Endovascular abdominal aortic aneurysm repair: Imaging review

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<th>Poster No.:</th>
<th>C-1801</th>
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<tr>
<td>Congress:</td>
<td>ECR 2012</td>
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<tr>
<td>Type:</td>
<td>Educational Exhibit</td>
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<tr>
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<tr>
<td>Keywords:</td>
<td>Computer Applications-Detection, diagnosis, CT-Angiography, Vascular, Arteries / Aorta, Abdomen, Grafts</td>
</tr>
<tr>
<td>DOI:</td>
<td>10.1594/ecr2012/C-1801</td>
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Learning objectives

The purpose of this review is to describe and illustrate computed tomography (CT) angiography findings in abdominal aortic aneurysms (AAA) with an impact in planning and follow-up of endovascular aneurysm repair (EVAR), based on selected cases presented to our department undergoing EVAR in the last two years.
Background

Endovascular aneurysm repair (EVAR) has emerged as the election treatment in the majority of abdominal aortic aneurysms, with multiple studies showing decreased hospital stay length and reduced perioperative morbidity with this procedure.  

Before proceeding to this technique is essential to evaluate individual patient anatomy in order to achieve success in the procedure, since anatomy fit between the patient and stent graft is an important for successful treatment.

Although alternative imaging methods can be used, contrast-enhanced CT has a crucial role, being the reference standard in the required accurate preoperative imaging planning.

Contrast-enhanced CT scans are also the choice modality for lifelong complications surveillance after EVAR, given its good reliability in the measurement of the AAA diameter, identification of endoleaks and stent graft integrity, patency and migration.

However, there is not a consensus on the follow-up timings, with several studies issuing alternative methods due to radiation exposure and contrast nephrotoxic effect concerns.

Contrast-enhanced computed tomography scan allows the measurement if the aneurysm volume, which has been suggested to be advantageous although is still a time consuming protocol.

However, CT protocol is still a matter of debate, particularly in routine EVAR follow-up studies.

Some authors such as Macari and co-workers favor eliminating arterial phase in post-EVAR scans because in their study they did not found acquisition of arterial phase images to be mandatory for the routine identification of endoleaks.

Others advocate eliminating delayed phase, while others acknowledge specific advantages in acquiring both arterial and delayed phase images.
However, in general, use of variable combination of non enhanced and contrast-enhanced CT acquisitions is considered appropriate for both pre-EVAR and post-EVAR evaluations, selected according to their advantages and disadvantages.

Nonenhanced CT images primarily help to characterize high attenuation areas such as calcifications and surgical clips and differentiate them from contrast material in the perigraft area.

Contrast-enhanced arterial scanning is useful to characterize anatomy prior to EVAR procedure and location of and planning procedures to treat endoleaks in post-EVAR evaluations.

In post-EVAR studies delayed phase imaging is considered to have higher sensitivity for detecting endoleaks, since endoleaks can have variable flow rates and be depicted at variable times after the contrast injection. In pre-EVAR studies delayed study can also help characterize suspected inflammatory aneurysm.
IMAGING BEFORE EVAR PROCEDURE:

EVAR requires accurate preoperative imaging evaluation for appropriate patient evaluation and selection based on aneurysm morphology and assessment of vessel size and patency.

Pre intervention aneurysm size is an important determinant of long-term outcome following endovascular repair, since patients with smaller AAAs are more favorable candidates for EVAR and have the best long-term outcomes.\(^{13}\)

Particularly, neck anatomy should be evaluated for the most common endograft failure predictors such as angulated and short infrarenal necks, large-diameter necks, and thrombus in the aneurysmal sac.\(^{14}\)

A neck size > 10-15mm in length and < 30 mm in diameter is usually required to provide adequate attachment proximally.\(^\text{1}\)

Mural thrombus and calcification covering more than 90 degrees of the circumference of the aortic diameter in the proximal neck is associated with a higher risk for type I endoleak and stent graft migration.\(^{15}\)

Additionally, preintervention total number of patent aortic branches predicts the formation of type II endoleak and can identify high risk patients that should be follow-up more frequently.\(^{16}\) In an immediate post-EVAR evaluation Fan et al\(^{17}\) found that IMA patency was a predisposing factor for type II endoleak. They also noticed that when 0 to 3 sac lumbar arteries where patent the probability of endoleak II was 13%, whereas when 6 sac lumbar arteries were patent, the endoleak type II probability would rise to 50%.

