Length Measurements of the Aorta After Endovascular Abdominal Aortic Aneurysm Repair

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Background: successful endovascular repair of abdominal aortic aneurysms (AAA) generally leads to a decrease in aneurysm size. Theoretically, this may lead to foreshortening of the excluded segment. If so, vertically rigid endografts may dislocate over time and cover renal or hypogastric arteries.

Aim: to assess length changes of the infrarenal aorta after endovascular AAA exclusion.

Patients and methods: forty-four consecutive patients were scheduled for the EndoVascular Technologies® endograft, a vertically non-rigid prosthesis which would potentially accommodate longitudinal changes. Twenty-four patients had completed at least 6 months of follow-up. In 18/24 patients a decrease in size was established by aneurysm volume measurements at 6 months’ follow-up. Helical computer tomography (CT) angiograms were processed on a workstation. Aortic lengths were measured along the central lumen line from the lower renal artery orifice to the native aortic bifurcation. The computer tomography angiogram (CTA) reconstruction thickness of 2 mm yields at least a 4-mm error for each length measurement.

Results: in the shrinking aneurysm group, the median length change was 0 mm (range −9 mm to +4 mm) at 6 months’ follow-up (n = 18) and also 0 mm (range −7 mm to +4 mm) at 12 months’ follow-up (n = 10). In 16/18 patients, length changes remained within the measurement error range of 4 mm.

Conclusion: in this group of shrinking aneurysms after endovascular AAA repair, foreshortening of the excluded aortic segment appears not to be a clinically significant problem.

Key Words: Abdominal aortic aneurysm; Endovascular repair; Computer tomography.

Introduction

The success of endovascular repair of an aneurysm of the abdominal aorta (AAA) is primarily determined by complete exclusion of the aneurysmal segment. Reaching this goal generally leads to a gradual decrease in aneurysm size. This may theoretically lead to foreshortening of the excluded segment.

Proper attachment of the endoprosthesis to the aortic wall is one of the main conditions to accomplish complete exclusion. A number of different devices are being used to achieve this goal. Non-rigid endografts use hooks or outward radial force of the stenting mechanism while fully stented endografts depend on column strength for proper fixation to the arterial wall.

In the case of foreshortening of the excluded aortoiliac segment, non-rigid endografts could adapt to the new anatomic situation whereas vertically rigid endografts might dislocate over time and migrate. This might in turn lead to covering of renal or hypogastric arteries or to endoleak.

The aim of this study was to assess length changes of the infrarenal aorta after endovascular AAA exclusion in the perspective of aneurysm morphology changes during follow-up.

Patients

From January 1994 until 1995 and from 1996 onward, 44 patients were programmed for endovascular AAA repair. All patients with a postoperative and at least a 6 months’ follow-up computer tomography angiogram (CTA) available were included in this study (n = 24). Eleven patients were scheduled for a tube graft and 13 patients for a bifurcated graft (EndoVascular Technologies Inc., Menlo Park, CA, U.S.A.). The median age at the time of the operation was 68.5 years (range 52–86 years). The male:female ratio was 5:1.
maximal aneurysm diameter at the time of the procedure was 55 mm (range 36–73 mm). The median follow-up period was 12 months (range 6–48 months).

**Methods**

**Data collection**

Spiral CTA was performed on each patient post-operatively, at 6 months and yearly thereafter. All datasets were composed according to a standardised acquisition protocol using a Philips EV-AP CT scan (Philips Medical Systems, Best, The Netherlands). Scanning started at the 12th thoracic vertebra, which is the presumed level of the coeliac trunk. Fifty to seventy rotations of one second each were made. A table speed of 5 mm/s and a collimation of 5 mm resulted in a scanned length of 25–35 cm. Intravenous contrast was administered at a rate of 3 ml/s. Scanning started with a delay of 30 s. The CTA data were reconstructed with a slice thickness of 2 mm, creating a dataset of at least 123 overlapping images.

**Data processing**

All datasets were processed on an Easy Vision workstation (Philips Medical Systems, Best, The Netherlands). A central lumen line was drawn manually by positioning points in the middle of the aortic lumen in 3 different cut-planes: axial, sagittal and coronal (Fig. 1). Multiplanar reformats were reconstructed perpendicular to this central lumen line. Using these reformatted images, the level of the orifice of the lower renal artery was determined (Fig. 2a) as well as the level of the aortic bifurcation (Fig. 2b). The distance between these levels was calculated.

The level at which all struts of the proximal attachment system were visible was also determined. This allowed assessment of the distance between the level of the orifice of the lower renal artery and the proximal stent in order to evaluate possible migration.

The same landmarks were also measured along the vertical body axis in 19/24 patients. Again, the distance between the levels was calculated.

