Acute Radiologic Manifestations of America’s Opioid Epidemic

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Abbreviation: FLAIR = fluid-attenuated inversion recovery

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

■ Identify the imaging features of emergent conditions commonly seen with opioid use and abuse.
■ Describe the pathogeneses of various opioid-related conditions.
■ Recognize the limitations of and appropriate modalities for diagnostic imaging of acute conditions related to opioid abuse.

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The United States is in the midst of an opioid use epidemic, which has severe medical, social, and economic consequences. Addictions to and abuse of prescription and illicit opioids are increasing, and emergency department radiologists are increasingly being faced with the task of examining patients who present with opioid-related complications. These complications may be the result of direct drug toxicity or nonsterile injection of the drugs. Neurologic, musculoskeletal, cardiopulmonary, genitourinary, and gastrointestinal complications may be evident at diagnostic imaging in emergent settings. Heroin-induced leukoencephalopathy, cerebral septic emboli, mycotic arterial aneurysms, soft-tissue infections, and infective endocarditis are some of the conditions that patients may be found to have after they present to the emergency department. In this article, the above topics, including clinical features, pathophysiology, imaging findings, and treatment options, are reviewed. Recognizing the limitations of diagnostic imaging modalities that are available to radiologists is equally important, as some conditions can be successfully diagnosed after the initial triage—for example, transesophageal echocardiography can be performed to diagnose infective endocarditis. The emergency department radiologist may be responsible for identifying acute conditions, which can be life threatening. Some of the more common emergent opioid-related conditions and complications are reviewed, with specific emphasis on cases in which emergency department radiologists encounter conditions for which additional expertise is required. Becoming familiar with the conditions directly related to the current opioid epidemic will enable the diagnosis of these entities in a timely and accurate manner.

Introduction

There is currently an epidemic of opioid addiction and abuse in the United States. During the past 15 years, the staggering increase in the number of drug overdose deaths related to prescribed and illicit opioid use (1) has prompted increased awareness of this crisis and a commitment to address it among large organizations such as the U.S. Food and Drug Administration (2) (Fig 1).

According to the most recent U.S. data (3), there were 33,000 deaths caused by opioid overdose in 2015, and the increased potency of street (ie, nonprescribed) drugs may have been a factor. Drug dealers looking for ways to increase their profits have begun to cut (ie, mix) heroin with highly potent fentanyl, with a fatal effect. According to a recent data brief from the Massachusetts Department of Health (4), toxicology screening results were positive for fentanyl in 75% of cases of fatal opioid overdose in 2016, as compared with approximately half of the cases with results positive for heroin (4).
Infectious complications are the most common reason (in mycotic aneurysms can affect any artery, including large-caliber vessels such as the aorta and pulmonary arteries. Infectious complications are the most common reason (60%–80% of cases) for the hospital admission of intravenous drug users. The presence of multiple foreign bodies in the gastrointestinal tract or vagina should raise suspicion for intracorporeal concealment of drugs, the packaging of which can rupture and expose the patient to a large amount of opioids at once. Pneumatosis intestinalis is associated with a poor prognosis in patients with embolic bowel infarcts.

Furthermore, toxicology analyses have revealed that a large proportion of the fentanyl in cases of overdose is produced illicitly rather than dispensed from licensed pharmacies (5).

The increased availability of opioid overdose reversal agents such as naloxone has been shown to have some benefit (6). In addition to the risk of fatal overdose, an increased number of nonfatal opioid-related conditions and complications can be expected. The life-threatening nature of opioid-related complications and the socioeconomic challenges that those who abuse these substances face often result in these individuals presenting to the emergency department, where emergency department radiologists have an important role (1). The manifestations of opioid-related conditions and complications are protean and may be neurologic, musculoskeletal, cardiopulmonary, vascular, gastrointestinal, or genitourinary in origin. Some of the complications, such as heroin leukoencephalopathy, are related to the metabolic effects of the drugs themselves. Other complications are attributable to the method of drug administration and include a wide range of infectious conditions related to the intravenous or subcutaneous injection of the opioid.

