Chapter 16

Postoperative imaging surveillance and endoleak management after endovascular repair of thoracic aortic aneurysms

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Endovascular repair offers a subset of thoracic aortic aneurysm (TAA) patients a less invasive technique to exclude their aneurysm.[1-7] It has also altered the manner in which patients are followed up after TAA repair. Although minimal imaging is required after open surgical repair, patients undergoing endovascular TAA repair require lifelong postoperative surveillance imaging[1-8] to detect some of the unique complications of endovascular TAA repair. These include endoleak formation, stent graft fracture, stent graft migration, and neck dilation.[8-10] Although the detection and management of endoleaks after endovascular abdominal aortic aneurysm repair (EVAR) has been well described, less is known about endoleaks after endovascular repair of TAAs.[8-12] This chapter discusses strategies for postoperative surveillance imaging and endoleak management in patients after endovascular repair of TAAs.

ENDOLEAK CLASSIFICATION

Endoleaks are defined as blood flow outside the lumen of the stent graft but within the aneurysm sac. An endoleak classification system has evolved over the last several years in which endoleaks are organized into five categories based on the source of the blood flow.[13,14]

Type I endoleaks have flow that originates from either the proximal or distal stent graft attachment site. Separation between the stent graft and the native arterial wall creates a direct communication with the systemic arterial circulation. This is the most common type of endoleak seen after endovascular TAA repair. Type II endoleaks occur from retrograde aortic branch vessel blood flow into the aneurysm sac, when blood travels through branches from the nonstented portion of the aorta through anastomotic connections into vessels with a direct communication with the aneurysm sac. These are the most common endoleaks seen after EVAR. Type III endoleaks occur when there is a structural failure with the stent graft, including holes in the stent graft fabric, stent graft fractures, and junctional separations that can occur with modular devices. Type IV endoleaks are identified at the time of implantation during the immediate postimplantation angiogram, when patients are fully anticoagulated. These endoleaks are caused by stent graft porosity. They require no specific intervention except the normalization of the coagulation profile. Endotension, sometimes called a type V endoleak, refers to expansion of the aneurysm without the presence of an endoleak. Although the exact etiology of endotension is unknown, causes may include an undiagnosed endoleak, ultrafiltration, or thrombus providing an ineffective barrier to pressure transmission.[12-14]

IMAGING SURVEILLANCE AFTER ENDOVASCULAR TAA REPAIR

Lifelong imaging surveillance of patients after endovascular TAA repair is critical to determine the long-term success of this procedure. Computed tomography angiography (CTA) has been the primary imaging modality for postoperative surveillance. At our institution, CTA is performed at 30 days, 6 months, and then annually for the life of the patient. Magnetic resonance angiography (MRA) may also be used for postprocedure surveillance when magnetic resonance (MR)-compatible stent grafts are used for the TAA repair.[15] Ultrasonography (US) is used for post-EVAR surveillance[16,17] and can be used after endovascular TAA repair; however, US is more difficult to perform in the chest than in the abdomen because of artifact from the ribs and lungs. Transesophageal echocardiography (TEE) has been used to assist in placement of thoracic aortic stent grafts and can be used to detect endoleak after the procedure.[18,19] The technique is invasive, however, and is generally not relied on for long-term surveillance. It is particularly useful in the case of aortic dissection. TEE is at greatest advantage in the most proximal aorta and clearly defines the true and false lumens and the separating flap with fenestration points. Guidewires can be clearly visualized on TEE images, and confirmation of true lumen vs false lumen positioning of wires is helpful during these challenging cases. TEE can be used to examine the proximal attachment zone of a stent graft during the

