Infected (Mycotic) Aneurysms: Spectrum of Imaging Appearances and Management

Infected aneurysms are uncommon. The aorta, peripheral arteries, cerebral arteries, and visceral arteries are involved in descending order of frequency. Staphylococcus and Streptococcus species are the most common causative pathogens. Early clinical diagnosis of infected aneurysms is challenging owing to their protean manifestations. Clinically apparent infected aneurysms are often at an advanced stage of development or are associated with complications, such as rupture. Nontreatment or delayed treatment of infected aneurysms often has a poor outcome, with high morbidity and mortality from fulminant sepsis or hemorrhage. Current state-of-the-art imaging modalities, such as multidetector computed tomography and magnetic resonance imaging, have replaced conventional angiography as minimally invasive techniques for detection of infected aneurysms in clinically suspected cases, as well as characterization of infected aneurysms and vascular mapping for treatment planning in confirmed cases. Doppler ultrasonography allows noninvasive assessment for infected aneurysms in the peripheral arteries. Imaging features of infected aneurysms include a lobulated vascular mass, an indistinct irregular arterial wall, perianeurysmal edema, and a perianeurysmal soft-tissue mass. Perianeurysmal gas, aneurysmal thrombosis, aneurysmal wall calcification, and disrupted arterial calcification at the site of the infected aneurysm are uncommon findings. Imaging-guided endovascular stent-graft repair and embolotherapy can be performed in select cases instead of open surgery. Familiarity with the imaging appearances of infected aneurysms should alert the radiologist to the diagnosis and permit timely treatment, which may include endovascular techniques.
Introduction
Infected aneurysm (or mycotic aneurysm) is defined as an infectious break in the wall of an artery with formation of a blind, saccular outpouching that is contiguous with the arterial lumen (1). Nontreatment or delayed treatment of infected aneurysms often leads to fulminating sepsis, spontaneous arterial rupture, and death (1–5). Earlier detection of infected aneurysms is critical for timely treatment to optimize patient outcome.

Current state-of-the-art imaging modalities, such as multidetector computed tomography (CT), magnetic resonance (MR) imaging, and Doppler ultrasonography (US), allow detection of infected aneurysms in clinically suspicious cases and characterization of infected aneurysms, as well as vascular mapping to facilitate treatment planning in confirmed cases, and have replaced conventional angiography. Advanced postprocessing techniques including multiplanar reformation, maximum intensity projection, volume rendering, and vascular segmentation allow image presentation in a visually concise manner. Development of more sophisticated endovascular techniques allows image-guided endovascular management of infected aneurysms with stents and embolotherapy in select cases in place of open surgery.

This article reviews the clinicopathologic and imaging manifestations of infected aneurysms. The characteristic findings at CT, MR imaging, and US are described and illustrated along with the findings of correlative imaging modalities, including conventional angiography. An overview of the current management strategies for infected aneurysms with an emphasis on endovascular techniques is presented.

Prevalence and Pathogenesis
Infected aneurysms are uncommon but can affect any artery (1,5,6). The aorta, peripheral arteries, cerebral arteries, and visceral arteries are involved in descending order of frequency (1,5,6). The true prevalence of infected aneurysms is unknown. The prevalence of infected aortic aneurysms is 0.7%–1% of all surgically treated aortic aneurysms (7–9). The most frequently involved peripheral artery is the femoral artery, and such cases are most commonly associated with intravenous drug abuse (3,10). The prevalence of infected cerebral aneurysms is 0.7%–4% among all patients with cerebral aneurysms (2,11). The most frequently involved visceral artery is the superior mesenteric artery (12). Synchronous or metachronous infected aneurysms occur in 20%–36% of cases (1,11,13,14).