Interestingly, the thickness of a thrombus and the percentage if the aortic sac perimeter that was covered by a thrombus especially at the levels of inferior mesenteric artery (IMA) and sac lumbar arteries ostia were inversely correlated with persistent type II endoleak development, with thrombus at the level of sac lumbar arteries ostia 66.67% high probability against the development if type II endoleaks.\(^{16}\)
Irregularities and ulceration of the mural thrombus represent increased risk for distal embolus occurrence.

Higher levels of common iliac thrombus and tortuosity can be associated with higher rates of complications following EVAR.\textsuperscript{18}

Also, distal landing zone anatomy (usually the common iliac artery) should be assessed. With new generation of devices, common iliac artery diameters of up to 20 mm can be considered to EVAR.\textsuperscript{1} A length of at least 10-15 mm is needed in the distal landing zone for an adequate seal.\textsuperscript{19}

Diameter of external iliac artery should at least be 7 mm to safely accept delivery devices.

**CHARACTERISTICS TO EVALUATE AND MENTION IN THE CONTRAST-ENHANCED CT pre-EVAR REPORT Fig. 1 on page 15:**

- Size and extent of the aneurysm Fig. 1 on page 15
- Morphology of proximal neck - defined as the segment of aorta between the most caudal renal artery and the proximal boundary of the aneurysm
  - Morphology: based on a diameter measured caudal to the inferior renal artery versus diameter measured 10 mm below inferior renal artery\textsuperscript{18}
    - Straight: unchanged diameters
    - Tapered: proximal diameter superior to distal
    - Reverse tapered: distal diameter superior to proximal by > 3mm
- Diameter of aorta at the renal artery ostium Fig. 1 on page 15
- Diameter of aorta at the extent of the aneurysm Fig. 1 on page 15
- Diameter of the flow channel (residual lumen)
- Length of the proximal neck Fig. 1 on page 15
- Angulation
- Presence of calcification and mural thrombus
- Irregularities and ulceration of the mural thrombus
- Distal landing zone diameter: involvement by the aneurysm/ stenosis/ tortuosity
- Diameter of aorta at 10 mm above aortic bifurcation Fig. 1 on page 15
- Maximum diameter of right and left common iliac artery Fig. 1 on page 15
• Minimum diameter of right and left external iliac artery Fig. 1 on page 15
• Length of infra-renal aorta Fig. 1 on page 15
• Patency of aortic branches (including involvement or stenosis of splanchnic arteries and internal iliac arteries) and sac thrombus formation
• Presence of accessory renal arteries or retroaortic left renal vein Fig. 2 on page 11
• Tortuosity of iliac arteries
• Inflammatory aneurysm and perianeurysomal fibrosis

**IMAGING IN EVAR FOLLOW-UP:**

After successful endovascular repair associated findings such as aneurysm wall or periaortic fat tissue stranding should disappear.

Successful aneurysm exclusion is expected to lead to shrinkage of the aneurysm sac over a period of months to years\(^1\) with decreasing size of AAA believed to indicate low risk of rupture.\(^1\)

On the other hand, a persisting endograft failure can be suspected based on stable or expanding volumes of the aneurysm sac.\(^8\)

Recently, three dimensional volume assessment has been presented as an alternative, claiming earlier definition on success and better recognition of patients requiring closer surveillance or earlier re-intervention.

However, Hahne and colleagues\(^8\) in a retrospective study correlating maximal orthogonal diameter measurements to volumetric measurements of AAA after EVAR using CT-angiography, found that orthogonal diameters seems to be as feasible as time-consuming volumetric measurements to exclude post interventional enlargement, since there is a high correlation between volumetric and diametric measurements of aneurysm.

