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Changes in Renal Anatomy After Fenestrated Endovascular Aneurysm Repair☆

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WHAT THIS PAPER ADDS

Fenestrated devices have become the standard of care for juxtarenal aneurysms. Knowing the impact that variability in renal stent position has on long-term outcomes may influence clinical pathways. This study explores the changing positions of renal anatomy after fenestrated repair.

Objective: To assess short- and long-term movement of renal arteries after fenestrated endovascular aortic repair (FEVAR).

Methods: Consecutive patients who underwent FEVAR at one institution with a custom-made device designed with fenestrations for the superior mesenteric (SMA) and renal arteries, a millimetric computed tomography angiography (CTA), and a minimum of 2 years' follow-up were included. Angulation between renal artery trunk and aorta, clock position of the origin of the renal arteries, distance between renal arteries and SMA, and target vessel occlusion were retrospectively collected and compared between the pre-operative, post-operative (<6 months), and last (>12 months) CTA.

Results: From October 2004 to January 2014, 100 patients met the inclusion criteria and 86% of imaging was available for accurate analysis. Median follow-up was 27.3 months (22.7—50.1). There were no renal occlusions. A significant change was found in the value of renal trunk angulation of both renal arteries on post-operative compared with pre-operative CTA (17° difference upward [7.5—29], $p < .001$), but no significant change thereafter ($p = .5$). Regarding renal clock positions (7.5° of change equivalent to 15 min of renal ostial movement): significant anterior change was found between post-operative and pre-operative CTA (15 min [0—30], $p = .03$ on the left and 15 min [15—30], $p < .001$ on the right), without significant change thereafter (15 min [0—30], $p = .18$ on the left and 15 min [0—15] on the right, $p = .28$). No changes were noted on the distance between renal and SMA ostia (difference of 1.65 mm [1—2.5], $p = .63$).

Conclusion: The renal arteries demonstrate tolerance to permanent changes in angulation after FEVAR of approximately 17° upward trunk movement and of 15—30 min ostial movement without adverse consequences on patency after a median of more than 2 years' follow-up. The distance between the target vessels remained stable over time. These results may suggest accommodation to sizing errors and thus a compliance with off the shelf devices in favourable anatomies.

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INTRODUCTION

Over the past two decades, endovascular repair of abdominal aortic aneurysms (EVAR) has gained popularity as a treatment option that offers many advantages over open surgical repair. However, specified anatomical characteristics are required to achieve durable outcomes, and up to 40% of patients are unsuitable for traditional infrarenal EVAR, mainly because of a hostile proximal neck anatomy.[1,2] To overcome these limitations, use of a fenestrated stent graft for fenestrated endovascular aneurysm repair (FEVAR) currently represents the most validated and reliable endovascular option to treat short neck or pararenal aneurysms, with high technical success rates (≥99%), low operative mortality (≤3.5%), and excellent mid- and long-term target vessel patency (≥97%).[3,4]

☆ This study has been presented in the plenary session at the ESVS 30th Annual Meeting in Copenhagen, Denmark, on 28—30 September 2016 (abstract n° 1357).

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Fenestrated stent grafts are custom-made to fit each patient's anatomy, implying a delay for planning, production, and implantation from 6 to 8 weeks. The success of the procedure relies on appropriate sizing of the stentgraft, including accurate determination of target vessel clock face position, distance from proximal stentgraft edge, and aortic diameter, to ensure aneurysm exclusion and target vessel patency. Sizing is commonly performed by the manufacturer in a centralised planning centre. If experienced surgeons do their own planning, it is a complex process that includes learning anatomical limitations to meet manufacturing constraints and requires a 3-dimensional workstation. Moreover, concerns have been raised over intra- and inter-observer variability and potential consequences.[5–7]

As not all patients are able to wait for a customised graft, off the shelf fenestrated devices, including three fenestrations for the superior mesenteric artery (SMA) and renal arteries, and a scallop for the coeliac trunk (CT), available for immediate use and designed to accommodate the majority of the patients are under investigation with encouraging early results.[8] It has been shown to be applicable in 70% of the patients, with the right renal artery as a primary cause of exclusion. However, long-term results are unknown and anatomical accommodation to fenestrated stent grafts with potential misalignments between the fenestrations and the target vessels because of sizing approximation or aneurysm shrinkage over time has not been previously described in literature.