Staphylococcus and Streptococcus species are the most common causes of infected aneurysms (10,11,15,16). Infected aneurysms due to methicillin-resistant Staphylococcus aureus have been reported, especially in intravenous drug abusers (17,18). Salmonella is most commonly associated with infected aortic aneurysms, especially in East Asia (16,19). Gram-negative bacteria, such as Escherichia coli, Klebsiella, and Pseudomonas, are uncommon causes of infected aneurysms that are becoming more frequent (10,15). Mycobacterium (15) and fungi, such as Candida albicans (11,20) and Aspergillus (9), are rare causes of infected aneurysms. Sterile blood cultures occur in 18%–50% of patients with infected aneurysms (3,4,10,15). Polymicrobial cultures in patients with infected aneurysms are uncommon (6) but are more frequently found in intravenous drug abusers (17,21).

Infected aneurysms can develop from (a) hematogenous spread of infectious microemboli into the vasa vasorum of a normal-caliber artery or a preexisting aneurysm, (b) infection of a pre-existing intimal defect by circulating infectious agent, (c) contiguous involvement of the vessel from an adjacent source of sepsis, or (d) direct infectious inoculation of the vessel wall at the time of vascular trauma (22). An infectious arteritis causes destruction of the arterial wall with subsequent contained rupture and formation of a pseudoaneurysm. An infected aneurysm can rapidly develop or enlarge (16,20). Pathologically, the wall of an infected aneurysm consists of compressed perivascular tissue, hematoma, and fibroinflammatory tissue (23). The infected aneurysm can subsequently undergo free rupture due to sustained systemic arterial pressure.

Clinical Features
In contrast to the preantibiotic era, when most infected aneurysms were associated with bacterial endocarditis, the majority of infected aneurysms now occur in intravenous drug abusers; in patients with depressed immunity such as those with diabetes mellitus, chronic illnesses, or malignancies; and after invasive intravascular procedures (9,10,15,21). The clinical manifestations of infected aneurysms are diverse. Infected aneurysms can manifest as systemic symptoms of oc-
cult infection, symptoms localized to the involved artery, or life-threatening hemorrhage or can be clinically silent. Most patients are febrile or septic at presentation (6,9,24).

Infected thoracic aortic aneurysms usually manifest as chest and interscapular pain, whereas infected abdominal aortic aneurysms usually manifest as abdominal pain with or without a pulsatile mass (4,9,24). Infected peripheral aneurysms may manifest as pain, a pulsatile mass, a palpable thrill, local inflammatory changes (cellulitis or abscess), vascular compromise (distal embolization, thrombophlebitis, or arteriovenous fistula), or compressive neuropathy (10,21). Infected cerebral aneurysms can cause headache, seizures, or focal neurologic symptoms (25,26), but many are asymptomatic until aneurysm rupture and hemorrhage occur (11,27). Infected superior mesenteric artery aneurysms are often symptomatic and can manifest as abdominal pain, a pulsatile mass, or gastrointestinal hemorrhage (12). Infected hepatic artery aneurysms are often asymptomatic but may cause abdominal pain, hemobilia, jaundice, or gastrointestinal hemorrhage (12). Infected renal artery aneurysms can cause hypertension (1) or hematuria (28). Only 7% of patients were asymptomatic in one series of infected aortic aneurysms (9).

In general, infected aneurysms have a poor natural history, with fatality from hemorrhage and fulminant sepsis. Seven percent to 24% of infected aortic aneurysms demonstrate free rupture and a further 47%–61% demonstrate contained or impending rupture at presentation (9,24). Freely ruptured infected aortic aneurysms have 63%–100% mortality, whereas ruptured infected intracranial aneurysms have 60%–90% mortality (9,24,27). Infected peripheral aneurysms have 0%–15% mortality; their better prognosis is likely due to their relatively superficial location, which makes them more clinically apparent and results in earlier presentation (10,17,21). Optimal outcome in the management of infected aneurysms depends on prompt diagnosis (24).

**Imaging Modalities**

Imaging is necessary to establish the diagnosis; to localize, characterize, and assess the number of infected aneurysms; to identify associated complications; to map relevant vascular anatomy for treatment planning; and for surveillance of treatment efficacy and the development of new infected aneurysms. Multidetector CT angiography is the current imaging modality of choice for the evaluation of suspected infected aneurysms (13,16,29,30). Its advantages include rapid examination time of a large volume; almost isotropic acquisition, which allows easy generation of high-resolution angiograms with three-dimensional reconstruction of vascular anatomy for surgical or endovascular treatment planning; and simultaneous identification of any associated complications.

