Imaging of Endoleaks

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The endovascular repair of abdominal aortic aneurysms is gaining widespread acceptance worldwide. It relies on the exclusion of the aneurysm sac from arterial pressure/blood flow to reduce the pressure within it and therefore prevent the fatal complication of rupture. The presence of an endoleak is clear evidence that communication between the native circulation and the aneurysm sac persists. Unfortunately, direct measurement of the sac pressure is not a practical or safe method for routine detection or follow-up of endoleaks. Therefore, a fast, safe, sensitive, and reproducible method must be available. Although many imaging modalities have been and continue to be investigated, computed tomography angiography remains the gold standard. This article describes the various modalities used for the detection of endoleaks and discusses their imaging characteristics.

The initial successful open surgical repair of an abdominal aortic aneurysm (AAA) took place approximately 50 years ago.[1] Since that time, the surgical technique has been refined and perfected. Minimally invasive techniques for endovascular repair of infrarenal AAAs have slowly been gaining widespread acceptance since 1991, when the first device was placed in a human. Although the advantages of endovascular repair are lower morbidity and mortality, reduced transfusion rate, and shorter length of hospital stay, there are disadvantages. These include uncertainty of morphologic changes in the aneurysm sac and possible delayed complications, such as graft limb thrombosis, aneurysm expansion, and rupture.[2] One complication that is controversial in terms of both its diagnosis and management are endoleaks, which can have the potentially disastrous consequence of aneurysm rupture.[3] In this article, the detection and imaging characteristics of endoleaks are addressed.

What Is an Endoleak?

The term "endoleak" was first described by White et al 5 years ago.[4] It is defined as a persistence of blood flow outside the endograft but within the aneurysm sac or its adjacent branches. The incidence of an endoleak has been reported in the literature to range from 5% to 47%, of which 50% may resolve without intervention.[3,5] According to Laplace's law, the wall tension in an aneurysm sac is directly proportional to its diameter and the pressure within it. Therefore, because an endoleak results in the aneurysm sac being perfused by arterial blood/pressure, it places the aneurysm sac at risk for expansion and/or rupture. Many investigators have shown that aneurysms that are excluded from arterial pressure decrease in diameter, whereas those that are not continue to expand.[6-11] Thus, the importance of detecting and imaging an endoleak is obvious.

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Classification

In current clinical practice, endoleaks that occur during the perioperative (30-day) period are termed *primary endoleaks.* Those that occur after successful endovascular repair and after the 30-day window are termed *secondary endoleaks.* White et al have classified endoleaks into 4 major types.[12,13]

Type I endoleaks are the result of flow around the proximal (type IA) or distal (type IB) ends of an endograft (Fig 1). Primary type I endoleaks can result from malposition of the stent-graft during placement of the device, from underdilatation of the graft material at the time of implantation, or from an error in preprocedure planning, when the endograft that has been selected is smaller than required. They can also occur as a result of an angulated proximal neck, short or noncircular attachment zones, and mural thrombus or severe calcification within the attachment zones. However, secondary type I endoleaks are caused by aneurysm remodeling or dilatation of the native artery at either the proximal or distal attachment sites. This results in a suboptimal seal between the graft material and the native arterial wall, resulting in a type I secondary endoleak. Because type I endoleaks are high-pressure leaks, they represent a failure of stent-graft therapy and must be treated if the patient is going to be protected from aneurysm rupture.

Unlike type I endoleaks, which represent a failure of aneurysm exclusion, type II endoleaks are caused by continued perfusion of the aneurysm sac via retrograde flow through patent aortic side branches, such as lumbar, sacral, gonadal, accessory renal, or inferior mesenteric arteries (Fig 2). This type is the most common and is unrelated to the type or configuration of the stent-graft used. As discussed elsewhere in this issue, this type of endoleak is often amenable to transcatheter interventional techniques. It should be noted, however, that the treatment of type II endoleaks is not without controversy. Many type II endoleaks spontaneously thrombose without further intervention. Therefore, some physicians simply follow type II endoleaks with serial computed tomography (CT) scans, whereas others take a more aggressive approach and treat the endoleak if and when it is detected.