All CTA datasets were studied for the presence of endoleak because this might be a sign of possible migration.
Total aneurysm volume was measured using semi-automatic and manual segmentations in axial slices. The volume of the lumen was segmented using a threshold technique, starting at the level of the orifice of the lower renal artery and ending at the level of the native bifurcation. Thrombus volume was segmented by drawing a line along the border of the thrombus on each individual slice. Composition of these individually segmented slices resulted in the volume of the thrombus itself and the lumen within. The actual thrombus volume was calculated by subtracting the volume of the lumen within the thrombus. Total volume was defined as the volume of the lumen plus the actual thrombus volume.

Accuracy

The CTA reconstruction thickness of 2 mm implies a measurement error of the same amount, because three-dimensional (3-D) volume data are projected in a two-dimensional plane. Due to the fact that a distance is always defined by 2 points, and both have an error of 2 mm, the error-of-length measurement is 4 mm.

Using the method of Bland and Altman, the 95% confidence interval of repeated measurements of 30 datasets was ±4%. Aneurysm shrinkage was therefore defined as a reduction in aneurysm volume of at least 4%. Volume changes less than 4% were classified as "no change".
Fig. 3. Model of probable length changes with renal arteries and bifurcation as fixed points, not encountered by either method.

Analysis

All collected length measurement data were analysed using the Wilcoxon rank test.

Results

In 18 out of 24 patients that were measured along the central lumen line, a decrease of aneurysm volume was established (median $-14\%$, range $-38\%$ to $-6\%$). Eight out of 11 patients with a tube graft showed shrinkage, as did 10 out of 13 patients with a bifurcated graft. In the 18 shrinking aneurysms the median length change was 0 mm (range $-9$ mm to $+4$ mm) after a follow-up period of 6 months, compared to the postoperative length. A period of 12 months of follow-up was available in 10 out of 18 patients, showing a median length change of 0 mm (range $-7$ mm to $+4$ mm).

In 16 out of the 18 shrinking aneurysms the length changes did not exceed the measurement error of 4 mm.

In the 19 patients who were measured along the vertical body axis as well, 7 out of 10 patients with a tube graft showed shrinkage, as did 7 out of 9 patients with a bifurcated graft. The 14 shrinking aneurysms showed a median length change of $-2$ mm (range $-8$ mm to $+4$ mm) after 6 months of follow-up. In 8/14 patients with 12 months of follow-up, the median length change was $-4$ mm (range $-6$ mm to $+10$ mm). All length changes were found not to be significant after analysis using the Wilcoxon rank test. Migration or endoleak was not encountered in this group of patients.

Discussion

Elongation of the aneurysmal abdominal aorta is often seen, during surgery as well as on CTA. This is probably a consequence of the increasing size of the aneurysm. In theory, one would expect a decrease of aortic length in shrinking aneurysms after endovascular AAA repair.

Broeders et al. reported on length measurements along the vertical body axis, and found no tendency
towards foreshortening or lengthening of the infra-
renal aorta after endovascular AAA repair in 100
patients. One of their recommendations regarding
length measurements of the infrarenal aorta was that
they might be best measured along the central lumen
line because morphologic changes occur in three di-
mensions. It has also been stated that measuring along
the vertical body axis may be a reliable method for
assessing length changes. Using either method, the
actually measured value is the distance between the
renal arteries and the aortic bifurcation, either along
the body axis or along the vessel axis.

If foreshortening does occur, it may follow two possible mechanisms. One is that only the elongated
segment between renal arteries and bifurcation de-
creases in length, with renal arteries and the aortic
bifurcation as fixed points in the human body. If so,
shrinking of the aneurysm will not affect the position
of these landmarks in the abdomen. Whatever method
is used, these length changes may not be encountered
(Fig. 3). Another possible mechanism of foreshortening
is that the complete aortoiliac segment decreases in
length; in this situation, length changes will
presumably be revealed by both methods (Fig. 4).

If a decrease in length does occur, either in the
aorta or in the aortoiliac segment, dislocation of rigid
prostheses is a probable complication, whereas non-
rigid endografts would presumably adapt to the new
anatomic situation.

In conclusion, we cannot make a firm statement
about length changes in this group of aneurysms after
endovascular repair and the best way to measure
them. However, foreshortening of the excluded aortic
segment in shrinking aneurysms with a flexible graft
in place does not appear to be a clinically significant
problem. It is our impression that morphologic
changes of the aorta may only be visualised by means
of 3-D segmentation of the excluded segment. The fact
that segmenting reliable 3-D reconstructions takes a
lot of time and effort raises the question of whether
this technique is worth performing in practice. In the
future, automatic 3-D reconstructions may facilitate
the follow-up of morphologic changes of the excluded
aneurysm.

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Accepted 22 February 1999