In this article, we use a systems-based approach to highlight the imaging findings of many conditions and complications associated with the current epidemic of opioid use in the United States.

Neuroradiologic Manifestations
A diverse range of pathologic entities that are a direct result of opioid abuse may be seen at cross-sectional imaging of the head, neck, and spine. In this section, we review some of the more commonly encountered neurologic conditions, including ischemic stroke, cerebral septic emboli, brain abscesses, ventriculitis, intracranial mycotic aneurysm, heroin-induced leukoencephalopathy, and hypoxic ischemic injury.

Cerebral Septic Emboli
Neurologic complications secondary to infected cardiac valves represent a major problem for patients involved with intravenous drug use and are associated with poor clinical outcomes (7). Dislodgement of infected cardiac vegetations followed by intracranial vessel occlusion may result in ischemic infarction, hemorrhage, and/or infection. Wilbring et al (8) reported acute neurologic events in 70 (14.1%) of 495 patients with native valve endocarditis (8). The most common (in 75.7% of cases) neurologic complication in that group was infarction (8). With left-sided endocarditis, the risk of cerebral septic emboli is increased with vegetations greater than 1 cm on the anterior mitral leaflet, during the 1st week of antibiotic therapy, and in the setting of a mobile valve vegetation (7) (Fig 2). In a study involving 78 patients with infective endocarditis (9), acute ischemic lesions and cerebral microbleeds were the most common MR imaging findings.

Subarachnoid hemorrhage, microabscesses, and finally mycotic aneurysms followed as the next most common MR imaging findings.

Cerebral emboli are predominantly characterized by small infarcts of varying ages distributed in watershed territories with cortical and subcortical microbleeds (10). Diffusion-weighted and FLAIR MR images will show multifocal areas of hyperintensity, with a corresponding loss of signal on apparent diffusion coefficient maps, predominantly in watershed areas. To a lesser extent, acute ischemic infarcts may have a single territorial distribution. Susceptibility-weighted MR images will show foci of low signal intensity with blooming artifact caused by hemosiderin deposition within microbleeds. This characteristic pattern aids in distinguishing cerebral emboli from other multifocal lesions such as metastasis, lymphoma, infection (eg, toxoplasmosis and neurocysticercosis), and nonembolic ischemia.

Subarachnoid hemorrhage is a sequela caused by vessel rupture at the site of occlusion. In the setting of endocarditis, subarachnoid hemorrhage tends to be convexal, occurring along the surface sulci of the brain without extension into the parenchyma, ventricles, or interhemispheric fissures (11). At nonenhanced head computed tomography (CT), acute subarachnoid hemorrhage will exhibit high attenuation in the subarachnoid spaces. For MR imaging examinations, the FLAIR sequence is the most sensitive for the detection of hyperintensity in the subarachnoid spaces, which corresponds to acute subarachnoid hemorrhage (12).

In a recent study, Kim et al (13) examined the neurologic outcomes of cardiac valve replacement surgery in patients with and without preexisting
protein–containing astrocytes in the basal lamina. Disruption of the basal lamina, which preserves the blood-brain barrier (14), predisposes individuals to cerebral infection. The natural history of brain infections was studied in animal models. Following the injection of streptococcal bacteria into the brains of 19 dogs, Britt et al (15) characterized the development of brain abscesses at CT and histologic analysis. They described four distinct stages of abscess development: early cerebritis at days 1–3 after the injection, late cerebritis at days 4–9, early capsule formation at days 10–13, and late capsule formation at day 14 and thereafter (15).

Early cerebritis involves immune-mediated unorganized inflammation and infection. Non-enhanced CT may reveal ill-defined areas of decreased attenuation in the white matter. Over time, a competent immune system will form a cerebral septic infarct. In that study, preoperative cerebral septic emboli alone were found to be associated with worse postoperative neurologic outcomes, and the associated microhemorrhage was suspected to have contributed to increased rates of postoperative neurologic complications. Heme-sensitive MR imaging sequences (eg, susceptibility-weighted and T2*-weighted imaging) may have prognostic value in the detection of hemosiderin deposition in emboli. Further research of this application is needed.

