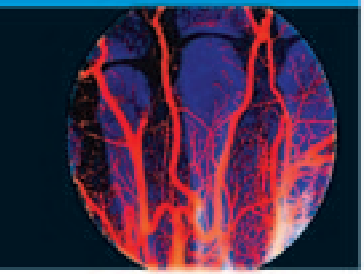
Patient selection and imaging assessment for abdominal aortic aneurysm stent grafting

Key words: abdominal aortic aneurysm; endovascular treatment; endoprosthesis; computed tomography; magnetic resonance imaging; Doppler ultrasound; X-ray angiography

Michel Nonent*, Ali Badra and Pierre Gouny****

*Department of Radiology and **Department of Vascular Surgery, University Hospital Centre, Brest, France

Address for correspondence:
Michel Nonent, MD, Service de Radiologie,
Hôpital de la Cavale Blanche, CHU, Bd Tanguy Prigent,
29609 Brest cedex, France
Tel: +33 (0)2 98 34 75 20
Fax: +33 (0)2 98 34 78 25
Email: michel.nonent@chu-brest.fr



Michel Nonent is Head of the Vascular Imaging Unit at the University of Brest, France. His main fields of interest are the development of multislice-computed tomography angiography (CTA) and magnetic resonance angiography (MRA). He also researches into the endovascular treatment of intracranial aneurysms and venous thrombo-embolic disease. He is currently coordinating a multicentre multidisciplinary trial to assess non-invasive imaging for the diagnosis of carotid stenosis. Dr Nonent is a member of the French Society of Radiology, the French Society of CardioVascular Imaging and the MRAngio Club. He is also a member of the Ethics Commitee of the University Hospital Centre of Brest.

Abstract

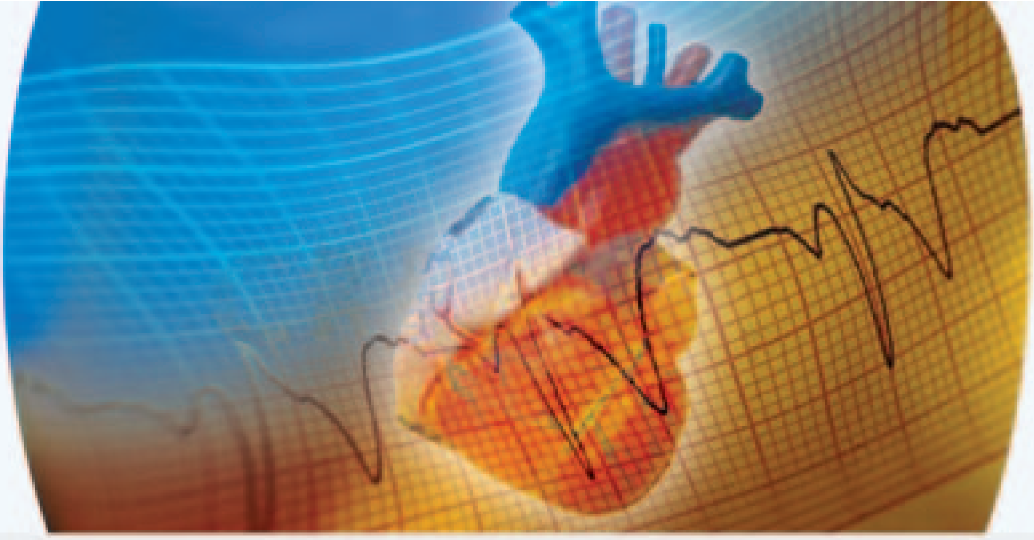
Endovascular repair using stent-grafts for abdominal aortic aneurysms (AAAs) is becoming increasingly employed worldwide. Imaging has great importance in the assessment of AAAs and in decision-making. Spiral-computed tomography (CT) is valuable in patient selection, morphologic assessment and follow-up. Recent improvements in technology (multislice CT) and in image processing (three-dimensional processing software, CT simulation before stent-grafting) allow an opportunity to replace X-ray angiography in the assessment of AAAs. Magnetic resonance imaging is becoming a favoured method, as it can be used without iodinated contrast agents; however, there are often limitations in the availability of equipment. Doppler ultrasound is the safest imaging method, but gives variable results and cannot be used alone. This article provides information and recommendations about the use of imaging techniques before and after endovascular repair of AAAs.