Less common are type III endoleaks, which occur at rate of less than 1%. These endoleaks are the result of 2 distinct entities. The first of these is a tear in the graft fabric, with a resultant endoleak (Fig 3). The second is a leak that arises when the different components of a modular graft separate. As with type I endoleaks, type III endoleaks leave the patient essentially untreated and unprotected from aneurysm rupture. As a result, it is imperative to properly identify this type of endoleak. The

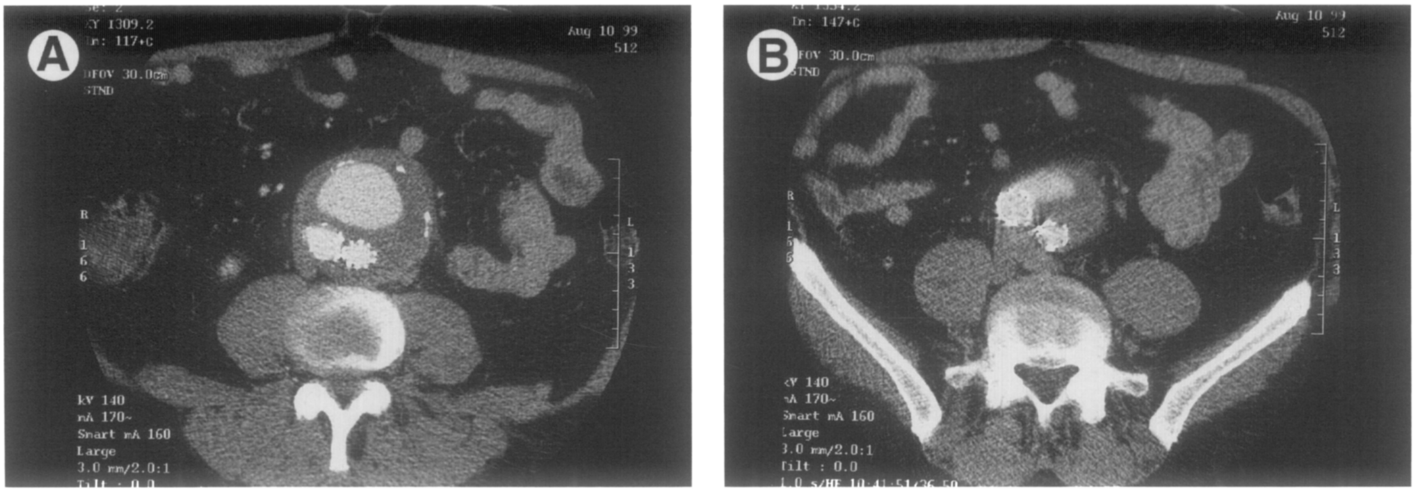

Fig 1. Type I endoleak. (A) Contrast-enhanced axial CT scan through the abdomen shows an endoleak with a nonspecific appearance. (B) Images of the pelvis in the same patient as in part A shows the leak in the right anterior aneurysm sac consistent with a distal right attachment site endoleak. This type IB endoleak was confirmed with digital subtraction angiography.

CT appearance of these leaks can be quite similar to that of a type II endoleak. However, a type III endoleak by definition typically develops over time. Therefore, any new endoleak should be carefully investigated.

Type IV endoleaks are the result of graft fabric porosity (Fig 4). This type of endoleak typically resolves within the first week and is of no clinical consequence by itself. The most significant problem with a type IV endoleak is that it can be confused with a type I endoleak on the postimplantation completion angiogram. This misidentification can lead to unnecessary further balloon dilation of the graft components or even the placement of additional unneeded graft extensions in an attempt to treat a finding that is due to graft porosity rather than a significant type I endoleak. A type IV endoleak typically appears late on the completion angiogram as a diffuse blush rather than a focal leak originating from a specific portion of the stent-graft.

Endoleak Surveillance

The importance of treating endoleaks is clear, but often there is disagreement regarding the optimal interval of surveillance and the method of detection. At the Miami Cardiac and Vascular Institute, all patients who have undergone AAA endovascular repair are monitored frequently with CT angiography. If final contrast abdominal angiography at the time of placement of the stent-graft is normal with no endoleak present, then the patient undergoes initial CT scanning at 1 month. However, if an endoleak is present on the final contrast angiogram, then the