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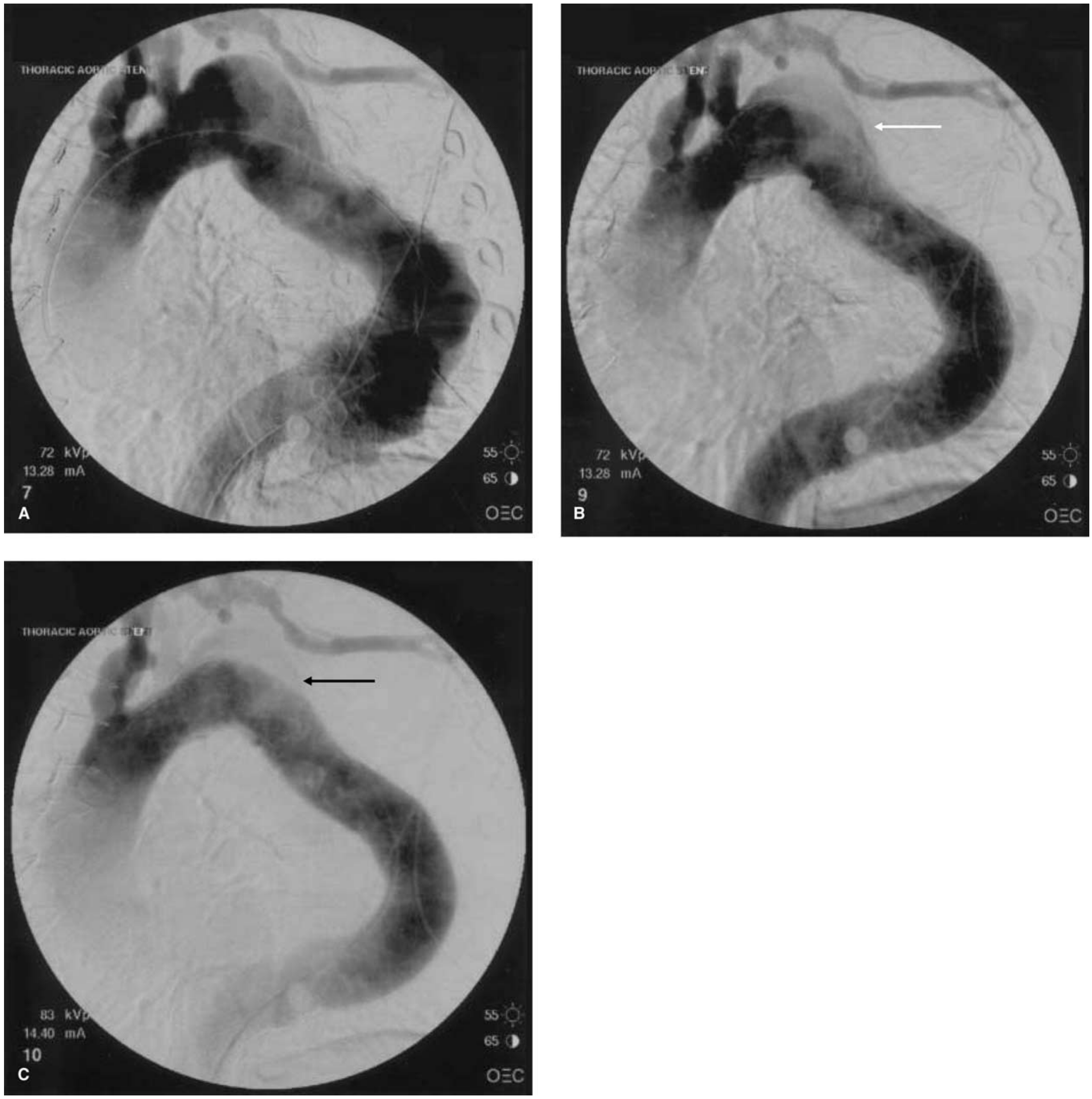

Fig 1. A, Digital subtraction angiography examination reveals a thoracic aortic aneurysm (TAA) before stent graft placement. **B,** A stent graft has been used to treat the TAA. There is a type I endoleak *(white arrow)* filling from the proximal attachment site. **C,** A proximal stent-graft extension has been placed to treat the type 1 endoleak. Digital subtraction angiography examination reveals a type IV endoleak *(black arrow)*. No endoleak was seen on 30-day computed tomography angiography.

course of the procedure and can facilitate both accurate proximal deployment and examination for adequacy of seal by using the color Doppler capabilities of the technique. Intravascular US provides similar information but can be positioned anywhere within the circulation, without the limitations of TEE, which is restricted to the more proximal aorta. Intravascular US is a valuable tool in the treatment of aortic dissection and is useful in the immediate assessment of endoleak status during the initial stent grafting procedure, but it is impractical as a surveillance method because of its invasive nature.

