Complications following thoracic aortic graft surgery are rare. They are not always clinically apparent and may occasionally be detected at computed tomography (CT) even in asymptomatic patients. Normal postoperative findings that may simulate complications include graft kinks, graft side branches, felt pledgets or rings, small amounts of low-attenuation perigraft material, native aortic wraps, and bovine pericardial wraps. Postoperative complications include anastomotic dehiscence and graft infection, which may lead to perigraft hematomas, pseudoaneurysms, abscesses, or fistulas. At CT, these complications may manifest as abnormally large collections of low-attenuation perigraft material, contrast material extravasation, perigraft gas collections, or fistulas to adjacent structures. Familiarity with both normal and abnormal postoperative CT findings and knowledge of the surgical technique used are essential to avoid misdiagnosing normal findings and to correctly diagnose potentially life-threatening complications. Following graft surgery, surveillance imaging may be needed, since the time of onset of complications seems highly variable.

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Introduction
Thoracic aortic diseases such as aneurysms, dissections, penetrating ulcers, and rupture are treated with a variety of thoracic aortic reconstructive procedures. Graft anastomotic dehiscence and infection are rare, being seen at computed tomography (CT) in approximately 2% of cases (1), but are potentially devastating when they do occur. Such postoperative complications may not always be clinically evident; instead, they are sometimes first detected on surveillance CT scans. At our institution, surveillance scans are obtained at approximately 3 and 12 months following surgery and yearly thereafter. It is essential to be familiar with both the spectrum of imaging findings in the normal postoperative aorta and the imaging appearances of postoperative complications to correctly diagnose the presence (or absence) of disease.

In this article, we discuss and illustrate the surgical techniques and normal postoperative CT appearance associated with thoracic aortic graft surgery, as well as the CT appearances of postoperative complications, such as abnormally large amounts of low-attenuation perigraft material, contrast material extravasation, and perigraft gas collections.

Surgical Techniques and Normal Postoperative CT Appearance
The choice of surgical technique is based on a variety of factors, including the anatomic extent of disease, patient age, need for long-term anticoagulation therapy, state of the native aortic tissue, status of the aortic valve, prior aortic surgeries, and surgeon and patient preference. For example, following acute type A aortic dissection, the extent of surgery on the aortic root depends on the proximal extent of dissection and the presence of aortic root or valvular disease. If the root is not

Figure 1. Aortic tissue valve graft with a stent. Lateral CT scout image (a) and axial CT scan (b) show three metallic structures (arrows) that represent the three prongs of a stent.
dissected or aneurysmal, there may be no need to replace it, and the surgical repair may involve just the ascending aorta. The type of surgical technique used affects the postoperative CT appearance; therefore, when interpreting a postoperative CT examination, it is important to have access to the surgical details.

Aortic valve replacements may be either tissue valves or mechanical (metallic) valves. Porcine or pericardial tissue valves may contain a three-pronged metallic stent (Fig 1). Tissue valves with a stent have the leaflets suspended from the stent posts (similar to native aortic commissural posts) and a sewing ring that is typically anastomosed to the native aortic annulus (2).

Aortic grafts may be made of tissue (porcine grafts) or of a synthetic material, such as the Hemashield Dacron graft (Medi-Tech; Boston Scientific, Natick, Mass). Tissue grafts are generally indistinguishable from native aortic tissue at CT. Synthetic grafts are often slightly higher in attenuation than native aortic tissue at unenhanced CT but are generally not visible at contrast material-enhanced CT. Porcine grafts are used only in the aortic root position, whereas synthetic grafts may be used anywhere throughout the aorta.

Tissue root grafts may be placed using the so-called full root interposition technique, with excision of the native root and end-to-end anastomoses between (a) the aortic annulus and the proximal end of the graft, and (b) the distal end of the graft and the ascending aorta. Buttons of tissue surrounding the native coronary ostia are excised and then anastomosed to holes that have been fashioned in the porcine root sinuses (Fig 2) (3).
Alternatively, the inclusion root technique may be used. With this technique, the tissue graft is placed within the native aortic root, which is wrapped around the graft (Fig 3) (3). Synthetic root grafts may or may not contain an attached, metallic prosthetic aortic valve (Fig 4). If there is no metallic valve, synthetic root grafts are generally indistinguishable from porcine full root grafts at CT.

A graft in the aortic arch may anastomose with an island (4) or peninsula of native arch roof that contains the origins of the great vessels. Alternatively, an arch graft may contain side branches that anastomose with the great vessels (Fig 5). If

**Figure 3.** Inclusion aortic root technique. (a–c) Drawings illustrate how a tissue graft is placed inside the native aortic root (a), the ostia of the native coronary arteries are sutured to holes in the graft (arrows in b), and the native ascending aorta is sutured to the distal end of the graft (arrow in c). (d) CT scan shows an inclusion root graft. Arrow indicates a small chronic hematoma between the graft and the surrounding native aorta.