The use of MR imaging for detection of infected aneurysms has been described in a few isolated case reports of infected aortic aneurysms (31,32). Its disadvantages relative to multidetector CT include longer examination time, increased susceptibility to motion artifact, lower spatial resolution, and smaller volume coverage. However, the development of three-dimensional contrast-enhanced MR angiography, faster gradient technology, use of advanced techniques (such as steady-state free precession, optimized k-space filling strategies, parallel imaging techniques, and time-resolved imaging), whole-body multidetector arrays, the moving table acquisition technique, and higher field strength (3 T) have improved the spatial and temporal resolution of MR angiography to enable comprehensive evaluation of the aorta, cerebral arteries, and peripheral arteries in patients who are unsuitable for CT angiography or conventional angiography (15,33–35). Cardiac-gating and respiratory gating techniques can be used to reduce motion artifact in the thoracic aorta. A fat-suppressed T1-weighted fast two-dimensional spoiled gradient-echo pulse sequence allows further evaluation of the vessel wall and perivascular tissues for abnormal contrast enhancement.

The use of sonography in diagnosis of infected aneurysms is limited to the peripheral arteries. Sonography is not reliable as an initial imaging modality for diagnosis of infected visceral or abdominal aortic aneurysms. Conventional angiography remains the standard of reference for diagnosis of infected aneurysms but is invasive, is associated with complications primarily related to arterial access and distal emboli, and does not permit detection of extravascular changes (16). The use of nuclear scintigraphy, such as gallium scanning and indium-labeled leukocyte scanning, for routine evaluation of infected aneurysms is limited and has been superseded by CT and MR imaging (16). There are isolated case reports of infected aneurysms detected with positron emission tomography (PET)/CT (36), but to our knowledge no data on the effectiveness of PET/CT are available.
Figures 1, 2. (1) Infected aneurysm of the infrarenal aorta in a 63-year-old woman with steroid-dependent rheumatoid arthritis and β-hemolytic Streptococcus sepsis. Sequential axial contrast-enhanced CT images, displayed from cephalic (a) to caudal (c) at 1.5-cm intervals, show stranding of the periaortic fat (arrows in a), prominent periaortic inflammatory soft tissue (arrows in b) with destruction of the L3 vertebral body (arrowhead in b), and a 2.5-cm saccular aneurysm (*) in c). Open surgery and endoluminal stent-graft placement were unsuitable owing to medical comorbidities and iliac arterial occlusions, respectively; the aneurysm was managed with lifelong antibiotic therapy. The patient remains alive 18 months after initial diagnosis. (2) Incipient free rupture of an infected aortic aneurysm in a 64-year-old man with Streptococcus pyogenes sepsis. (a) Axial contrast-enhanced CT image obtained at presentation shows a concentric hypoattenuating rim (arrows) around a normal-caliber infrarenal aorta, a finding indicative of periaortic edema and inflammatory soft tissue. (b) Axial contrast-enhanced CT image obtained 2 weeks later for assessment of acute abdominal pain shows a 5.4-cm saccular aneurysm (*) arising from the right posterolateral aspect of the aorta (arrow). High-attenuation fluid is evident in the left anterior pararenal space (arrowheads), a finding consistent with hematoma, but without active extravasation of intravenous contrast material. At emergent infrarenal aortic resection and placement of an axillofemoral bypass graft, rupture of the right posterolateral aspect of the aorta was confirmed.
At CT, an infected aortic aneurysm appears as a focal, contrast-enhancing dilatation that is usually saccular (Figs 1, 2) (16,40). The lumen can be central or eccentric and can be a single compartment or multiloculated. At MR imaging, the lumen shows flow voids and intense gadolinium enhancement. Disrupted arterial wall calcification can occur adjacent to the infected aneurysm (Fig 3) (20,38). Calcification within the aneurysm wall and thrombus within an infected aneurysm are uncommon (39). In one study, 26% of infected aortic aneurysms demonstrated calcification within the aneurysm wall and only one of 29 infected aortic aneurysms (3.4%) showed mural thrombus (16). Ruptured infected aortic aneurysms show active extravasation of intravascular contrast material at CT, and hematoma formation adjacent to the aneurysm can occur (29). Periaortic blood from a ruptured infected abdominal aortic aneurysm may extend into the pararenal space, perirenal space, and peritoneal cavity.