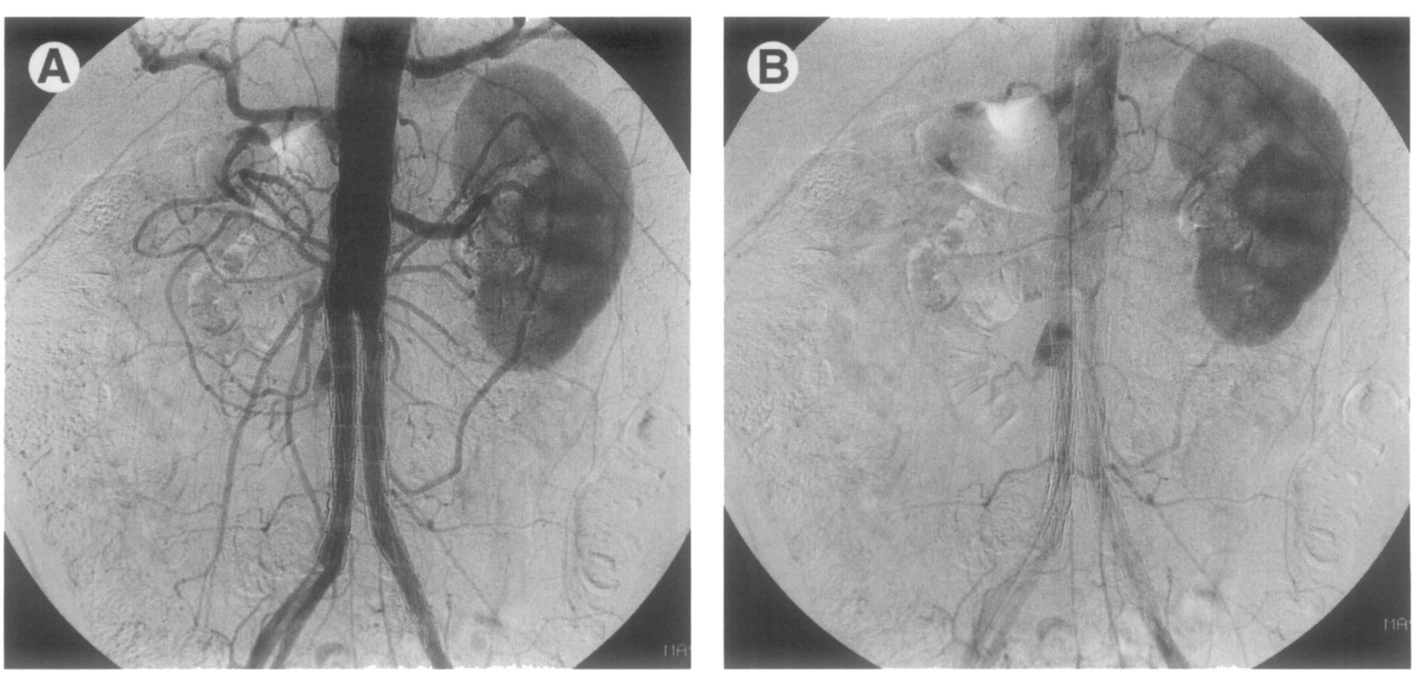

Fig 2. Type II endoleak. (A) Anteroposterior aortogram shows retrograde filling of the inferior mesenteric artery via an intermesenteric arterial communication. (B) Delayed image from the same aortogram shows the endoleak more clearly. Note the antegrade filling of lumbar arteries as well as occlusion of the right renal artery.