**Figure 4.** Coronal reformatted CT image shows a composite aortic root graft (arrow) with a tilting disk aortic valve prosthesis (arrowhead).
future descending aortic surgery is planned, an “elephant trunk” graft may be placed in the distal aortic arch and proximal descending aorta (Fig 6) (5). At times it can be difficult to determine the exact type of aortic arch surgery on the basis of axial CT images; sometimes multiplanar reformatted images are helpful, and correlation with the surgical report is often crucial.

**Figure 5.** Aortic arch graft. (a, b) Drawings illustrate how the origins of the great vessels may be anastomosed with use of an island (a) or peninsula (b) of native aortic arch. (c, d) Drawings illustrate how, alternatively, the arch graft may contain one or more side branches, which are individually anastomosed to the great vessels. (e, f) CT scans show the distal anastomosis of an aortic arch graft (arrowhead in e) and anastomoses of the side branches to the great vessels (arrows in f). Arrow in e indicates a kink in the graft.
When the descending aorta is grafted, the native aorta is usually left in situ in the posterior mediastinum. The native aorta may appear as an irregular, curvilinear area of dense calcification and should not be mistaken for an ulcer or extravasated contrast material (Fig 7). Occasionally, intercostal arteries are reimplanted into the graft. Sometimes a side-to-side anastomosis is constructed between the posterior portion of the native aorta (containing the ostia of the intercostal arteries) and the graft. This anastomosis may be created using an inclusion technique, in which the lateral and anterior portions of the native aorta are wrapped around the graft. These types of surgery may have an unusual appearance at CT (Fig 8).

Aortic grafts may be covered by a strip of bovine pericardium or, rarely (in the presence of infection), by omentum, to separate them from adjacent structures and prevent fistulas. Bovine pericardium usually has somewhat lower CT attenuation than does soft tissue, whereas the omentum shows fat attenuation (Fig 9).

Often, strips of felt are used to buttress an aortic anastomosis in patients with fragile aortic wall tissue due, for example, to cystic medial necrosis; these strips have high attenuation at CT (Fig 10) and should not be mistaken for contrast material leaks. Similarly, small, focal high-attenuation felt pledgets may be seen at the sites of intraoperative needle or cannula placement within the graft or native aorta (Fig 11). Images obtained prior to
Figure 8. (a) Drawing illustrates an intercostal patch (arrow) placed on the posteromedial aspect of a descending aortic graft. (b) CT scan shows an intercostal patch (straight arrow), felt at the anastomosis (curved arrows), and an intercostal artery (black arrowhead). Bovine pericardial wrap (white arrowhead) was also used to cover the graft.

Figure 9. (a) CT scan shows a bovine pericardial wrap (straight arrow) appearing as a low-attenuation structure surrounding a descending aortic graft. Curved arrow indicates felt at the anastomosis. (b) CT scan shows an omental wrap (arrow) appearing as a fat-attenuation structure surrounding an ascending aortic graft. Graft wraps are used to prevent fistula formation between the aorta and adjacent structures such as the lungs.

Figures 10, 11. (10) Unenhanced (a) and intravenous contrast-enhanced (b) CT scans show a high-attenuation felt ring (arrow) around a graft anastomosis. Felt is used to reinforce the integrity of the anastomosis. (11) CT scan shows a small focus of high-attenuation material in the aortic arch wall (arrow). This finding represents a felt pledget that was used to repair a cannulation hole made in the aorta during surgery.
the administration of contrast material may help differentiate felt strips and pledgets from contrast material leaks. Needles are generally used to evacuate air bubbles, and cannulas are used for cardiac bypass procedures. Sometimes a cannula may be placed through a graft side branch and the branch oversewn after completion of the cardio-pulmonary bypass procedure used during graft surgery (Fig 12). An oversewn graft side branch may have a felt pledget at the margin and may appear as an outpouching at CT, thereby mimicking a pseudoaneurysm or leak (Fig 13).

Occasionally, an aortic graft may be slightly kinked, thereby simulating a dissection flap on axial images; however, the correct diagnosis of a kink is usually made easily on multiplanar reformatted images (Fig 13). Such kinks are generally of no clinical significance.

It is common to see small to moderate amounts of low-attenuation perigraft material within the first several months following graft replacement (Fig 14). This material probably represents a combination of seroma, liquefying chronic hematoma, fibrosis, and granulation tissue. Such collections tend to resolve slowly over many months or years, although they may remain stable.

