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Bacterial and Parasitic Zoonoses

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Body Imaging of Bacterial and Parasitic Zoonoses

Speciality
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Body Imaging of Bacterial and Parasitic Zoonoses: Keys to Diagnosis

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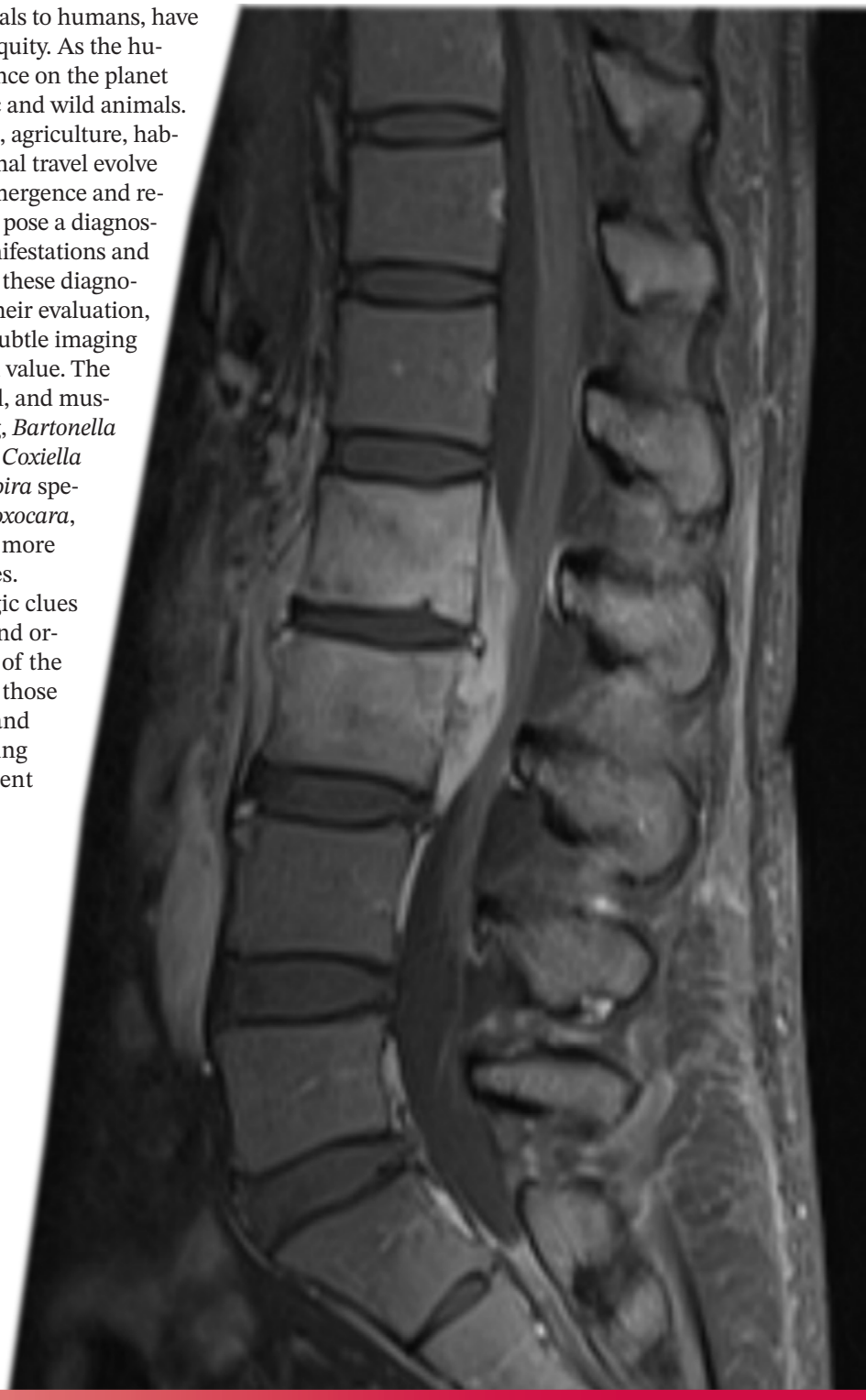
Zoonotic infections, which are transmitted from animals to humans, have been a substantial source of human disease since antiquity. As the human population continues to grow and human influence on the planet expands, humans frequently encounter both domestic and wild animals. This has only increased as deforestation, urbanization, agriculture, habitat fragmentation, outdoor recreation, and international travel evolve in modern society, all of which have resulted in the emergence and reemergence of zoonotic infections. Zoonotic infections pose a diagnostic challenge because of their nonspecific clinical manifestations and the need for specialized testing procedures to confirm these diagnoses. Affected patients often undergo imaging during their evaluation, and a radiologist familiar with the specific and often subtle imaging patterns of these infections can add important clinical value. The authors review the multimodality thoracic, abdominal, and musculoskeletal imaging findings of zoonotic bacterial (eg, *Bartonella henselae*, *Pasteurella multocida*, *Francisella tularensis*, *Coxiella burnetii*, and *Brucella* species), spirochetal (eg, *Leptospira* species), and parasitic (eg, *Echinococcus*, *Paragonimus*, *Toxocara*, and *Dirofilaria* species) infections that are among the more commonly encountered zoonoses in the United States. Relevant clinical, epidemiologic, and pathophysiologic clues such as exposure history, occupational risk factors, and organism life cycles are also reviewed. Although many of the imaging findings of zoonotic infections overlap with those of nonzoonotic infections, granulomatous diseases, and malignancies, radiologists' familiarity with the imaging patterns can aid in the differential diagnosis in a patient with a suspected or unsuspected zoonotic infection.



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Content Codes: CH, CT, GI, GU, MK, MR

Abbreviations: FDG = fluorine 18 fluorodeoxyglucose, VLM = visceral larva migrans

TEACHING POINTS

- Infection with *Bartonella* should be considered in any child with multiple hepatic lesions, especially in the context of prolonged fever.
- Bacillary angiomatosis can be considered in the differential diagnosis for hyperenhancing liver lesions and lymphadenopathy in patients with AIDS, with clinical and imaging features similar to those of Kaposi sarcoma. Tissue sampling is often required for differentiation.
- The primary imaging manifestations of brucellosis encountered by radiologists are spondylodiscitis, sacroiliitis, and hepatosplenomegaly. *Brucella* spondylodiscitis is most commonly seen in the lumbar spine and mimics tuberculosis.
- The most common imaging manifestation of leptospirosis is diffuse pulmonary hemorrhage.
- The combination of omental or peritoneal stranding, pleural effusion (especially with empyema), and nodules with linear tracks to the pleura strongly suggests paragonimiasis. Peripheral and pleural eosinophilia are common.

Introduction

Rudolph Virchow, one of the leaders of medicine and pathology in the 19th century, coined the term *zoonosis* for a disease that can be transmitted to humans from nonhuman animals, when he recognized the link between humans and animals in his description of the life cycle of *Trichinella spiralis* (1). Some estimates are that nearly two-thirds of human pathogens can readily infect other animals, and the interplay between human and animal pathogens is well documented but underappreciated (2).

As human population and influence on the planet continue to expand, so does globalization of commerce, industry, and culture. Advancement of human civilization including urbanization, agriculture, deforestation, and habitat fragmentation have altered the dynamics of human-wildlife interactions. Alterations in natural habitats of animals has resulted in closer proximity to humans, enhancing the "leap" of zoonotic diseases to humans (3). Occupational, recreational, and environmental exposures are also important factors. As such, the emergence and reemergence of zoonotic diseases are growing public health concerns. The unrelenting effect of the COVID-19 pandemic has made this clear.

Zoonoses are caused by a diverse spectrum of pathogens including bacteria, parasites, and viruses that often exist in complex life cycles involving definitive hosts, intermediate hosts, arthropod vectors, and environmental reservoirs. Diagnostic challenges may arise from gaps in clinician knowledge about these uncommon conditions, their nonspecific clinical manifestations, and the inability to identify many organisms with routine microbiologic studies. However, many patients with these infections present with imaging manifestations that radiologists encounter.

The scope of this review is limited to bacterial, spirochetal, and parasitic infections that humans contract through interactions with animals or the environment and that demonstrate recognizable or well-described imaging manifestations in the body (eg, in the thorax, abdomen, or axial skeleton). These manifestations include infections caused by extracellular bacteria (eg, *Pasteurella multocida*), intracellular bacteria (eg, *Bartonella henselae*, *Coxiella burnetii*, *Brucella* species, and *Francisella tularensis*), spirochetes (eg, *Leptospira* species), and parasites (eg, *Echinococcus* species, *Paragonimus* species, *Dirofilaria* species, and *Toxocara* species) (Tables 1, 2). A comprehensive examination of all zoonotic infections is beyond the scope of this review, which excludes zoonoses with predominantly neurologic imaging manifestations (eg, arthropod-borne encephalitis viruses, Lyme disease, and rickettsial infections) and viral zoonoses that have fully "leapt" to humans (eg, COVID-19 and influenza).

Bacterial Infections

Bartonellosis (Cat Scratch Disease)

Bartonella henselae is an intracellular gram-negative bacterium transmitted to humans from cats. Although up to one-half of all domestic cats have antibodies to *B henselae*, human infections are uncommon and are usually transmitted by a cat scratch or bite. The clinical history of cat exposure is common, but it is not always present. Especially in children, bartonellosis is an important cause of fever of unknown origin (ie, fever without an identifiable cause lasting for 2 weeks or more) (4). The diagnosis is confirmed with serologic tests, but polymerase chain reaction tests are increasingly used.

Cat scratch disease is a febrile illness, with regional necrotizing granulomatous lymphadenopathy draining the site of inoculation. Common sites of lymphadenopathy include axillary, epitrochlear, cervical, and inguinal chains. Uncomplicated cases often resolve within a month and may not require treatment (5), but systemic dissemination is estimated to occur in 5%–10% of patients. The liver, spleen, and bones are the most common sites of involvement in disseminated disease, and culture-negative endocarditis may occur (6).

US is often the initial modality of choice in patients suspected of having cat scratch disease. On US images, involved lymph nodes are enlarged, centrally hypoechogenic, and hypervascular (7) (Fig 1). Posterior through-transmission can be seen (8). On CT images, involved lymph nodes are enlarged and centrally hypoattenuating (Fig 1), and the infection may mimic other granulomatous infections (eg, tuberculosis or histoplasmosis). In two-thirds of patients, lymphadenopathy is limited to a single nodal group (6).

Hepatosplenic involvement is characterized by necrotizing granulomas or granulomatous hepatitis (7) and is well characterized with US, CT, or MRI. In children, US is the preferred initial imaging modality, and CT should be reserved for complicated infections that are not fully imaged with US. Hepatosplenic involvement most commonly demonstrates multiple small scattered lesions with a size range of 0.3–3.0 cm (6). On US images, lesions are usually hypoechoic and can demonstrate through-transmission. On CT images, lesions are often ill-defined, centrally hypoattenuating, and peripherally enhancing (6) (Fig 2). The imaging findings in the liver and spleen overlap with those of other granulomatous diseases

Table 1: Bacterial Zoonotic Infections

Organism	Host	Transmission	Imaging Features	Laboratory Findings
Bartonella henselae	Cats	Animal bite or scratch	Cat scratch fever: regional lymphadenopathy, dissemination to the liver, spleen, and/or bones Bacillary angiomatosis (immunosuppression): liver, bone, and/or skin lesions	Serologic testing Polymerase chain reaction testing for biopsy specimens
Pasteurella multocida	Cats, dogs, livestock	Animal bite	Soft-tissue infection, osteomyelitis, and/or abscess at bite site Dissemination: vascular infections, intra-abdominal infection, and/or pneumonia	Grows on multiple culture media
Coxiella burnetii	Cattle, sheep, goats	Arthropod vectors, ingestion of unpasteurized animal products, or direct animal contact	Acute Q fever: pneumonia Chronic Q fever: endocarditis, vascular and graft infections with spondylodiscitis, or autoimmune-like large-vessel vasculitis	Serologic test Culture discouraged because of risk to laboratory personnel
Brucella species	Cattle, sheep, pigs	Ingestion of unpasteurized animal products, or direct animal contact	Osteoarticular infection: spondylodiscitis or sacroiliitis Hepatosplenomegaly, granulomatous hepatitis, or vascular infections	Serologic testing and agglutination testing Bone marrow biopsy culture
Francisella tularensis	Rabbits, rodents, squirrels	Arthropod vectors, ingestion of unpasteurized animal products, direct animal contact, or water sources	Ulceroglandular tularemia: regional lymphadenopathy Typhoidal tularemia: hepatic abscesses Pneumonic tularemia: pneumonia, lung nodules, and/or thoracic lymphadenopathy	Serologic testing Culture is discouraged because of risk to laboratory personnel
Leptospira species	Livestock, dogs, rodents, raccoons, bats	Water sources contaminated with animal urine	Diffuse alveolar hemorrhage	Serologic testing

Table 2: Parasitic Zoonotic Infections

Organism	Host	Transmission	Imaging Features	Laboratory Findings
Echinococcus granulosus	Dogs	Ingestion of contaminated soil	Unilocular and multilocular cystic lesions in liver, lung, heart, spleen, kidneys, or brain Lesions can calcify	Peripheral eosinophilia Serologic testing
Paragonimus species	Dogs, cats, wild mammals	Ingestion of crustacean (snail, crayfish) intermediate hosts	Abdomen: omental and peritoneal stranding Thorax: pleural effusion with or without pneumothorax Solid and ground-glass nodules with or without linear "worm tracks" to pleura Cardiophrenic lymphadenopathy	Peripheral and pleural eosinophilia Immunoblot testing
Toxocara species	Dogs (*Toxocara canis*), cats (*Toxocara catis*)	Ingestion of contaminated soil or paratenic host (fowl, rabbit)	Visceral larva migrans Liver lesions Migratory lung nodules Ground-glass opacities	Peripheral eosinophilia Elevated immunoglobulin E level Serologic testing Negative stool studies
Dirofilaria immitis	Dogs, cats	Arthropod vectors	Acute: pulmonary infarction Chronic: pulmonary nodule(s) extending from pulmonary artery branch can be mistaken for malignancy	Peripheral eosinophilia in patients with acute infection Incidental on nodule resection

such as sarcoidosis or fungal infections, as well as hematologic malignancy and metastatic disease.