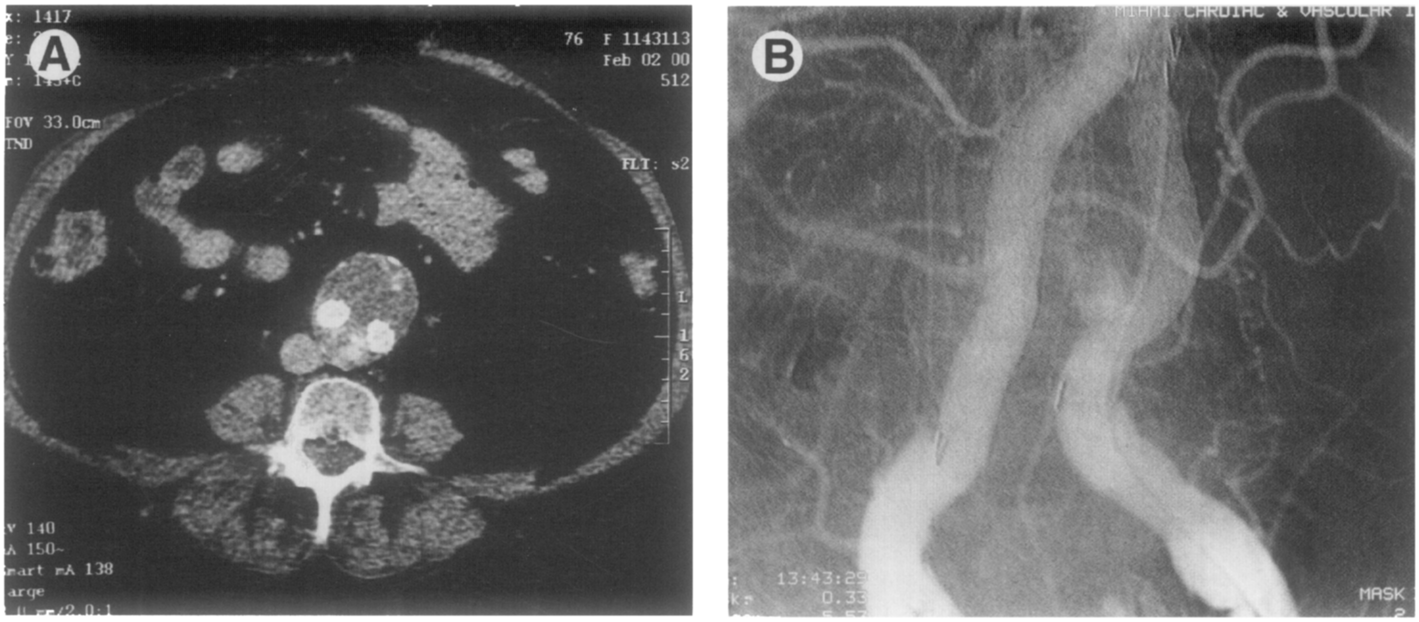

Fig 3. Type III endoleak. (A) Contrast-enhanced axial CT scan through the abdomen shows a leak in the posterior aneurysm sac. (B and C) Digital subtraction angiography shows the leak arising from within the left limb of the graft. This must therefore be related to a fabric tear.

patient may undergo initial CT scanning before discharge. This allows assessment of the endoleak size and helps determine the urgency of intervention that may be needed for treatment. Although no follow-up schedule has been standardized, patients at the Institute undergo CT scanning at 1 month, 6 months, 1 year, and annually afterward, assuming that no endoleak is present.[3] A 3-month postprocedure CT scan may be obtained if the implanting physician is concerned about findings on the initial 1-month study. If an endoleak is present on any of these CT scans, then management is based on a host of clinical and imaging factors. Refer to the appropriate article in this issue for an in depth discussion of endoleak management.

Imaging of Endoleaks

Although the interval of surveillance is important, the method of endoleak detection is equally important.[2] It is necessary to have a method that is highly sensitive and specific, inexpensive, reproducible, and that carries little risk to the patient. Although direct measurement of the sac pressure would be the ideal, this is not a practical method at present. As a result, many imaging studies are and have been evaluated for endoleak detection, including ultrasound, contrast angiography, and magnetic resonance angiography. In most centers, contrast-enhanced CT angiography has remained the gold standard for the routine detection and follow-up of endoleaks.[2,3,5]

Plain Film Radiographs

Although abdominal plain film radiographs are excellent for evaluating device malfunction, such as kinks, breaks, modular disconnection, tilting, or migration, there is no role for it in endoleak detection.

Ultrasound

Unlike plain film radiographs, duplex ultrasound can be used for the detection of endoleaks. Its usefulness is unclear, however, because there are few studies that define its indications. Potential benefits include reduced cost and the avoidance of the risks and complications associated with iodinated intravenous