**Imaging Features**

**Aorta**

Infected aneurysms commonly involve parts of the aorta that are not commonly involved by atherosclerosis. Although the infraabdominal aorta is the most frequently involved part of the aorta, the combined involvement of the descending thoracic, thoracoabdominal, and suprarenal aorta accounts for more cases than the infrarenal aorta (9). Early changes of aortitis preceding aneurysm formation include an irregular arterial wall, periaortic edema, a periaortic soft-tissue mass, and periaortic gas.

Periaortic edema can appear as fat stranding or a hypoattenuating concentric rim at CT (Figs 1, 2) (16,20,37). At MR imaging, periaortic edema has low signal intensity on T1-weighted images and high signal intensity on T2-weighted images. Concentric or eccentric periaortic inflammatory soft tissue can develop. At CT, it initially appears as a homogeneous contrast-enhancing mass (17,21,38). At MR imaging, it has low signal intensity on T1-weighted images and high signal intensity on T2-weighted images and demonstrates uniform enhancement (20). The inflammatory mass can develop necrosis and then has heterogeneous attenuation at CT and variable signal intensity at MR imaging and demonstrates rim enhancement or poor enhancement after administration of contrast material (Fig 1) (39). Periaortic mass or stranding is the most common imaging finding with infected aortic aneurysms and is found in 48% of cases (16). Periaortic gas is an uncommon feature (16,40).

Figure 3. Infected aneurysm of the paravisceral abdominal aorta in a 56-year-old man with a renal transplant and methicillin-resistant S aureus sepsis. Axial contrast-enhanced CT image, obtained at the level of the origin of the celiac trunk (arrowhead), shows a 2.5-cm saccular aneurysm (*) arising from the left lateral aspect of the aorta. Note the disrupted aortic calcifications at the neck of the aneurysm (arrows). The aneurysm was successfully excluded with a covered endoluminal stent, but the patient died 6 weeks later of multiorgan failure and sepsis.

**Peripheral Arteries**

The most frequently involved peripheral artery is the femoral artery, and such cases are most commonly associated with intravenous drug abuse (3,10). Infected aneurysms distal to the knee and of the upper limb are uncommon (10,21). The brachial artery is the most common site of infected aneurysms of the upper limb, and such cases usually occur in patients with a history of intravenous drug abuse (10,21).
At gray-scale sonography, an infected peripheral aneurysm appears as a circumscribed, hypoechoic lesion adjacent to an artery (Figs 4, 5). Larger infected aneurysms demonstrate turbulent flow that can be appreciated during dynamic examination, and color Doppler US demonstrates the characteristic yin-yang sign (Figs 4, 5) (41). Pulsed Doppler US demonstrates a characteristic to-and-fro waveform within the neck of the aneurysm to the parent artery (Fig 5) (41,42). Blood flow into the aneurysm during systole and out of the aneurysm in diastole, respectively, accounts for the “to” and “fro” components of the waveform that can be shown at color and pulsed Doppler sonography. Concentric or eccentric periarterial inflammatory...
soft tissue and hematoma appear as a heterogeneous rind of variable echogenicity surrounding the lumen of the infected aneurysm (Fig 4). Doppler sonography has 94% sensitivity and 97% specificity for detection of femoral pseudoaneurysms after percutaneous arterial catheterization (43). However, sonography does not allow differentiation of infected aneurysms from noninfected pseudoaneurysms; correlation with the clinical scenario and other imaging modalities is required for a more confident diagnosis of infected aneurysms. Infected peripheral aneurysms have similar CT and MR imaging findings as infected aortic aneurysms.