Ideally previous images should be reviewed and comparable diameters at similar axial levels should be taken.
A sac diameter increase of greater than 5 mm between observations should be considered significant.\textsuperscript{19}

Also complications should be assessed in the follow-up scans.

**TYPICAL COMPLICATIONS**

**Endoleak**

The most common unwanted complication after AAA repair is endoleak, the persistence of blood flow within aneurysm sac and outside the endograft, which may contribute to aneurysm sac enlargement and rupture.

With modern endostents, endoleak prevalence is reported approximately as 4-11\%.\textsuperscript{5}

Because endoleaks can develop at any time after stent insertion, lifetime surveillance is mandatory with cases been reported as late after 7 years after successful EVAR.

**Type I** a) Fig. 3 on page 11 and b) **endoleak** is a persistent perigraft blood extravasation caused by an inadequate seal at proximal (a) or distal (b) end of the stent graft. Type I a) can be found in association with stent-graft migration, both representing increased incidence of rupture of abdominal aneurysm and re-intervention.\textsuperscript{14}

Type I a) probably is related to the specific device involved.

An increased incidence of stent graft migration has been associated with severe infrarenal neck angulation (> 60 degrees) between the infrarenal aortic neck and the longitudinal axis of the aneurysm). A severe neck angulation increases type I incidence by predisposing to small leaks through the gaps between the stent and the neck.\textsuperscript{14}

**Type II** Fig. 4 on page 12 **endoleaks** are caused by retrograde perfusion from collateral aortic branches are the most common with a frequency varying from 10-25\% in EVAR procedures.

The most common branches involved are fourth lumbar arteries and inferior mesenteric artery.

There are different endoleak II presentations, with some with only one channel and others with multiple inflow and outflow channels.
Most of the type II endoleaks are reported as transient and resolve spontaneously during follow-up. Fig. 5 on page 13 Even so, there is evidence that persistent type II endoleaks for at least six months after an EVAR may be associated with sac growth and potential rupture.

If sac expansion occurs, a more aggressive management protocol could be considered, however no consensus in these patients approach has been reached.16

**Type III Fig. 6 on page 13 endoleak** is caused by disruption seal at the graft junction points, between segments of overlapping graft segments or rupture of the graft fabric.5

This ineffective seal is thought to be caused by repetitive stress from arterial pulsation and shrinkage of aneurysm sac with displacement of one of the extensions conducting to device breakdown.

It can be difficult to differentiate them from endoleak type II.

These are concerning endoleaks, since may cause increase of aneurismal sac and warrant intervention.

**Type IV endoleak** is related to porosity and passage of blood through the fabric of the graft and are uncommon with contemporary endografts.

This endoleak does not require treatment and resolve spontaneously, with deposition of fibrin in the pores.

**Type V endoleak (endotension)** is defined as continuous enlargement of aneurysm sac without an endoleak in delayed contrast CT.

Transudation from the graft has been proposed as the underlying etiology, with higher prevalence in PolyTetraFluoroEthylene fabric grafts, however, the exact cause of this endoleak is still unknown.20

The presence of endotension alone does not appear to predict aneurysm rupture.

**Fracture Fig. 7** on page 13 of the stent material can be appreciated on conventional plain radiographs, although MIP and volume-rendered displays may also demonstrate such events. It was more common with first generation stent grafts.

**Migration Fig. 7** on page 13 of the stent graft is believed to be a late-occurring event and is defined by Society for Vascular Surgery and the American Association for Vascular
Surgery as device movement of greater of 10 mm or movement less than or equal to 10 mm when this last results in secondary interventions.\textsuperscript{14}

**Stent graft limb thrombosis Fig. 8 on page 14:**

EVAR trial\textsuperscript{4} reported a rate of 26\% of thrombosis at more than 1 year follow-up.

