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Stent graft Surface Movement after Infrarenal Abdominal Aortic Aneurysm Repair: Comparison of Patients with and without a Type 2 Endoleak

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WHAT THIS PAPER ADDS

This study adds information on the behavior of type 2 endoleaks. The presence of a type 2 endoleak is associated with decreased surface movement of the proximal anchoring zone and the distal modular limb of bifurcated stent grafts, which is associated with a trend towards more stable anchorage zones. To detect morphological changes of the anchoring zones, it is suggested that performance of MSCT follow up after endovascular aneurysm repair is justifiable at defined intervals even in endoleak free patients with stable and decreasing sac diameters.

Objectives: The aim was to compare multidirectional stent graft movement in patients with and without a type 2 endoleak.

Methods: This was a retrospective case control study of patients being followed up after elective endovascular aneurysm repair of abdominal aortic aneurysms. The post-procedural and final follow up multislice computed tomography (MSCT) of 69 patients with and 74 without a type 2 endoleak were analyzed. Three dimensional (3D) surface models of the stent graft, delimited by landmarks using custom built software, were derived from these MSCT data. The stent graft was segmented in different zones, and the proportion of the total stent graft surface moving >9 mm between the post-procedural and the final follow up MSCT was calculated, given in percentages, and compared between groups. Changes of infrarenal neck, renal artery to stent graft distance, and freedom from stent graft related endoleaks were evaluated.

Results: Overall surface movement was higher in the no endoleak (18.8%, IQR 0.1—45.1%) than in the type 2 endoleak group (5.3%, IQR 0—29.7%; $p = .06$). Furthermore, significantly higher surface movement in the no endoleak group was found in the proximal anchoring zone ($p = .04$) and the distal left limb ($p = .01$), which was the modular limb in 81.1% ($p < .01$). Neck diameter increase (1.0 mm, IQR 0—3.0 mm; $p < .01$) and renal artery to stent graft distance difference (0 mm, IQR 0—3.3 mm; $p < .01$) were significantly higher in the no endoleak group. Five patients in the no endoleak and one patient in the type 2 endoleak group suffered from a stent graft related endoleak ($p = .27$).

Conclusions: The presence of a type 2 endoleak is associated with decreased surface movement of the proximal anchoring zone and the distal modular limb of bifurcated stent grafts.

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INTRODUCTION

Stent graft migration has a reported prevalence ranging from 3% to 28%.[1—4] It is responsible for a large part of the late complications after endovascular aneurysm repair (EVAR), including late stent graft related endoleaks that result in aneurysm sac enlargement, and even rupture.[5—8]

For stent graft migration, different mechanical mechanisms have been described during the last few years. Two different working groups reported that pulsatile forces of blood flow, referred to as migration forces, displacement forces, or drag forces, are responsible for the longitudinal movement of the stent graft.[9,10] Rafii et al.[11] focused on the lateral movement of the stent graft, and reported a significantly higher longitudinal migration in patients with a mean 9 mm of lateral deflection. Furthermore, this patient group presented with a significantly higher rate of type 1 endoleaks and the need for secondary interventions. In addition to these described transverse and longitudinal motions, Figueroa et al.[9] demonstrated significant

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movements of the stent graft in all three spatial directions. Owing to higher pressurization of the aneurysm sac, as described by different working groups,[12–14] type 2 endoleaks might be a parameter that could influence displacement forces.[15]

The primary aim of this study was to evaluate potential differences in stent graft movement in three dimensions in patients with and without a type 2 endoleak. Consistently, the influence of stent graft surface movement on morphological parameters (i.e. neck diameter changes, renal artery to stent graft distance), and late stent graft related endoleaks was evaluated.

METHODS

Study design

This was a retrospective case control study of patients being followed up after elective EVAR for abdominal aortic aneurysm (AAA). The institutional review board approved the study protocol, and waived written, informed consent.

