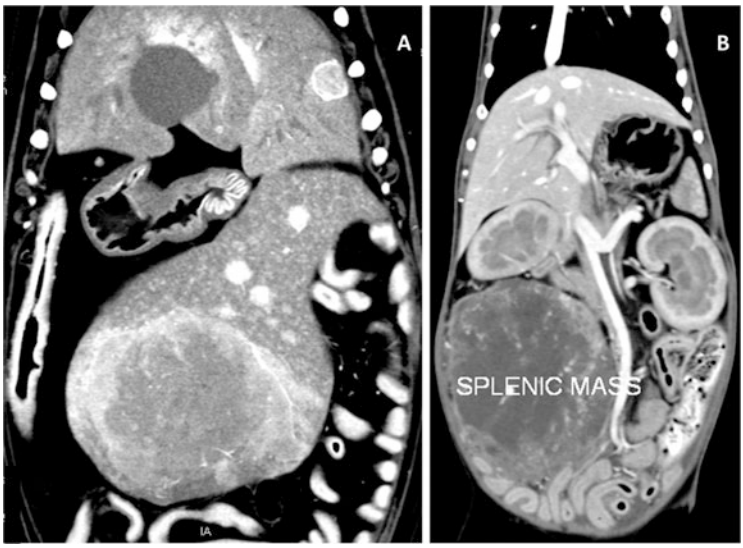

Fig. 18 Malignant splenic neoplasia. (**a**) Dorsal MPR of a dog with histiocytic sarcoma. A large hypervascular mass at the splenic tail and other small hypervascular nodules can be seen. Note the hypervascular nodule in the left lateral hepatic lobe. (**b**) Dorsal MPR of the abdomen in a cat with a large splenic mass (sarcoma)

Benign lesions may assume a mottled pattern or nodular appearance, or may present as large masses, some of which cause organ surface deformation. Thus, size is not a criterion that predicts the malignancy of a splenic lesion. A few studies have explored the CT appearance of various splenic masses in dogs. In a single-phase CT study, with images acquired prior to and approximately 60 s after intravenous CM administration, the malignancy of a splenic mass (i.e., presence of hemangiosarcoma) was associated with hypoattenuation on pre-contrast images and minimal contrast accumulation on post-contrast images. The authors defined a threshold value of 55 HU on post-contrast images to distinguish malignant (<55 HU) from nonmalignant (>55 HU) masses. However, a recent multiphasic MDCT analysis showed that most splenic masses (benign and malignant) were slightly heterogeneous, with median attenuation similar to that of the adjacent parenchyma, in pre-contrast series. Splenic hemangiosarcoma and benign nodular hyperplastic lesions most frequently showed marked, generalized enhancement on early-phase images, with no difference in median enhancement of malignant and nonmalignant masses on delayed-phase images. Independent of their nature, the masses exhibited a wide range of post-contrast attenuation values that spanned 55 HU. The presence of hemoabdomen has been related to the rupture of malignant and benign masses of the spleen. However, it is associated more commonly with hemangiosarcoma and is thus a sign of potential malignancy (Fig. 17c). Lymphoproliferative and myeloproliferative disorders can primary or secondarily involve the spleen (Figs. 19 and 20). Lymphoma of the spleen can present as generalized splenomegaly without focal

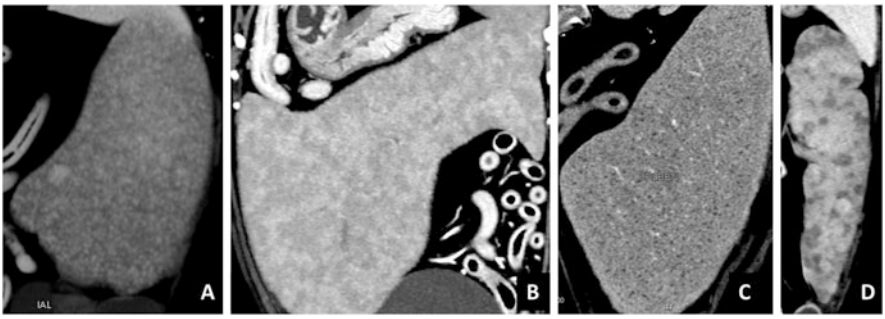

Fig. 19 Different patterns of splenic lymphoma in dogs. (**a**) Miliary diffuse pattern (similar to hyperplastic changes). (**b**) Diffuse infiltrative pattern. (**c**) Diffuse "honeycombing" pattern (B-cell lymphoma). (**d**) Multifocal pattern of lymphoma (B-cell lymphoma) in another dog

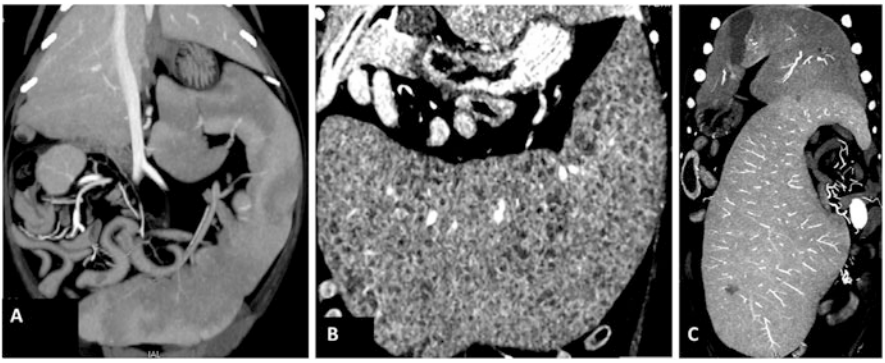

Fig. 20 (**a**) Dorsal MPR view of the abdomen in a cat with multiple myeloma. The spleen is enlarged and diffusely inhomogeneous. (**b**) Dorsal MPR in a dog with Waldenstrom macroglobulinemia. The spleen shows noticeable enlargement with a "honeycombing" pattern. (**c**) Diffuse splenomegaly in myeloid leukemia in a dog

lesions, as multiple focal lesions, or as a single solitary lesion. The presence of hilar lymphadenopathy is suggestive of splenic lymphoma (Fig. 21).

