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Seminars in
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CT Signs in the Lungs

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Radiologic signs are often based on items or patterns that are encountered in everyday life. They are especially useful because their observation allows the differential diagnosis to be narrowed, and in some cases, enables a diagnosis to be made. In this review, several classic and newer computed tomography signs in the lungs are discussed.
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Introduction

Radiologic signs are often based on items or patterns that are encountered in everyday life. They are especially useful because their observation allows the differential diagnosis to be narrowed, and in some cases, enables a diagnosis to be made. Furthermore, early recognition of signs associated with aggressive infections may be life-saving. In this review, the following computed tomography (CT) signs in the lungs will be discussed: pipe cleaner, halo, reversed halo, air crescent, Monod, Cheerio, straight edge, air bronchogram, tree-in-bud, headcheese, signet ring, and feeding vessel.

Pipe Cleaner Sign

Pulmonary lymphatics are found in the peribronchovascular regions, in interlobular septa, and in the pleura and subpleural regions (including in and along the interlobar fissures). The pipe cleaner sign refers to a beaded appearance of bronchovascular bundles, interlobular septa, or interlobar fissures as a result of a preponderance of nodules occurring in and along pulmonary lymphatics.[1] The beaded appearance resembles a pipe cleaner, a type of brush used originally to clean smoking pipes and now frequently used in arts and crafts projects (Fig. 1). Diseases in which nodules predominate in and along pulmonary lymphatics include sarcoidosis, lymphangitic carcinomatosis, and silicosis and coal worker's pneumoconiosis; these conditions should be considered when the pipe cleaner sign is seen (Fig. 2). Nodule distribution varies slightly among the conditions—in sarcoidosis, nodules tend to predominate along larger bronchovascular bundles and in the subpleural regions whereas in silicosis and coal worker's pneumoconiosis, nodules tend to predominate in the centrilobular and subpleural regions.[2] Smooth or nodular interlobular septal thickening is usually the dominant feature in lymphangitic carcinomatosis. Interlobular septal thickening is typically absent in granulomatous diseases such as sarcoidosis and silicosis.

Halo Sign

The halo sign refers to a nodular opacity surrounded by a halo of ground glass attenuation. In neutropenic patients, the halo sign is strongly suggestive of angioinvasive aspergillosis (AIA) infection (Fig. 3). Aspergillus organisms are found within the normal environmental flora in the soil; although the spores of aspergillus species are routinely inhaled by humans, infection is rare in immunocompetent hosts. In immunocompromised patients (eg, patients with neutropenia), angioinvasive infection occurs when fungal hyphae invade and occlude small to medium-sized pulmonary arteries, leading to hemorrhagic infarction. A hemorrhagic infarct caused by invasive fungal infection characteristically manifests with the halo sign on CT.[3] The halo sign is considered an early sign of AIA and is found in greater than 90% of patients at presentation but in only approximately 20% of patients after 1 week.[4,5] Recognition of the halo sign is critical since AIA infection is rapidly progressive, associated with high mortality rates yet CT imaging establishes the diagnosis earlier and thus improves survival.[6]

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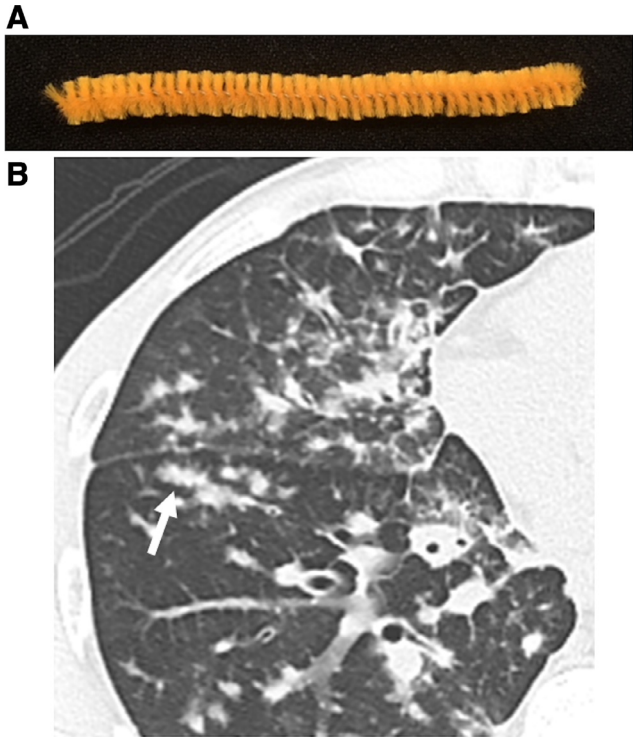

Figure 1 (A) Photograph of a pipe cleaner, a type of brush used originally to clean smoking pipes. (B) Pipe cleaner sign. Axial CT in a patient with lymphangitic carcinomatosis from Kaposi's sarcoma showing an example of the pipe cleaner sign along a bronchovascular bundle in the right lower lobe (arrow). The pipe cleaner sign usually indicates a perilymphatic pattern and is most commonly seen with sarcoidosis or lymphangitic carcinomatosis.

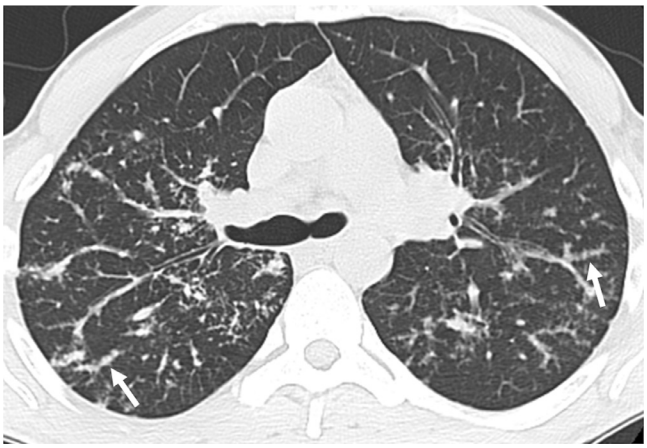

Figure 2 Pipe cleaner sign in sarcoidosis. CT shows peribronchovascular predominant pulmonary nodules. Note bilateral examples of the pipe cleaner sign along bronchovascular bundles (arrows). Nodules in sarcoidosis tend to predominate in the peribronchovascular and subpleural regions.