Study population

The institutional database was screened for patients who met the following inclusion criteria: (a) elective endovascular AAA repair with a second or third generation bifurcated stent graft; (b) availability of a standardized multislice computed tomography (MSCT) angiogram pre-intervention and within one week post-procedure, and after a time interval of at least 6 months. There were 215 patients who met the inclusion criteria. Patients with stent graft related endoleaks ($n = 33$), the presence of limb stenosis ($n = 7$), and type 2 endoleaks causing continuous aneurysm sac enlargement that necessitated secondary intervention ($n = 2$) were excluded. An additional 30 patients were excluded due to insufficient image quality that rendered image processing impossible. This left 143 patients (129 men) with a mean age of 73.6 $\pm$ 7.9 years for final analysis. In order to obtain a three dimensional model of the stent graft surface, the Digital Imaging and Communications in Medicine (DICOM) volumetric data of the arterial phase MSCT images were downloaded to a standard personal computer (Xeon X5650 processor; Intel, Santa Clara, CA, USA) with 2.66 GHz, and 75 GB RAM. Image processing steps are illustrated in Fig. 1A—E. Four reference points were manually placed at the following levels: covered stent graft body cranially, distal ends of stent graft limbs, and at the flow diverter. Automatically defined regions of interest (ROI) around these reference points were used to gain information about the CT density of the vessel lumen and for calculation of an intensity model. This model provided an appropriate threshold for approximate binary segmentation of the stented part of the vessel. The centerline was defined as the longitudinal axis of each limb of the stent graft and was estimated by skeletonization[16] and subsequent interpolation (spline fitting process). As the next step, multi-level cut planes were applied orthogonally on the centerline. These cut planes were used to estimate the diameter of the stent graft by Hough transformation,[17] resulting in a 3D surface model of the stent graft. Prior to quantitative measurement of stent graft movement between the post-procedural and final follow up MSCT scan of each patient, the two scans had to be aligned. This was achieved by automated segmentation and rigid alignment of the imaged bone structures. Displacement of the aorta relative to the skeleton of the patient was accounted for by matching manually annotated branching points of the renal arteries. Movements of the stent graft between examinations were estimated by matching the corresponding surface models using a non-rigidly constrained Iterative Closest Point method.[18] Consequently, the software calculated a vector for each point of the stent graft surface, describing the surface movement between the post-procedural and final follow up MSCT, which was given in millimeters.

Measurements and definitions

Rafii et al.[11] observed a mean lateral stent graft movement of 9 mm, which was defined as the threshold value in this analysis. For analysis, the proportion of the total stent graft surface, moving more than 9 mm between the post-procedural and the final follow up MSCT was calculated, and given as a percentage. To assess the surface movement in different zones, the stent graft was segmented as shown in Fig. 2. Zone 1 was defined as the proximal 3 cm of the covered stent graft, followed by Zone 2 extending to the flow diverter. Zone 3 included the distance from the flow diverter down to the beginning of the last 4 cm of the limb on each side. Zone 4 was defined as the distal 4 cm of the right (4R) and the left (4L) stent graft limb.

In both pre- and post-interventional MSCT scans, the aneurysm sac diameter, the maximum diameter of the proximal and distal anchoring zones, the neck length, the renal artery to stent graft distance, and the neck angulation were measured in accordance with the Society for Vascular Surgery standards for EVAR.[19] The oversizing factor of the stent grafts was calculated, and the stent graft fixation level was noted. In addition, changes in neck diameters and renal artery to stent graft distance and presence, and time intervals to stent graft related endoleaks were noted.

The study population was divided with respect to the presence or absence of a type 2 endoleak. The type 2 endoleak group was sub-categorized into patients with a transient or a persistent type 2 endoleak. Type 2 endoleaks that were identifiable on the post-procedural and the final MSCT scans were classified as persistent; leaks detected only on one MSCT scan were classified as transient. Data collections were compared between defined groups.

Statistical analysis

Normally distributed, continuous data were presented as the mean $\pm$ standard deviation and 95% confidence interval. Potential differences between groups were tested using analysis of variance (ANOVA), or the *t* test, as appropriate. Non-normally distributed data, or ordinal variables, were described by medians and interquartile ranges (IQRs).