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Radiological Evaluation of Abdominal Endovascular Aortic Aneurysm Repair

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Abstract

Endovascular aortic aneurysm repair (EVAR) is an alternative to open surgical repair of aortic aneurysms offering lower perioperative mortality and morbidity. As experience increases, clinicians are undertaking complex repairs with hostile aortic anatomy using branched or fenestrated devices or extra components such as chimneys to ensure perfusion to visceral branch vessels whilst excluding the aneurysm. Defining the success of EVAR depends on both clinical and radiographic criteria, but ultimately depends on complete exclusion of the aneurysm from the circulation. Aortic stent grafts are monitored using a combination of imaging modalities including computed tomography angiography (CTA), ultrasonography, magnetic resonance imaging, plain films, and nuclear medicine studies. This article describes when and how to evaluate aortic stent grafts using each of these modalities along with the characteristic features of several of the main stent grafts currently used in clinical practice. The commonly encountered complications from EVAR are also discussed and how they can be detected using each imaging modality. As the radiation burden from serial follow up CTA imaging is now becoming a concern, different follow-up imaging strategies are proposed depending on the complexity of the repair and based on the relative merits and disadvantages of each imaging modality.

Résumé

La réparation endovasculaire d'un anévrisme de l'aorte (REVA) est une solution de rechange qui présente des taux de mortalité et de morbidité périopératoires moins élevés que le traitement des anévrismes de l'aorte par chirurgie effractive. À mesure qu'ils gagnent en expérience, les cliniciens entreprennent des réparations complexes dans l'environnement anatomique difficile de l'aorte à l'aide d'endoprothèses munies de fenêtres ou de branches, auxquelles peut s'ajouter une cheminée, pour assurer la perfusion des branches viscérales et l'exclusion de l'anévrisme. La réussite d'une REVA est définie par des critères à la fois cliniques et radiographiques, mais repose en définitive sur sa capacité à complètement exclure l'anévrisme de la circulation. Les endoprothèses aortiques font l'objet d'une surveillance en combinant plusieurs modalités d'imagerie, notamment l'angiographie par tomodensitométrie (ATDM), l'échographie, l'imagerie par résonance magnétique (IRM), les images radiologiques sans produits de contraste et les examens de médecine nucléaire. Le présent article décrit quand et comment chaque modalité se prête à l'évaluation des endoprothèses, ainsi que les caractéristiques propres aux principales endoprothèses en usage dans la pratique clinique. Il aborde également les complications courantes de la REVA et la façon de les détecter à l'aide de chacune des modalités d'imagerie. Enfin, compte tenu des inquiétudes que suscite maintenant la réalisation périodique d'ATDM de suivi sur le plan de la radioexposition, il propose diverses stratégies de suivi qui varient selon la complexité de la réparation et selon les avantages et les inconvénients relatifs de chaque modalité.

Key Words: Endovascular aortic aneurysm repair; Fenestrated; Surveillance; Aortic aneurysm; Computed tomography; Ultrasound; Magnetic resonance imaging; X-ray; Nuclear medicine

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Endovascular aortic aneurysm repair (EVAR) was introduced in 1991, as an alternative to open surgical repair of aortic aneurysms, offering lower perioperative mortality and morbidity [1]. The repair involves placing a fabric covered stent graft into the aneurysmal segment of aorta to bypass the aneurysm thereby excluding it from systemic arterial blood pressure. The stent graft scaffold can be made of stainless steel, nitinol, or elgiloy (an alloy of cobalt, chromium, and nickel) and the graft fabric made of either polyester (eg, polyethylene terephthalate) or plastic (eg, polytetrafluoroethylene). Defining the success of EVAR depends on both clinical and radiographic criteria, but ultimately depends on complete exclusion of the aneurysm from the circulation.

Abdominal Aortic Stent Graft Design

Aortic stent grafts are modular in construction, made up of a bifurcated main body and 1 or 2 iliac limbs. During standard EVAR, a bifurcated stent graft is placed below the renal arteries, which has a main body that then extends into each iliac artery with a tube graft limb. When the bifurcation is narrow or when there is no suitable iliac landing zone (ie, due to an aneurysmal iliac artery), an aorto uni-iliac (AUI) stent graft can be used with a surgical femorofemoral cross over graft to maintain perfusion to the excluded leg. In cases where there is an insufficient seal at either the proximal or distal landing zone, extra components can be added (ie, proximal extensions/cuffs or covered stents) to create tighter apposition between the stent graft and the aortic wall.