Infection with *Bartonella* should be considered in any child with multiple hepatic lesions, especially in the context of prolonged fever. Osseous involvement primarily manifests with nonspecific osteolytic lesions, most commonly involving the axial skeleton, with long-bone lesions, and joint involvement is seen less commonly (9) (Fig 2).

Bacillary Angiomatosis

In patients with cell-mediated immunodeficiency such as AIDS and in patients after solid organ transplant, disseminated bartonellosis manifests with vasoproliferation (bacillary angiomatosis), rather than with necrotizing granulomatous disease. Vasoproliferative lesions (eg, involving the skin, mucous membranes, visceral organs, bones, and brain) are seen. Patients typically present with skin lesions and systemic

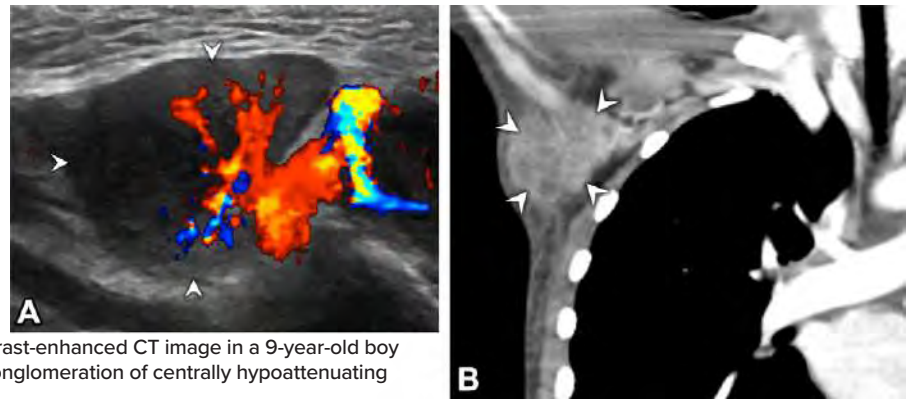


Figure 1. Cat scratch disease in two patients. **(A)** Color Doppler US image in a 6-year-old boy who was scratched by a feral cat shows enlarged, hypoechoic, and hypervascular cervical lymph nodes (arrowheads). **(B)** Coronal contrast-enhanced CT image in a 9-year-old boy who was scratched by a stray kitten shows an enlarged conglomeration of centrally hypoattenuating axillary lymph nodes (arrowheads).

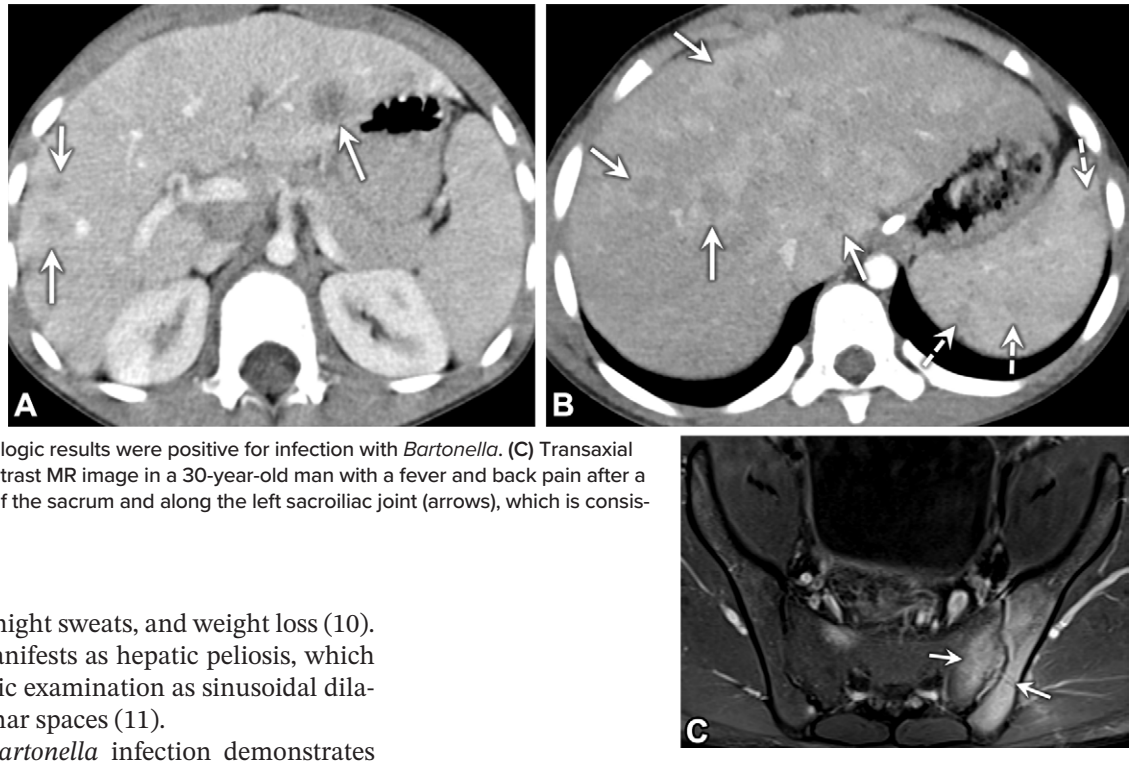


Figure 2. Disseminated bartonellosis in three patients. **(A)** Transaxial contrast-enhanced CT image in a 9-year-old boy with prolonged fever weeks after he was scratched by a cat shows multiple hypoattenuating lesions throughout the liver (arrows). **(B)** Transaxial contrast-enhanced CT image in a 9-year-old boy with a fever after being scratched by a cat shows multiple peripherally enhancing and centrally hypoattenuating lesions in the liver (solid arrows) and spleen (dashed arrows). Liver biopsy results showed granulomatous hepatitis, and serologic results were positive for infection with *Bartonella*. **(C)** Transaxial fat-saturated T1-weighted postcontrast MR image in a 30-year-old man with a fever and back pain after a cat scratch shows enhancement of the sacrum and along the left sacroiliac joint (arrows), which is consistent with osteitis and sacroiliitis.

symptoms such as anemia, night sweats, and weight loss (10). Involvement of the liver manifests as hepatic peliosis, which is characterized at pathologic examination as sinusoidal dilatation and blood-filled lacunar spaces (11).

Hepatic peliosis from *Bartonella* infection demonstrates imaging findings similar to those of other causes of peliosis, which include drug reactions, toxins, and other wasting infections such as tuberculosis (11) (Fig 3). Multifocal hepatic lesions are typical and are hypoattenuating compared with the liver parenchyma, or less commonly, hyperattenuating if there is intralesional hemorrhage on noncontrast CT images. Dynamic postcontrast CT and MRI of the liver demonstrate early arterial phase hyperenhancement with either centripetal or centrifugal enhancement patterns. The lesions retain contrast material instead of showing washout, and this is a feature that allows them to be distinguished from hepatocellular carcinoma. If lesions enhance peripherally, they tend to have contiguous enhancement, which helps to differentiate them from hemangiomas, but they can mimic liver metastases (11). On MR images, lesions tend to be T2 hyperintense and T1 hypointense relative to the background liver (11). In patients with AIDS, the hypervascular nature of the lesions can mimic Kaposi sarcoma.

Organ involvement beyond the liver is common in patients with bacillary angiomatosis. Hypervascular abdominal lymphadenopathy and osteolytic bone lesions with soft-tissue masses can be seen in addition to ascites, pericardial effusions, splenic lesions, and bronchocentric lung nodules (10). Bacillary angiomatosis can be considered in the differential diagnosis for hyperenhancing liver lesions and lymphadenopathy in patients with AIDS, with clinical and imaging features similar to those of Kaposi sarcoma. Tissue sampling is often required for differentiation.

Pasteurellosis

Pasteurella multocida are gram-negative bacteria that normally colonize the oral and nasal cavities of mammals and are opportunistic pathogens in both animals and humans. Infections with *P multocida* require a breach in the integument or mucosal barrier to cause disease, and a history of animal contact (most commonly, a cat or dog bite) is nearly universally present in human infections (12). Cellulitis and soft-tissue infections are common at the site of the bite, but septicemia and dissemination can occur (13). Cat bites often

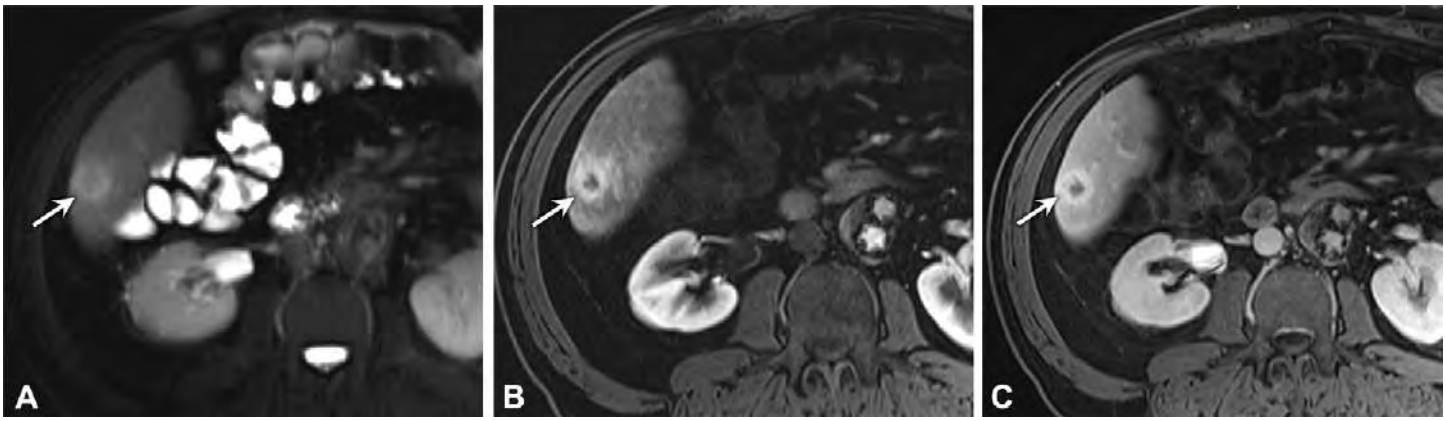


Figure 3. Bacillary peliosis in a 63-year-old man receiving long-term immunosuppression therapy after a heart transplant. **(A)** Transaxial fat-saturated T2-weighted MR image shows a focal lesion in the liver that is mildly hyperintense along the periphery (arrow). **(B)** Transaxial fat-saturated T1-weighted contrast-enhanced MR image acquired during the arterial phase shows peripheral hyperenhancement in the lesion (arrow). **(C)** Transaxial fat-saturated T1-weighted contrast-enhanced MR image with a 5-minute delay shows retention of contrast material in the lesion (arrow). On precontrast T1-weighted images (not shown), the lesion was hypointense in comparison with the background liver. Biopsy results demonstrated sinusoidal dilatation consistent with peliosis, and the polymerase chain reaction test result was positive for *B henselae*.

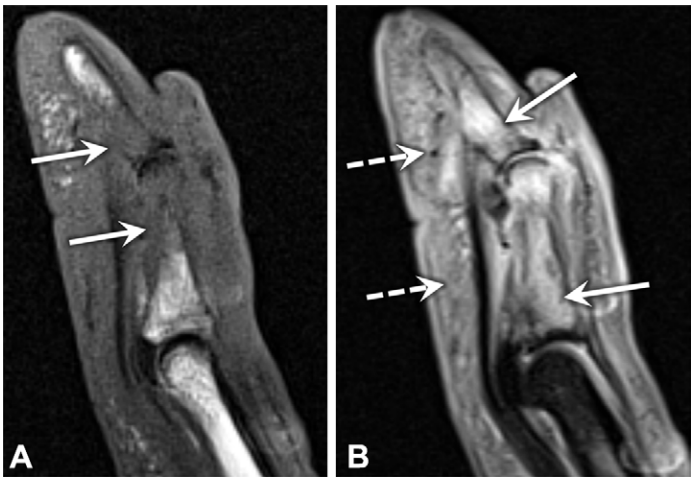


Figure 4. Localized infection with *P multocida* in a 68-year-old man who was bitten on the finger by a cat several weeks previously. **(A)** Sagittal T1-weighted MR image of the finger shows marrow replacement in the middle and distal phalanges (arrows), which is consistent with osteomyelitis. **(B)** Sagittal short-tau inversion-recovery MR image of the finger shows corresponding marrow edema in the middle and distal phalanges (solid arrows) and overlying soft-tissue edema (dashed arrows), corresponding to cellulitis. Biopsy culture grew *P multocida*. Although extremity MRI is outside the scope of body imaging, this case shows the typical local soft-tissue complications that can be seen in any body part with an infected bite.

predispose patients to more severe disease than do dog bites, likely because of a deeper inoculation of organisms. Exposure to open wounds or the puncture of indwelling catheters are also known routes of infection (12,14). *Pasteurella* grows well on multiple culture media, but selective techniques are often needed for confirmation. Broad-spectrum antibiotics including those routinely used for animal bite prophylaxis are generally effective against *Pasteurella* infection (12).

Imaging features of soft-tissue infections with *P multocida* at the site of a bite are similar to those of other bite-related infections. Radiographs may demonstrate retained teeth or claws and/or soft-tissue gas. CT and MRI are useful for assessment of underlying vascular injury or osseous involvement, but MRI is also more sensitive to signs of complicated infection such as cellulitis, myositis, fasciitis, tenosynovitis, septic arthritis, and osteomyelitis (15) (Fig 4).

In patients with disseminated disease, thoracic involvement can include pneumonia, tracheobronchitis, cavitary lesions, lung abscess, and empyema, which are similar to other bacterial infections (16). Intra-abdominal infections can manifest with peritonitis, liver abscess, tubo-ovarian abscess, and intra-abdominal abscess. *P multocida* has rarely been associated with infectious pseudoaneurysm of the aorta and vascular graft infections (17) (Fig 5).