The primary goals of postoperative surveillance CTAs are to evaluate for aneurysm expansion or shrinkage, detect stent graft migration or fracture, and detect endoleaks. Thin-section, triple-phase CTA (images obtained before, during, and after contrast administration) is well suited for this job because it is safe, widely available, highly accurate, and fairly straightforward to interpret. Triple-phase imaging gives important information as to when contrast enters and exits the aorta. The characteristic finding of an endoleak on CTA is a collection of contrast outside the stent graft lumen and inside the aneurysm sac. The delayed images often give important information, because the accumulated contrast "pools" into the endoleak while the intravascular bolus has already exited the main vessel. Because curvilinear calcifications can appear similar to contrast on some images, noncontrast computed tomographic (CT) images should be performed before CTA. Delayed CT images should also be performed after the CTA because some endoleaks are due to slow perigraft flow and are seen only on the delayed images.[20]

MRA is another option for postoperative surveillance, particularly in patients who cannot have CTA because of decreased renal function or severe iodinated contrast allergy. MRA has been used to successfully detect endoleaks after EVAR in patients with stent grafts made from materials such as nitinol or Elgiloy (Elgiloy Specialty Metals, Elgin, IL), which produce little MR artifact because of their low magnetic susceptibility.[21] Because of the large MR artifacts caused by most stainless-steel stent grafts, evaluation for potential endoleaks in patients with these devices is very difficult. Newer MR techniques such as blood pool imaging and time-sensitive techniques may make MRA even more sensitive than CTA for endoleak detection and classification in the future.[15]

ENDOLEAK MANAGEMENT

Series involving stent graft repair of TAAs have shown that endoleaks occur in anywhere from 5% to 20% of patients, which is similar to the endoleak incidence after EVAR.[1-10] Once an endoleak has been confirmed with angiography, management has generally consisted of aggressive endovascular repair of type I and type III endoleaks and observation of type II endoleaks.[3-10,22]

Type I endoleaks can be classified on CTA according to the location of the endoleak in contiguity with the proximal or distal attachment site, as well as early filling of the endoleak sac on the CTA. Catheter angiography is then performed to confirm the diagnosis. These leaks are more prevalent in the thoracic than in the abdominal aorta, because the curved nature of the proximal attachment in the aortic arch and the frequently short attachment zones present a challenge to sealing. These leaks are usually observed on the initial CT scan after operative repair but can appear later as a result of migration or failure of the metallic elements within the attachment zone. Failure of proximal or distal sealing can be expected to result in the transmission of systemic pressure to the aneurysm sac, thus leaving the patient unprotected from fatal rupture of the aneurysm. Therefore, it is essential that type I endoleaks be repaired immediately after diagnosis. These leaks can be corrected by securing the attachment sites. Initial attempts at type I endoleak repair are made with angioplasty balloons. These large-diameter balloons are used to more fully expand the stents, thus encouraging them to conform to the vessel wall and produce an adequate seal. Balloon inflation in the thoracic aorta produces significant hemodynamic shifts, and careful monitoring and regulation of the blood pressure is essential during this interval. The use of a balloon that allows continual flow through the aorta by means of its trilobe design (W.L. Gore, Flagstaff, Ariz) can decrease this hemodynamic effect but does not eliminate it. If the endoleaks persist, balloon-mounted bare metal stents or stent graft extensions can be used to secure the proximal or distal attachment sites (Fig 1). Bare stents are useful when the device position is acceptable in the sealing zone, but the vessel wall contact is insufficient. Balloon expandable stents provide greater radial force than do self-expanding stents, which are contained in the stent graft itself. If, conversely, the device does not fully cover the allotted seal zone, the use of a supplemental extension stent graft is preferred to take full advantage of all the available aorta in which a seal may be accomplished. Because of the lack of available large-diameter balloon-expandable bare stents, the placement of stent grafts of large diameter within each other can also be performed to increasing the sealing force of a failed attachment zone. If the type I endoleak cannot be resolved by endovascular means, open conversion should be considered, because this leak is virulent and the patient would not be expected to be protected against aneurysm rupture.

Fig 2. A type II endoleak is demonstrated on computed tomography angiography with contrast filling the aneurysm sac *(arrow)* and in communication with an intercostal artery.

