Diagnostic and Interventional Imaging (2016) **97**, 19—27

ELSEVIER MASSON

REVIEW / *Cardiovascular*

Aortic stent-grafts: Endoleak surveillance

L. Cassagnes[a,b,*], R. Pérignon[a], F. Amokrane[c], A. Petermann[a], T. Bécaud[a], B. Saint-Lebes[c], P. Chabrot[a,b], H. Rousseau[c], L. Boyer[a,b]

[a] *Pôle de radiologie, CHU de Clermont-Ferrand, 58, rue Montalembert, 63003 Clermont-Ferrand cedex 1, France*
[b] *ISIT UMR 6284 CNRS, faculté de médecine, université d'Auvergne, 28, place Henri-Dunant, 63001 Clermont-Ferrand, France*
[c] *Services de radiologie et chirurgie vasculaire, CHU Toulouse-Rangueil, 1, avenue du Pr-Jean-Poulhès, TSA 50032, 31059 Toulouse cedex 9, France*

KEYWORDS
Aortic stent-grafts;
Endoleaks;
CT;
MR;
Contrast-enhanced ultrasound

Abstract Endoleaks have been referred to as the ''Achilles heel'' of endovascular aortic aneurysm repair (EVAR) and are the most common complication of this procedure. An endoleak can maintain a high systemic blood pressure within the aneurysm sac, potentially leading to rupture. Follow-up is therefore mandatory to detect and classify possible endoleaks. Computed tomography (CT) remains the gold standard for follow-up, but provides no hemodynamic information on endoleaks and has the disadvantages of exposing patients to iodine contrast and X-ray radiation. Exposure to radiation could be reduced in various ways, by simplifying the triphasic protocol using dual-energy CT imaging, limiting the amount of radiation per slice using iterative reconstruction, and reducing the follow-up schedule that could be altered to include non-ionizing radiation imaging techniques. Contrast-enhanced ultrasound (CEUS) is an interesting alternative to CT, as is magnetic resonance (MR) imaging that can be used as an alternative or for complementary imaging. Long-term follow-up schedules are currently based on repeated CT. However, more recently alternative follow-up protocols have been proposed for patients with no endoleaks nor increase in aneurysmal sac size. These new protocols consist of CT imaging at 1 month and 1 year after treatment, subsequently followed by CEUS. Nevertheless, the mechanical structure of the stent-graft must still be verified by CT. The use of patient-specific risk-adjusted follow-up protocols, based on preoperative imaging and the first postoperative results, is gradually becoming more and more widespread.

* Corresponding author at: Pôle de radiologie, CHU de Clermont-Ferrand, 58, rue Montalembert, 63003 Clermont-Ferrand cedex 1, France.
E-mail address: lcassagnes@chu-clermontferrand.fr (L. Cassagnes).

http://dx.doi.org/10.1016/j.diii.2014.12.014
2211-5684/

Why is it essential to diagnose and classify endoleaks?

Endoleaks occur when the aneurysmal sac continues to be pressurized following the placement of an aortic stent-graft. They are often referred to as the ''Achilles heel'' of the endovascular approach to both abdominal endovascular aortic repair (EVAR) and thoracic endovascular aortic repair (TEVAR) procedures.

In 1998, White et al. [1] classified endoleaks into five types:

- type 1: leak between the stent and the aortic or iliac wall. There are four type-1 subtypes:
  - 1a—proximal leak,
  - 1b—distal leak,
  - 1c—exclusion zone formed by an iliac plug with aorto-uni-iliac devices,
  - 1d—''gutter''-like leak following fenestrated EVAR or chimney/periscope techniques;
- type 2: aneurysm sac filling via a branch vessel (for abdominal EVAR: patency of the inferior mesenteric or lumbar artery);
- type 3: leak at the junction of stent-graft segments. Three type-3 subtypes have been described:
  - 3a—hole or defect within the stent-graft,
  - 3b—leak between two modular components,
  - 3c—defective stent-graft material;
- type 4: leak across the graft due to its porosity;
- type 5: ''Endotension'' leak—no evidence of a leak site can be found but the aneurysmal sac continues to expand.