Q Fever

Q fever was first described in 1935 in workers at a slaughterhouse in Australia. Because the cause was not known at the time, it was named "query" fever, but the disease was later attributable to infection with *Coxiella burnetii*. *C burnetii* is an obligate intracellular bacterium that infects mononuclear phagocytes, and the primary reservoirs include cattle, sheep, and goats. Transmission to humans requires exposure to as little as a single organism and can occur from inhalation of contaminated excretions, tick bites, or ingestion of unpasteurized dairy products. Q fever is an important occupational hazard for slaughterhouse workers, veterinarians, and farmers (18).

Q fever has classically been divided into acute and chronic types. Acute Q fever is a febrile illness that most commonly manifests with fever, headache, and pneumonia and is estimated to be a cause of 2.3% of community-acquired types of pneumonia in the United States (18). Acute Q fever has also been a reported cause of granulomatous hepatitis, pericarditis, myocarditis, and meningoencephalitis. Chronic Q fever (or persistent localized infections) are more commonly associated with predisposing infections such as abnormal heart valves or immunocompromised states and can manifest as culture-negative endocarditis, vascular and graft infections, or osteoarticular infections (19,20). Serologic and polymerase chain reaction testing are preferred to confirm the diagnosis, and cultures are generally avoided because of their time-consuming nature and the danger to laboratory workers (20).

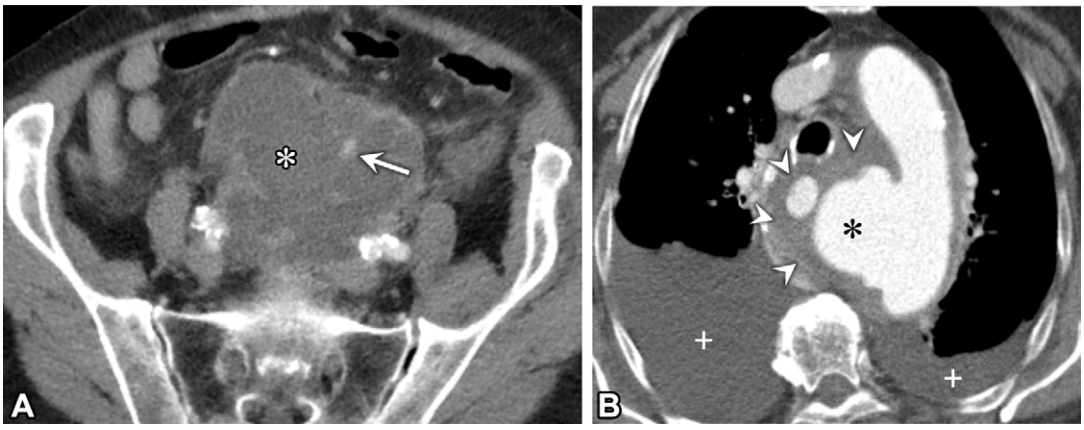


Figure 5. Disseminated *Pasteurella* infection in two patients. **(A)** Transaxial contrast-enhanced CT image in a 67-year-old man who presented weeks after a cat bite to the foot shows a large centrally necrotic lymph node mass (*) in the abdomen that encases the inferior mesenteric artery (arrow). Blood and biopsy cultures were positive for *P multocida*. **(B)** Transaxial contrast-enhanced CT image in a 94-year-old woman who presented weeks after a cat bite shows a large saccular outpouching (*) of the aorta, which is consistent with a pseudoaneurysm, with an adjacent hematoma (arrowheads) and bilateral pleural effusions (+). Blood cultures were positive for *P multocida*.

When patients with acute Q fever are imaged, they most commonly present with a pulmonary illness. Q fever pneumonia typically has a nonspecific appearance, most commonly with unilateral or bilateral consolidations (21,22) (Fig 6) that are similar to those seen in patients with community-acquired pneumonia of other causes. Authors of some studies (21) have emphasized ground-glass halos surrounding consolidations as a characteristic finding. Pleural effusion and lymphadenopathy are uncommon (21,22).

Chronic Q fever most commonly results in culture-negative endocarditis, but vascular and graft infections can be seen as well. The combination of a vascular graft infection, lumbar spondylodiscitis, and psoas abscess is a well-described pattern and should prompt consideration of Q fever as a potential cause (23) (Fig 6). In patients with serologically confirmed chronic Q fever, PET/CT has been an increasingly used modality in the detection of occult, previously unidentified sites of disease (24). Case reports have also been published of Q fever–associated large-vessel vasculitis, which mimics Takayasu arteritis (25) (Fig 7).

Brucellosis

Brucellosis is a chronic febrile granulomatous infection caused by intracellular gram-negative coccobacilli of the *Brucella* genus, most commonly *Brucella melitensis* and *Brucella abortus* (26). Cattle, sheep, goats, and pigs are the main reservoirs of disease (27), and transmission to humans occurs through the consumption of unpasteurized dairy products, direct contact with infected animal parts, or inhalation of aerosolized particles. Shepherds, veterinarians, dairy industry professionals, and slaughterhouse workers are at risk of occupational exposure (26). The disease has nearly been eradicated in the United States and Northern Europe because of prevention programs for livestock, and as a result, most cases in the United States are imported from regions of higher prevalence (26). *Brucella suis*, which primarily infects pigs, has been eradicated in domestic populations of pigs in North America and Europe but remains prevalent in populations of feral hogs and wild boars. Clinical cases in humans are rare but can occur in hunters with direct exposure (28).

Brucellosis manifests as a febrile illness, and the most common complication is osteoarticular involvement (26,29). Epididymitis, granulomatous hepatitis, endocarditis, aortitis, and pregnancy loss are known but less-common complications (26,30). Confirmation of infection is made with culture or serologic tests, and multidrug antibiotic regimens are usually needed to avoid relapse (26).

Osteoarticular involvement most commonly results in arthritis, sacroiliitis, or spondylodiscitis (29). MRI is the most useful modality for evaluation of musculoskeletal involvement in brucellosis. Spinal disease from a *Brucella* infection most commonly involves the lumbar spine and demonstrates imaging findings similar to those of other causes of discitis and osteomyelitis: T1 hypointensity, T2 hyperintensity, and contrast enhancement in the affected bone along the endplates of an intervertebral disk (29,30) (Fig 8). A characteristic "Pedro-Pons sign" of steplike erosion of the anterior-superior endplate has been suggested as a specific radiographic feature of *Brucella* spondylodiscitis (29,31). In comparison with pyogenic discitis, the intervertebral disk may be spared or only mildly involved. The imaging features overlap with those of tuberculosis, but the gibbus deformity is less common in a patient with a *Brucella* infection (30).

Sacroiliitis can be unilateral or bilateral (29) and result in destructive or erosive changes when it is chronic (30). Similar to other causes of sacroiliitis, common findings are increased synovial fluid and bone marrow edema on T2-weighted MR images, marrow hypointensity on T1-weighted MR images, and enhancement on postcontrast images. Bone scintigraphy demonstrates increased uptake along affected joints (29).

Abdominal manifestations of brucellosis are mainly hepatic and splenic enlargement. Although granulomatous hepatitis can be seen, liver abscesses are rare and focal lesions tend not to be present in the liver on images (26) (Fig 9).

The primary imaging manifestations of brucellosis encountered by radiologists are spondylodiscitis, sacroiliitis, and

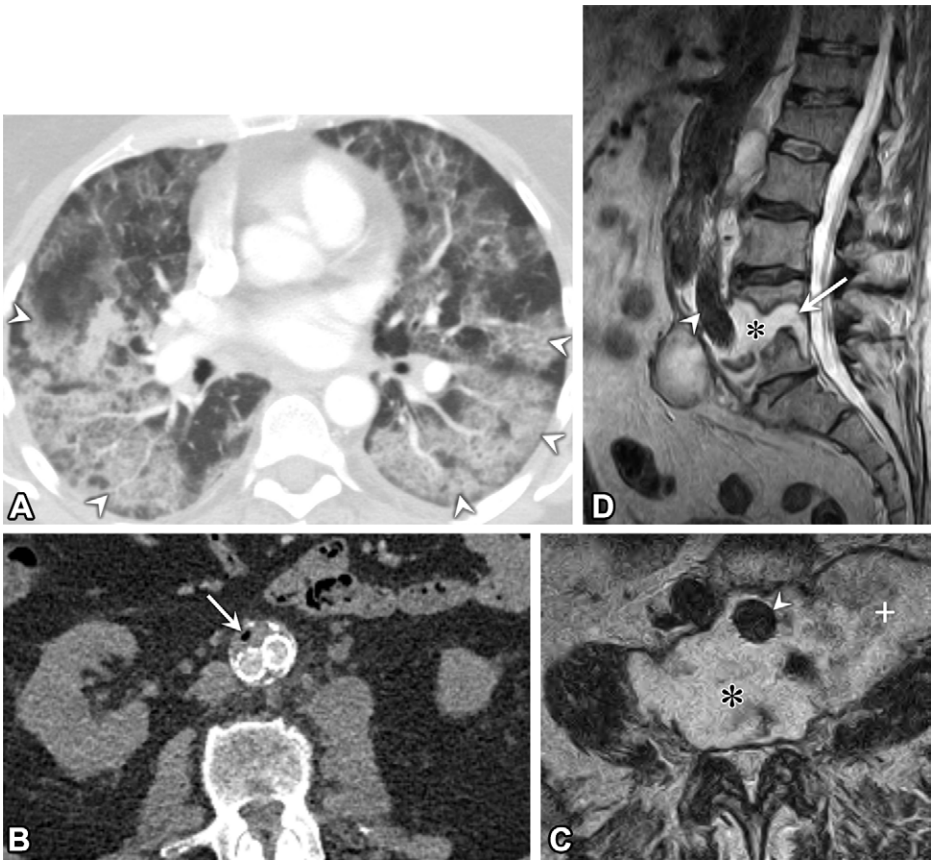


Figure 6. Q fever in two patients. **(A)** Transaxial contrast-enhanced CT image in a 44-year-old woman with Q fever pneumonia shows bilateral multifocal ground-glass opacities with smooth interlobular septal line thickening in the lungs (arrowheads). The diagnosis was confirmed with serologic evaluation. **(B–D)** Chronic Q fever in a 62-year-old man with a history of placement of an abdominal aortic endograft years previously. Transaxial contrast-enhanced CT image **(B)** shows an abdominal aortic endograft with gas (arrow in **B**) in the aneurysm sac, which is suspicious for infection. Subsequently, lumbar spine MR images were obtained to evaluate the osseous extent of infection. Transaxial **(C)** and sagittal **(D)** T2-weighted MR images show hyperintense inflammatory changes (∗ in **C** and **D**) extending from the L4-L5 disk (arrow in **D**) to involve the aortic graft (arrowhead in **C** and **D**) and the left psoas muscle (+ in **C**), which are consistent with spondylodiscitis, with a contiguous infection in the aortic graft and an abscess in the psoas muscle. Results of a polymerase chain reaction test of the aorta resection specimen were positive for *C burnetii*.

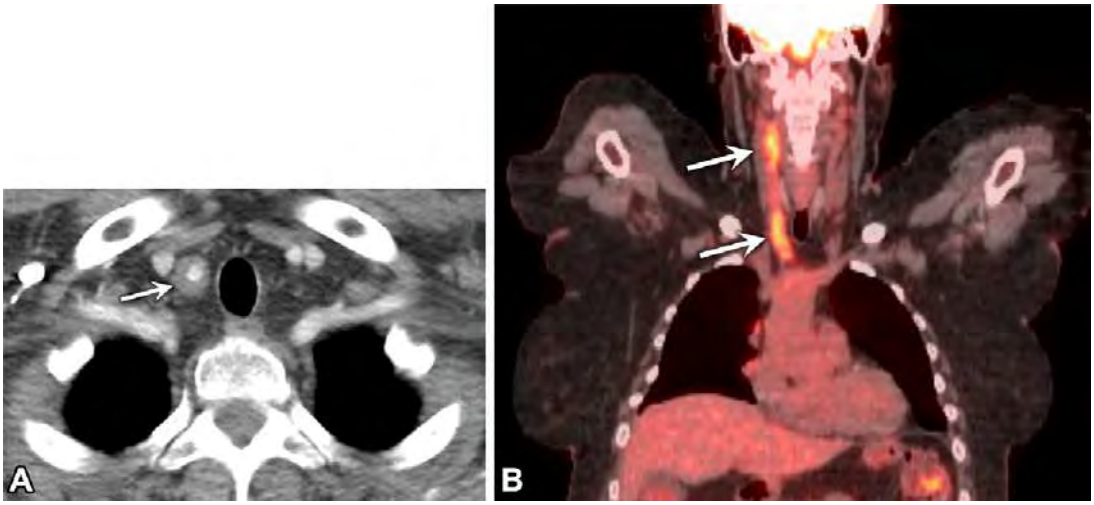


Figure 7. Chronic Q fever in a 68-year-old woman who presented with unintentional weight loss. **(A)** Transaxial contrast-enhanced chest CT image shows circumferential soft-tissue thickening of the right common carotid artery (arrow), which is consistent with vasculitis. **(B)** Coronal fluorine 18 fluorodeoxyglucose (FDG) PET/CT image shows hypermetabolic activity that is associated with the right common carotid artery (arrows), which is consistent with active inflammation. The appearance overlaps with that of other large-vessel vasculitides, such as Takayasu arteritis and giant cell arteritis.

hepatosplenomegaly. *Brucella* spondylodiscitis is most commonly seen in the lumbar spine and mimics tuberculosis.

Tularemia

Tularemia is a necrotizing granulomatous infection caused by *Francisella tularensis*, an intracellular gram-negative bacterium harbored naturally in ticks, water sources, and wild animals. Tularemia is most commonly encountered in Arkansas, Missouri, and Oklahoma, with approximately 100 sporadic cases reported in the United States each year (32,33). Patients with tularemia often have a history of a tick bite, exposure to rabbits, recreational outdoor activity, or work in veterinary medicine or with wildlife. (32). Infamously, tularemia is considered a potential agent of bioterrorism and was developed as an aerosolized weapon by the U.S. Armed Forces in the 1960s (34). Serologic tests are most commonly used to confirm the diagnosis because culturing the organism poses a risk of infection to laboratory personnel (35). Antibiotic therapy is essential, and there is a 2% reported mortality rate even with antibiotic treatment (36).