Introduction

Imaging techniques are of tremendous importance in the assessment and selection of patients for stent grafting of abdominal aortic aneurysms (AAAs) (see Table 1).[4] Firstly, imaging helps to identify the lesion and localize visceral arteries originating from the aorta relative to the position of the aneurysmal sac, especially the main and accessory renal arteries. Secondly, images allow precise measurement of the diameter and length of the aneurysm, diameter of the proximal and distal necks, and dimensions of the iliac arteries. Four imaging modalities are available for the assessment of stent-grafting in AAAs: spiral-computed tomography (CT), X-ray angiography, magnetic resonance imaging (MRI) and Doppler ultrasound. Most investigators consider CT as the best imaging method. X-ray angiography is most often used as a complementary technique to CT, but may not be strictly necessary in the future because of the development of three-dimensional processing of CT and MRI. The use of CT and X-ray angiography can be limited due to the risk of nephropathy from the large volumes of iodinated contrast media that may be required, although this risk is dependent on the type of iodinated contrast media employed.[5] Doppler ultrasound is also important in the follow-up of AAAs after endovascular repair. Finally, magnetic resonance angiography (MRA) is becoming favoured in the assessment of AAAs, because (i) it is a non-invasive method, (ii) it uses a non-nephrotoxic and well-tolerated contrast medium (gadolinium) and (iii) because of recent improvements in acquisition techniques. This paper reviews important information required by radiologists and surgeons to select patients for stent grafting of AAAs, and compares imaging modalities in the assessment and follow-up of endovascular repair.

Table 1. Characteristics of abdominal aortic aneurysms (AAAs)

Parameter for AAA	Description
Definition	Increase in diameter of the aorta to more than double its normal size (maximal diameter of normal aorta: 23 mm in men and 19 mm in women)
Prevalence	5% of people >65 years old[1] Occurs more frequently in people >60 years old More frequent in men than in women
Cause	Atherosclerosis – associated with cardiovascular risk factors such as smoking, hypertension, dyslipidemia Genetic factors Proteolytic activity inside the aortic wall resulting in elastin fibre degradation[2]
Diagnosis	Back pain, abdominal pain, complications (rupture, fissuration), collapses (three out four AAAs are asymptomatic at the time they are diagnosed)
Mortality risk	The main risk is rupture Lower risk of rupture for aortic diameters <50 mm
Criteria for endovascular repair	AAAs >50 mm in diameter or growing >10 mm/year in high surgical risk patients[3]



Morphologic assessment

Diameter

Endovascular repair is indicated for AAAs ≥50 mm in diameter in patients considered to be at high risk from open surgery. As a result, the external diameter of the abdominal aorta must be carefully measured. For these measurements, CT is the most accurate method due to its efficacy in imaging all components of the aneurysmal wall, especially thrombi and calcifications. Doppler ultrasound has some limitations, particularly in obese patients, or when gas in the intestinal tract prevents aortic visualization. X-ray angiography can only measure the diameter of the aneurysm lumen, which can be misleading in the case of thick calcification of the arterial wall. MRI could become the most favoured method for the estimation of aortic diameter; however, it still suffers from insufficient spatial resolution, inadequate visualization of calcified plaques, variability in processing software and poor availability of equipment. Despite these problems, MRI – including contrast-enhanced magnetic resonance angiography (MRA) – is very useful in patients with chronic renal insufficiency.

Proximal neck

Anatomic configuration of the proximal neck, the part of aorta located below the renal arteries and above the upper extremity of the AAA, is important for decision-making in endovascular repair because the stent-graft must be intimate with the arterial wall in order to prevent a leak. The proximal neck must be ≥15 mm in length and <30 mm in diameter and, to allow the stent-graft to conform with the aortic curve, the proximal neck must be at an angle of <60°. CT is undoubtedly the best method for the complete assessment of the proximal neck.