The aim of this study was to assess the short- and long-term positional change of renal arteries after FEVAR in the axial, sagittal, and coronal planes, and the consequences on renal stent patency as these changes may induce renal stent stenosis or occlusion.

METHODS

All fenestrated custom-made devices implanted at a single institution (Aortic Centre, University Hospital Centre of Lille, France) between October 2004 and January 2014 were identified from a prospectively maintained electronic endovascular aortic database.

Patient inclusion

Inclusion criteria for enrolment in the study were juxtarenal, pararenal, or thoraco-abdominal aortic aneurysms repaired with a custom-made device designed with fenestrations for at least one renal artery and the superior mesenteric artery (SMA) in a procedure performed more than 2 years ago; 1 mm thickness or less computed tomography angiography (CTA) of the chest, abdomen, and pelvis, available pre-operatively, post-operatively (within 6 months after the procedure), and during follow-up (at least 1 year after the procedure). Patients with branches or a scallop for the SMA or the renals were excluded, as well as patients with poor quality CTA, or either the post-operative (within 6 months) or the last CTA during follow-up (performed after 1 year) not available.

Sizing and implantation of the stent grafts

The sizing of the stent grafts was performed either by the manufacturer (Cook's European planning centre, London, UK) or by an experienced vascular surgeon who reviewed and approved the graft plan in every case (S.H.). The same experienced vascular surgeon performed or supervised all of the procedures (S.H.). Prior to December 2012, all cases were performed in an operating room with a mobile motorised C-Arm (OEC 9900 Elite MD; GE OEC Medical Systems, Inc., Salt Lake City, UT, USA). More recently, they have been performed in a dedicated hybrid operating room (Discovery; GE Healthcare, Chalfont St Giles, UK) under image fusion guidance. The endovascular devices were all custom-made and designed with fenestrations for the renal arteries and the SMA. A detailed description of the implantation procedure for complex endovascular aortic repair has been published previously.[9]

Imaging analysis

For each patient, the high resolution pre-operative CTA dedicated to stent graft sizing, the post-operative CTA, and the last CTA available during follow-up, were analysed using the dedicated 3-dimensional workstation AquariusNET software (TeraRecon Inc., San Mateo, CA, USA). One trained vascular surgeon (L.Y.) has performed the measurements after the completion of an intra-operator concordance test (details in Statistical analysis). The following criteria were extracted from the CTA for analysis: left (LRA) and right renal artery (RRA) angulation; clock face position of the LRA and the RRA according to the SMA; and length between the SMA and the LRA and RRA (Fig. 1). The LRA, RRA, and SMA ostium were defined as the interface between the aorta and each target vessel. Segmentation of the aorta and the target vessels was performed as previously described,[10] using a semi-automated centreline generated from the thoracic aorta to the aortic bifurcation. The centreline was assessed with multiplanar reconstruction views perpendicular to the centreline of flow, and then manually edited if necessary. Accessory renal arteries were not evaluated.

Renal artery angulation

The assessment of pre- and post-operative renal artery angulation was performed according to the technique described by Conway et al.[11] The angle between the aortic centreline and the renal artery implantation was measured using the angular measurement tool provided by the workstation. A positive or negative renal artery implantation angle was defined as, respectively, above or below the horizontal plane perpendicular to the aortic centreline. This measurement was performed for both main renal arteries.

Renal artery clock position

Pre-operative renal artery orientation in a circumferential position was assessed using the graft plan with the SMA considered as the central position at 12:00 o'clock and the clock position of each renal artery amended according to