The clinical presentation of patients with tularemia is classically acute, with a severe febrile illness developing within 3–6 days, but symptoms can occur more quickly in inhalational forms (35). The three major clinical forms

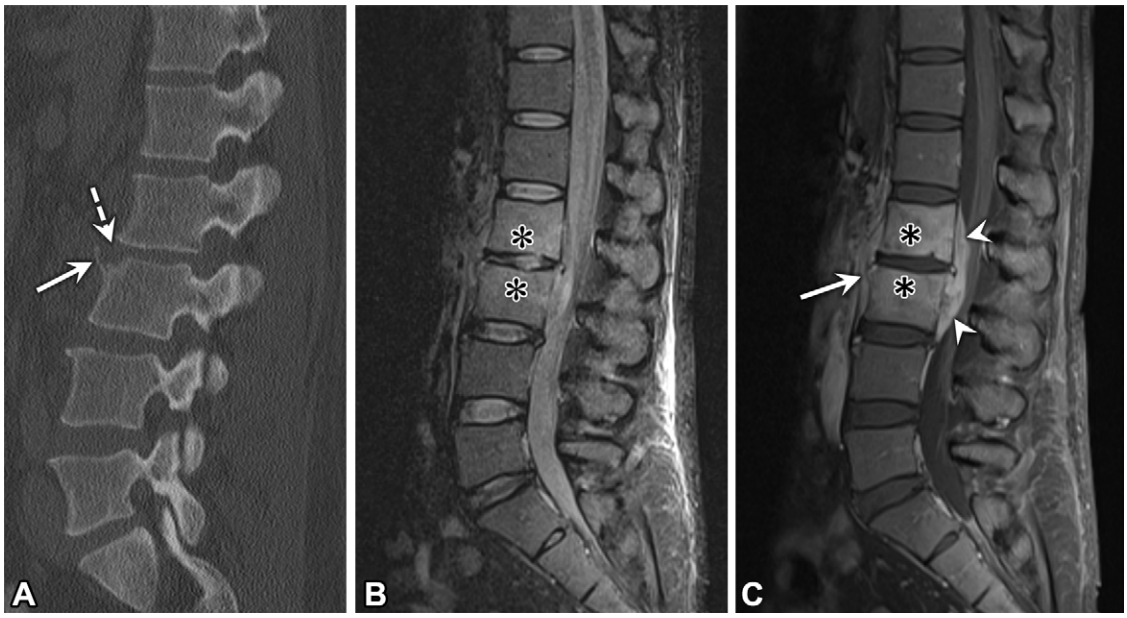


Figure 8. Brucellosis in a 30-year-old man in Texas with a 2-week history of fever and back pain after ingesting unpasteurized cheese from Mexico. **(A)** Sagittal noncontrast CT reconstruction image of the lumbar spine shows anterior-superior endplate erosion (dashed arrow) with an anteriorly projecting hook of osseous sclerosis (solid arrow) at the L2-L3 disk space (ie, Pedro-Pons sign). Lumbar spine MRI was performed to further evaluate the osseous extent. **(B)** Sagittal short-tau inversion-recovery T2-weighted MR image of the lumbar spine shows increased signal intensity (*) involving L2 and L3. **(C)** Sagittal fat-saturated contrast-enhanced T1-weighted MR image of the lumbar spine shows enhancement (*) involving L2 and L3 that is consistent with spondylodiscitis. Epidural extension is seen posteriorly (arrowheads), and subligamentous spread is seen anteriorly (arrow).

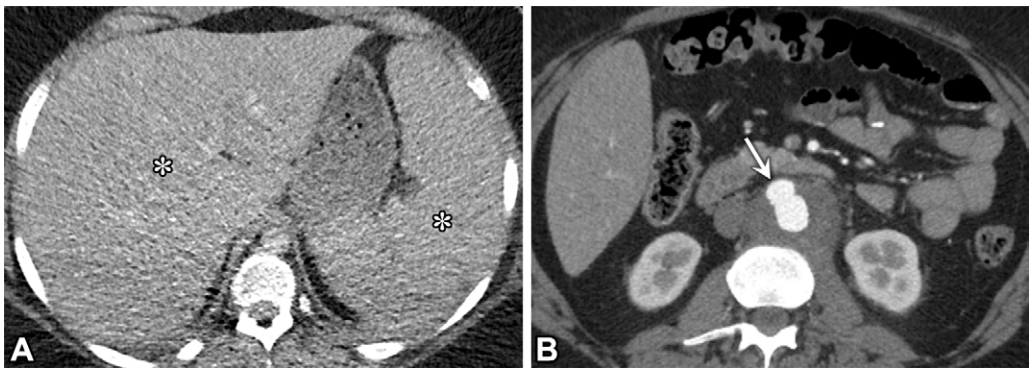


Figure 9. Brucellosis in two patients. **(A)** Transaxial contrast-enhanced CT image in a 17-year-old adolescent girl with a *B melitensis* infection from direct animal exposure shows hepatosplenomegaly (*). After a 6-week treatment course with doxycycline and rifampin, the liver and spleen returned to normal size at follow-up imaging (not shown). **(B)** Transaxial contrast-enhanced CT image in a 40-year-old woman with *B suis* infection from direct exposure to feral hogs while hunting in Texas shows a saccular outpouching (arrow) of the aorta, which is consistent with an infectious pseudoaneurysm. Surgical excision of the aorta and an extended course of antibiotics were needed to clear the infection.

of tularemia are ulceroglandular (from cutaneous inoculation), typhoidal (from ingestion), and pneumonic (from inhalation) (34).

Ulceroglandular tularemia manifests with necrotizing granulomatous lymphadenopathy in a regional distribution, with lymph nodes draining from a skin ulcer at the site of inoculation, and is usually the result of an arthropod bite (35). The granulomatous nature of the inflammation demonstrates centrally hypoattenuating lymph nodes on CT images and centrally hypoechoic and suppurative lymphadenopathy on US images (32) (Fig 10). This appearance can be confused with that of a *Bartonella* infection when a patient has multiple zoonotic exposures.

Extranodal dissemination of tularemia to the liver can occur in either the typhoidal or ulceroglandular forms. Hepatic involvement of tularemia can manifest with a solitary hepatic abscess, multiple microabscesses, or granulomatous hepatitis (37,38) (Fig 11). Pulmonic involvement is seen in one-third of patients with tularemia and can occur from direct inhalation (primary pneumonic form) or be a complication of hematogenous dissemination from ulceroglandular or typhoidal tularemia (35,39,40). Imaging findings include unilateral or

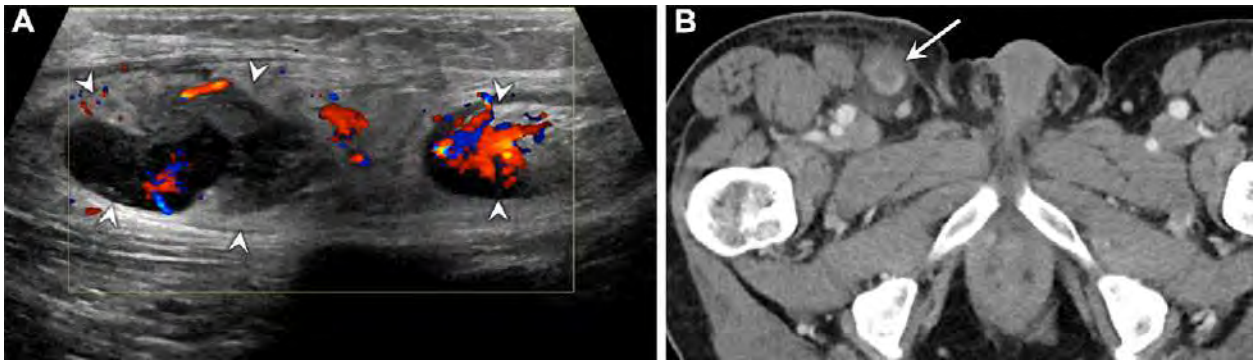


Figure 10. Ulceroglandular tularemia in two patients. **(A)** Color Doppler US image in a 40-year-old man with ulceroglandular tularemia from a tick bite to the right lower extremity after a hiking trip in Arkansas shows enlarged, hypoechoic, and hypervascular inguinal lymph nodes (arrowheads). **(B)** Transaxial contrast-enhanced CT image in a 43-year-old man with ulceroglandular tularemia from a tick bite to the right lower extremity while hiking in Missouri shows enlarged centrally hypoattenuating inguinal lymphadenopathy (arrow) and adjacent fat stranding.

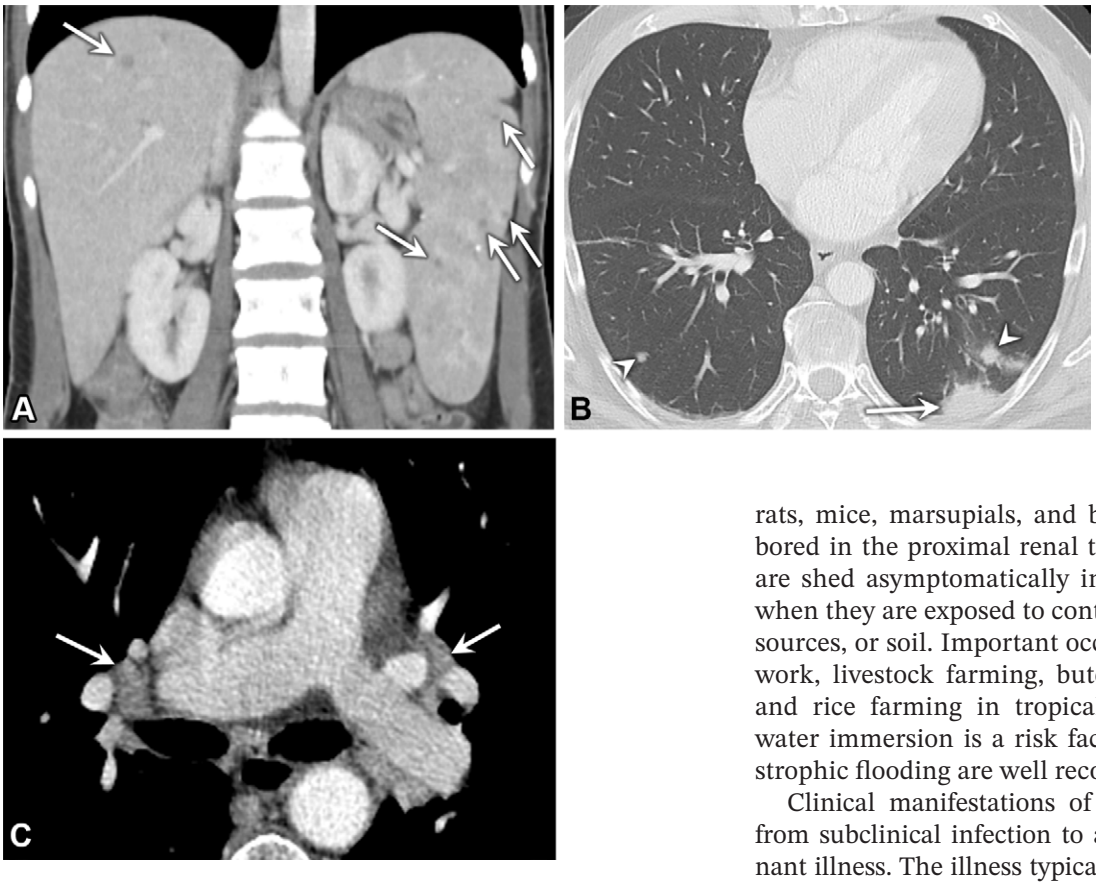


Figure 11. Tularemia in two patients. **(A)** Coronal contrast-enhanced CT image in a 42-year-old woman with disseminated tularemia from a tick bite shows multiple small liver and splenic lesions (arrows). **(B, C)** Transaxial contrast-enhanced CT images (**B**, lung window; **C**, soft-tissue window) in a 51-year-old man with pneumonic tularemia after running over an infected rabbit with a lawnmower show bilateral lung nodules (arrowheads in **B**) and consolidations (arrow in **B**) and mildly enlarged hilar lymph nodes (arrows in **C**).

bilateral airspace consolidations or nodules (with or without cavitation), hilar lymphadenopathy, and/or pleural effusions (32,39) (Fig 11). Ground-glass halos may be seen surrounding the areas of consolidation. The appearance of tularemia in the chest and abdomen can mimic those of other granulomatous conditions such as sarcoidosis and other disseminated granulomatous infections.

Leptospirosis

Leptospirosis is a globally distributed disease caused by spirochetes of the *Leptospira* genus. Carriers include numerous animals such as pigs, cattle, horses, dogs, sheep, raccoons, rats, mice, marsupials, and bats. The spirochetes are harbored in the proximal renal tubules of carrier animals and are shed asymptomatically in urine. Humans are infected when they are exposed to contaminated animal urine, water sources, or soil. Important occupational risks include sewer work, livestock farming, butchering, veterinary medicine, and rice farming in tropical environments. Recreational water immersion is a risk factor, and outbreaks after catastrophic flooding are well recognized (41).

Clinical manifestations of leptospirosis vary and range from subclinical infection to a potentially lethal and fulminant illness. The illness typically begins with a sudden-onset fever, headache, jaundice, and myalgia. The most severe variant, Weil disease, occurs in 5%–10% of cases, with the triad of jaundice, renal failure, and hemorrhage as symptoms (41). Pulmonary involvement occurs in 20%–70% of cases and corresponds to alveolar hemorrhage, which may be the result of direct capillary injury from bacterial toxins or coagulopathy (42). The diagnosis is confirmed serologically because culturing the organism is challenging and can take weeks (41). The most common imaging manifestation of leptospirosis is diffuse pulmonary hemorrhage.