**Cerebritis, Brain Abscess, and Ventriculitis**

Brain abscess is a complication of the hematogenous spread of bacteria. Data in the pathology literature suggest that drug abuse may directly lead to impairment of the blood-brain barrier by causing a decrease in the number of glial fibrillary acidic protein–containing astrocytes in the basal lamina. Disruption of the basal lamina, which preserves the blood-brain barrier (14), predisposes individuals to cerebral infection. The natural history of brain infections was studied in animal models. Following the injection of streptococcal bacteria into the brains of 19 dogs, Britt et al (15) characterized the development of brain abscesses at CT and histologic analysis. They described four distinct stages of abscess development: early cerebritis at days 1–3 after the injection, late cerebritis at days 4–9, early capsule formation at days 10–13, and late capsule formation at day 14 and thereafter (15).

Early cerebritis involves immune-mediated unorganized inflammation and infection. Non-enhanced CT may reveal ill-defined areas of decreased attenuation in the white matter. Over time, a competent immune system will form a
capsule of granulation tissue that confines the infection. During the late phase of cerebritis, contrast-enhanced CT typically reveals a hypoenhancing collection that has an enhancing rim. During this phase, the collection, as compared with a fully developed abscess, eventually fills with contrast material up to 20–40 minutes after the injection (16).

An abscess represents an organized containment of infection with a well-formed capsular wall composed of collagen and granulation tissue (16). At MR imaging, a cerebral abscess often demonstrates a T1- or T2-hypointense enhancing peripheral rim that smoothly and completely circumscribes a homogeneous T2-hyperintense center. Centrally, the cavity of an abscess typically demonstrates restricted diffusion, which manifests as hyperintensity on diffusion-weighted images, with corresponding low apparent diffusion coefficient values. This restricted diffusion aids in distinguishing a pyogenic abscess from a necrotic tumor (17,18) (Fig 3). In addition, susceptibility-weighted MR images of pyogenic abscesses typically show a double rim. The abscess capsule appears uniformly hypointense; this appearance is believed to result from the production of paramagnetic free radicals by macrophages. The inner granulation layer remains relatively hyperintense, producing the double rim (19).

Characteristic spectra on MR spectroscopic images may help to differentiate a lesion suspected of being an abscess versus a cystic or necrotic tumor (17,20). MR spectra, based on chemical shift phenomena, exploit the nature of pyogenic infections to break proteins into amino acids. Peaks in levels of amino acids (ie, valine, leucine, isoleucine), lactate, and acetate are unique to pyogenic infections and aid in distinguishing abscesses from necrotic tumors (12,14). However, the specific aspects of this differentiation are beyond the scope of this article.

Pyogenic ventriculitis is a complication of brain abscesses and may be caused by the iatrogenic introduction of bacteria due to neurosurgical procedures, meningitis, or brain abscess rupture (21). When a brain abscess ruptures into the ventricular system, the affected patient may exhibit clinical deterioration (22). Once an abscess has developed, there is a propensity for intraventricular rupture and subsequent ventriculitis. Although the reason that brain abscesses tend to rupture into the ventricles is unknown, it has been proposed that this occurs owing to a thinner capsule along the ventricular surface of abscess cavities or less resistance along major white matter tracts that extend toward the ventricles (23).

The most common imaging finding of ventriculitis is ventricular debris. At CT, ventricular debris may appear as hyperattenuating intraventricular fluid, as compared with normal cerebrospinal fluid, that can impede cerebrospinal fluid flow and result in hydrocephalus (19). At MR imaging, ventricular debris can be characterized by an abnormal hyperintense signal at FLAIR imaging or restricted diffusion layering within the ventricles. Diffusion-weighted and FLAIR MR imaging sequences are equally sensitive for the detection of intraventricular debris (24). In addition to ventricular debris, periventricular white matter hyperintensity at FLAIR imaging and thin enhancement of the ependymal lining of the ventricles also may be conspicuous findings of ventriculitis at MR imaging (19).
Furthermore, it has been shown that apparent diffusion coefficient values for the purulent ventricular debris are inversely correlated to pleocytosis and protein levels in the cerebrospinal fluid obtained by means of lumbar puncture (25). Low apparent diffusion coefficient values have been correlated to high levels of infectious cerebrospinal fluid markers. The main implication of this finding is that apparent diffusion coefficient values might be useful for the noninvasive evaluation of treatment response in patients with pyogenic ventriculitis (16).