Distal neck

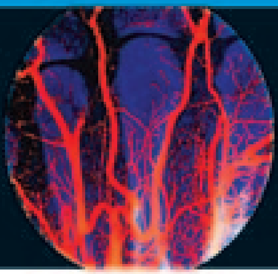
Similar considerations are required for assessment of the distal neck – the part of aorta located between the inferior extremity of the AAA and the aorto-iliac bifurcation. As for the proximal neck, the distal neck must be ≥15 mm in length for treatment using an aortic tube alone. CT is also accurate enough for the assessment of the inferior neck.

Iliac arteries

Visualization of the iliac arteries is strictly necessary for endovascular repair, especially when a bifurcated stent-graft is required. At least 10 mm of common iliac artery above the internal iliac arteries is necessary to place a bifurcated stent-graft. It is not permissible to cover both of the internal iliac arteries because of the high risk of colonic necrosis, due to the absence of collateral pathways supplying the inferior mesenteric artery territory. The diameters of common and external iliac arteries must be measured to evaluate the feasibility of stent-graft access and advancement. A diameter of ≥12 mm for common iliac arteries and ≥6 mm for external iliac arteries is generally required for safe vascular access. It is also important to consider calcifications and tortuosities before an endovascular repair decision. Thick calcifications of the arterial wall or excessive tortuosities may prevent catheterization. Most reviews on this topic point out that CT images give relatively low visualization of the tortuosities of iliac arteries. For this reason, X-ray angiography using a graduated catheter is still recommended for the assessment of iliac arteries, but contrast-enhanced CT, especially multislice CT, is being recognised as an effective technique. Using thin-slice collimation and overlapped reconstructions, multislice CT provides multiplanar reconstructions (MPR), maximal intensity projections (MIP) and volume rendering technique (VRT) reconstructions. These images are sufficiently accurate for the estimation of diameters, lengths and curves and for accurately locating the iliac artery bifurcation. CT images effectively demonstrate calcifications that do not mask the arterial lumen, when specific processing software such as VRT with transparency is used.

Patient selection and imaging assessment for abdominal aortic aneurysm stent grafting *continued*

Michel Nonent, Ali Badra and Pierre Gouny



Follow-up

The reported rate of conversion to open surgery for stent-grafted AAAs is 1% in the first year, increasing to 3.7% in the second year post-implant. Post-implant surgery carries a mortality risk of approximately 25% irrespective of the reason for graft failure.[6] Imaging is essential for the follow-up of AAAs after endovascular repair. Four issues must be checked by imaging following endovascular treatment: aneurysm size, detection of an endoleak, reduction of limb flow and migration of the device. Early detection of an endoleak is particularly important as it can cause failure and delayed rupture. Faries *et al*. recently reported results from 597 patients treated by stent graft, which showed that endoleaks requiring secondary treatment developed in 11.7% of patients.[7] In a registry of 2464 patients, delayed rupture was reported at a rate of 1% over 1 year. In 1046 patients recruited in an investigational device study, 2% experienced delayed rupture 3 years post procedure.[8]

A distinction must be made between primary endoleaks occurring immediately after the procedure and secondary endoleaks detected during follow-up. White *et al*. have defined a commonly used classification of endoleaks: type I is an endoleak related to an incompetent seal at one of the graft attachment sites; type II is retrograde filling of the aneurysm by collaterals; type III is the result of perforation or modular dysjunction; and type IV is porosity of the fabric used in the graft.[9] A non-graft related type II endoleak must be treated only in the case of enlargement of the aneurysmal sac.[10]

Secondary endoleaks are detected by different imaging techniques with varying results. CT is often considered the best modality for detection of endoleaks. However, some investigators have found better sensitivity with MRA, especially in the case of a low-flow endoleak. Kramer *et al*. observed similar performances for CT and MRA in the detection of leaks, but a better result with MRA for visualization of collaterals.[11] Doppler ultrasound is the least invasive method, but the variability of inter- and intra-observer results is the main drawback of this technique. Despite these problems, recent studies have shown high sensitivity with Doppler ultrasound in the detection of endoleaks, especially if ultrasound contrast media are used.[12–14]

In France, an expert panel of the Agency of Security in Health Products (AFSSAPS) has published recommendations for imaging in the follow-up of AAAs managed with stent-grafts.[3] Apart from the angiographic control performed immediately at the end of the procedure, the protocol recommended by the agency is the following:

- Plain radiographs (antero-posterior, lateral, obliques) and contrast-enhanced CT before discharge
- Same protocol at 3, 6, 12, 18 and 24 months
- In usual cases, after a delay of 24 months following endovascular treatment, a CT and plain radiograph must be obtained every year
- In the case of an endoleak, dislocation of the endoprosthesis or aneurysm growth, a repair treatment must be discussed. If a repair is not necessary, the follow-up is repeated 3 months later, otherwise corrective treatment may be indicated. In the case of stability or a decrease in aneurysm size, a 6-month follow-up is mandatory.