Type II endoleaks can be classified with CTA if the endoleak sac cannot be seen communicating with the distal or proximal attachment site or if there was delayed enhancement of the endoleak sac (Fig 2). This can be a difficult diagnosis to confidently make by using CTA alone, and it may need to be confirmed with catheter angiography if classification is not certain. If the aneurysm is stable or shrinking, patients with type II endoleaks should be ob-

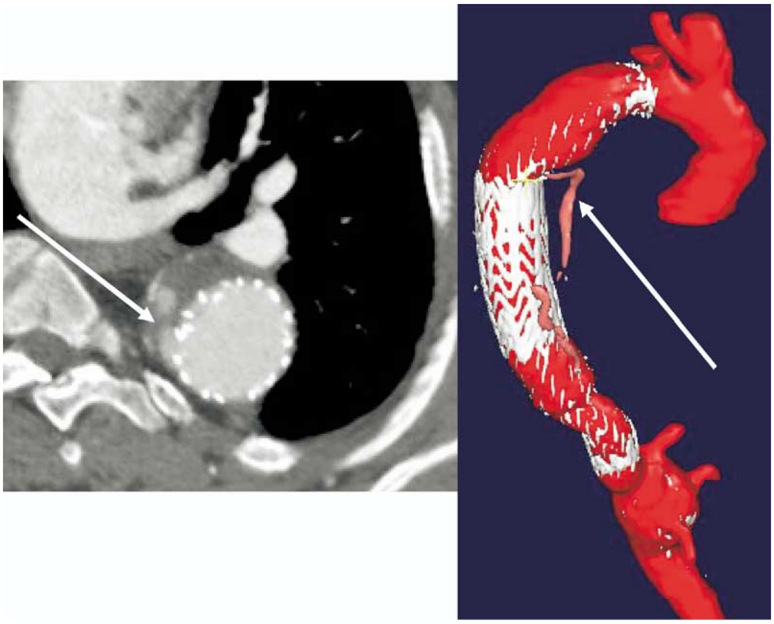

Fig 3. A type III endoleak between endograft components *(arrow)* is demonstrated on computed tomography angiography. The aneurysm sac contained thrombus and is not included in the reconstructed image.

served closely. We have not observed any late appearance of type II endoleaks: all of them have been appreciated on the initial CT scan after repair. Many type II endoleaks will spontaneously thrombose. If the aneurysm is expanding and the patient has an angiographically confirmed type II endoleak, attempts can be made to embolize it. Embolization with coils and *n*-butyl cyanoacrylate (Trufill; Cordis, Miami, Fla) can be performed percutaneously through a transthoracic approach if a safe window into the aneurysm can be located. Treatment of type II endoleaks via transarterial or transthoracic embolization is more difficult than treatment of type II endoleaks after abdominal aortic aneurysm repair. This is because collateral circulation in the chest involving the thoracic aorta is not as well developed as the collateral vessels of the abdomen. In addition, accessing the endoleak sac in TAA patients by using a direct transthoracic puncture may involve traversing lung. This has a greater risk associated with it than translumbar embolization of endoleaks in abdominal aortic aneurysm patients.[12,23]

A type III endoleak can be diagnosed on CTA if the endoleak is associated with a junctional separation of two stent graft sections or a hole in the stent graft diagnosed on multiplanar reformations (Fig 3). Although some of these leaks are noted on the initial CT scan after repair, many appear later and presumably are the result of the migration of components or separation of components as the result of conformational changes of the aneurysm sac after repair. Similar to type I endoleaks, type III endoleaks provide direct communication between systemic arterial blood and the aneurysm sac and are therefore fixed immediately upon diagnosis. Type III endoleaks can be corrected by covering the defect with a stent graft extension by using an endovascular approach.

Type IV endoleaks are seen during the immediate postdeployment angiogram while a patient is fully anticoagulated with heparin. These leaks are self-limited and resolve once the patient's anticoagulation status has been corrected.

Treatment of type V endoleaks or endotension typically requires conversion to open aneurysm repair. Nonoperative management of endotension patients after EVAR has been described.[14]

CONCLUSION

The occurrence of endoleaks after endovascular repair of TAAs remains one of the principal limitations of this procedure. Endoleak detection requires rigorous follow-up with high-quality imaging. CTA is currently the most widely used imaging modality for endoleak detection, although MRA and TEE also have an important role, which may expand in the future. After endoleaks have been diagnosed and classified, most can be repaired with endovascular techniques.

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