**Figure 4.** Mycotic aneurysm in a 30-year-old male intravenous drug user with a visual field deficit. (a, b) Axial diffusion-weighted brain MR images show cerebral infarcts affecting the right occipital lobe (arrow in a) and left frontal lobe (arrow in b). (c) Axial head CT angiogram shows a 4-mm mycotic aneurysm (arrow) in the distal left middle cerebral artery. Blood cultures were positive for *Granulicatella adiacens*, an oral flora. (d) Axial head CT angiogram obtained after antimicrobial therapy shows resolution of the aneurysm.

**Intracranial Mycotic Aneurysm**

In addition to the brain parenchyma and ventricular system, the intracranial vasculature may be affected in cases of endocarditis or bacteremia. When a focal infection of the vasculature occurs, mycotic aneurysms can develop. In such cases, mycotic aneurysms are most commonly due to intravenous drug use (26), although rheumatic heart disease has been a frequent cause in the past. With intravenous drug use, microemboli hematogenously spread through the vasa vasorum to the arterial wall. Successful treatment of intracranial mycotic aneurysms with antimicrobial therapy alone has been reported (27); however, careful monitoring of the aneurysm is needed owing to the risk of rupture. Small mycotic aneurysms of the cerebral arteries may be managed with antimicrobial therapy alone; surgical or endovascular intervention is not always required.

In addition to the typical gram-positive cocci that can be expected in association with endocarditis, atypical bacteria may be present. These may be due in part to a practice involving the drug administration process; in one study, 32.5% of intravenous drug users reported licking the needle before injecting the substance (28). The most common reported reason for licking the needle was to clean it before the injection. The next most common reasons were ritualistic practice, to check the quality of the drug, to ensure that none of the drug was wasted, enjoyment of the taste, and to ensure that the needle was in working condition (28). Approximately one-third of intravenous drug users report licking the needle before injecting the substance—a behavior that influences the type of microbe involved in the associated infection (Fig 4).

The characteristic imaging finding of a mycotic aneurysm, as with other types of vascular aneurysms, is focal dilatation of the affected
blood vessel. CT angiography is the modality of choice for the noninvasive detection of these aneurysms, and digital subtraction angiography is the reference-standard examination. CT angiography performed with a 64-section scanner has a sensitivity of 97%–100% for the detection of aneurysms larger than 3 mm. Time-of-flight 1.5- and 3.0-T MR angiography has a comparable sensitivity of 95%. For the detection of aneurysms smaller than 3 mm, CT angiography performed with 16- and 64-section scanners has a sensitivity of 82%–96% (29,30). Overall, CT angiography is less susceptible to artifacts caused by motion and hemorrhage and can be performed more reliably in critically ill patients.

Mycotic aneurysms tend to favor the anterior circulation—the middle cerebral artery and its distal branches in particular (31). The location of intracranial mycotic aneurysms is less predictable than that of nonmycotic aneurysms, as mycotic dilatations reportedly have been identified in many locations, including the basilar system, around the circle of Willis, and in the distal branches of the cerebral arteries (32–35). In the appropriate clinical setting, a mycotic aneurysm should be suspected when the abnormality is in a location that is atypical for a bland cerebral aneurysm—particularly in the terminal branches of the cerebral vessels as opposed to a more proximal location characteristic of berry aneurysms. Moreover, the adventitial layer of the wall of mycotic aneurysms is weakened by microorganisms and proinflammatory cytokine secretions and neutrophils and thus becomes thin and friable. Morphologically, a mycotic aneurysm may have a wide neck with an eccentric shape or an absent neck, giving it a fusiform shape. Pressure from sustained arterial pulsatile flow in conjunction with a thin friable wall predisposes the aneurysm to rupture. Rupture of the vessel wall can lead to infarction as well as subarachnoid, intraparenchymal, and/or intraventricular hemorrhage (31). The mortality rate associated with a ruptured mycotic aneurysm can be as high as 80% (31,36). Early detection and subsequent medical management, endovascular coil placement, and/or surgical management can lead to substantially improved patient survival (31).