Centrilobular ground-glass opacities (with or without adjacent interlobular septal line thickening) and consolidations are the primary findings on CT images (42) (Fig

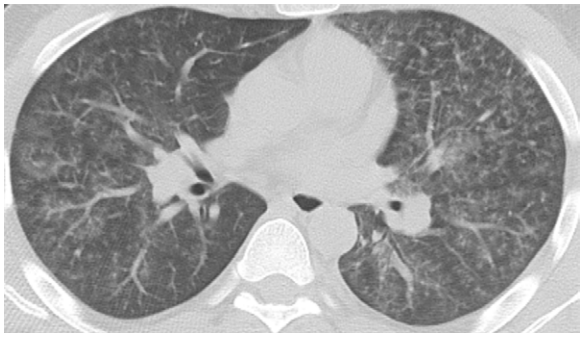


Figure 12. Leptospirosis in a 37-year-old man employed as a sewer worker who presented with fever, elevated liver enzyme levels, and hypoxia. Transaxial noncontrast CT image shows centrilobular ground-glass nodules and opacities corresponding to areas of alveolar hemorrhage. Serologic titers confirmed *Leptospira* infection.

12). Small pleural effusions can be seen as well (42). These findings can overlap with those of other causes of diffuse alveolar hemorrhage (including small vessel vasculitis) and other diffuse lung injuries such as those from toxins, drugs, inhalational injury, and acute interstitial pneumonia. After initiation of treatment, patients may temporarily experience a Jarisch-Herxheimer reaction characterized by fever, rigors, and hypotension due to release of toxins from bacterial cell lysis. The imaging findings can transiently worsen, but treatment should not be discontinued (43).

Parasitic Infections

Echinococcosis

Echinococcosis, also known as hydatid disease, is caused by cestodes (tapeworms) of the genus *Echinococcus* and comprises the diseases caused by *Echinococcus granulosus* (ie, cystic echinococcosis) and *Echinococcus multilocularis* (ie, alveolar echinococcosis). Cystic echinococcosis is endemic in South and Central America, Eastern Africa, and the Mediterranean region, and most cases in the United States and Western Europe are imported (44). Imaging is central to detection and categorization of echinococcal infection. Management is multidisciplinary and may require combinations of antiparasitic medication, surgery, or minimally invasive interventions (44).

The life cycle of *Echinococcus* is complex and requires both a definitive mammalian host (eg, dogs or cats) and an intermediate host (45) (Fig 13). Humans become infected on ingestion of eggs shed in the feces of the definitive host (44,45). After ingestion, eggs hatch into oncospheres in the intestine that seed the liver via the portal vessels and lymph nodes to develop into larvae that can disseminate to organs throughout the body. Cystic lesions then develop with fertile forms of the parasite in the affected organs (44). Symptoms are often nonspecific such as abdominal discomfort, poor appetite, chest pain, cough, or seizures, depending on organ involvement. Cyst rupture in any organ can be silent or result in severe and potentially lethal allergic reactions; therefore, iatrogenic puncture of the lesions has typically been avoided (44,46).

Histologically, hydatid cysts are composed of three layers. The outer pericyst is composed of fibrous reaction and compressed host tissue. The middle and inner layers are composed of the acellular laminated membrane and the germinative layer, respectively, the latter of which produces daughter cysts containing protoscolices (47). On images, the appearance of the cysts depends on multiple factors including the stage of cyst evolution and can be unilocular (Type I), multilocular with peripheral daughter cysts (Type II), calcified (Type III), or complicated (Type IV) (46,47) (Table 3).

Hepatic involvement is most common and is seen in 70%–75% of cases. Type I cysts are unilocular and can mimic simple epithelial cysts on images with all modalities. MRI findings suggestive of a hydatid cyst include a T2-hypointense wall (corresponding to the fibrous pericyst) (47) and centrally low apparent diffusion coefficients on diffusion-weighted MR images (48). Lesions that demonstrate daughter cysts or detached membranes strongly suggest the diagnosis (Fig 14). Curvilinear and coarse calcifications can be seen. Complicated liver lesions can rupture into the peritoneum or involve the diaphragm and pleura (46,49). The spleen is involved in less than 10% of cases, but the appearance is similar to lesions in the liver. Involvement of other abdominal solid organs such as the kidneys is rare (46).

The lung is the second most involved organ, and concurrent involvement of the lungs and liver is present in 6% of cases (46,47). Lesions are most commonly seen in the lower lobes and are bilateral in 20% of cases. Because of the compressibility of lung tissue, lesions may grow to as large as 20 cm (46). Most commonly, lesions in the lung are fluid-filled type I lesions with daughter cysts. Daughter cysts and calcification are seen less commonly (46,47). As cysts enlarge, they can erode into bronchioles, which can introduce air into the lesions between the pericyst and the laminated membrane, producing air-fluid levels and detachment of the inner membrane (eg, type IV cysts with "meniscus" and "water lily" signs) (46,47) (Fig 15). Complications of pulmonary hydatid cysts include pleural involvement, rupture, and superinfection. Mediastinal, pericardial, and myocardial involvement is rare.

Paragonimiasis

Paragonimiasis is caused by parasitic flukes of the genus *Paragonimus*. Human infections are endemic in Asia due to *Paragonimus westermani*, but *Paragonimus kellicotti* is the most common member of the genus causing human infections in North America (50). The life cycle of *Paragonimus* is complex and involves snails, crustaceans, and mammals (51) (Fig 16). Human infection occurs on ingestion of raw or undercooked crustacean intermediate hosts. In the United States, most cases of *P kellicotti* infection occur along the Mississippi River drainage basin from ingestion of raw crayfish. In our experience, most cases are associated with recreational outdoor activity and alcohol consumption (52,53). The clinical findings are nonspecific and insidious, with fever, cough, and peripheral eosinophilia all common (50).

The radiographic and CT findings of *P kellicotti* document the course of the parasite through the body (Figs 17–19). After ingestion, the parasite penetrates the small bowel and enters the peritoneal cavity, which results in peritoneal and/or omental stranding and ascites. The organism then burrows

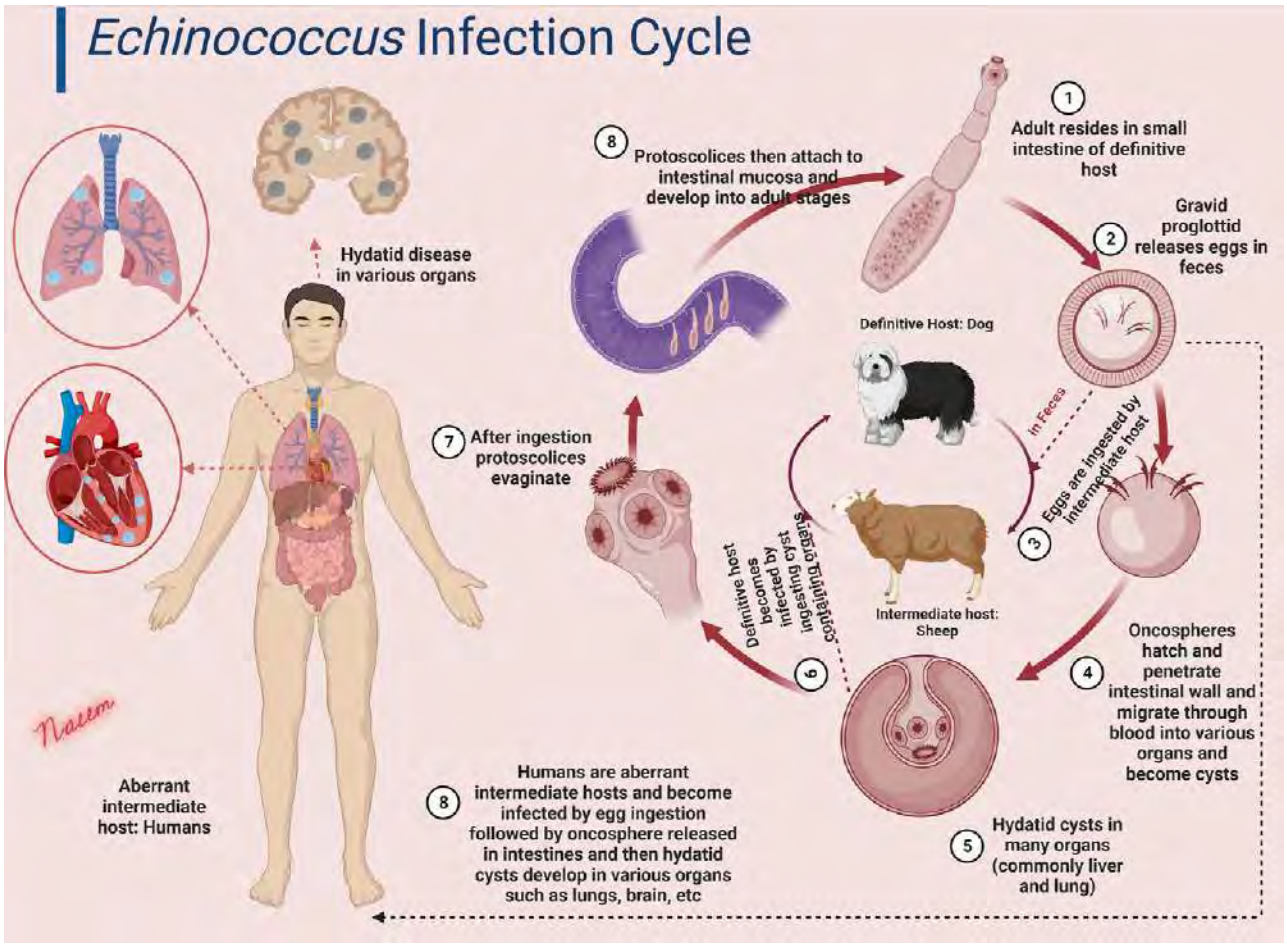


Figure 13. Life cycle of *Echinococcus* (45). (Created with *www.BioRender.com*.)

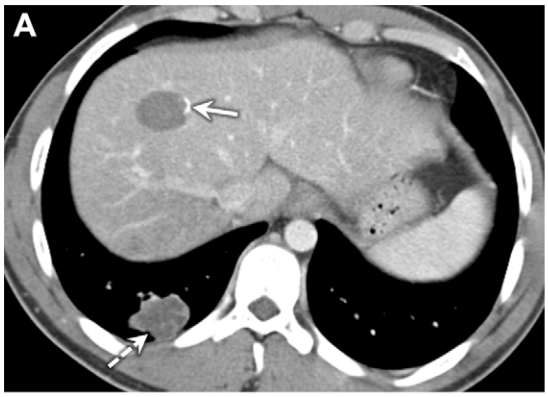
Table 3: Echinococcal Cyst Types

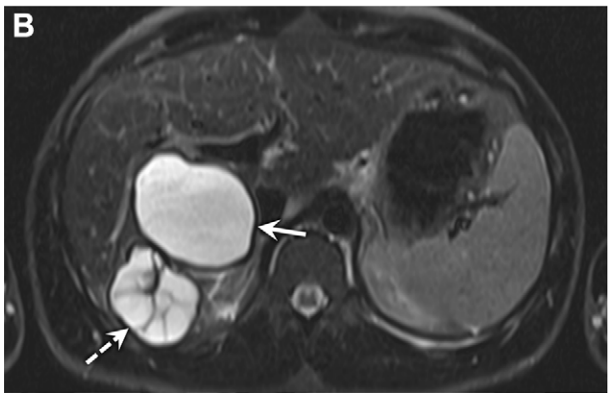
Cyst type	Appearance	Additional Features
Type I	Unilocular	T2-hypointense rim Low central apparent diffusion coefficients on diffusion-weighted MR images
Type II	Multilocular; peripheral "daughter" cysts	IIA: "wheel spoke" appearance—small peripheral daughter cysts IIB: "rosette" appearance—large peripheral daughter cysts occupying majority of lesion IIC: calcification
Type III	Calcified	
Type IV	Complicated	Detached membranes: "water lily" and "meniscus" signs Rupture or fistula to adjacent organs or cavities Infection: lesional or perilesional inflammation, air-fluid levels, or foci of gas

Sources.—References 46,47,49.

into the pleural space, with all imaged patients demonstrating a pleural abnormality such as effusion, pneumothorax, or pleural thickening. The organism then migrates through the lung to the airway, resulting in focal solid or ground-glass nodules, often with a linear track extending from the pleura (53) (Fig 18). Pericardial effusions and cardiophrenic lymphadenopathy can be seen as well. *P westermani* infection can show similar imaging patterns, but signs of chronic infection including bronchiectasis and extrapleural fat thickening have also been found in Asia, where the disease is endemic (54). The combination of omental or peritoneal stranding, pleural effusion (especially with empyema), and nodules with linear tracks to the pleura strongly suggests paragonimiasis. Peripheral and pleural eosinophilia are common.

The imaging differential diagnosis of a typical case of North American paragonimiasis includes atypical infection (including fungal and mycobacterial infections) and malignancies. Omental and peritoneal stranding can be mistaken for carcinomatosis or tuberculosis. Other uncommon pulmonary diseases with eosinophilia are often considered in





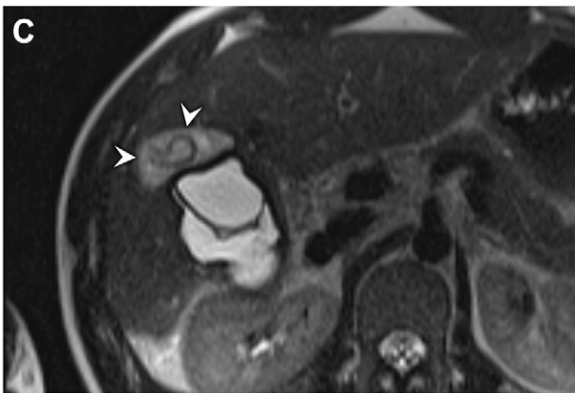


Figure 14. *Echinococcus* infection in a 24-year-old man who recently emigrated from Palestine to the United States. **(A)** Transaxial contrast-enhanced CT image shows a unilocular cyst with a curvilinear calcification in the liver (solid arrow) and a cystic lesion with daughter cysts in the right lower lobe of the lung (dashed arrow). **(B)** Transaxial fat-saturated T2-weighted MR image shows a large unilocular simple cyst in the liver (solid arrow) and a multilocular cyst with daughter cysts occupying the majority of the lesion (dashed arrow, "rosette" appearance). **(C)** Transaxial half-Fourier rapid acquisition with relaxation enhancement MR image shows a cyst in the liver, with a detached membrane (arrowheads). Serologic testing allowed confirmation of *Echinococcus* infection.