**Cerebral Arteries**

Infected cerebral aneurysms are more common in the anterior circulation (Fig 6) than the posterior circulation (Fig 7) (11). They tend to be peripherally located (segment 2 and beyond) and fusiform in appearance (11,13,14,26). Twenty percent to 33% of infected cerebral aneurysms...
**Figures 6, 7.** (6) Infected aneurysm of the middle cerebral artery in a 40-year-old man with a history of intravenous drug abuse, sepsis, and headache. (a) Axial nonenhanced CT image shows an evolving acute infarct (arrow) in the left insular cortex with an adjacent poorly defined area of high attenuation (arrowhead). (b, c) Axial maximum intensity projection CT angiogram (b) and lateral selective left carotid angiogram (c) show a bilobed, partly fusiform and saccular, 6 × 10-mm aneurysm (arrows) arising from an insular branch artery. The aneurysm corresponds to the area of high attenuation seen in a. Urgent aneurysmectomy was performed. (7) Infected aneurysm of the posterior cerebral artery in a 28-year-old man with a history of intravenous drug abuse, *Streptococcus mutans* endocarditis, and sudden collapse. (a) Axial nonenhanced CT image shows a large acute parenchymal hematoma in the left occipital lobe (arrow). Note the gliosis (arrowheads) in the right posterior central sulcus; the gliosis was presumably due to a prior silent thromboembolus. (b) Frontal image from selective left vertebral angiography shows a 5-mm aneurysm (arrow) in the calcarine branch of the left posterior cerebral artery. Urgent aneurysmectomy and clot evacuation were performed.

are centrally located (proximal to the first bifurcation of the circle of Willis) and can be difficult to differentiate from berry aneurysms (28). CT features that may help differentiate a centrally located infected cerebral aneurysm from a berry aneurysm include arterial stenosis or occlusion close to the aneurysm, rapid change in morphology of the aneurysm, or presence of other infected aneurysms (13). A combination of these features improves the certainty of the diagnosis of an infected aneurysm.

The diagnostic performance of CT angiography performed with 16-row multidetector CT is comparable to that of two-dimensional digital subtraction angiography (DSA) for detection of cerebral aneurysms (44–46). The overall sensitivity and specificity of CT angiography in the detection of cerebral aneurysms on a per-aneurysm basis are 92.5%–96.2% and 93.3%–100%, respectively (44,45). The mean sensitivity and specificity of 64-row multidetector CT compared with those
of DSA for detection of cerebral aneurysms are 92.8%–94% and 90.2%–100%, respectively (47,48). The performance of CT angiography in detection of cerebral aneurysms under 3 mm is less robust than that of DSA, with a sensitivity of 70.4%–91.7% (44,45,48). DSA has a higher intrinsic spatial resolution and may be required to exclude small (<3-mm) infected cerebral aneurysms in cases of strong clinical suspicion but negative CT angiography findings. The positive and negative predictive values for CT angiography performed with 16-row multidetector CT in triage of cerebral aneurysms for suitable endovascular embolization are 96% and 88%, respectively (46).

The sensitivity of contrast-enhanced MR angiography and three-dimensional time-of-flight MR angiography for detection of cerebral aneurysms is 95%–100% and 82%–96%, respectively (46,49). The performance of contrast-enhanced MR angiography at 3 T in detection of cerebral aneurysms is comparable to that of CT angiography performed with 16-row multidetector CT (50).

Visceral Arteries and Arteries to Other Organs
Infected aneurysms of the visceral arteries most commonly involve the superior mesenteric artery (SMA) (Fig 8) (12) and have been described in the liver (51), spleen (Fig 9) (12), kidneys (Fig 10)
To our knowledge, there are no large case series of infected aneurysms involving the visceral arteries or arteries to other organs. However, isolated case reports and smaller case series suggest that infected aneurysms tend to be within the distal arterial bed and hence are peripherally located or lie within the parenchyma of the involved organ (28,51). The imaging appearances of infected visceral aneurysms are similar to those described earlier. Infected visceral aneurysms can develop or enlarge rapidly (16,20,38).