Heroin-induced Leukoencephalopathy
Heroin-induced leukoencephalopathy is a metabolic condition that is seen in association with opiate abuse and has characteristic imaging features. Because of the relatively distinct imaging features of heroin leukoencephalopathy (Fig 5), the emergency department radiologist may be the first to consider this condition as a possible diagnosis in a patient with neurologic symptoms and the appropriate history of opiate abuse. The flashy moniker for this condition, “chasing the dragon,” originates from a unique manner in which opiates were historically used: The smoke from heated free-base heroin is inhaled through a straw as it rises in a serpiginous manner (37).

During the acute phase, toxic encephalopathy typically appears as symmetric confluent deep white matter changes that correspond to cytotoxic edema. This edema might not be apparent at CT or seen as low areas of attenuation. Rather, the imaging findings are most conspicuous at MR imaging, with a confluent hyperintense signal in the white matter seen on T2-weighted and FLAIR images. Restricted diffusion, indicative of cytotoxic edema, also will be present (38). Chronic heroin-induced leukoencephalopathy
more commonly manifests as deep white matter changes, with sparing of the dentate nuclei and cerebellar cortex. Hyperintense lesions seen on T2-weighted and FLAIR MR images have a predilection for the posterior limbs of the internal capsule and the white matter of the temporal lobes. Restricted diffusion of these deep white matter tracts, with or without symmetric restricted diffusion in the basal ganglia pallidus, is a classic MR imaging finding that is specific to heroin abuse (39,40). Although the relationship is not entirely understood, the pathophysiology of toxic encephalopathy is thought to be due to oligodendrocyte apoptosis and microvascular dysregulation (41), with spongiform degeneration of the white matter (38). Differential considerations include other conditions that affect the deep white matter, such as infectious encephalitis (mucormycosis in an immunocompromised patient in particular) (42), acute disseminated encephalomyelitis, progressive multifocal leukoencephalopathy, posterior reversible encephalopathy syndrome, vasculitis, and demyelinating disease. However, the clinical history, including laboratory markers, and concordant imaging findings can suggest heroin-induced leukoencephalopathy.

The treatment of patients with heroin-induced leukoencephalopathy is supportive, and the prognoses are variable. It is important to be aware that in the absence of additional drug use, the imaging features may progress although the patient’s clinical status is improving. Thus, the progression of imaging features is not necessarily indicative of clinical deterioration; rather, it may reflect evolution of the original insult (39).

Hypoxic Ischemic Injury
The practicing emergency radiologist should be familiar with certain imaging findings and pitfalls associated with opioid overdose and the associated hypoxic ischemic injury to the brain. First, the diffuse loss of gray matter–white matter differentiation at nonenhanced head CT indicates that hypoxic brain injury has occurred, as cytotoxic edema progresses and effaces the sulci (Fig 6).

Second, the high attenuation in the subarachnoid space seen in the setting of opioid overdose may be mistaken for subarachnoid hemorrhage at nonenhanced head CT. The finding of pseudosubarachnoid hemorrhage can be seen in as many as 20% of patients following nontraumatic cardiopulmonary arrest and is associated with a poor prognosis (43,44). This appearance is the result of diffuse severe cerebral edema that causes decreased density of the brain parenchyma and engorgement and/or distention of the superficial veins due to increased intracranial pressure (44). In addition, preserved blood flow in the posterior circulation in the setting of increased intracranial pressure can result in the
“white cerebellum” sign (45). The attenuation of gray and white matter may be reversed and result in the appearance of the “reversal” sign (46).