The construction of the aortic stent grafts consist of a combination of an exostent (ie, the stent structure is located outside the graft material) and endostent (ie, the stent structure is located inside the graft material). The AFX (Endologix, Irvine, CA) stent graft is a complete endostent with only the very top and bottom of the graft material adherent to the stent, thereby allowing the graft material to expand into irregular portions of the landing zones; this is an important feature of this graft as it can mimic an endoleak on follow up imaging (Figure 1). Most stent grafts have a bare metal stent to allow for suprarenal proximal fixation (Figure 2, B-D), often with barbs to prevent migration. Three exceptions are the C3 Excluder (Gore Medical, Flagstaff, AZ) (Figure 2A), Aorfix (Lombard Medical, Irvine, CA) (Figure 2, E and F), and Anaconda (Inchinnan, Renfrewshire, Scotland) stent grafts, which have infrarenal fixation. The shape of the top of the stent graft material also varies between devices; straight (Cook Zenith, Medtronic Endurant [Medtronic, Dublin, Ireland], Endologix AFX) (Figure 2, B-D), castellated (Gore C3 Excluder) (Figure 2A), or fish mouth (Lombard Aorfix and Vascutek Anaconda) (Figure 2, E and F). The Ovation (TriVascular, Santa Rosa, CA) stent graft combines a conventional type suprarenal stent with active barb fixation along with a proximal sealing ring that is inflated using a polymer. The Nellix (Endologix) is a newer device, which uses a stent graft with surrounding inflatable endobags, which are filled with polymer that mould to the surrounding aneurysm sac (Figure 3).

Standard infrarenal stent grafts require a uniform infrarenal neck length between 10-15 mm to ensure an adequate seal between the stent graft and the aortic wall, however, neck lengths as short as 4 mm can be treated successfully [2]. An insufficient neck, which is too short, too angulated (ie, greater than 60° angle between the suprarenal aorta and proximal neck) [3] or too large in diameter (ie, juxta- or suprarenal aortic aneurysms), may require fenestrated or branched aortic stent grafts. Grafts for fenestrated endovascular aortic aneurysm repair have scallops (incomplete sections of the top of the stent graft material) and/or fenestrations (holes in the stent graft material) in their main body through, which additional covered stents can be deployed into visceral arteries (ie, celiac, superior mesenteric, and renal arteries) to maintain patency. Fenestrated stent grafts are made by Cook (Zenith) (Figure 2, G and H) and Vascutek (Anaconda). Other techniques include deploying chimneys or parallel grafts, which include snorkels and periscopes (for more information, please see the review by Wilson et al [4]) (Figure 4). Snorkels are branches that arise above the proximal end of the endograft to supply branches below the proximal endograft whereas periscopes are branches that arise below the distal end of the endograft to supply branches above the distal endograft. There are also sandwich grafts, which can run between 2 endograft components. When there is an unsuitable distal landing zone in the common iliac artery (ie, short or significant aneurysmal disease of the common iliac artery), the stent graft limb can be extended into the normal calibre external iliac artery, with prior embolization of the ipsilateral internal iliac artery (IIA) to prevent an endoleak (Figure 5, A and B). In these cases, flow in the contralateral IIA should be preserved to supply the pelvic organs and hence proper evaluation of the planning computed tomography angiography (CTA) should be undertaken to identify any IIA disease. Branched iliac devices allow the limb to extend and seal in a normal calibre external iliac artery whilst the branch portion of the device preserves flow into the IIA (Figure 5, C and D).

Complications from Endovascular Aortic Aneurysm Repair

The most common complications from EVAR are endoleaks. There are 5 types of endoleaks based on the source/origin of blood flow into the aneurysm sac [5]:

- Type I endoleak – caused by blood flowing between the stent graft and the native arterial wall at either the proximal aortic (Type Ia) or distal (Type Ib) attachment site. A Type Ic endoleak occurs with incomplete occlusion of the contralateral iliac artery in AUI stent grafts. Type I endoleaks are most commonly seen at the time of stent graft deployment. Late development of Type I endoleaks (ie, delayed endoleaks) can be due to progressive aneurysmal disease involving the infrarenal neck (Type Ia; Figure 6, A and B) or iliac landing zone (Type Ib; Figure 6, C and D).