Depending on the time to occurrence, endoleaks are described as early-onset, late-onset or recurrent.

Endoleaks that cause aneurysmal sacs to be under persistent systemic pressure increase the risk of rupture [2].

Based on the 6787 patients of the Eurostar registry, the incidence of type-1 and -3 endoleaks was 6%, whereas that of type-2 endoleaks was 5% [3]. The frequency of type-5 endoleaks is less well documented although it was estimated at 3.1% in the cohort of 160 patients studied by Mennander et al. [4].

The risk of rupture induced by post-EVAR type-1 and -3 endoleaks has long been considered as significant [5].

The risk of rupture related to type-2 endoleaks is less clear. Reinterventions are more frequent with this kind of endoleak, but, as shown by Van Marrewijk et al. who analyzed 3595 cases from the Eurostar database, neither post-EVAR rupture nor conversion to open surgery are significantly associated with type-2 endoleaks [6]. Among the five cases of type-5 endoleaks studied by Mennander et al., 3 were followed by rupture of the aneurysm [4].

How can endoleaks be detected?

Angiography

Historically, angiography was used to detect endoleaks and assess both antegrade and retrograde flow. Nowadays however, non-invasive techniques are implemented with the same results. In current clinical practice, angiography is used to assess the success of endoleak treatment immediately after its implementation; it is no longer used as a detection technique or as part of follow-up.

Conventional X-ray imaging

Monitoring the mechanical structure of the stent-graft is still an essential part of follow-up. Typically, stent-graft migration and possible mechanical defects (kinking, dilation, fracture, module or branch disconnection, etc.) can be visualized clearly on anteroposterior and oblique projections. However, endoleaks cannot be visualized directly using this imaging modality.

In practice, following accurate thresholding, current multislice CT techniques (from 16 slices) enable volume reconstruction and therefore, analysis of metal structures. Hence, conventional X-ray imaging techniques are no longer used to detect endoleaks [7].

Computed tomography

Endoleak detection using CT is relatively simple. It is based on detecting, after administration of contrast agent, a peri-graft flow that reflects the flow of contrast out of the stent-graft and into the aneurysm. The radiologist must locate the site of the endoleak precisely, and determine whether it involves the ends of the stent-graft (type-1) and other collateral vessels (type-2). Such leaks may be detected either in the early arterial phase (type-1 and -3 endoleaks) or during the delayed phase (type-2 endoleaks and minor leaks) [8] (Figs. 1—4).

Three main disadvantages are associated with CT imaging.

Determining the direction of flow

Although of great importance for endoleak classification and determining the therapeutic approach to be used, the direction of flow within the aneurysmal sac and/or in collateral vessels is sometimes difficult to detect with conventional CT imaging. For example, opacification of a lumbar artery can reflect both a type-2 endoleak (retrograde flow) and a type-1 endoleak combined with antegrade flow into a lumbar artery. As demonstrated by Sommer et al., this problem can be overcome by using a time-resolved CT angiographic protocol to examine the patient. Indeed, the authors recommended a protocol consisting of 12 low-dose phases, with a scan frequency of 5 seconds and a scan range of 27 cm [9]. This protocol resulted in the characterization of type-1 endoleaks with an early enhancement time of 0.28 seconds (± 0.83), and type-2 endoleaks with a delayed enhancement time of 9.17 seconds (± 3.59). However, patient exposure to radiation with this protocol was high with a total dose of 14.6 mSv.

Administration of iodinated contrast agent

Approximately 80—120 ml of iodinated contrast agent is injected when performing CT angiography to detect endoleaks. In a cohort of 398 patients monitored following EVAR, 83% showed a glomerular filtration rate of less than 90 ml/min [10]. In such renally-impaired patients, clinicians should either attempt to use lesser amounts of contrast