Endovascular repair of abdominal aortic aneurysm (EVAR): Normal findings and common signs of complications on CT-angiography (CTA) and MR-angiography (MRA) with emphasis on the detection and classification of endoleaks

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Learning objectives

To explain the principles of conventional and advanced CTA and MRA imaging techniques for the evaluation of EVAR.

To review CTA and MRA findings of normal and complicated aortic stent-grafts.

To present the types, incidence and diagnostic signs of endoleaks.

Background

- Incidence of abdominal aortic aneurysms (AAAs) is 36.2 per 100,000.

- Prevalence is 4% to 7% in adults 65 to 80 years old. This increases with advancing age.

- Ratio of men to women with AAA: 5:1.

- AAAs are associated with smoking, increasing age, coronary artery disease (CAD), hypercholesterolemia, peripheral vascular disease, hypertension, and family history (higher incidence in first-degree relatives).

- Complications of AAA include rupture and distal embolization. There is a 90% mortality rate after rupture.

- Ruptured AAA is the tenth leading cause of death in men and thirteenth in women. Many patients die before reaching the hospital.

- Risk factors for AAA rupture include poorly controlled hypertension, COPD, and smoking.

- Traditionally, a diameter of a 5 cm has been the criterion for elective repair. This has recently been challenged, with some advocating the repair of aneurysms from 4.0 to 5.0 cm diameter. Elective operative mortality is 4% to 6%, and emergent repair operative mortality is 50% 60%.
- Dr. Charles Dotter first proposed endografts in 1969.

- Endovascular repair of aortic aneurysm (EVAR) was developed as a minimally invasive alternative to open abdominal surgery.

- The aim is to discuss the advantages and limitations of various imaging modalities and to demonstrate the different types of complications encountered in EVAR.

GOALS OF ENDOGRAFT REPAIR OF AAA

- To provide a less invasive surgical alternative for low-risk patients, resulting in decreased procedural morbidity and mortality, decreased postprocedure pain and complications, and shortened postprocedure convalescent period.

- To provide treatment to high-risk patients who are not surgical candidates and would otherwise have no therapeutic option for AAA repair.

- To prevent enlargement and rupture by excluding the aneurysm from arterial circulation. There are two configurations of stent graft: bifurcated graft and aorto-uni-iliac graft (AUI).

ANATOMY OF AAA

- Definition of AAA: Aorta diameter is 50% larger than the normal aorta.

- Most small aneurysms increase in size by 2.5 mm; 4mm is maximum normal growth.

- Risk of rupture (5-year rate): Less than 4.0 cm: 2%

  Greater than 5.0 cm: 25% to 41%

- With progressive enlargement of an AAA, there are also changes in the aorta above and below the aneurysm. The lengths of the proximal neck and distal cuff shorten, overall aortic length increases and becomes more tortuous, iliac tortuosity increases, and iliac aneurysms may form.

INDICATIONS

  - Emergent

- Known or suspected rupture.

- Symptomatic aneurysm.
- Rapidly expanding aneurysm.

  • **Elective**

- Fusiform aneurysm 5.0 cm in diameter.

- Saccular aneurysm twice the diameter of normal infrarenal aorta.

- Uncontrolled hypertension.

**SELECTION CRITERIA FOR ENDOGRAFT REPAIR**

- Successful endovascular repair of AAA depends upon anatomical considerations and patient selection.
- Anatomical considerations include the morphology of the aorta and access arteries. Correct measurements of the diameter and length are essential to maximize the success of the endograft procedure.
- Patient selection is based on elective operative risk, aneurysm rupture risk, concomitant disease, life expectancy, and patient preference.
- An estimated 40% to 50% of AAA patients meet criteria for endovascular repair.

**CONTRAINdicATIONS**

- In patients who meet anatomical criteria for successful endograft placement, there are no widely accepted absolute contraindications for endovascular repair of AAA.
- Relative contraindications include severe concomitant disease with short life expectancy, renal insufficiency, and severe contrast reactions.
- The long-term durability of the various devices employed remains uncertain and thus the need for continued life long surveillance. Potential complications, including aneurysm expansion, endoleaks, migration, graft limb thrombosis and disruption of the stent graft integrity, occur at a not insignificant rate.

**Imaging findings OR Procedure details**

**COMPLICATIONS**
Endoleak

Endoleak is a condition unique to stent grafts defined by the persistence of blood flow outside the lumen of the stent graft but within an aneurysm sac or adjacent vascular segment being treated by the device.

There are five categories based on the source of blood flow.

The reported incidence of endoleaks ranged from 15% to 25% within 30 days postoperatively.

**Type I.** This type of endoleak occurs when a persistent channel of blood flow develops due to inadequate seal at the graft ends. It is subdivided into proximal (type 1a) and distal (type 1b). Type 1c endoleaks relate to non-occluded iliac artery in patients with aorto-uni-iliac (AUI) stent graft.

Factors contributing to proximal (type 1a) endoleak include a short neck (<15mm), large diameter neck (>32 mm), tapered necks, increased angulations (>60%), thrombus and calcification and non-circular landing zone.

The distal (type 1B) endoleaks are more common in patient with dilated, calcified, short, and tortuous iliac artery. It can also occur if the limb of the graft is too short or migrates upward due to sacs retraction and aortic distortion.

Type 1C leaks occur in cases where an AUI stent graft has been deployed, in conjunction with an occluder device placed in the contra lateral common iliac artery and femoral-femoral bypass graft.

**Type II.** This is the most common type of endoleak encountered after endovascular repair of abdominal aortic aneurysm. It occurs when there is persistent blood flow into the aneurysm sac due to retrograde blood flow from patent lumbar arteries, inferior mesenteric artery (IMA), or other collateral vessels.