In our opinion, plain radiographs are not necessary if CT is performed with an up-to-date processing technique, and especially with volume rendering, which allows effective visualization and control of the structure and position of the stent itself. In our experience, three-dimensional VRT with carefully selected densities and multiple-view angles, is at least as effective as plain radiographs for detecting a distortion of the stent. Doppler ultrasound must also be systematically performed in association with CT. The risk of delayed rupture is sufficient to justify the need for indefinite monitoring of AAAs in patients treated with endovascular grafts.[8]

Practical considerations of multislice CT in AAA assessment

Acquisition protocols

With multislice CT, it is now possible to scan 4, 8 or 16 slices per rotation depending on the equipment available. Acquisition with multislice CT is faster than with conventional computed tomography techniques, and there is significant improvement of temporal and spatial resolution. Multislice CT provides the opportunity to choose the slice thickness and gap size after the scan. For vascular imaging with multislice CT, it is necessary to overlap the slices and to choose a soft filter to obtain high quality three-dimensional reconstructions. It is now possible to concomitantly explore the abdominal aorta and the lower limb arteries and run-off vessels. With four-slice equipment, our protocol for abdominal aorta and iliac artery exploration is a 4 x 2.5 mm acquisition after injection of 120 ml iodinated contrast medium (300 mg iodine/ml) at a flow rate of 3 ml/second, with a delay of 30 seconds between injection and acquisition. Reconstructions are performed with a 3 mm slice thickness and a slice increment of 1.5 mm. With 16-slice equipment, we use a 16 x 1.5 mm acquisition, 80 ml of iodinated contrast medium at a flow rate of 3 ml/second, delay-optimised with automatic detection of contrast material, and reconstruction with a 2.5–3.0 mm slice thickness and 1.25–1.50 mm slice increment.

Image processing

Particular care must be taken with image processing to ensure that the images are clinically relevant and accurate. Various processing techniques are available: two-dimensional MPR, MIP (Figure 1) and three-dimensional VRT. Of these modalities, three-dimensional VRT and MPR reconstruction are particularly interesting in AAA assessment and follow-up. Three-dimensional VRT permits a realistic view of the AAA and iliac arteries with minimum loss of information. With this technique, it is possible to

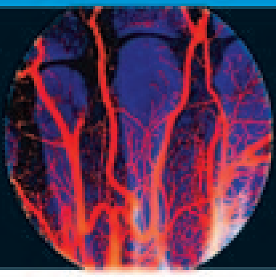
Figure 1. Abdominal aortic aneurysm: multislice computed tomography with maximal intensity projection reconstructions and measurements of diameters and lengths.

choose a range of opacities for preferential visualization of structures of different densities in a trapezoid section. Selection of maximum opacity for dense structures provides visualization of tissues such as bone (Figure 2a, overleaf), while using minimal opacity for higher density structures gives a transparency effect resulting in visualization through bones, calcifications and metallic structures such as stent grafts (Figure 2b).

Three-dimensional VRT is also useful for the assessment of calcified iliac arteries and for verifying the patency of the aorta and iliac arteries through the endoprosthesis. The other interesting imaging technique for the follow-up of stent-grafting procedures is MPR reconstruction through the axis of the vessel, also known as vessel analysis, mastercut or vessel view,

Patient selection and imaging assessment for abdominal aortic aneurysm stent grafting *continued*

Michel Nonent, Ali Badra and Pierre Gouny



which allows accurate estimation of the diameter and length of the aorto-iliac axis (Figures 3a and b). 'Virtual endograft' software is also available and is an interesting tool for simulating endografts according to the specific vascular anatomy of the patient.[4]

Diameters and volumetric measurements

An increase of ≥4 mm in the maximum transverse diameter (DMAX) of the aorta, with or without an endoleak, is a sensitive indicator of the risk of an impending aneurysm rupture. In contrast, neither failure of an aneurysm to diminish in size nor systolic pulsatile pressure (endopressure) on the aneurysm wall, have been established as related to aneurysm rupture.