Though highly suggestive of AIA infection in the appropriate clinical setting, the halo sign is not specific for this organism. The sign can be seen in a number of other conditions, both infectious and noninfectious, that are associated with

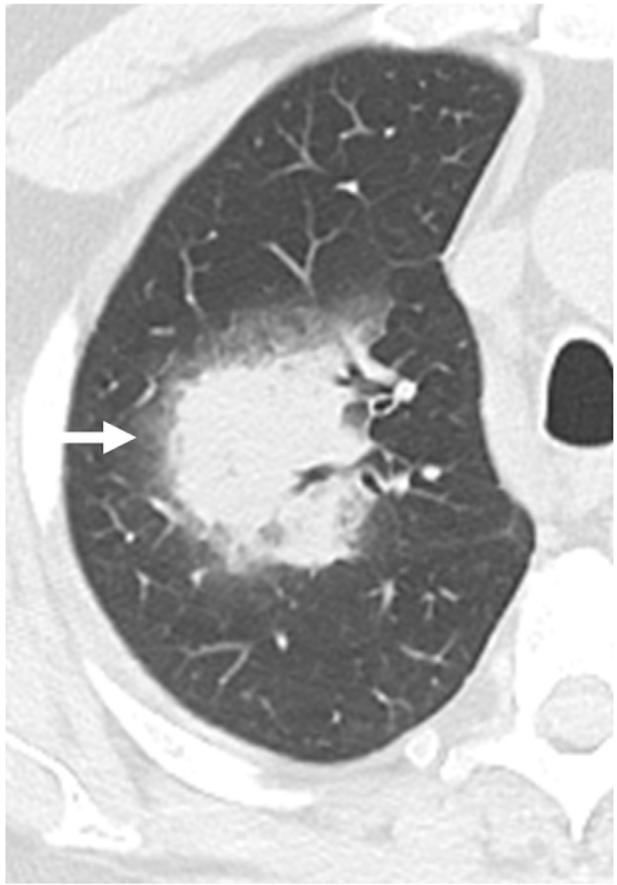

Figure 3 Halo sign. CT in a 66-year-old man with multiple myeloma and neutropenic fever shows the halo sign (arrow), a nodule or masslike opacity surrounded by a halo of ground glass attenuation. The halo sign is strongly suggestive of angioinvasive aspergillosis in neutropenic patients.

hemorrhagic pulmonary nodules.[7] Other infectious causes of the halo sign include other fungal infections, including mucormycosis and candidiasis, as well as nonfungal infections such as legionellosis and cytomegalovirus.[8-11] Noninfectious causes include hemorrhagic metastases (eg, melanoma, angiosarcoma, and choriocarcinoma), lung adenocarcinoma, Kaposi sarcoma, and granulomatosis with polyangiitis (formerly known as Wegener's granulomatosis; Fig. 4).[12]

Reversed Halo Sign

The reversed halo sign (RHS) is a central ground-glass opacity surrounded by a crescent or ring of consolidation.[13,14] Because of its resemblance to a coral atoll, the RHS is also known as the atoll sign. First described with organizing pneumonia, the RHS is now known to occur with several other conditions, infectious, and noninfectious (Fig. 5). When the RHS occurs in immunosuppressed patients, it should be considered an indication of invasive fungal infection until proven otherwise.[13,14] The sign is more common with mucormycosis, but can also be seen in AIA infection.[15] Pulmonary infarction is also a relatively common cause and

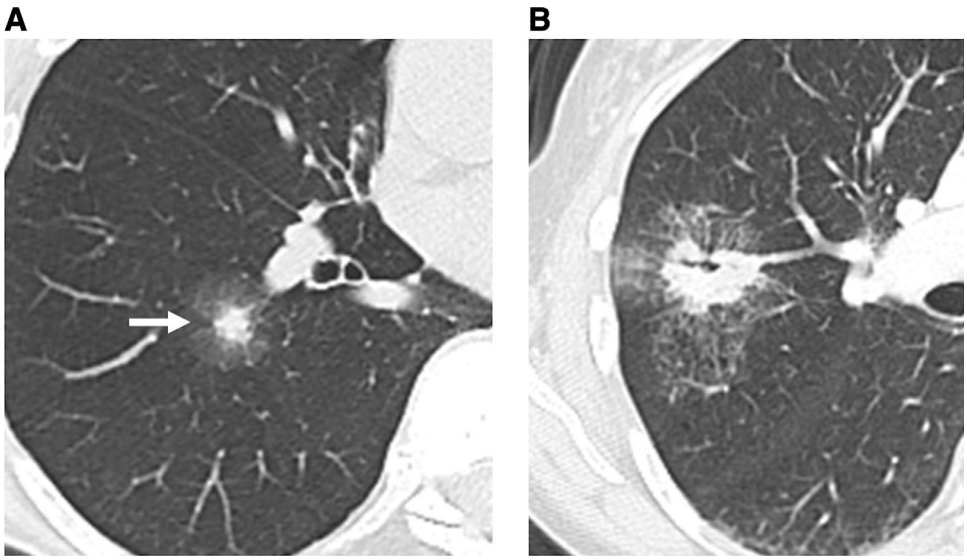

Figure 4 Halo sign, noninfectious causes. (A) CT in a patient with melanoma shows a right lower lobe nodule surrounded by a halo of ground glass attenuation (arrow). Nodule biopsy revealed metastatic melanoma. (B) CT in another patient shows a right upper lobe nodule surrounded by a halo of ground glass attenuation. Biopsy revealed lung adenocarcinoma. Noninfectious causes of the halo sign include hemorrhagic metastases, lung adenocarcinoma, Kaposi sarcoma, and granulomatosis with polyangiitis.

should be considered especially when the sign is seen in the subpleural region(s) of lung (Fig. 6).