Most common underlying causes for this complication are stent kinking and small diameters of distal aorta (less than 20mm). Others causes though to be associated with this complication are complex aortoiliac anatomy including tortuous, narrow access, small graft limb diameter and extension to the external iliac.

**Stent graft infection:**

According to some authors, shortly after the EVAR procedure air can be seen surrounding the graft, accompanied by leukocytosis and fever, being this findings not indicative of graft infection Fig. 9 on page 14.\textsuperscript{5}

However, gas bubbles seen later in the course of follow-up should raise suspicion for graft infection Fig. 10 on page 15 or aorto-enteric fistula.

**Renal dysfunction:**

Renal dysfunction occurs in 2.1-19\%.\textsuperscript{5} Regardless of the involved graft there is a decrease in creatinine clearance in 10\% in the first year following EVAR.

**CHARACTERISTICS TO EVALUATE AND MENTION IN THE FOLLOW-UP EVAR CONTRAST-ENHANCED CT REPORT \textsuperscript{21}:**

- Position of the stent graft
- Diameter (or volume) of native aneurismal sac
- Presence of endoleaks
- Structural fractures /kinks in the stent graft
- Native vessels above and below the stent graft
- Parenchymal (especially renal) infarction
Fig. 2: Retroartic left renal vein. Axial contrast enhanced CT showing a retroartic left renal vein in a patient previously submitted to EVAR.

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**Fig. 3:** Type Ia) endoleak. Axial a) and coronal b) and c) contrast enhanced CT images demonstrate an endoleak related to the proximal graft (white arrows)

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**Fig. 4:** Type II endoleak. axial a),b),c) and Maximum Intensity Projection (MIP)images showing a contrast blush within the aneurysm outside the confines of the stent graft (white arrows) originating in inferior mesenteric artery (IMA) collateral.
**Fig. 5:** Transient type II endoleak. Axial contrast enhanced CT images a) 12 months after EVAR procedure and b) 20 months after EVAR procedure illustrate spontaneous endoleak resolution (white arrows).

**Fig. 6:** Type III endoleak. Axial a) and coronal b) contrast enhanced CT selected images depict a small contrast blush from the antero-lateral aspect of the left common iliac branch.
Fig. 7: Graft fracture and limb migration. Coronal a), sagital b) and axial c) MIP selected images showing a markedly distorted device displaying fractures within the stent rings in the upper body of the device and migration of limb graft. (white arrows)

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Fig. 8: Stent graft limb thrombosis. Axial a) sagital b) and coronal c) contrast enhanced CT selected images depicting complete occlusion (white arrows) of the right limb of the stent graft in contrast to a patent left limb.

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Fig. 9: Immediate post-EVAR air bubble in the aneurysmal sac. Axial a) coronal b) and sagittal c) contrast enhanced CT reveal air bubble 1 day after the EVAR procedure. This finding is considered by some authors as non-specific if seen in the first week.

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Fig. 10: Axial a) contrast enhanced and b) non enhanced biopsy guided CT images displaying aneurismal sac ill definition, perigraft fluid collection and bone erosion due to aneurysm sac infection (confirmed by CT guided biopsy) in a 63 year-old patient presenting with back pain and fever 2 months after EVAR.

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Fig. 1: Schematic drawing showing points at which diameter and length should be measured in CT angiography in a AAA. 1) Aorta diameter at renal artery ostium 2) diameter of aorta at extent of aneurysm 3) length of proximal neck 4) length of infra-renal aorta 5) diameter of aorta 10 mm above aortic bifurcation 6) proximal diameter of right common iliac artery 7) proximal diameter of left common iliac artery 8) maximum diameter of right common iliac artery 9) maximum diameter of left common iliac artery 10) minimum diameter of right external iliac artery 11) minimum diameter of left external iliac artery

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Conclusion

CT is the election method in the evaluation of abdominal aortic aneurysms pre- and post-EVAR, being essential for the radiologist to be familiar with the imaging spectrum and valuable details to mention in the report in this scenario.
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References