Last, heroin has direct effects on the vasculature, inducing a reversible vasospasm, and crystalline impure additives can become emboli that occlude vessels and cause heroin-induced ischemia. The globus pallidus is particularly sensitive to ischemic injury; 5%–10% of heroin users are found to have globus pallidus infarcts after presentation (47).

**Cardiopulmonary Manifestations**

Patients addicted to opioids are prone to bacterial and fungal infections because of their tendency to repeatedly inject nonsterile material directly into the venous circulation. As venous blood returns to the heart, the cardiac valves, pulmonary vasculature, and lung parenchyma may be affected.

**Infective Endocarditis**

Infective endocarditis is a complication of intravenous drug abuse and notoriously difficult to treat. The estimated incidence of infective endocarditis in the general population increased from 11 in 100,000 individuals in 2000 to 15 in 100,000 individuals in 2011 (48). Among intravenous drug users, the incidence is increased 50- to 100-fold (49). Patients involved with abusive intravenous drug use are prone to develop recurrent infections following valve replacement and thus pose a unique challenge for the cardiothoracic surgeons who treat them (49). Clinical diagnostic models have aided in the diagnosis of endocarditis and have been shown to yield comparably accurate results in patients involved in intravenous heroin use, regardless of their human immunodeficiency virus status (50).

In addition to clinical parameters, imaging findings have a key role in the diagnosis of endocarditis. Once infective endocarditis is clinically suspected, an initial evaluation with transthoracic echocardiography (TTE) should be performed. According to year 2010 recommendations from the European Association of Echocardiography, TTE should be followed by transesophageal echocardiography (TE) if (a) a vegetation is found, (b) TTE results are negative but clinical suspicion remains high, (c) TTE results are suboptimal, or (d) a prosthetic valve or cardiac device is present (8). The sensitivity of TTE for the detection of native valve infective endocarditis is approximately 70%—and lower for the detection of smaller vegetations. Transesophageal echocardiography has the highest sensitivity for the detection of native valve endocarditis—approximately 96% (10). Both of these modalities have reported specifics of approximately 90% (10). TTE and transesophageal echocardiography are the mainstay examinations for the diagnosis of infective endocarditis and are generally under the purview of cardiologists. CT and MR imaging may be of some use, although their role is not well established (51). The emergency radiologist should, at minimum, be familiar with the appearance of a cardiac valve vegetation on chest CT images (Fig 7).

**Septic Pulmonary Emboli**

Given the predisposition for right-sided infective endocarditis among intravenous drug users, septic pulmonary emboli are not uncommon. However, the clinical manifestations of these emboli are nonspecific. Fever is the most common clinical feature (seen in 85.7% cases), with chest pain, dyspnea, cough, fatigue, and hemoptyisis following as the next most common clinical features (52).

Owing to the lack of specific clinical features, cross-sectional imaging has an important role in the diagnosis of septic pulmonary emboli. Ye et al (52) reviewed the available published literature regarding patients with septic pulmonary emboli between 1978 and 2012. Their analysis revealed that septic pulmonary emboli were more often bilateral (82.1%) and that the most common imaging features seen at cross-sectional CT included lung nodules (66.4%), cavitation (56.0%), local infiltrates (35.8%), pleural effusion (29.9%), a feeding vessel (27.6%), and wedge-shaped opacities (17.2%) (52). Pulmonary nodules, seen in 82% of cases, are the most common imaging feature of septic pulmonary emboli (Fig 8).

**Pulmonary Artery Mycotic Aneurysm**

Mycotic aneurysms can affect any artery, including large-caliber vessels such as the aorta and pulmonary arteries. Although mycotic aneurysms of the pulmonary arteries are rare, they are associated with a high (80%) mortality rate (53). The main pulmonary artery or its major branches are most commonly involved; these aneurysms occur less commonly in the more peripheral smaller branches (53). Pulmonary mycotic aneurysms can be managed surgically or with endovascular coil placement performed by an interventional radiologist (54,55). Timely recognition and treatment, including the initiation of antimicrobial therapy, are essential to achieving a favorable outcome (Fig 9).