Despite the difficulty of determining the nature of a splenic mass based on its characteristics, MDCT has the advantage of enabling simultaneous assessment of other abdominal parenchyma, the lung, and any other body tissue. Metastatic lesions from primary splenic hemangiosarcoma or other malignancies can be detected easily by whole-body MDCT, aiding in definitive diagnosis.

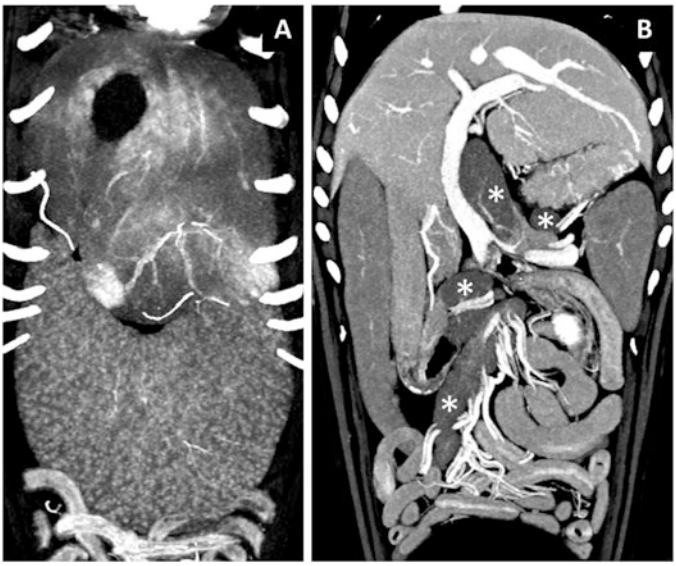

Fig. 21 Multiphasic examination of the abdomen in a dog with T-cell lymphoma. (**a**) EAP. Splenomegaly and diffuse miliary pattern. Note the hepatic perfusion disorders. (**b**) PVP showing abdominal lymph node enlargement (*asterisks*). Note the homogeneous parenchymal enhancement in this vascular phase

Further Readings

Baldo CF, Garcia-Pereira FL, Nelson NC, Hauptman JG, Shih AC. Effects of anesthetic drugs on canine splenic volume determined via computed tomography. Am J Vet Res. 2012;73 (11):1715–9. doi:10.2460/ajvr.73.11.1715.

Fife WD, Samii VF, Drost WT, Mattoon JS, Hoshaw-Woodard S. Comparison between malignant and nonmalignant splenic masses in dogs using contrast-enhanced computed tomography. Vet Radiol Ultrasound. 2004;45(4):289–97.

Irausquin RA, Scavelli TD, Corti L, Stefanacci JD, DeMarco J, Flood S, Rohrbach BW. Comparative evaluation of the liver in dogs with a splenic mass by using ultrasonography and contrast-enhanced computed tomography. Can Vet J. 2008;49(1):46–52.

Jones ID, Lamb CR, Drees R, Priestnall SL, Mantis P. Associations between dual-phase computed tomography features and histopathologic diagnoses in 52 dogs with hepatic or splenic masses. Vet Radiol Ultrasound. 2016;57(2):144–53. doi:10.1111/vru.12336. Epub 2016 Jan 13.

Kim M, Choi S, Choi H, Lee Y, Lee K. Diagnosis of a large splenic tumor in a dog: computed tomography versus magnetic resonance imaging. J Vet Med Sci. 2016;77(12):1685–7. doi:10.1292/jvms.15-0262. Epub 2015 Jul 19.

Laurenson MP, Hopper K, Herrera MA, Johnson EG. Concurrent diseases and conditions in dogs with splenic vein thrombosis. J Vet Intern Med. 2010; 24(6):1298–304. doi:10.1111/j.1939-1676.2010.0593.x. Epub 2010 Sep 14.

Moss AA, Korobkin M, Price D, Brito AC. Computed tomography of splenic subcapsular hematomas: an experimental study in dogs. Investig Radiol. 1979;14(1):60–4.

Ohta H, Takagi S, Murakami M, Sasaki N, Yoshikawa M, Nakamura K, Hwang SJ, Yamasaki M, Takiguchi M. Primary splenic torsion in a Boston terrier. J Vet Med Sci. 2009;71(11):1533–5.

Patsikas MN, Rallis T, Kladakis SE, Dessiris AK. Computed tomography diagnosis of isolated splenic torsion in a dog. Vet Radiol Ultrasound. 2001;42(3):235–7.

Prosser KJ, Webb JA, Hanselman BA. Ectopic spleen presenting with anemia and an abdominal mass in a dog. Can Vet J. 2013;54(11):1071–4.

Ramírez GA, Altimira J, García-González B, Vilafranca M. Intrapancreatic ectopic splenic tissue in dogs and cats. J Comp Pathol. 2013;148(4):361–4. doi:10.1016/j.jcpa.2012.08.006. Epub 2012 Oct 11.