Air Crescent Sign

The air-crescent sign is a crescent-shaped lucency within a nodule or area of consolidation (Fig. 7). As is the case with the halo sign, the air-crescent sign is strongly suggestive of AIA infection in neutropenic patients. Originally described in 1979 by Curtis et al,[16] this hallmark of invasive infection is unfortunately often confused with the Monod sign (see below). In some cases of AIA-associated pulmonary infarction, retraction of infarcted lung is associated with leukocyte-mediated resorption of necrotic tissue at the periphery, leading to a sequestrum of dead tissue.[17]

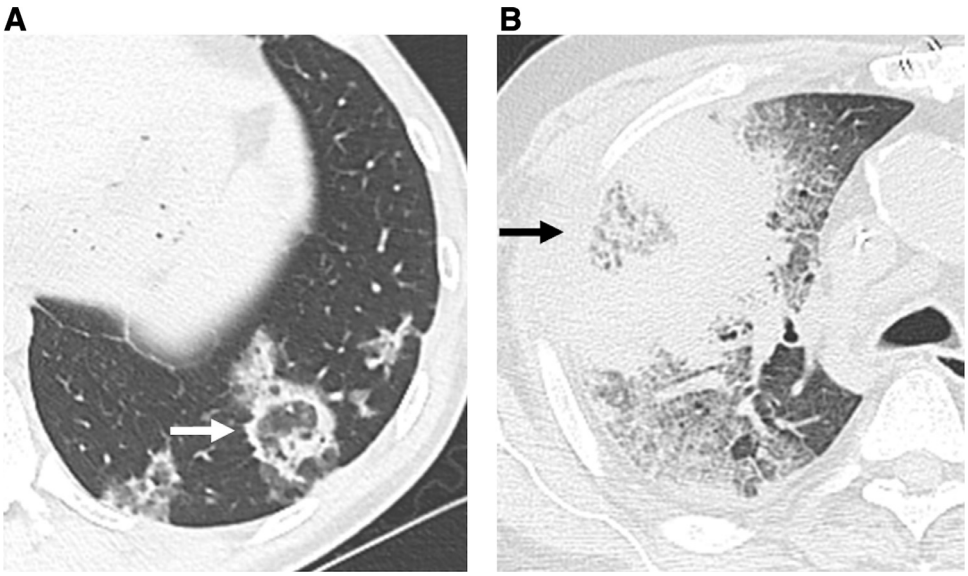

Figure 5 Reversed halo sign (RHS), a central ground-glass opacity surrounded by a crescent or ring of consolidation. (A) CT in a 21-year-old man with acute lymphoid leukemia shows the RHS in the left lower lobe (arrow). Biopsy revealed organizing pneumonia. (B) CT in a 72-year-old male with acute myeloid leukemia and neutropenic fever shows the RHS in the right upper lobe (arrow). When the RHS occurs in immunosuppressed patients, it should be considered an indication of invasive fungal infection.

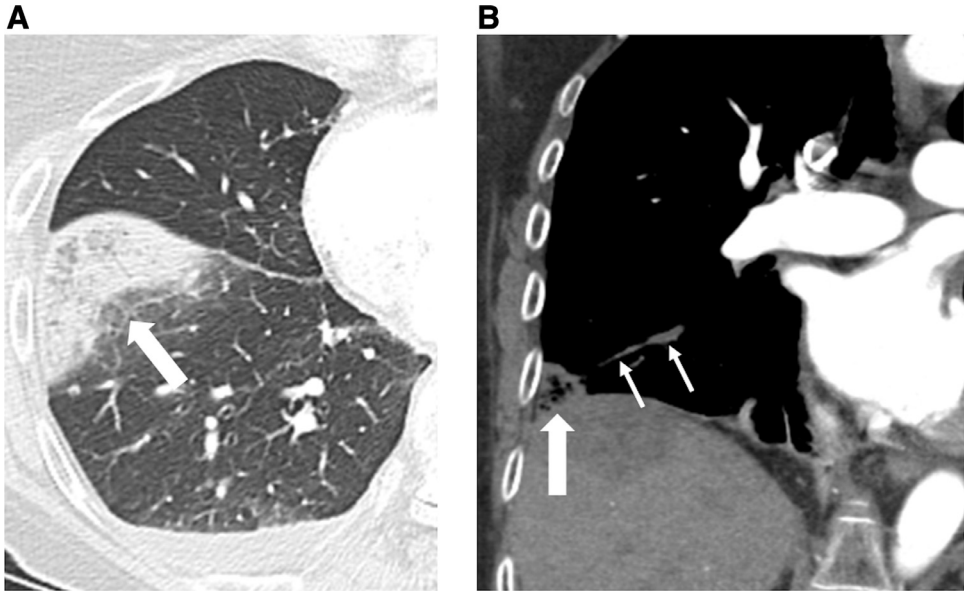

Figure 6 Reversed halo sign (RHS). (A) Axial CT (lung window) in a 67-year-old woman who presented with dyspnea shows the RHS in the right lower lobe (arrow). (B) Coronal reformation (soft tissue window) in the same patient shows thrombus (thin arrows) in the pulmonary artery leading toward the right lower lobe opacity (thick arrow). In this case, the RHS was due to pulmonary infarction. Pulmonary infarction should be considered when the RHS is seen in the subpleural region(s) of lung.