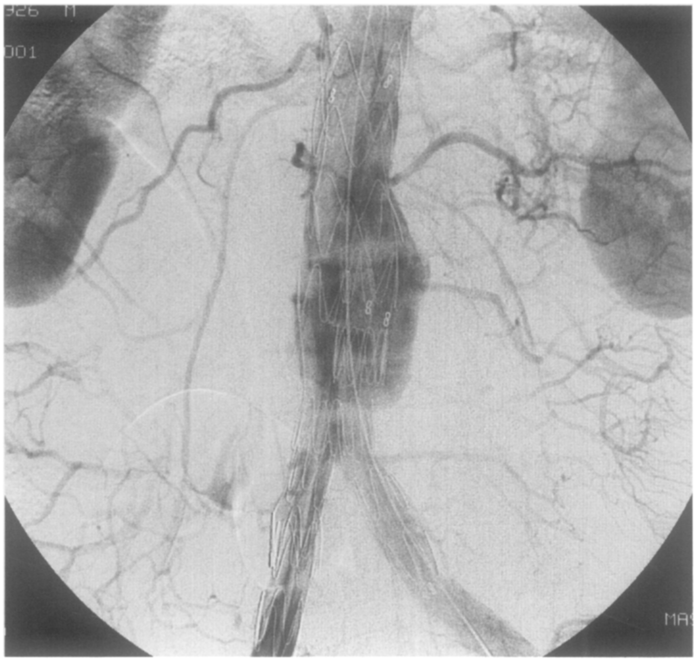

Fig 4. Type IV endoleak. Anteroposterior aortogram immediately after stent-graft implantation shows an endoleak. Contrast was noted to slowly fill the aneurysm sac during the angiogram. It did not appear to originate from the attachment sites or the modular component junctions. This endoleak subsequently resolved on a CT scan performed several days later.

contrast and ionizing radiation.[14] Several studies have shown that the sensitivity and specificity have approached greater than 95% for the detection of endoleaks. Unfortunately, these same studies have also shown that only 19% of the examinations were technically optimal and that there was significant operator variability and a lack of guaranteed reproducibility.[2,14-16] The authors of these studies therefore concluded that duplex ultrasound was less reliable than CT angiography for the detection of endoleaks.[2,14-16] Duplex ultrasound, however, remains a valuable initial tool for endoleak detection for patients who cannot undergo contrast-enhanced CT scanning either because of renal insufficiency or a severe iodine allergy.

Contrast Angiography

Contrast angiography has long been considered the modality of choice for arterial imaging. Two reasons, however, preclude its routine use for endoleak detection. First, it is an invasive technique. Second, because it is a projectional imaging modality, overlap of structures can often obscure the visualization of an endoleak.[17] Contrast angiography, however, can be an effective tool both in diagnosis and therapy. For example, there are instances when an aneurysm sac does not decrease in size or continues to expand despite the absence of an endoleak on other imaging modalities. In this situation, it can be quite effective as a diagnostic tool because specific areas related to the aneurysm and the endograft can be selectively catheterized and studied. Furthermore, once the endoleak is discovered, transcatheter interventional techniques can be used for management and treatment of the endoleak. This is discussed in depth elsewhere in this issue.

The appearance of endoleaks during angiography is similar to CT. Generally, contrast will be seen outside the confines of the stent-graft and within the aneurysm sac or its adjacent branches. Large leaks may be obvious, and smaller leaks, which are often clearly shown on CT, may not be visualized at the time of angiography. Contrast angiography, however, can often be of great benefit in determining the cause of small endoleaks. For example, a small type II endoleak arising from retrograde flow from a patent inferior mesenteric artery can have an identical CT appearance as that of a type II endoleak arising from a patent lumbar artery. Because of the sequential imaging that occurs during a diagnostic angiogram, this study can almost certainly differentiate between these 2 types of endoleaks, as retrograde flow can be seen in the artery causing the leak. Thus, if used properly, contrast arteriography can be a useful adjunct to other imaging examinations.

Magnetic Resonance Imaging

Whereas contrast angiography has changed very little in recent years, advances in magnetic resonance (MR) imaging technology have substantially improved the quality of MR angiography. Its advantages include the lack of ionizing radiation and multiplanar capability. Unfortunately, metallic clips or hardware related to stent-grafts can produce considerable magnetic susceptibility artifacts, which is not a problem with some of the other imaging modalities, such as CT angiography. Also, branch vessels are often not clearly visualized because of the artifact from metal related to the endograft or from calcified plaques. Finally, although intravenous contrast can help produce shaded surface displays, they have limited value because the stent-graft and the intraluminal contrast enhancement cannot be distinguished on the final display images. At present, MR imaging has a limited role in the routine poststent-graft implantation imaging of endoleaks.