Figures 9–11. (9) Infected aneurysm of the spleen in a 25-year-old man with a history of intravenous drug abuse, S. mitis endocarditis, and acute abdominal pain (same patient as in Fig 8). Coronal maximum intensity projection CT angiogram shows a 1.0-cm aneurysm (arrow) in the spleen. The asymptomatic aneurysm was not present at CT performed 10 days earlier. Conventional angiography performed 1 month later for embolization of the aneurysm showed spontaneous thrombosis of the aneurysm; no further intervention was performed. (10) Infected aneurysm of the renal artery in a 40-year-old man with a history of intravenous drug abuse, sepsis, and headache (same patient as in Fig 6). Coronal maximum intensity projection CT angiogram (a) and image from selective angiography (b) show a 1.0-cm aneurysm (arrow) in the superior pole of the right kidney. The aneurysm was asymptomatic. (11) Infected aneurysm of the pulmonary artery in a 54-year-old man with multiple myeloma treated with high-dose steroid therapy and with left lower lobe zygomycosis. Coronal contrast-enhanced maximum intensity projection CT image shows a 2.3-cm aneurysm (arrow) of the left lower lobe pulmonary artery against a background of extensive cavitary pneumonia. Left pneumonectomy was performed due to extensive pulmonary necrosis.
To our knowledge, there are no published studies that have assessed the accuracy of CT angiography in detection of infected visceral aneurysms. CT angiography is reported to be accurate in the detection of visceral artery pseudoaneurysms complicating acute pancreatitis (53). In that study, CT angiography performed with four-row multidetector CT had 94.7\% sensitivity for detection of the source of major arterial bleeding complicating acute pancreatitis; 10 pseudoaneurysms were detected at CT angiography and confirmed with DSA.

**Treatment**

The specific management of an infected aneurysm must be individualized and is dependent on the characteristics of the aneurysm (location, morphology, and presence and extent of hemorrhage), patient characteristics, and available expertise. A detailed discussion of all the management options for infected aneurysms specific to the location and clinical setting is beyond the scope of this article. However, an overview of the various management strategies is presented. Therapeutic options include open surgery, endovascular stent placement, endovascular embolization, medical therapy, or a combination of these.

In general, small, asymptomatic, and unruptured infected aneurysms can be managed with a trial of intravenous antibiotics for 4–6 weeks along with surveillance imaging (11,26,54). Large, ruptured, or symptomatic infected aneurysms require emergent or urgent open surgery in combination with antibiotic therapy. Infected aneurysms show a mixed response to medical therapy, and there are no predictive imaging features (11,13,14). They can undergo complete thrombosis (Fig 12), decrease in size, or enlarge or new infected aneurysms can develop. Enlarging or residual aneurysms at surveillance imaging are triaged to surgical management. However, newer endovascular techniques are challenging open surgery, but they remain controversial because the introduction of a foreign body within an infected field is against general surgical principles.

**Surgery**

In general, open surgery involves aneurysmectomy or aneurysmorhaphy with or without primary reanastomosis or patch closure as well
Circumferalization is technically demanding (Fig 13) (55,59). The management of infected aneurysms involving peripheral and cerebral arteries with endovascular covered stents has been recently reported (18,60). Advantages of endovascular stent repair include a smaller incision, reduced need for blood transfusion, avoidance of cardiopulmonary bypass and aortic cross-clamping in infected aortic aneurysms, and reduced stay in intensive care. Early complications include postimplantation syndrome, access-related arterial injury, stent misplacement, arterial embolism, visceral infarcts, renal failure, and death (61). Late complications include stent infection, migration, endoleak, and fracture.