If air fills the space between retracted infarcted tissue and surrounding parenchyma, the air-crescent sign can be seen. Because development of an air crescent is leukocyte mediated, it occurs during bone marrow recovery[18]; visualization of this sign is thought to indicate that the infection is improving. Unlike the halo sign, the air-crescent sign is a late sign of AIA infection and is not typically seen at presentation. It is seen in approximately one-third of patients by day 7 and 60% of patients 14 days after presentation.[4] The differential diagnosis of the air-crescent sign includes other cavitary infections (eg, bacterial and mycobacterial) and cavitary neoplasms.[18]

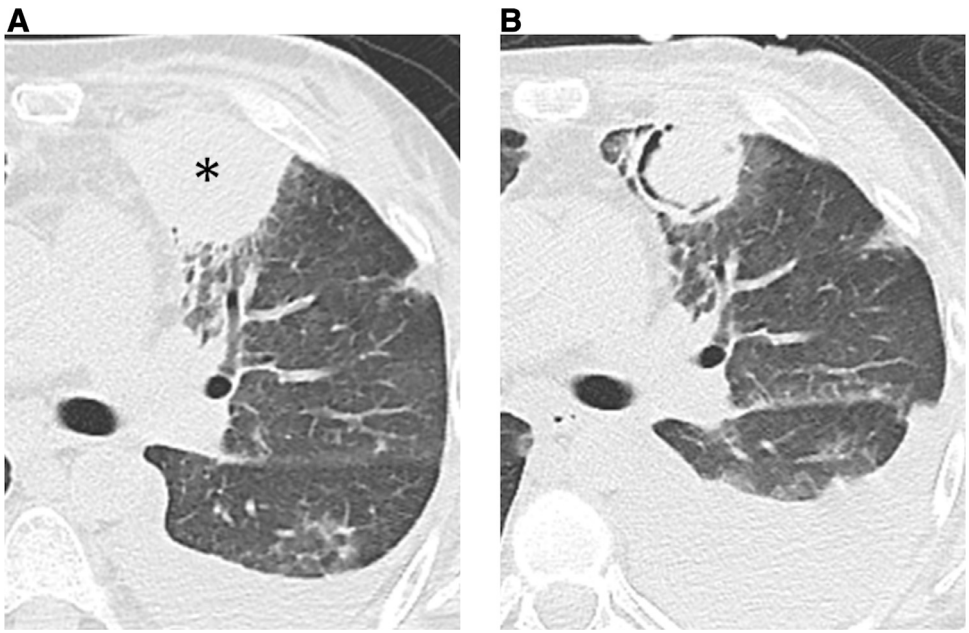

Figure 7 Air-crescent sign. (A) CT done 3 weeks after hematopoietic stem cell transplantation in a patient with acute myeloid leukemia shows left upper lobe masslike consolidation (*), suspicious for angioinvasive aspergillosis (AIA) infection. (B) CT done 2 weeks later shows a crescent of air in the area of consolidation, the air-crescent sign. The air-crescent sign is a late sign of AIA infection. Visualization of this sign is thought to indicate that the infection is improving.

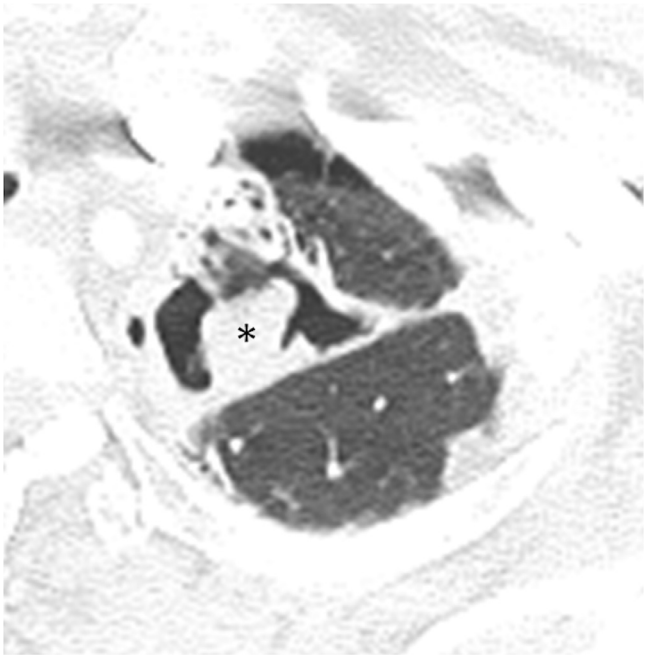

Figure 8 Monod sign. CT in a 50-year-old woman with sarcoidosis, presenting with hemoptysis, shows a soft tissue nodule consistent with mycetoma (*) in a pre-existing left upper lobe cavity. The patient underwent bronchial artery embolization for control of hemoptysis. Mycetomas can occur in any lung cavity including those caused by tuberculosis and sarcoidosis.

Monod Sign

First described by Pesle and Monod in 1954, the Monod sign refers to the presence of air around a mass within a pre-existing pulmonary cavity.[19] The sign usually indicates the presence of a mycetoma (ie, a fungus ball [often mobile] that is comprised of fungal hyphae, debris, mucous, fibrin) within the cavity (Fig. 8).[20] Mycetomas are usually caused by Aspergillus but other fungi (eg, Candida and coccidioides) are occasionally responsible.[21] Most frequently documented in residual tuberculous cavities, mycetomas can occur in any lung cavity including cavitary regions in sarcoidosis, emphysematous bullae, pneumatoceles, and bronchiectatic airways.[21] Though they may be clinically silent, mycetomas can be associated with hemoptysis as a result of rich blood supply to the cavity wall.[21,22] Treatment options include surgical resection as well as strategies to control hemoptysis such as bronchial artery embolization or intracavitary antifungal therapy.[21] Though it may resemble the air-crescent sign of AIA infection that occurs in immunocompromised hosts, the Monod sign occurs in immunocompetent hosts with pre-existing cavitary lung disease.