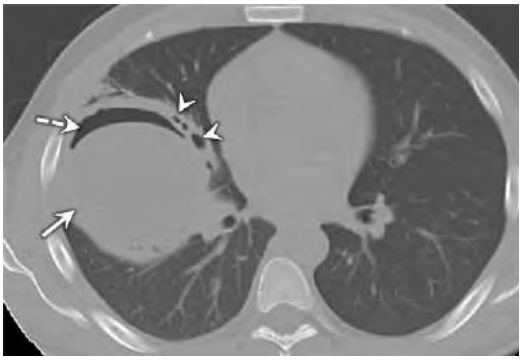


Figure 15. *Echinococcus* infection in a 30-year-old man from Argentina. Transaxial noncontrast chest CT image shows a fluid-filled lung mass (solid arrow), which is consistent with an echinococcal cyst in the right lower lobe. A crescent of air is seen from detachment of the anterior membrane (dashed arrow), with multiple additional air-filled cavities in the cyst membranes (arrowheads). (Case courtesy of Sebastian Rossini, MD, and Fernando Gutierrez, MD.)

the differential diagnosis (eg, other parasitic infections, eosinophilic pneumonia, or vasculitis). A distinguishing feature of paragonimiasis is the presence of linear tracks from nodules to the pleura, which is not common in these other entities (53). Nodules from paragonimiasis can demonstrate fluorine 18 fluorodeoxyglucose (FDG) avidity and be confused with lung malignancies (54).

Dirofilariasis

Dirofilariasis is caused by parasitic filarial nematodes of the *Dirofilaria* genus, with *Dirofilaria immitis* causing severe canine infection that can lead to pulmonary hypertension and congestive heart failure (55). The primary life cycle occurs between dogs and mosquitoes, but humans and other mammals can be infected from mosquito bites (Fig 20) (56). In humans, larvae develop into adult worms and become lodged in pulmonary artery branches. The subsequent immune response destroys the worm, resulting in pulmonary nodules (55). Because pulmonary infection with *D immitis* itself does not pose much clinical threat to humans, discovery of the infection is generally incidental, and no treatment is required. The diagnosis is often made unexpectedly during surgical resection or biopsy of nodules suspected to be malignant (57).

In a patient with an acute infection, the worm lodged in a distal pulmonary artery can result in a pulmonary infarction (58). Otherwise, the primary imaging manifestation of pulmonary dirofilariasis in humans is visualization of the dead organism as a pulmonary nodule, either solitary or multiple (Fig 21) (57). Authors of case reports (59,60) have described variable degrees of FDG avidity for nodules, but the standardized uptake value may be elevated and may mimic malignancy.

Visceral Larva Migrans

Visceral larva migrans (VLM) is a clinical entity used to describe infection in humans as accidental hosts with second-stage nematode larvae (61). While *Toxocara canis* (dog roundworm) is the most common etiologic organism, roundworms such *Toxocara catis* (cat roundworm), *Ascaris suum* (pig roundworm), and others can cause the disease in humans (62).

The life cycle of *Toxocara* species is complex and can involve multiple animal hosts (Fig 22) (63). Humans can become infected either through ingestion of eggs or from the environment. The larvae hatch and penetrate the gut, but

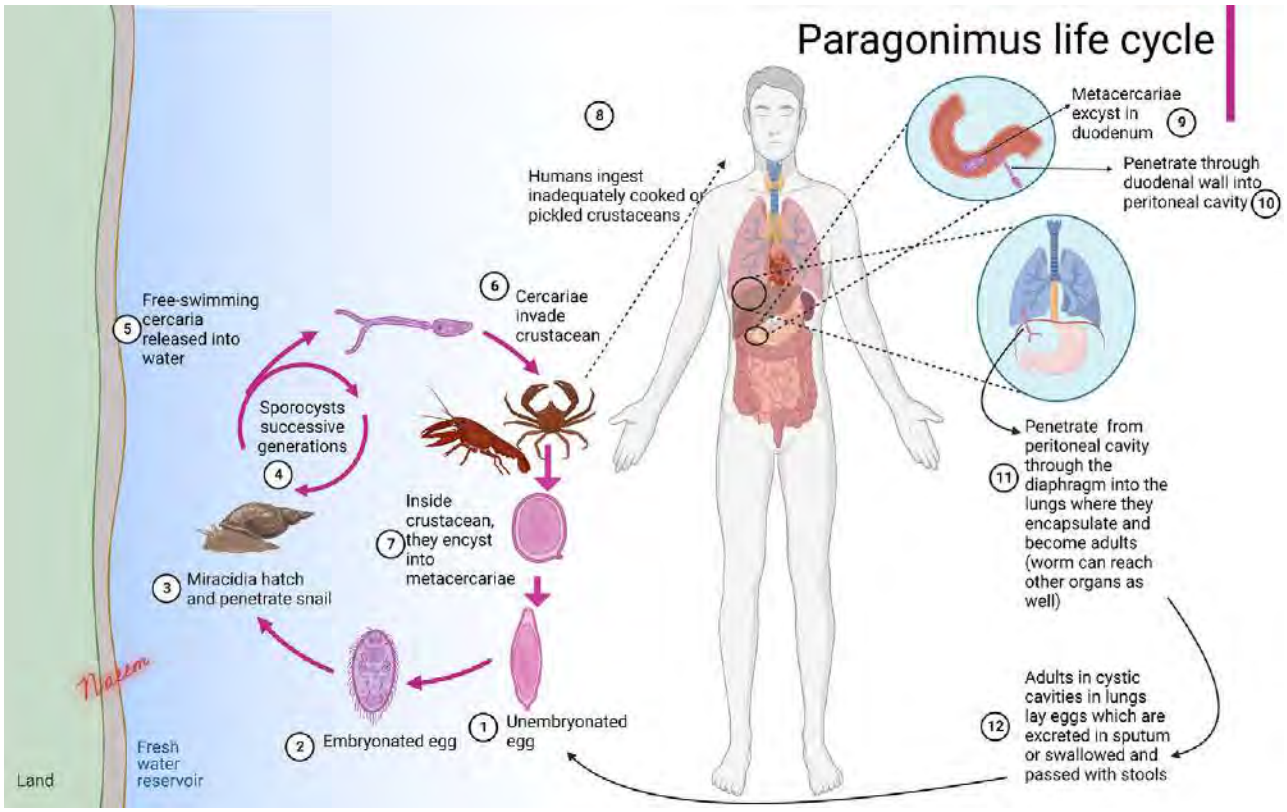


Figure 16. Life cycle of *Paragonimus* (51). (Created with *www.BioRender.com.)*

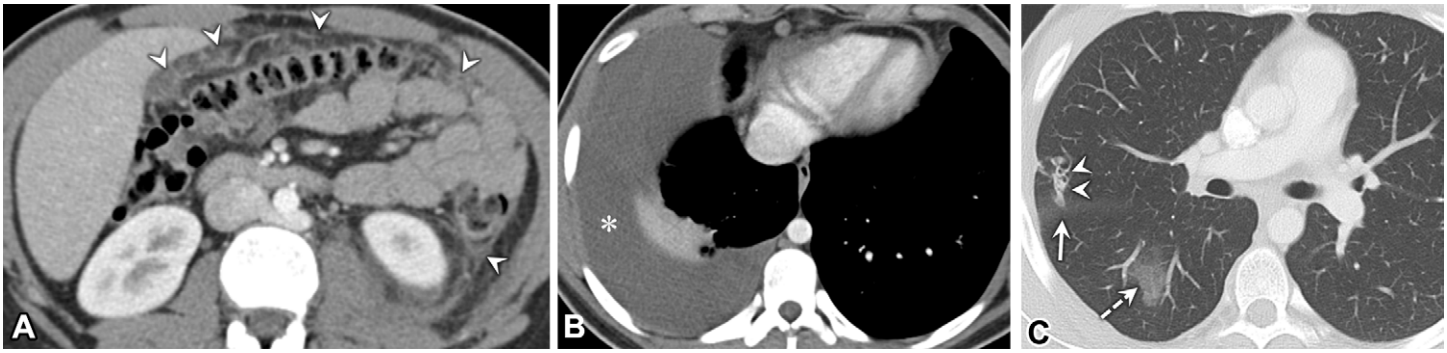


Figure 17. North American paragonimiasis in a 23-year-old man who ingested raw crayfish on a trip in Missouri and presented with weeks of fevers and peripheral eosinophilia. **(A, B)** Transaxial contrast-enhanced CT images show fat stranding (arrowheads) in the omentum and a right-sided pleural effusion (* in **B**). **(C)** Transaxial contrast-enhanced CT image (lung window) shows a ground-glass opacity in the right lower lobe (dashed arrow) and a serpiginous cavitary "worm track" (arrowheads) extending from the minor fissure (solid arrow). Results of immunoblot studies allowed confirmation of a *Paragonimus* infection.

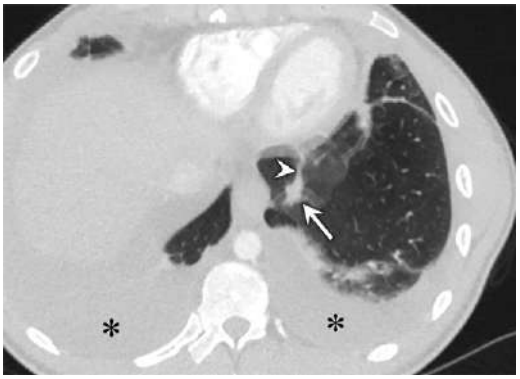


Figure 18. North American paragonimiasis in a 25-year-old man with weeks of fever after ingestion of raw crayfish while inebriated on a trip in Missouri. Transaxial contrast-enhanced chest CT image shows a nodule (arrow) with a characteristic "worm track" to the pleura (arrowhead). Bilateral pleural effusions are present (*). Omental stranding was seen in the upper abdomen (not shown).

their development is arrested (64). The larvae migrate from the bowel to the liver, after which the parasite can become widespread throughout the body to involve the lungs, heart, eyes, and central nervous system (65). In many instances, VLM is self-limiting and may not require treatment, but infiltration of eosinophils into affected tissues can result in a febrile illness (62,66). VLM is preventable with routine deworming of pets (especially new kittens and puppies),

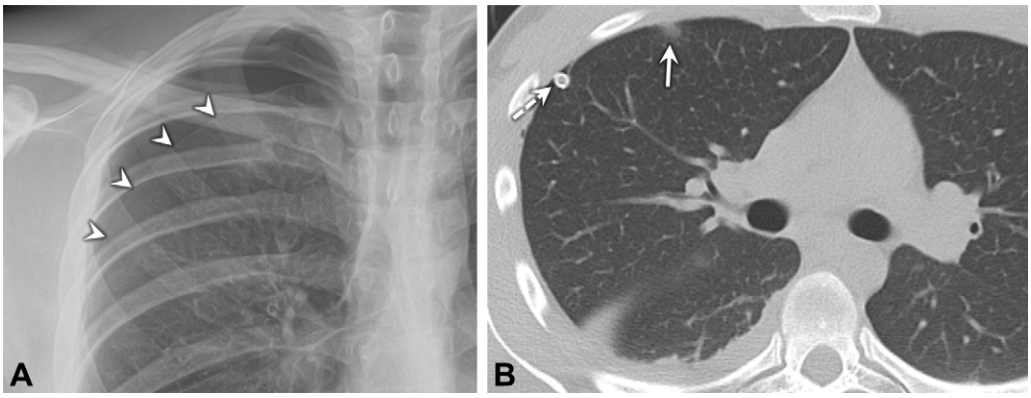


Figure 19. North American paragonimiasis in a 24-year-old man who ingested raw crayfish from the Missouri River and presented to the emergency department with chest pain. **(A)** Chest radiograph shows a pneumothorax (arrowheads). **(B)** Transaxial noncontrast chest CT image after placement of a chest tube (dashed arrow) shows a small pleural effusion and a subpleural ground-glass nodule (solid arrow). Pleural eosinophilia was present on thoracentesis. Immunoblot studies confirmed *Paragonimus* infection.

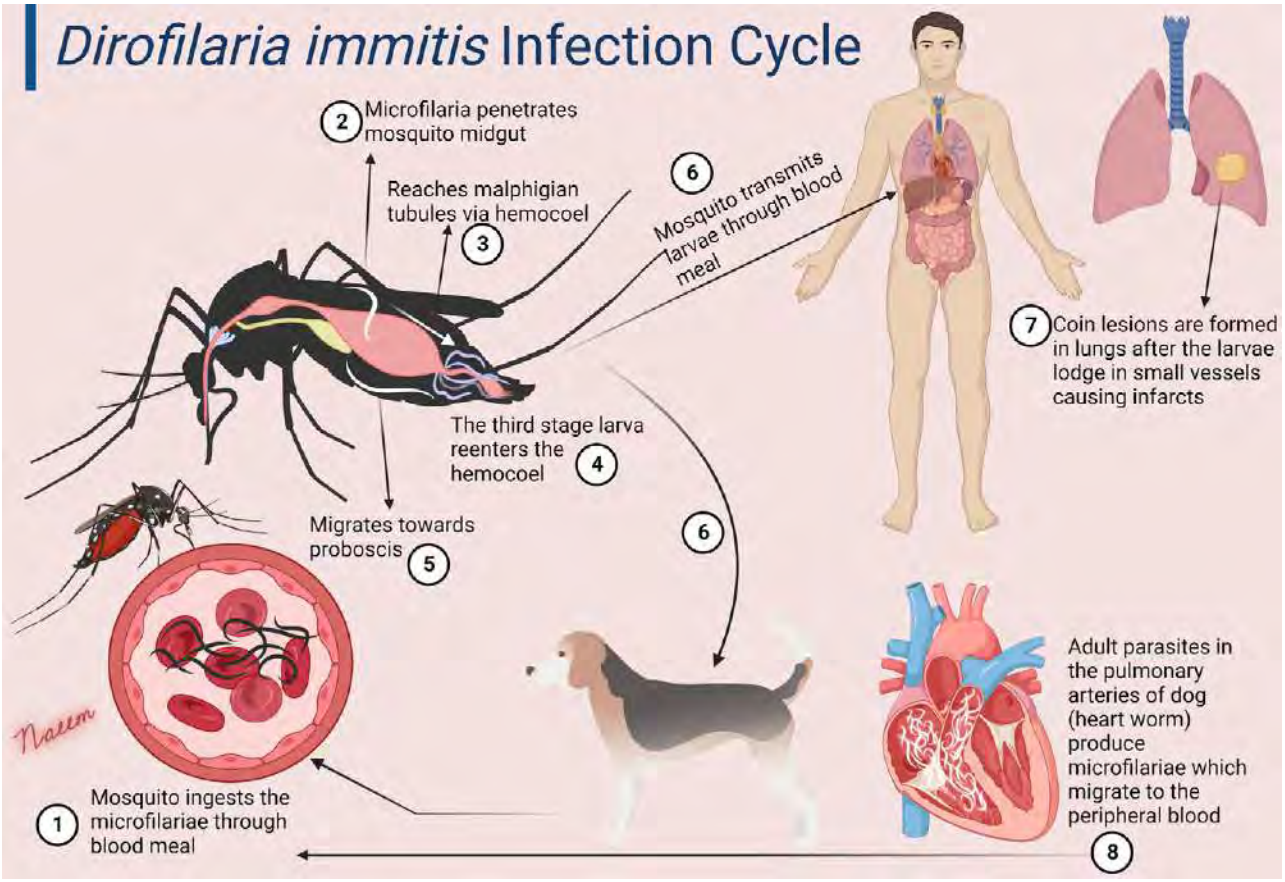


Figure 20. Life cycle of *Dirofilaria immitis* (56). (Created with *www.BioRender.com*.)

proper and prompt disposal of pet waste, and preventing children from ingesting soil (66).