Measurements of DMAX cannot detect changes in aneurysm size following endovascular repair in over one-third of cases. In 37% of DMAX measurements, discordance was found between DMAX and volume measurements. Using DMAX, a decrease in aneurysm size was missed in 14% of cases and an increase was missed in 19% of cases.[15] Volumetric measurement is more accurate than DMAX assessment for CT and MRA.[16] According to Pollock *et al.*, a 10% change in sac volume is considered significant for an increased risk of rupture. Aneurysms that increase in volume are significantly associated with type I and III endoleaks.[17]

Conclusion

Imaging provides an expanding array of tools, allowing increasingly accurate assessment of AAAs and patient selection for endovascular repair. Surgeons and radiologists in this field must be aware of the technological improvements in each imaging modality, to make the right choices before, during and after stent-grafting (see Table 2).

Figure 2a. Abdominal aortic aneurysm treated by a stent graft: multislice computed tomography with volume rendering reconstruction. The location and structure of the endoprosthesis is well defined

Figure 2b. Transparency imaging allows visualization of the aorto-iliac lumen inside the stent graft

Figure 3a. MPR reconstruction of artery: image through the axis of Philips software)

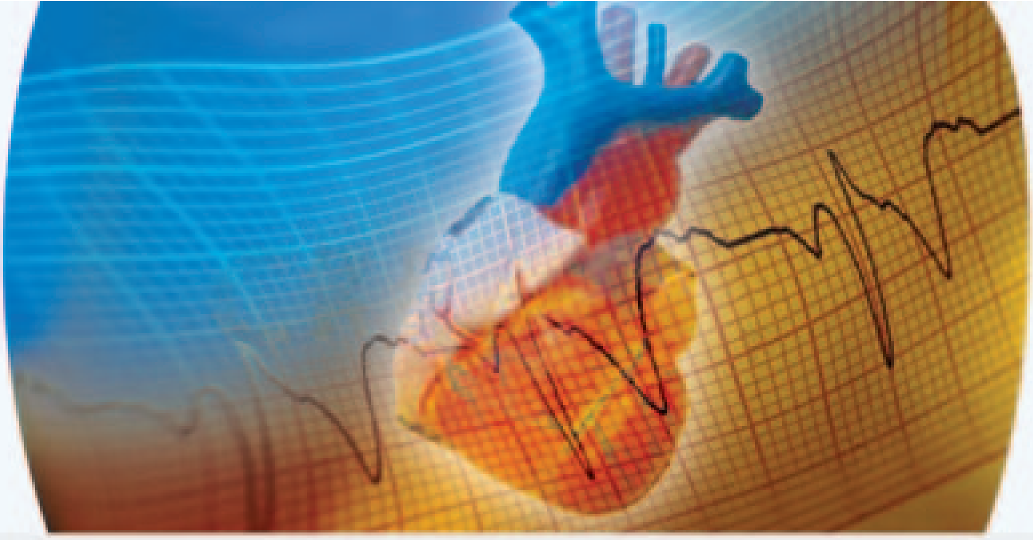


Table 2. Summary of recommendations for imaging in stent-grafting of abdominal aortic aneurysm (AAA)

Stage of stent-grafting	Preferred technique
Before	CT multislice is best for: • AAA diameter and length • neck diameters and lengths • iliac artery diameters and lengths and location of the origins of hypogastric arteries • assessment of mural calcifications If necessary, complete with X-ray angiography using a graduated catheter MRI replaces CT in patients with renal insufficiency
During	X-ray angiography using graduated catheter
After: Before discharge	CT and Doppler ultrasound (plain radiographs recommended but might be replaced by special CT post-processing)
24-month follow-up period	CT and Doppler ultrasound at 3, 6, 12, 18 and 24 months (plain radiographs if needed)
After 24 months	CT and Doppler ultrasound every year (plain radiographs if needed) • If an endoleak appears during the follow-up without the need for endovascular repair, repeat CT and Doppler ultrasound 3 months later

...on of the aorta and right iliac ...xis of the vessel (MasterCut,

Figure 3b. Reformatted image (3a) is extracted from this three-dimensional VRT reconstruction (the line inside the vessel represents the axis)

References

1. The UK Small Aneurysm Trial: design, methods and progress. The UK Small Aneurysm Trial participants. *J Vasc Endovasc Surg* 1995;**9**:42–8.