Cheerio Sign

The Cheerio sign, so named because of its resemblance to the ring-shaped Cheerios breakfast cereal, refers to a lung nodule with a central air lucency.[23] The sign is often the result of cellular proliferation, either neoplastic (eg, in adenocarcinoma) or non-neoplastic (eg, in pulmonary Langerhans cell histiocytosis [PLCH]), around an air lucent region (Fig. 9).[23] In regards to lung adenocarcinoma, the Cheerio sign can be seen with adenocarcinoma in situ (formerly bronchioloalveolar carcinoma), minimally invasive adenocarcinoma, invasive lepidic predominant adenocarcinoma, and invasive mucinous adenocarcinoma when tumor cells proliferate around air lucent regions caused by patent intratumoral bronchioles, pseudocavitation (bubble-like lucencies), or cavitation.[23-25] PLCH, a smoking-related interstitial lung disease that manifests on CT with upper lobe predominant nodules and cysts, can also manifest with the Cheerio sign. PLCH is

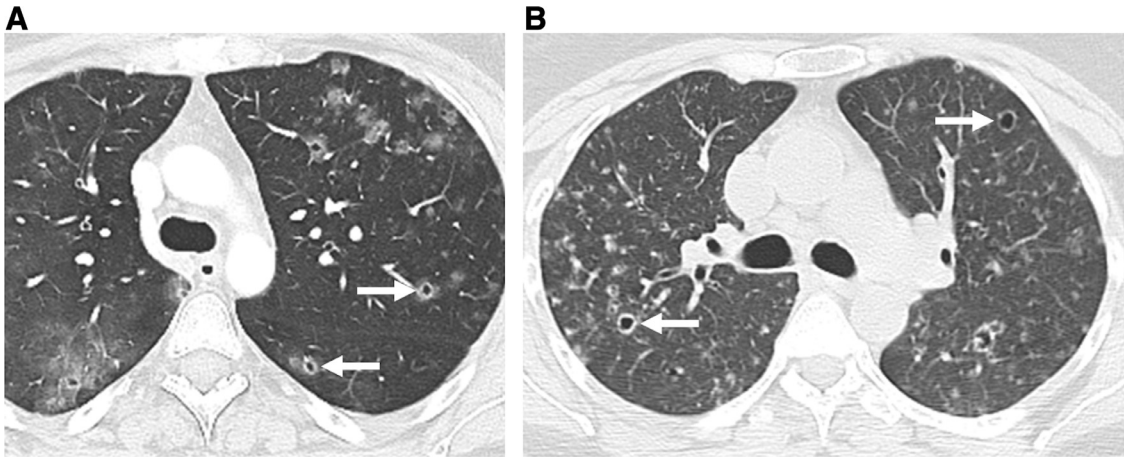

Figure 9 Cheerio sign. (A) CT in a 34-year-old woman with multifocal lung adenocarcinoma shows multiple ground-glass lesions and small thin-walled nodules with central air lucency (Cheerio sign, arrows). (B) CT in a different patient with pulmonary Langerhans cell histiocytosis (PLCH) shows centrilobular nodules in addition to thin-walled nodules with central air lucency (arrows). The Cheerio sign is often the result of cellular proliferation, either neoplastic (eg, in adenocarcinoma) or non-neoplastic (eg, in PLCH), around an air lucent region.

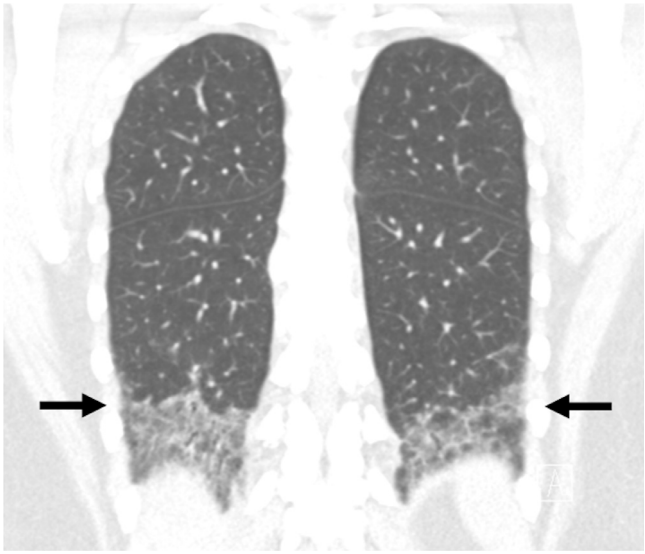

Figure 10 Straight edge sign (SES). Coronal CT reformation in a 45-year-old woman with a history of polymyositis and restrictive lung disease by pulmonary function tests shows presence of the SES bilaterally. Lung biopsy was diagnostic for nonspecific interstitial pneumonia (NSIP). The SES may be useful in differentiating usual interstitial pneumonia (UIP) from NSIP—a strong association has been found between the absence of the SES and UIP on surgical biopsy.

characterized histologically by peribronchiolar nodules that contain Langerhans cells and inflammatory cells.[26] Peribronchial inflammation in PLCH destroys bronchiolar walls, leaving small dilated airways that resemble Cheerios.[27] Cysts in PLCH can also form when solid nodules undergo cavitation. Other causes of cavitary nodules that may manifest with the Cheerio sign include infection (eg, fungal pneumonia), metastatic disease, granulomatosis with polyangiitis, and necrobiotic rheumatoid nodules.[23]

Straight Edge Sign

Usual interstitial pneumonia (UIP) and nonspecific interstitial pneumonia (NSIP) are common patterns of interstitial lung disease. The ability to differentiate between the 2 patterns on high-resolution CT (HRCT) is important not only because of prognostic implications but also because the presence of a high-confidence pattern of UIP obviates the need for surgical lung biopsy.[28] The straight edge sign (SES), defined as reticulation isolated to the lung bases with a sharp demarcation in the craniocaudal plane and without substantial extension along the lateral margins of the lungs, was recently shown by Zhan et al to be useful in differentiating UIP from NSIP—a strong association was found between the absence of the SES and UIP on surgical biopsy (Fig. 10).[28] When comparing the performance characteristics of the SES with standard axial HRCT for identifying UIP on surgical biopsy, unilateral or bilateral absence of the SES was associated with similar diagnostic performance as standard HRCT interpretation.[28] Bilateral absence of the SES had a greater specificity and PPV for UIP diagnosis than standard HRCT interpretation (93.3% and 96.7% compared with 66.7% and 88.9%).[28] Furthermore, in a validation cohort of patients with UIP, NSIP, and chronic hypersensitivity pneumonitis (HP), the SES was significantly and substantially (10×) more