Computed Tomography

Currently, CT angiography is considered the gold standard for the detection and evaluation of AAAs as well as for surveillance after endovascular repair. Acquisition of volumetric data allows for the evaluation of calcified and tortuous aortas, branch vessels, and adjacent structures. The administration of intravenous contrast allows the visualization of true and false lumen flow channels, slow perigraft flow around aortic stent-grafts, graft limb thrombosis, and intramural hematomas. In addition, the aneurysm sac diameter can be accurately measured and compared with previous studies. These advantages, along with the fast, minimally invasive nature of CT angiography, make it the most sensitive imaging modality for endoleak detection.[16]

Endoleaks have a distinct appearance on CT. A collection of contrast outside the confines of the stent-graft and within the aneurysm sac is the most common finding. In addition, because CT scans allow branch vessel analysis, the source of an endoleak can often be predicted.[17] A potential pitfall, however, is calcification or high-attenuation thrombus within the aneurysm sac. This finding can frequently mimic an endoleak, but comparison with precontrast CT scans will clarify the nature of the finding in most patients. Another potential pitfall occurs when evaluating CT scans for endoleaks the day after endovascular repair. Contrast used during the endovascular repair procedure can remain within the aneurysm sac for several days afterward. Therefore, CT scanning during this time period will often show what looks like an endoleak, when in fact it is better termed a *pseudoleak* (Fig 5).

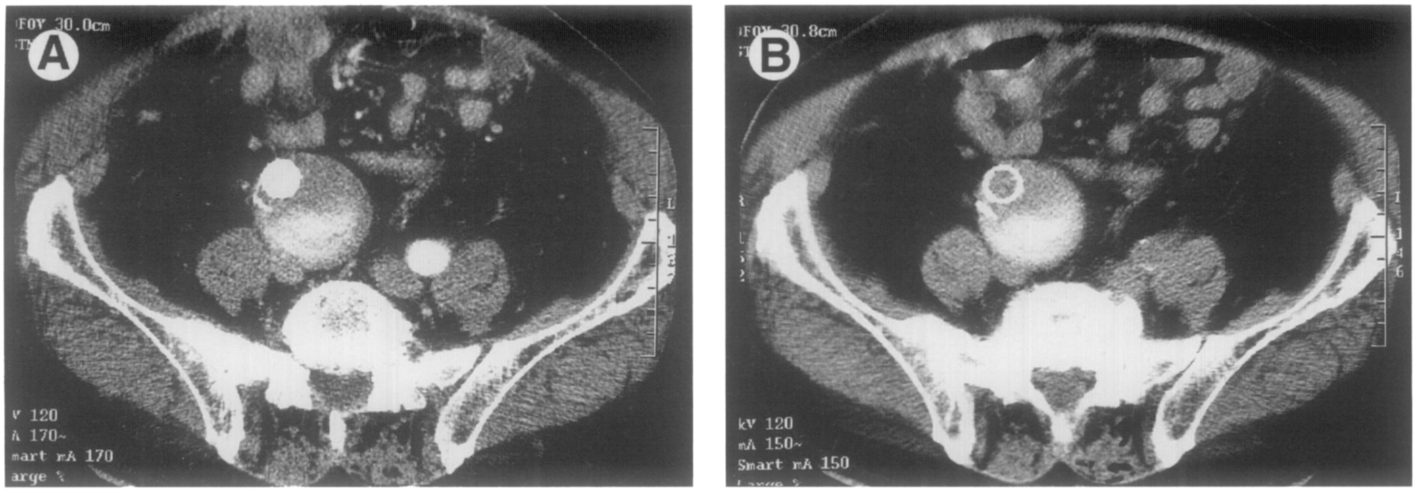

Fig 5. Pseudoleak. Contrast-enhanced CT scan (A) through the pelvis shows a possible endoleak within the posterior aneurysm sac. On the noncontrast CT scan (B) at the same level, there is a similar collection of contrast in terms of shape, size, and location. This represents residual contrast from the previous day's contrast angiogram performed during the stent-graft implantation procedure. This does not represent an endoleak.

Conclusion

Endoleaks are a major complication of endovascular repair of AAAs. Persistent pressurization of the aneurysm sac after stent-graft placement places the patient at risk for possible fatal rupture. Thus, detection is of the utmost importance. Although many imaging modalities exist that can detect or image endoleaks, CT angiography is currently the safest, most sensitive, most reliable, and least invasive method for detecting and following endoleaks.[17]

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