Hepatic manifestations are most commonly multiple elongated or nodular liver lesions. On CT images, lesions are best seen during the portal venous phase as ill-defined low-attenuating lesions with or without peripheral rim enhancement (Fig 23). Less commonly, lesions are hyperenhancing or solitary. Coexisting ground-glass pulmonary nodules can also be seen in the lung bases. On US images, lesions tend to be ill-defined, multiple, and hypoechoic (65). Peripheral eosinophilia is an important clue, because other nonparasitic infectious causes of liver lesions such as *Bartonella* do not result in eosinophilia.

Pulmonary involvement is seen in 20%–80% of cases (62). Chest radiography usually shows normal results, with characteristic lesions better depicted on chest CT images. Subcentimeter nodules and ground-glass opacities are the most common findings, with the majority of nodules demonstrating a ground-glass halo. At pathologic examination, the ground-glass halo surrounding the nodules corresponds to eosinophilic infiltration into the alveolar septa. On images from follow-up studies, it is common for the nodules to migrate and disappear from their original location, only to appear somewhere else (67,68). Pleural effusions and lymphadenopathy are uncommon, which allows *Toxocara* infection to be distinguished from paragonimiasis (68). The differential diagnosis of VLM in the lungs can include other parasitic infections (eg, tropical pulmonary eosinophilia and Löffler syndrome) and noninfectious eosinophilic pneumonias.

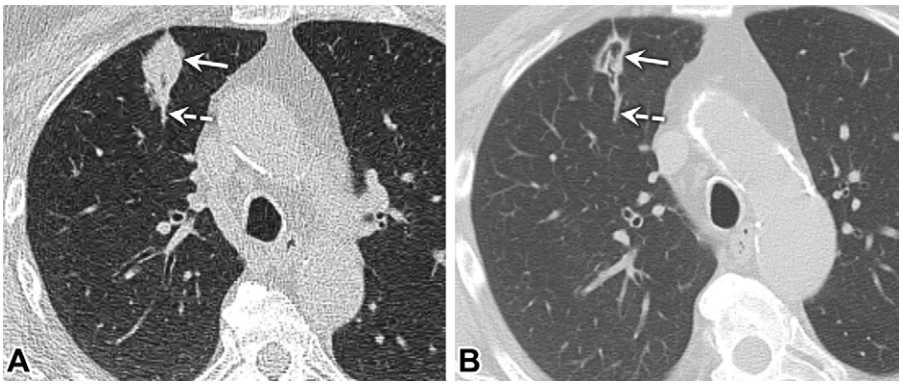


Figure 21. Dirofilariasis in a 57-year-old man with a lung nodule. **(A)** Transaxial noncontrast low-dose lung-screening CT image shows a solitary pulmonary nodule (solid arrow) that extends from a pulmonary arterial branch (dashed arrow). Percutaneous core-needle biopsy results showed nematode fragments consistent with a *D immitis* infection. **(B)** Transaxial noncontrast CT image acquired 2 years later shows interval cavitation and a decrease in the size of the nodule (solid arrow) without treatment, extending from a pulmonary arterial branch (dashed arrow).

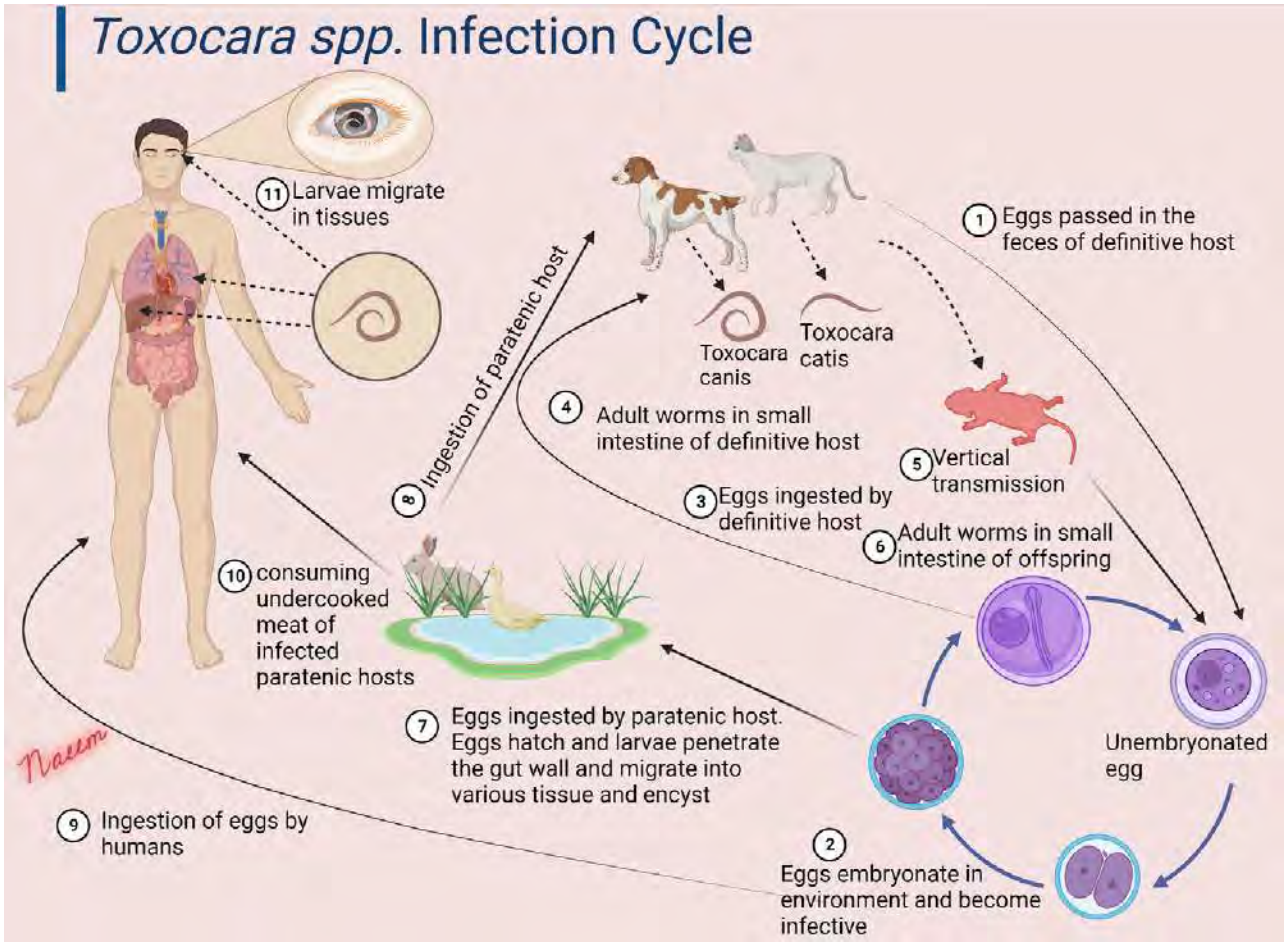


Figure 22. Life cycle of *Toxocara* species (63). (Created with *www.BioRender.com*.)

Conclusion

Bacterial and parasitic zoonotic infections pose challenges to clinicians and radiologists because of the varied clinical and radiologic manifestations and the rarity of these entities. Awareness of the patterns of disease and helpful radiologic clues can aid in the workup of patients with exposure to zoonotic infections (Fig 24).

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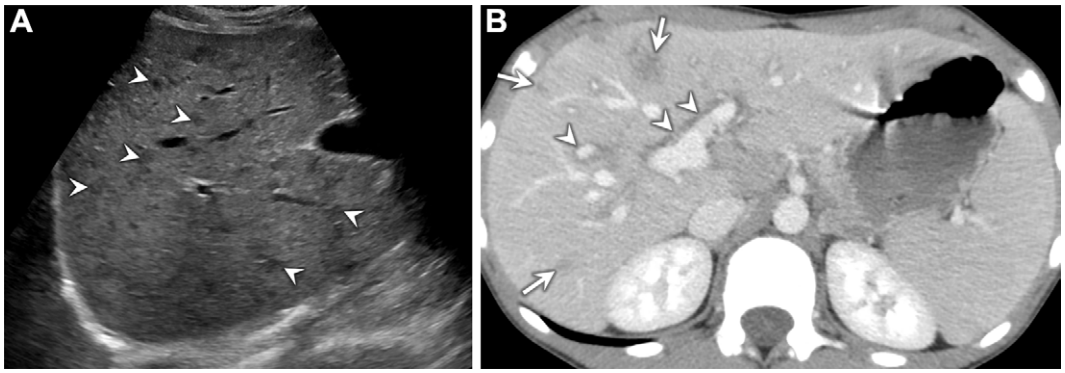

Figure 23. VLM in two patients. **(A)** US image in a 6-year-old girl with *Toxocara* infection shows multiple hypoechoic lesions (arrowheads) throughout the liver. Peripheral eosinophilia was present, and the diagnosis was confirmed serologically. **(B)** Transaxial contrast-enhanced CT image in a 14-year-old boy with *Toxocara* infection shows multiple hypoattenuating lesions (arrows) through the liver and periportal edema (arrowheads). Peripheral eosinophilia was also present. Liver biopsy results showed eosinophilic aggregates and abscesses, and the serologic test results were positive for infection with *Toxocara*.

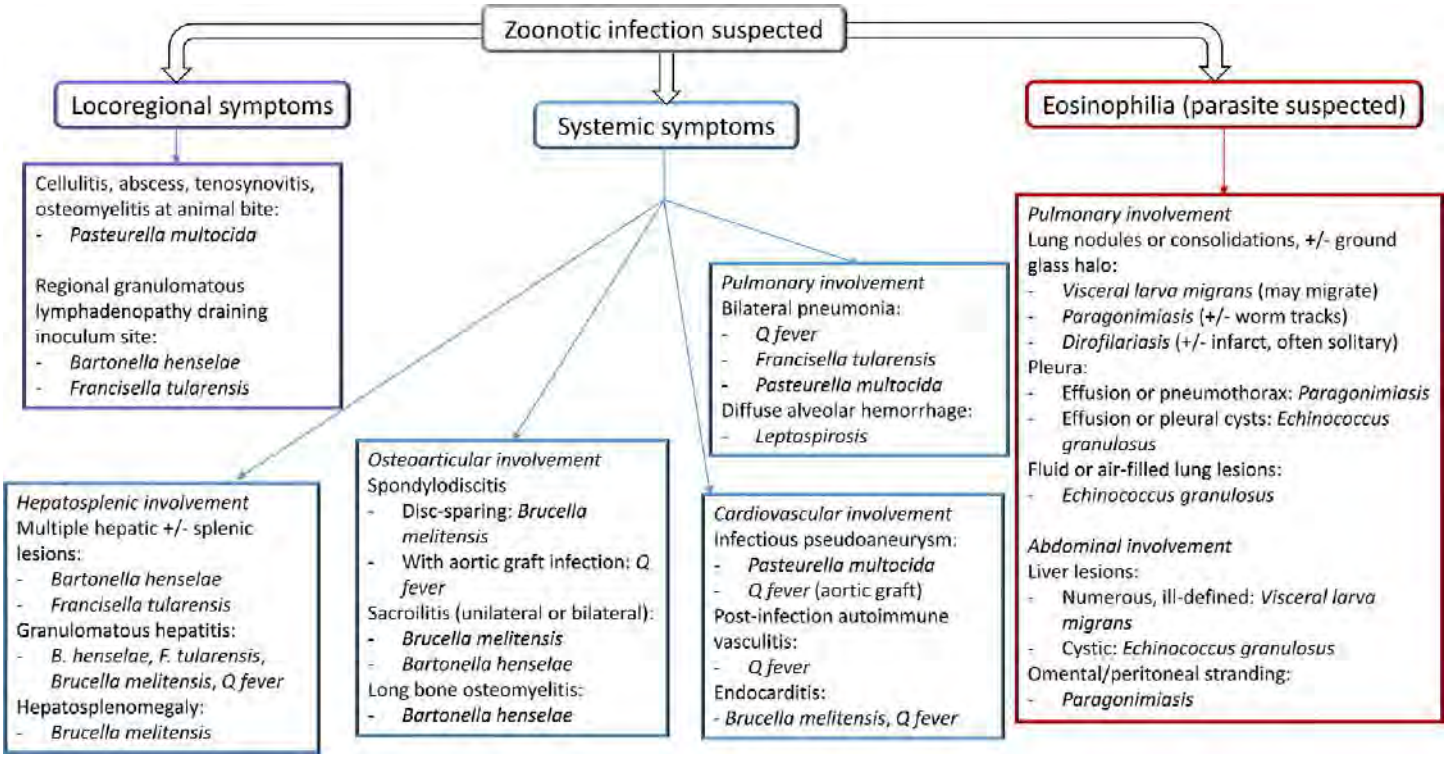

Figure 24. Flowchart categorization of zoonotic infections by their imaging manifestations.