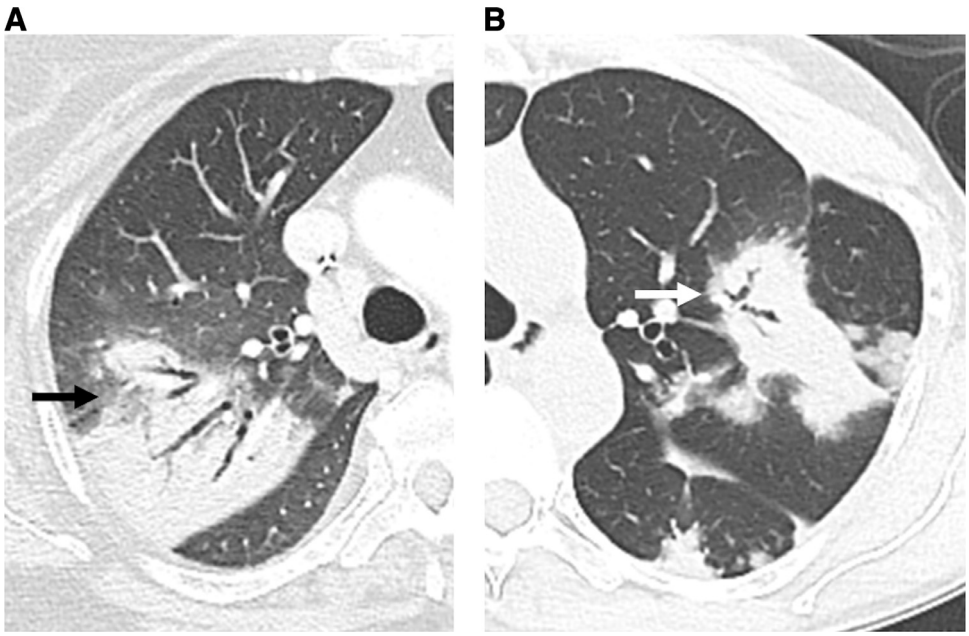

Figure 11 Air bronchogram sign. (A) CT in a 66-year-old woman with fever and cough shows right upper lobe consolidation with air bronchograms (arrow) consistent with pneumonia. (B) CT in a different patient shows left upper lobe masslike consolidation with air bronchograms (arrow), proven to represent lung adenocarcinoma. Multiple other foci of adenocarcinoma are seen in the left lung. The air bronchogram sign can be seen with any alveolar filling process (eg, pneumonia, hemorrhage, edema, or tumor).

common in NSIP than in UIP or in HP but did not differentiate UIP from HP.[28] Chung et al found that the SES had high specificity (94.0%) and low sensitivity (25.4%) in distinguishing connective tissue disease-associated interstitial lung disease from idiopathic pulmonary fibrosis in patients with UIP pattern on CT.[29]

Air Bronchogram Sign

The air bronchogram sign refers to a pattern of air-filled (low-attenuation) bronchi on a background of opaque (high-attenuation) airless lung.[30] and is considered a classic sign of an alveolar filling process (ie, consolidation). The sign implies (1) patency of proximal airways and (2) evacuation of alveolar air either by an alveolar filling process (eg, pneumonia, hemorrhage, and edema, tumor; Fig. 11) or by absorption (eg, nonobstructive atelectasis).[30] Obstructive atelectasis (ie, atelectasis caused by airway obstruction) is unlikely when air bronchograms are visible. The air bronchogram sign is most commonly seen with bacterial pneumonia but any pneumonia can manifest the sign.[31] While the sign is often seen in areas of consolidation, its absence does not exclude consolidation. Pulmonary infarction, for example, often results in consolidation without air bronchograms as a result of blood filling the alveoli.[32] Along similar lines, air bronchograms will not be visible in cases of pneumonia when bronchi are filled with mucus or pus.[32]

Tree-in-Bud

Tree-in-bud opacities, so named because of their resemblance to a budding tree, are the result of bronchiolar thickening and dilatation secondary to impaction with mucus, pus, or fluid.[33] They occur in the center of secondary pulmonary lobules and manifest on CT as small centrilobular nodules connected to Y- or V-shaped branching opacities.[34] Tree-in-bud opacities are most commonly due to pneumonia—they can be seen with any infectious agent including bacterial, mycobacterial, viral, fungal, and parasitic organisms (Fig. 12). Aspiration is the next most common etiology of tree-in-bud opacities and is suggested when the opacities predominate in the dependent portions of the lungs (Fig. 13). Tree-in-bud opacities can also be seen in congenital disorders that are associated with deficiencies in mucociliary clearance, for example, cystic fibrosis, and Kartagener syndrome.[34]

Tree-in-bud opacities have rarely been reported to be malignant in origin and may occur as a result of aerogenous metastatic spread in cases of primary lung adenocarcinoma.[35] Small centrilobular pulmonary arteries course alongside centrilobular bronchioles in secondary pulmonary lobules; distension of these centrilobular arteries by intravascular tumor emboli can mimic tree-in-bud opacities (Fig 14). Tree-in-bud opacities related to infection or aspiration typically resolve with appropriate treatment whereas aerogenous or intravascular metastases persist and grow.[35]

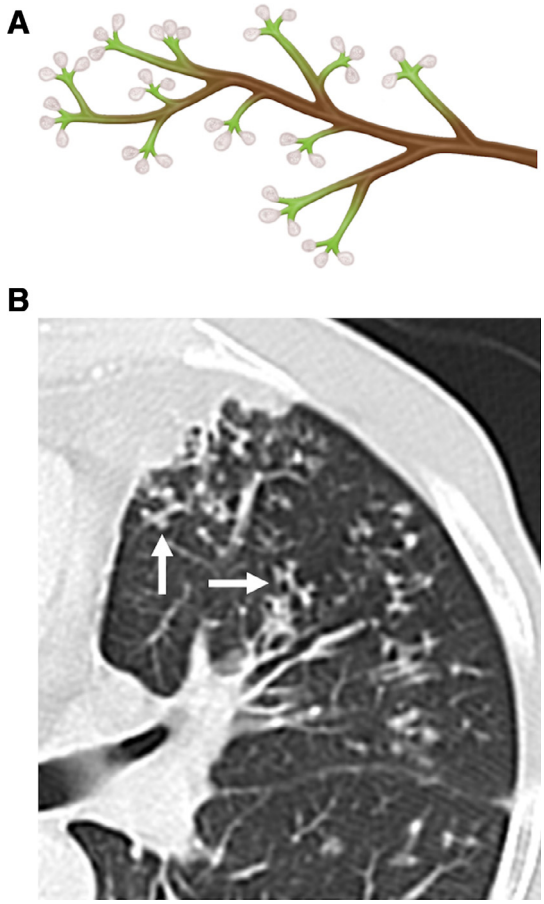

Figure 12 Tree-in-bud sign. (A) Artistic illustration of tree-in-bud sign shows a budding tree. (B) Axial CT of the left lung in a patient with tuberculosis shows several tree-in-bud opacities (arrows). Tree-in-bud opacities can be seen with any infectious agent including bacterial, mycobacterial, viral, fungal, and parasitic organisms.