**Type III.** This endoleak is related to inadequate or in effective seal at the graft junction points, between segments of overlapping graft segments, or rupture of the graft fabric. This endoleaks were infrequent with an estimated incidence of 4% after 1 year [28].


Repetitive stresses from arterial pulsation and aneurysmal sac shrinkage may cause displacement of one of the extensions and leading to device breakdown.
**Type IV.** This type of endoleak is related to the porosity and passage of blood through the fabric of the graft. It appears as a blush on the post-deployment angiogram, when the patients are fully anticoagulated.

**Type V (endotension).** It is defined as continuous growth of the aneurysm sac with no apparent endoleak. The exact cause of this type of endoleaks is uncertain. It may be caused by slow flow endoleak beyond the resolution of CTA or MRA, pressure transmission from thrombus from the stent graft and infection.

Other stent graft complications are:

- Stent graft migration.
- Stent graft wire fracture.
- Stent graft- limb thrombosis.
- Stent graft infections.

**IMAGING**

For a conventional open repair, a surgeon only needs to know the anatomical extent of the aneurysm. Graft size requirements are estimated at the time of surgery, and the graft is shaped and sewn to accommodate the aneurysm. As opposed to surgical open repair, endovascular repair of AAA is entirely dependent upon radiological imaging for pre-, intra-, and postprocedure management.

Careful imaging to obtain accurate diameter and length measurements is essential to maximize the technical success of the stent-graft deployment. The standard workup for endograft repair involves thin-section CT with three-dimensional (3D) reconstruction and an abdominal aortic and pelvic arteriogram using a marking catheter. Both modalities provide useful and complementary information regarding aneurysm morphology, length and diameter.

**Computer tomography angiography**

**Advantages**

- Non-invasive
- High resolution; able to remove anatomical details such as calcium and small amounts of mural thrombus.

- Accurate measurements of diameter.

- Able to generate 3D images.

Disadvantages

- Nephrotoxic contrast.

Protocols for vascular CT imaging and computed tomographic angiography vary among different institutions. Presently, at our Institution CT scan is performed on a 64 slice scanner as follows:

- Scan from the celiac axis through common femoral arteries.

- Collimation: 64x0.6 mm

- Reconstruction: 1-mm interval

- Respiration suspended during acquisition.

- Contrast: 350 - 400mg iodine/mL, injection of 100 to 120 mL per exam.

- Delay: bolus tracking 150HU ROI placement within aneurismal sac

- Postprocessing: multiplanar reformotions and 3D image reconstruction.

CTA has high accuracy for detection of endoleaks, determining aneurysm growth and evaluating stent graft migration.

Endoleaks have variable flow rates and the leaks are seen at different time after contrast infusion. If there is any endoleaks, the majority will be detected at the arterial phases.

If there is persistent clinical concern and arterial phase does not show endoleaks, an additional delayed scan may enable to detect slow flowing endoleaks. A precontrast scan is helpful in differentiating calcification in the aneurysm sac from endoleaks.

CTA remains the modality of choice in surveillance of EVAR; correct scan entails non-contrast, arterial and delayed phase (usually 70 s).

Magnetic resonance angiography
Advantages
- Avoids the use of nephrotoxic contrast agents.
- Possible multiple phases; dynamic, time resolved imaging.
- Non-invasive.
- Can generate 3D images.

Disadvantages
- NSF
- Expensive.
- Lengthy examination time.
- Unable to demonstrate calcium.
- May miss collateral vessels.

Contrast enhanced MRA has been used in some cases for endoleak detection, although its use is limited to stent grafts which are made of MR compatible material.

MRA is at least as sensitive as CTA and in some cases better to demonstrate endoleaks that are not visible on CT. MRA is equally reliable as CTA in measurement of the aneurysm size and stent position. The majority of MRA studies employ dynamic gadolinium enhanced three-dimensional gradient echo and delayed two-dimensional gradient echo sequences. Recent technique implements parallel imaging and ultrafast gradient system allows time resolved MRA to be constructed. This new technique offers better characterization of endoleaks. New imaging modalities like dynamic MR and dual-source CT could improve the detection accuracy of endoleaks.

Images for this section:
Fig. 1: is due to incomplete adhesion between prosthesis and vessel wall at the proximal end (aneurysm neck) or distal end
**Fig. 2:** more frequent, due to hypertrophic lumbar arteries and inferior mesenteric arteries
**Fig. 3:** due to erroneous attachment of the whole prosthesis or of some components.
Fig. 4: due to porosity of the prosthesis; it is extremely rare
Fig. 5: CT angiography shows type 2 endoleak in a patient with a stent-graft, filling from lumbar arteries (arrow) and superior mesenteric artery (arrowhead).
Fig. 6
**Fig. 7:** Stent migration: CT aorta angiogram demonstrates a left limb migration from the main body graft. A large type 3 endoleak is seen. This patient was treated with urgent open surgical conversion.
Fig. 10: Type II endoleak
Fig. 11: An infrarenal aortic stent graft previously placed, appears migrated distally and kinked. (a: VR, b: MIP)
**Fig. 12:** Type II endoleak (CT-MR)
Fig. 13: Type II endoleak
Fig. 14: Type II endoleak
**Fig. 15:** Type II endoleak
Conclusion

EVAR is an effective alternative for treatment of AAA with high success rate and relatively low complications. The use of CTA and MRA has significantly improved diagnostic performance for the follow-up of patients that underwent EVAR of abdominal aneurysms. However, short-term and long-term surveillance is mandatory to identify and treat potential complications.

Personal Information

References