**Noncardiogenic Pulmonary Edema and Acute Lung Injury**

Another entity that can occur in association with opioid abuse is noncardiogenic pulmonary edema (NCPE) (56,57). In one cohort of patients who presented with symptoms of opioid overdose, NCPE was found in 10% of these patients, with...
a male predominance. The pulmonary edema is most often caused by the opioid itself and is seen in association with the use of different \( \mu \)-receptor agonists, including heroin and buprenorphine \((56,57)\). It is worth mentioning that in some cases, NCPE has also been attributed to naloxone use rather than the opioid itself \((58)\). Bilateral perihilar opacities without pleural effusion or cardiomegaly (more commonly associated with cardiogenic pulmonary edema) are typical radiographic findings. CT findings include multifocal areas of ground-glass opacity with septal thickening.
Opioid use is associated with a multitude of respiratory complications, including NCPE, pneumonia, aspiration pneumonitis, lung abscess and/or empyema, septic pulmonary emboli, bronchiectasis caused by repeated infections, foreign-body aspiration, atelectasis, and pneumothorax. Furthermore, intravenously injected solutions made from oral tablets contain talc and other fillers, which can become emboli and develop foreign-body granulomas. Foreign-body granulomas can appear as multifocal areas of opacity that mimic neoplasms and are often confirmed with biopsy (59,60). A pneumothorax may develop after an attempted supraclavicular venous injection, known as a “pocket shot.”

**Musculoskeletal Manifestations**

**Soft-Tissue Infections**
Owing to the proclivity of opioid users to inject the drug by way of an intravenous or subcutaneous route (so-called “skin popping”), soft-tissue infections are common (61). In fact, infectious complications are the most common reason (in 60%–80% of cases) for hospital admission of intravenous drug users (62). Most practicing radiologists are familiar with the imaging appearance of soft-tissue abscesses—namely, rim-enhancing fluid collections at CT, with restricted diffusion at MR imaging. Ultrasonographic (US) images may show a fluid collection with debris or internal echoes that are indicative of the complexity of the fluid. The abscesses may occur locally at the site of injection, or they may be seen in deeper locations such as the psoas muscle (63), having spread via the bloodstream. Osteomyelitis due to local extension of a soft-tissue infection or hematogenous spread also may occur (Figs 10–12).

**Retained Needle Fragments**
In addition to local skin infections, retained needle fragments are frequently encountered in opioid drug users. Although hypodermic needle fragments...
can be subtle and difficult to identify on radiographs and CT images, efforts should be made to identify them in patients known to inject drugs. This is important for the safety of these patients and the clinicians who examine and treat them. These needles are often small and may be seen in the subcutaneous tissues; however, they reportedly also have been found in the upper extremity veins, femoral artery, neck, right ventricle, and lungs (64–68). Needle fragments may enter the venous circulation and migrate to the right heart and/or lungs, where they may become embedded. One report (66) describes a hypodermic needle fragment from a forearm vein that migrated to and became embedded in the lungs during an attempt to remove the needle. Management decisions regarding the retrieval of needle fragments are specific to the given clinical setting (Fig 13).

Figure 12. Epidural abscess in a 37-year-old female intravenous drug user who had a history of lumbar laminectomy for an epidural abscess and presented with low back pain. Sagittal T2-weighted (a) and T1-weighted (b) MR images show abnormal signal intensity in the epidural space (arrow) and L5 and S1 vertebral bodies (*). (c) Axial T2-weighted MR image shows phlegmon (dashed arrow) in the canal, as well as a hyperintense collection (solid arrow) in the epidural space and extending to the laminectomy bed. (d) Axial contrast-enhanced MR imaging findings confirm the presence of a nonenhancing collection (arrow) and thus the diagnosis of epidural abscess.