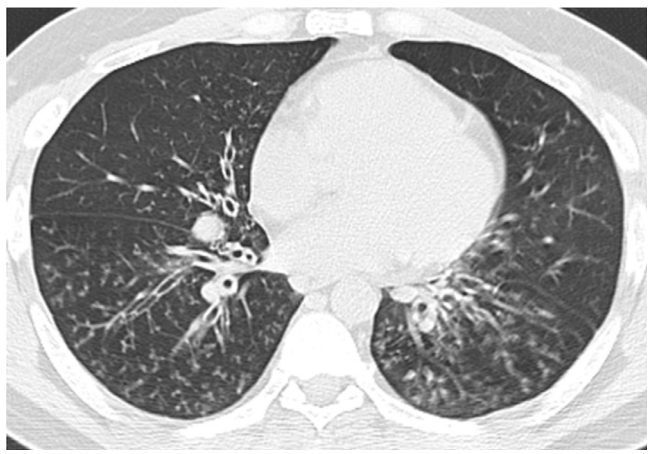

Figure 13 Tree-in-bud sign. CT shows bilateral lower lobe tree-in-bud opacities secondary to aspiration. Aspiration is the second most common etiology of tree-in-bud opacities (after pneumonia) and is suggested when the opacities predominate in the dependent portions of the lungs.

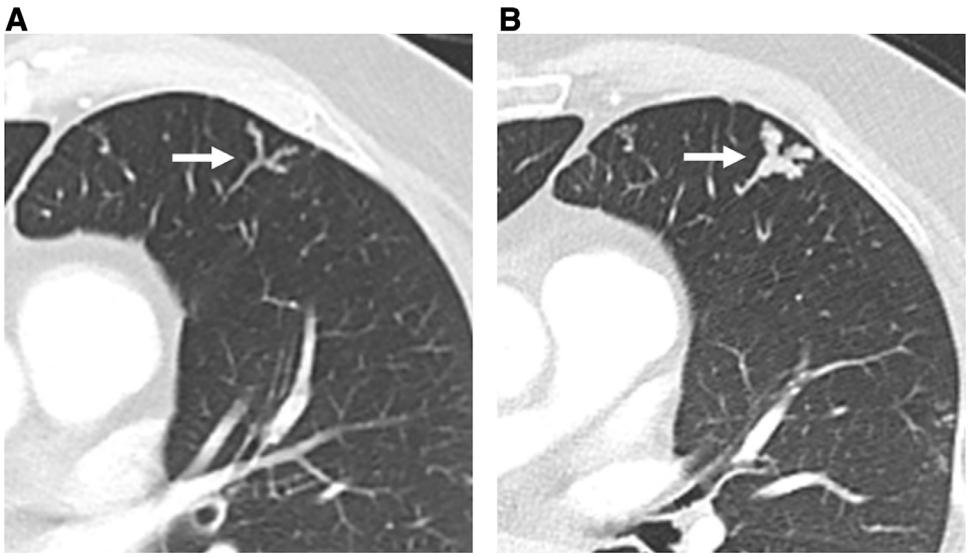

Figure 14 Tree-in-bud mimic from intravascular metastasis. (A) CT in a 63-year-old man with femoral chondrosarcoma shows a tubular branching opacity in the left upper lobe (arrow), thought to represent a tree-in-bud opacity related to infection. (B) Follow-up CT done 8 months later shows enlargement of the opacity (arrow). Biopsy revealed metastatic chondrosarcoma. Small centrilobular pulmonary arteries course alongside centrilobular bronchioles; distension of these centrilobular arteries by intravascular tumor emboli can mimic tree-in-bud opacities.

Headcheese Sign

Head cheese is not a cheese but rather a type of multicolored meat jelly consisting of chunks of different meats from parts of the head of a calf or pig. The headcheese sign, so named because of its resemblance to head cheese, represents a juxtaposition of geographic areas of increased, normal, and decreased lung attenuation and usually indicates a combination of infiltrative and obstructive disease (Fig. 15).[2] Infiltrative disease manifests as areas of increased attenuation (either ground-glass opacity or consolidation) and obstructive disease (ie, small airways obstruction) manifests as areas of decreased attenuation due to air trapping.[36] Air-trapping is typically accentuated on expiratory scans. The most common etiologies of the headcheese sign are subacute HP, atypical infections, sarcoidosis, and desquamative interstitial