CT Appearances of Postoperative Complications

Abnormal Low-Attenuation Perigraft Material

CT scans occasionally show an abnormally large amount of low-attenuation material surrounding an aortic graft or increasing amounts of such material on serial scans. Such a finding causes suspicion for infection with perigraft abscess (Fig 15). However, graft anastomotic dehiscence with blood leakage may also cause this appearance if there is no active leak at the time of scanning, the leak is too slow to detect, or the timing of the scanning is not optimal relative to the intravenously administered contrast material bolus.

Figures 12, 13. (12) Tied-off graft side branch. At the completion of surgery, any unused graft side branches are tied off. Intravenous contrast-enhanced CT scan shows a small area of contrast material protrusion from the graft (straight arrow) that could potentially be mistaken for a pseudoaneurysm. Curved arrow indicates the dissection flap in the descending aorta. (13) Axial unenhanced CT scan (a), axial contrast-enhanced CT scan (b), and sagittal reformatted contrast-enhanced CT image (c) show a kink in an aortic arch graft (black arrow). White arrow in a and b indicates an oversewn graft side branch.
Anastomotic dehiscence is often due to graft infection; therefore, abscess and hematoma may contribute to the CT appearance simultaneously. It has been postulated that perigraft fluid may accumulate in some patients due to an inflammatory response to (a) foreign material such as bio-glue used at the anastomosis, (b) bovine pericardium, or perhaps even (c) the graft itself (Fig 16) (1,6,7). Although these fluid collections are not in themselves clinically significant, they have the

Figure 14. Contrast-enhanced CT scan obtained in a patient who had undergone graft replacement shows the usual amount of low-attenuation perigraft material (arrow). Arrowhead indicates the dissection flap in the native descending aorta.

Figure 15. Graft infection in an 80-year-old woman who had undergone ascending aortic graft replacement 15 months earlier. CT scan demonstrates the graft in the ascending aorta (curved arrow) and abnormal low-attenuation perigraft material (straight arrows). Surgical drainage revealed purulent fluid due to graft infection.

Figure 16. Perigraft fluid accumulation in a 62-year-old woman who had undergone arch graft replacement for an aortic aneurysm 3 months earlier. The patient was asymptomatic, with no clinical evidence of infection. (a) CT scan shows minimal low-attenuation perigraft material (arrow). Arrowheads indicate the graft anastomosis. (b) Routine follow-up CT scan obtained 12 months after a demonstrates a significant interval increase in the amount of low-attenuation perigraft material (arrows). The patient was not treated for this finding.
potential to become infected. If an abnormally large collection of low-attenuation perigraft material is identified, correlation should be made with clinical indicators of infection. Patients with infected grafts may present with fever, chest discomfort, or leukocytosis, or they may be asymptomatic. Percutaneous needle aspiration under CT guidance can be attempted if the collection is accessible. Treatment options for infected grafts include long-term antibiotic therapy and resection of the infected graft, as well as extraanatomic bypass grafting. If infection is not confirmed, careful follow-up with serial imaging is a viable option.

Contrast Material Extravasation
Graft anastomotic dehiscence can be definitively diagnosed at CT when a collection of contrast material is seen outside the graft (Fig 17). The dehiscence may occur at a proximal, distal, or side branch anastomosis or at a needle or cannula placement site. Dehiscence may result from a mechanical phenomenon such as violent coughing,
although it is more commonly due to graft infection. It may result in fistula formation with adjacent structures such as the bronchi, lungs, or esophagus (Fig 18). Dehiscence may be seen at any time following surgery, even many years afterward. Treatment options include suspension of anticoagulation therapy, administration of antibiotics (if there is coexistent infection), angiographic embolization of the leak, and surgical graft replacement.

Contrast material extravasation usually represents an urgent finding; occasionally, however, small amounts of contrast material may pool between the graft and the surrounding native aortic wrap in patients with an inclusion root graft (Fig 19). This phenomenon is likely due to partial dehiscence at a coronary artery or proximal graft anastomosis and is probably of little or no clinical significance. One study noted that this finding does not tend to progress and, in fact, may regress either spontaneously or with discontinuation of anticoagulation therapy (1).

**Perigraft Gas Collections**

The presence of gas bubbles adjacent to an aortic graft may indicate infection with a gas-forming organism (Fig 20) or a fistula with an airway or lung, the esophagus, or the skin. Fistulas may also be suspected if there is tethering of the adjacent structure; rarely does CT show frank extravasation of contrast material into the structure. Fistulas are clinically suspected if the patient develops hemoptyis or hematemesis.
Conclusions
Graft-related complications are rare, although they may occasionally be detected at CT in patients with no clinical evidence of disease. Knowledge of the surgical technique used in patients with grafts is essential to avoid misdiagnosing normal postsurgical findings and to correctly diagnose potentially life-threatening complications. Patients with aortic grafts must be followed up indefinitely, since the time of onset of complications is variable and onset may occur many years after surgery.

References
CT Findings Following Thoracic Aortic Surgery

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