2. Blanchard JF. Epidemiology of abdominal aortic aneurysms. *Epidemiol Rev* 1999;**21**:207–21.

3. AFSSAPS. Evaluation des endoprothèses aortiques utilisées pour le traitement endovasculaire des anévrismes de l'aorte abdominale sous-rénale. *Rapport Juillet* 2001;46.

4. Beebe HG, Kritpracha B. Imaging of abdominal aortic aneurysm: current status. *Ann Vasc Surg* 2003;**17**:111–8.

5. Rudnick MR, Goldfarb S, Wexler L, *et al*. Nephrotoxicity of ionic and nonionic contrast media in 1196 patients: a randomized trial. The Iohexol Cooperative Study. *Kidney Int* 1995;**47**:254–61.

6. Harris PL, Vallabhaneni PR, Desgranges P, *et al*. for the Eurostar Collaborators. Incidence and risk factors of late rupture, conversion and death after endovascular repair of infrarenal aortic aneurysms: the EUROSTAR experience. European Collaborators on Stent/graft techniques for aortic aneurysm repair. *J Vasc Surg* 2000;**32**:739–49.

7. Faries PL, Cadot H, Agarwal G, *et al*. Management of endoleak after endovascular aneurysm repair: cuffs, coils and conversion. *J Vasc Surg* 2003;**37**:1155–61.

8. Sapirstein W, Chandeysson P, Wentz C. The Food and Drug Administration approval of endovascular grafts for abdominal aortic aneurysm: an 18-month retrospective. *J Vasc Surg* 2001;**34**:180–3.

9. White GH, Yu W, May J, *et al*. Endoleak as a complication of endoluminal grafting of abdominal aortic aneurysms: classification, incidence, diagnosis, and management. *J Endovasc Surg* 1997;**4**:152–68.

10. van Marrewijk C, Buth J, Harris P, *et al*. Significance of endoleaks after endovascular repair of abdominal aortic aneurysms: the EUROSTAR experience. *J Vasc Surg* 2002;**35**:461–73.

11. Kramer SC, Gorich J, Pamler R, *et al*. The contribution of MRI to the detection of endovascular aneurysm repair. *Rofo Fortschr Geb Rontgenstr Neuen Bildgeb Verfahr* 2002;**174**:1285–8.

12. Thompson MM, Boyle JR, Hartshorn T, *et al*. Comparison of computed tomography and duplex imaging in accessing aortic morphology following endovascular aneurysmal repair. *Br J Surg* 1998;**85**:346–50.

13. Bendick PJ, Bove PG, Long GW, *et al*. Efficacy of ultrasound scan contrast agents in the noninvasive follow-up of aortic stent grafts. *J Vasc Surg* 2003;**37**:381–5.

14. Greenfield AL, Halpern EJ, Bonn J, *et al*. Application of duplex US for characterization of endoleaks in abdominal aortic stent-grafts: report of five cases. *Radiology* 2002;**225**:845–51.

15. Wever JJ, Blankensteijn JD, Mali WP Th M, Eikelboom BC. Maximal aneurysm diameter follow-up is inadequate after endovascular abdominal aortic aneurysm repair. *Eur J Vasc Endovasc Surg* 2000;**20**:177–82.

16. Lutz AM, Willmann JK, Pfammatter T, *et al*. Evaluation of aortoiliac aneurysm before endovascular repair: Comparison of contrast-enhanced magnetic resonance angiography with multidetector row computed tomographic angiography with an automated analysis software tool. *J Vasc Surg* 2003;**37**:619–27.

17. Pollock JG, Travis SJ, Whitaker SC, *et al*. Endovascular AAA repair: classification of aneurysm sac volumetric change using spiral computed tomographic angiography. *J Endovasc Ther* 2002;**9**:185–93.