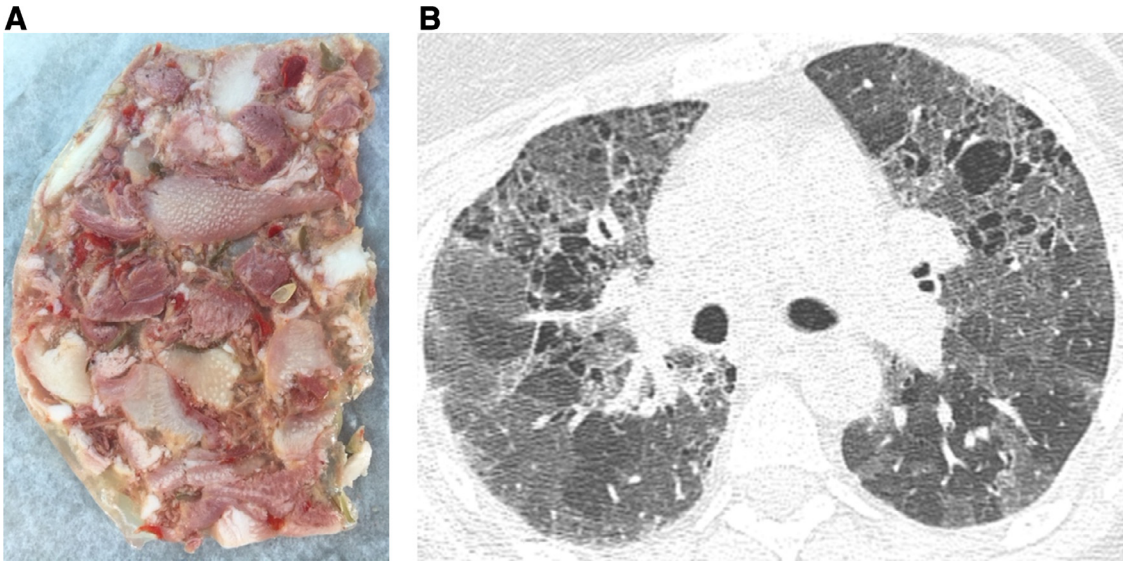

Figure 15 Headcheese sign. (A) Photograph of a slice of head cheese, made up of chunks of different meats from a head of a pig. (B) Headcheese sign in hypersensitivity pneumonitis. CT in a 55-year-old woman who presented with progressive dyspnea over the last several years shows sharply demarcated areas of increased and decreased attenuation as well as signs of fibrosis. Questioning revealed that the patient keeps multiple birds in her home. The most common etiologies of the headcheese sign are hypersensitivity pneumonitis and atypical infections.

pneumonitis (a rare smoking-related interstitial lung disease).[2]

Signet Ring Sign

In most normal subjects, the bronchoarterial ratio (ie, the ratio of the internal diameter of the bronchus to the diameter of the adjacent pulmonary artery) is less than 1, averaging 0.65-0.7.[37] The association of a dilated bronchus with a much smaller adjacent pulmonary artery has been termed the signet ring sign and is indicative of bronchiectasis (Fig. 16).[38] Bronchiectasis represents bronchial dilatation and has myriad causes including infection, aspiration, bronchial obstruction (eg, by endobronchial tumor), immune reactions (eg, allergic bronchopulmonary aspergillosis), mucociliary clearance abnormalities (eg, cystic fibrosis), bronchial wall abnormalities (eg, tracheobronchomegaly, Williams–Campbell syndrome), and immune deficiency states (eg, acquired immune deficiency syndrome).[39] The sign is named after the signet ring, a ring traditionally seen as a symbol of family heritage, historically bearing a family crest or coat of arms on its flat bezel.

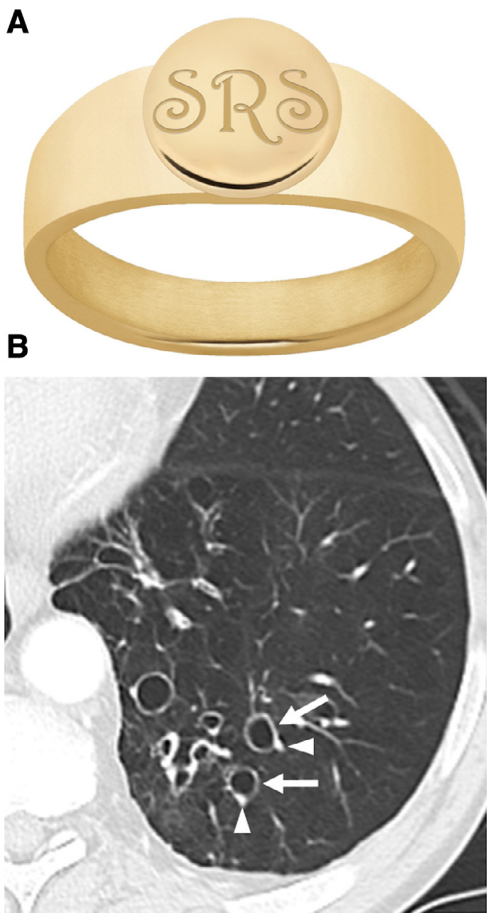

Figure 16 Signet ring sign. (A) Artistic illustration of a signet ring. (B) Axial CT of the left lower lobe in a patient with recurrent aspiration shows several examples of the signet ring sign, indicative of bronchiectasis. Note that the diameter of bronchi (arrows) is much larger than the diameter of the adjacent pulmonary arteries (arrowheads). Normally, broncho arterial ratio is less than 1.

Figure 17 Feeding vessel sign. Staging CT in a 74-year-old man with melanoma shows a right lower lobe nodule with a feeding vessel (arrow). Wedge resection revealed metastatic melanoma. The feeding vessel sign has been considered an indicator of hematogenous spread of disease.

Feeding Vessel Sign

The feeding vessel sign is defined as a distinct pulmonary vessel leading directly into a pulmonary nodule or mass (Fig. 17). Commonly observed in cases of septic emboli, pulmonary infarction, and hematogenous metastases, the sign has been considered an indicator of hematogenous spread of disease.[17,40-41] Dodd et al, however, showed that most vessels that appear to enter lung lesions on axial CT images actually pass around lung lesions when examined with multiplanar reconstructions and maximum intensity projection images; in their review, all vessels that appeared to enter lung lesions were pulmonary veins.[42] They concluded that septic emboli, infarcts, and hematogenous metastases are supplied by small arteriolar branches that are too small to detect by CT. The sign has also been described in cases of pulmonary arteriovenous malformations, which is distinguished from the aforementioned conditions by the presence of both a feeding artery and a draining vein.

Conclusion

Radiologic signs are based on items or patterns that are encountered in everyday life. Recognition of these signs in the lungs on CT allows the differential diagnosis to be narrowed and, in some cases, enables a diagnosis to be made.

Early recognition of signs associated with aggressive infections can be life-saving.

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