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QUESTIONNAIRE
A18(26) Part 1 of 2
Body Imaging of Bacterial and Parasitic Zoonoses

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Bacterial infections
Bartonellosis (Cat scratch disease)

Bartonellosis is present in South Africa in both human and animal populations. Various studies have confirmed the presence of different *Bartonella* species in the region.

Prevalence and Key Findings:

- **In Humans:**
  - ***Bartonella* species** are considered an important cause of culture-negative endocarditis (BCNE) in the Western Cape of South Africa.
  - **One study in Gauteng** province found a 22.5% PCR prevalence of *Bartonella* DNA in HIV-positive patients and a 9.5% prevalence in clinically healthy volunteers, highlighting a significant presence in the population. (AI result on the question: does Bartonellosis occur in South Africa?)

Question 1: Which of the following statements are **TRUE**?

A: The clinical history of cat exposure is always present
B: Up to one-half of all domestic cats have antibodies to *B henselae*
C: Especially in children, bartonellosis is an important cause of fever of unknown origin
D: The liver, spleen and bones are the most common sites of involvement of disseminated disease

Question 2: Is it **TRUE** that systemic dissemination is estimated to occur in 5% - 10% of patients?

A: YES
B: NO

Question 3: Regarding imaging ……?

A: US is often the initial modality of choice
B: On US images, involved lymph nodes are enlarged, centrally hypoechogenic, and hypervascular
C: Posterior through-transmission cannot be seen
D: All the above

Question 4: On CT ……?

A: Involved lymph nodes are enlarged and centrally hypoattenuating
B: The infection can mimic other granulomatous infections (e.g. tuberculosis or histoplasmosis)
C: Hepatosplenic involvement is characterized by necrotising granulomas or granulomatous hepatitis
D: Lesions are well-defined

Question 5: Which CT image in Figure 2 shows multiple hypoattenuating lesions throughout the liver?

A: A
B: B
C: C
D: D

Question 6: Which zoonotic infection is most commonly associated with spondylodiscitis?

A: Bartonellosis
B: Pasteurellosis
C: Brucellosis
D: Tularemia

Bacillary angiomatosis

Bacillary angiomatosis (BA) has been seen and reported in South Africa. The first case in the country was reported in 1993, and multiple other cases, including "giant" presentations, have been documented since.

Key Details:

- **Association with HIV:** BA in South Africa is predominantly seen in individuals with advanced HIV disease or other immunocompromised conditions.
  - **Causative Agents:** The condition is caused by the bacteria *Bartonella henselae* and *Bartonella quintana*, which are known to be present in human and animal populations (such as domestic cats and dogs) in the region. (AI result on the question: does Bacillary angiomatosis occur in South Africa?)

Question 7: Which zoonotic infection is characterized by vasoproliferation, rather than with necrotising granulomatous disease?

- **A:** Pasteurellosis
- **B:** Bacillary angiomatosis
- **C:** Echinococcosis
- **D:** Visceral larva migrans

Question 8: Hepatic peliosis from *Bartonella* infection demonstrates imaging findings similar to those of other causes of peliosis. Against this background which of the following statements are **TRUE**?

- **A:** Multifocal hepatic lesions are typical and are hypoattenuating compared with the liver parenchyma
- **B:** Dynamic postcontrast CT and MRI of the liver demonstrate early arterial phase hyperenhancement with either centripetal or centrifugal enhancement patterns
- **C:** On MR images, lesions tend to be T2 hyperintense and T1 hypointense relative to the background liver
- **D:** Kaposi sarcoma is never mimicked in patients with AIDS

Pasteurellosis

Pasteurellosis is seen in humans worldwide, including in South Africa, and is primarily a zoonotic infection resulting from close contact with animals.
While specific recent South African human case statistics are limited in the provided results, the bacterium responsible, *Pasteurella multocida*, is widespread in animals throughout South Africa. The disease in humans typically occurs through:

- **Animal bites or scratches**, most commonly from domestic cats and dogs, which harbour the bacteria as normal flora in their upper respiratory tract.
- **Contact with animal saliva** on skin abrasions or mucous membranes.
- **In rare cases,** respiratory infection **via exposure to an animal's respiratory secretions, particularly in elderly or immunocompromised individuals with underlying chronic lung conditions** (AI result on the question: does Pasteurellosisoccur in South Africa?)

Question 9: Regarding imaging features of soft-tissue infections with *P multocida* ……..?

- **A:** It is similar to those of other bite-related infections
- **B:** Radiographs may demonstrate retained teeth or claws and /or soft-tissue gas
- **C:** CT and MRI are not useful for assessment of underlying vascular injury
- **D:** All the above

Question 10: Intra-abdominal infections can manifest with ……?

- **A:** Peritonitis
- **B:** Liver abscess
- **C:** Intra-abdominal abscess
- **D:** Infectious pseudoaneurysm (often)

Q fever

Q fever (caused by *Coxiella burnetii*) is present and seen in humans in South Africa, though it's considered an under-recognized and under-diagnosed zoonotic disease, often mistaken for other illnesses due to non-specific symptoms and a lack of widespread surveillance, but evidence confirms its circulation in animals and documente58d cases in people.

Evidence of Q Fever in South Africa:

- **Historical Cases:** The first documented human case in South Africa dates back to the 1950s.
- **Animal Reservoirs:** The bacteria are found in various South African livestock (cattle, sheep) and wildlife, and in ticks, indicating widespread circulation.
- **Human Seroprevalence:** Studies show human exposure (antibodies) to *C. burnetii*, confirming human infections.
- **Occupational Risk:** It is an important occupational disease for those in contact with livestock, abattoirs, and farms (AI result on the question: does Q fever in South Africa?)

Question 11: Which bacterium is the causative agent of Q fever?

- ***A:*** *Bartonella henselae*
- ***B:*** *Pasteurella multocida*
- ***C:*** *Coxiella burnetii*
- ***D:*** *Brucella abortus*

Question 12: Is the following statement **TRUE** or **FALSE**?

"Transmission to humans requires exposure to as little as a single organism and can occur from inhalation of contaminated excretions, tick bites, or ingestion of unpasteurized dairy products."

- **A:** TRUE
- **B:** FALSE

Question 13: Should you receive a request for imaging for suspected Q-fever), and the occupation of the patient is not provided, for which of the following will you prompt?

- **A:** Farmer
- **B:** Hair stylist
- **C:** Veterinarian
- **D:** Cattle herder

Question 14: Regarding imaging, which of the following statements are **TRUE**?

- **A:** When patients with acute Q fever are imaged, they most commonly present with a pulmonary illness
- **B:** Authors of some studies have emphasized ground-glass halos surrounding consolidations as a characteristic finding
- **C:** In chronic Q fever, case reports have also been published of Q fever–associated large-vessel vasculitis, which mimics Takayasu arteritis
- **D:** None of the above

Question 15: Which zoonotic infection is most likely to cause culture-negative endocarditis?

- **A:** Bartonellosis
- **B:** Q fever
- **C:** Leptospirosis
- **D:** Tularemia

THE END

QUESTIONNAIRE
A18(26) Part 2 of 2
Body Imaging of Bacterial and Parasitic Zoonoses

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Brucellosis

Question 1: Which zoonotic disease is transmitted primarily through ingestion of unpasteurized dairy products, direct contact with infected animal parts, or inhalation of aerosolised particles?

- **A.** Brucellosis
- **B.** Leptospirosis
- **C.** Q fever
- **D.** Tularemia

Question 2: What is the most common complication of brucellosis?

- **A.** Respiratory distress
- **B.** Gastrointestinal symptoms
- **C.** Osteoarticular involvement
- **D.** Neurological impairment

Question 3: A characteristic "Pedro-Pons sign" of steplike erosion of the anterior-superior endplate has been suggested as a specific radiographic feature of *Brucella* spondylodiscitis.

Is this statement **TRUE**?

A. YES
B. NO

Question 4: Which imaging modality is most useful for evaluating musculoskeletal involvement in brucellosis?

- **A.** Ultrasound
- **B.** MRI
- **C.** CT
- **D.** X-ray

Tularaemia

Tularaemia (rabbit fever) is generally considered absent or extremely rare in South Africa and the rest of the Southern Hemisphere, typically occurring in the Northern Hemisphere (North America, Europe, Asia) and occasionally Australia, with recent *Francisella* detection in African animals needing further confirmation, but no definite human cases confirmed yet. (AI result on the question: "Does Tularaemia occur in South Africa?)

Leptospirosis

Question 5: What organism is the primary cause of leptospirosis?

- **A.** Leptospira genus
- ***B.*** *Bartonella henselae*
- ***C.*** *Coxiella burnetii*
- ***D.*** *Francisella tularensis*

Question 6: Which of the following statements are **TRUE**?

A. The illness typically begins with a sudden-onset fever, headache, jaundice, and myalgia
B. The most severe variant, Weil disease, occurs in 5%–10% of cases, with the triad of jaundice, renal failure, and hemorrhage as symptoms
C. Pulmonary involvement occurs in 20%–70% of cases and corresponds to alveolar hemorrhage, which may be the result of direct capillary injury from bacterial toxins or coagulopathy
D. The most common imaging manifestation is diffuse pulmonary haemorrhage

Question 7: Which zoonotic disease is most commonly associated with pulmonary haemorrhage?

- **A.** Leptospirosis
- **B.** Tularemia
- **C.** Brucellosis
- **D.** Pasteurellosis

Question 8: TRUE or **FALSE**?

"Centrilobular ground-glass opacities (with or without adjacent interlobular septal line thickening) and consolidations are the primary findings on CT images".

A. TRUE
B. FALSE

Parasitic Infections
Echinococcosis

Question 9: Which of the following statements are **TRUE**?

A. Imaging is central to detection and categorization
B. Humans become infected on ingestion of eggs shed in the feces of the definitive host
C. Symptoms are always specific
D. Cyst rupture in any organ can be silent and never results in potentially lethal allergic reactions

Question 10: What imaging feature is commonly seen in echinococcal cysts?

A. Air-fluid levels
B. Ground-glass opacities
C. Wheel-spoke appearance
D. Central calcification

Question 11: Which of the following statements are correct?

A. Type I cysts are unilocular and can mimic simple epithelial cysts on images with all modalities
B. MRI findings suggestive of a hydatid cyst include a T2-hypointense wall (corresponding to the fibrous pericyst) and centrally low apparent diffusion coefficients on diffusion-weighted MR images
C. Lesions that demonstrate daughter cysts or detached membranes dispute the diagnosis
D. None of the above

Question 12: As cysts enlarge, they can erode into bronchioles, which can introduce air into the lesions between the pericyst and the laminated membrane, producing air-fluid levels and detachment of the inner membrane (eg, type IV cysts with "meniscus" and "water lily" signs).

Is this statement **TRUE** or **FALSE**?

A. TRUE
B. FALSE

Question 13: Which signs or appearances would you be on the lookout for in Type II cysts?

A. Water lily
B. Wheel spoke
C. Half-moon
D. Rosette

Question 14: Which image in Figure 14 shows the "rosette" appearance?

A. A
B. B
C. C
D. D

Paragonimiasis

Paragonimiasis has been reported in South Africa, though it is not considered widely endemic in the country as a whole. All known cases have originated from a specific, narrow focus in the coastal lowlands of the **KwaZulu-Natal (KZN) province**.

Key Details:

- **Geographic Focus:** The cases are highly localized to a specific region in KwaZulu-Natal, generally below 100 meters (approx. 330 feet) above sea level.
- **Case Numbers:** Only a small number of cases have been reported since the 1920s, involving both domestic animals (cats and dogs) and a few children and one adult human patient. This suggests that while transmission is likely active, it is not common.
- **Transmission:** Humans and animals become infected by consuming raw or undercooked freshwater crabs that contain the parasite's larvae. In the KZN focus, the common river crab (*Potamonautes sidneyi*) is the likely second intermediate host.
- **Misdiagnosis:** The pulmonary symptoms of paragonimiasis, such as chronic cough and bloody sputum, often mimic those of tuberculosis (TB), which can lead to misdiagnosis in areas where TB is prevalent. (AI response to the question: "Does Paragonimiasis occur in SA?)

Dirofilariasis

Dirofilariasis is seen in South Africa in both animals and humans. The most common species found is *Dirofilaria repens***,** which typically causes subcutaneous or ocular infections.

Occurrence in South Africa:

- **In Animals:** *Dirofilaria repens* infection is considered autochthonous (originating in the region) in dogs and cats, with high prevalence rates reported in provinces like KwaZulu-Natal, Gauteng, Mpumalanga, and North West.
- **In Humans:** Human cases have been documented, with the first local human infections reported in 2015. These cases involved ocular and subcutaneous presentations and were also linked

to autochthonous transmission, particularly in the KwaZulu-Natal Province.

Type of Dirofilariasis:

- ***Dirofilaria repens*** is the primary species responsible for dirofilariasis cases in South Africa.
- ***Dirofilaria immitis*** (heartworm), while widespread in many tropical and temperate regions, is generally considered absent in animals bred and reared in South Africa, though cases in imported dogs have been reported. (AI response to the question: "Does Dirofilariasis occur in SA?)

Visceral larva migrans

Question 15: Regarding imaging ……?

A. On CT images, lesions are best seen during the portal venous phase as ill-defined low-attenuating lesions with or without peripheral rim enhancement
B. Coexisting ground-glass pulmonary nodules cannot be seen in the lung bases
C. Chest radiography usually shows normal results
D. On US images, lesions tend to be ill-defined, multiple, and hypoechoic

THE END

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ANSWER SHEET

A18(26)

Body Imaging of Bacterial and Parasitic Zoonoses

***Time spent on activity hour min**

PART 1												PART 2											
	A	B	C	D	E		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E
1						8						1						9					
2						9						2						10					
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7						14						7						15					
						15						8						16					

How relevant was the content of this activity to your scope of practice?			
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