Figure 13. Retained needle fragments in a 41-year-old male intravenous drug user who presented for examination. (a) Posteroanterior chest radiograph shows a right apical opacity but otherwise clear lungs. (b) Closer inspection of the radiograph in a reveals multiple hypodermic needle fragments (arrows) projecting over the heart and right lung base. (c) Chest CT image findings confirm the presence of needle fragment emboli, with one fragment (arrow) clearly seen in the right ventricle.

Rhabdomyolysis after Overdose
Rhabdomyolysis with subsequent renal failure has been reported in the setting of opioid overdose (11,69,70). The likely cause of this condition is prolonged immobilization and impairment following an overdose. Cardiac rhabdomyolysis also has been reported in the setting of opioid overdose (70) and is thought to be caused by prolonged coronary capillary hypoxia. CT is the most commonly used modality for the initial emergency department examination of patients with opioid overdose–related rhabdomyolysis. CT findings described in the setting of rhabdomyolysis include heterogeneous low attenuation of the affected muscle, which is often seen with adjacent subcutaneous edema and subfascial fluid (71). With rhabdomyolysis, subcutaneous edema is often seen adjacent to the affected muscles and is probably caused by prolonged immobilization. There may be some peripheral enhancement; however, low attenuation is not specific to rhabdomyolysis and can
and respiratory support (76), or they may present and then suddenly die (Fig 15) (77).

Alternatively, emergency department radiologists may discover intracorporeally concealed drugs incidentally when interpreting the findings of imaging performed for another reason—for example, to examine a patient with a trauma injury. Multiple foreign bodies seen in the gastrointestinal tract or vagina may raise suspicion for intracorporeally concealed drugs, which can be confirmed with physical examination or endoscopy. The presence of multiple foreign bodies in the gastro-

Abdominal Manifestations

Intracorporeal Concealment of Drugs

Intracorporeal concealment of drugs is a well-known entity and is sometimes referred to as “body-packer syndrome.” The packaged drug(s) may be ingested or stored in the vagina or rectum. One of the main risks associated with this practice is that of the packaging that contains the intracorporeal drugs rupturing, exposing the host to large levels of opioids at once. In this scenario, patients may present with respiratory distress and require naloxone administration and respiratory support (76), or they may present and then suddenly die (Fig 15) (77).

Alternatively, emergency department radiologists may discover intracorporeally concealed drugs incidentally when interpreting the findings of imaging performed for another reason—for example, to examine a patient with a trauma injury. Multiple foreign bodies seen in the gastrointestinal tract or vagina may raise suspicion for intracorporeally concealed drugs, which can be confirmed with physical examination or endoscopy.
intestinal tract or vagina should raise suspicion for intracorporeal concealment of drugs, the packaging of which can rupture and expose the patient to a large amount of opioids at once (76,77).

Embolic Infarcts in Abdominal Viscera
Because intravenous drug use predisposes individuals to endocarditis, it also predisposes them to the associated embolic sequelae. Left-sided endocarditis can lead to the release of septic emboli into the spleen, kidneys, adrenal glands, or bowel. Owing to the robust blood supply to the stomach and liver, these sites are less commonly affected. Multiple viscera may be affected at once (Fig 16), or the inflammation can affect one organ at a time. Findings associated with a poor prognosis in the setting of embolic bowel infarct include bowel dilatation, pneumatosis, mesenteric or portal venous gas, and extraluminal air (78). Pneumatosis intestinalis is associated with a poor prognosis in patients with embolic bowel infarcts.

Mycotic Aneurysm of the Superior Mesenteric Artery
By the time Laufer and Smith (79) reported a mycotic aneurysm of the superior mesenteric artery secondary to endocarditis that resulted from rheumatic fever in 1944, nearly 30 cases had been reported in the literature. As with mycotic aneurysms seen elsewhere, such as the cerebral and pulmonary arteries, with superior mesenteric artery mycotic aneurysms, the risk of rupture is the main concern (Fig 17). Given this risk, surgical resection remains the treatment of choice (80).

Conclusion
Familiarity with the wide range of potential complications associated with opioid abuse will assist emergency radiologists in making timely diagnoses. Prompt diagnoses will aid in giving these patients the best chance for recovery.

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