A recent meta-analysis of endovascular stent repair for infected aortic aneurysms showed an overall mortality of 20.8% and persistent infection in 22.9% of cases (59). The 12-month survival in the group with persistent infection was as extensive local débridement of surrounding tissues (55). Distal revascularization can be performed with an in situ graft or extraanatomic reconstruction, depending on the location of the infected aneurysm. In situ grafts are necessary for the thoracic and suprarenal aorta (7,24). In situ grafts used include synthetic grafts (7), cryopreserved allografts (56), or arterial and venous homografts. These grafts can be soaked or impregnated with antibiotics and wrapped with pedicled muscle or omental flaps to protect them from infection. Extraanatomic reconstruction can be performed for infected aneurysms of the infrarenal aorta (axillofemoral bypass) (57) and peripheral arteries (10). The mortality associated with placement of in situ grafts for treatment of infected aortic aneurysms is 14%—36% (7,8,24,58); the mortality associated with extraanatomic bypass is 7% (57).

**Endovascular Stent Repair**

Endovascular covered stents have been primarily used to exclude infected aortic aneurysms, especially in the thoracic aorta, where surgical revas-
39%, whereas in the infection-free group it was 94%. Predictors of adverse outcome in endovascular stent repair of infected aortic aneurysms are ruptured aneurysms and the presence of active infection at the time of stent deployment (59).

**Endovascular Embolotherapy**

Endovascular embolization is mainly used to exclude infected aneurysms in the cerebral arteries (13), visceral arteries (51,62), and arteries of other organs (63). Occlusion of the infected aneurysm or its parent artery is most commonly performed with detachable coils (Fig 14), but use of detachable balloons, N-butyl-2-cyanoacrylate (glue), and thrombin has also been described (13,55). Thrombin converts fibrinogen to fibrin, resulting in thrombus formation. Its use has been reported in the primary management of infected hepatic aneurysm (62). Thrombin or glue can be injected into a coil-filled sac to facilitate thrombosis, especially with persistent sac perfusion after primary treatment (64). Complications include access-related arterial injury, postembolization syndrome, end-organ infarct, and persistent aneurysm perfusion.

For infected intracranial aneurysms, technical success rates of 80%-100% with no procedure-related mortality and stable occlusions have been reported in small series of patients treated with endovascular embolization (11,13). There were no cases of persistent infection. To our knowledge, endovascular embolization for infected aneurysms in the visceral arteries and arteries to other organs has been limited to case reports with no large series or meta-analyses to assess the long-term durability of this technique, especially the risk of persistent infection. However, the technical success rate for endovascular embolization of noninfected visceral pseudoaneurysms is high with low procedural mortality (65).

**Medical Therapy**

Prolonged culture-specific antibiotic therapy in combination with conventional surgery or endovascular techniques is advocated as a key component for successful treatment of infected aneurysms, but there is no consensus on the optimal
duration of antibiotic therapy (59). Intravenous antibiotic therapy is commonly given for the initial 4–6 weeks, but the necessity of lifelong oral antibiotics is controversial. One study showed no re-infection with mean follow-up duration of 3 years when long-term antibiotics were not used (56).

Medical treatment alone is controversial because of persistent infection and the high risk of aneurysm rupture. In patients with infected aortic aneurysms, primary medical treatment is reserved for non–surgical candidates or those patients who refuse surgery. In one series, six of 11 patients with infected aortic aneurysms who underwent primary medical treatment with intravenous antibiotics died from rupture of their aneurysms, but the survivors were able to be discharged from the hospital (19).

Conclusions
The key to a successful outcome in this uncommon but difficult to manage entity is early diagnosis and aggressive treatment. Early diagnosis requires a high index of clinical suspicion and awareness by the radiologist of the spectrum of imaging appearances, especially early changes. Treatment needs to be individualized and can be technically difficult owing to the location of the infected aneurysm, such as in the thoracic aorta; preexisting patient comorbidities; sepsis and its associated complications; and compliance issues, especially in intravenous drug abusers owing to psychosocial problems. Surveillance imaging permits assessment of treatment efficacy in patients with early uncomplicated infected aneurysms, which are conservatively managed with antibiotics, and prompt triage of refractory cases to surgery or endovascular management; evaluation of the durability of surgical and endovascular treatment; and assessment for metachronous lesions in at-risk patients.

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