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Endograft apposition and infrarenal neck enlargement after endovascular aortic aneurysm repair

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Abstract

BACKGROUND: Sufficient apposition and oversizing of the endograft in the aortic neck are both essential for durable endovascular aneurysm repair (EVAR). These measures are however not regularly stated on post-EVAR computed tomography angiography (CTA) scan reports. In this study endograft apposition and neck enlargement (NE) after EVAR with an Endurant II(s) endograft were analyzed and associated with supra- and infrarenal aortic neck morphology.

METHODS: In 97 consecutive elective patients, the aortic neck morphology was measured on the pre-EVAR CTA scan on a 3mensio vascular workstation. The distance between the lowest renal artery and the proximal edge of the fabric (shortest fabric distance, SFD), and the shortest length of circumferential apposition between endograft and aortic wall (shortest apposition length, SAL) was determined on the early post-EVAR CTA scan. NE, defined as the aortic diameter change between pre- and post-EVAR CTA scan, was determined at eight levels: +40, +30, +20, +15, +10, 0, -5 and -10 mm relative to the lowest renal artery baseline. The aortic neck diameter and preoperative oversizing were correlated to NE with the Pearson correlation coefficient. The effective post-EVAR endograft oversizing is calculated from the nominal endograft diameter and the post-EVAR neck diameter where the endograft is circumferentially apposed.

RESULTS: The median time (interquartile range, IQR) between the EVAR procedure and the pre- and post-EVAR CTA scan was 40 (25, 71) days and 36 (30, 46) days, respectively. The Endurant II(s) endograft was deployed with a median (IQR) SFD of 1.0 (0.0, 3.0) mm. The SAL was <10 mm in 9% of patients and significantly influenced by the pre-EVAR aortic neck length (p=0.001), hostile neck shape (p=0.017), and maximum curvature at the suprarenal aorta (p=0.039). The median (interquartile range) SAL was 21.0 (15.0, 27.0) mm with a median (IQR) pre-EVAR infrarenal neck length of 23.5 (13.0, 34.8) mm. The median (IQR)
difference between the SAL and neck length was -5.0 (-12.0, 2.8) mm. Significant (p<.001) NE of 1.7 (0.9, 2.5) mm was observed 5 mm below the renal artery baseline, which resulted in an effective post-EVAR endograft oversizing <10% in 43% of the patients. No correlation was found between NE and aortic neck diameter or preoperative oversizing.

**CONCLUSIONS:** Circumferential apposition between an endograft and the infrarenal aortic neck, SAL, and NE can be derived from standard postoperative CT scans. These variables provide essential information about the post-procedural endograft and aortic neck morphology regardless of the preoperative measurements. Patients with SAL <10 mm or effective oversizing <10% due to NE may benefit from intensified follow-up, but clinical consequences of SAL and NE should be evaluated in future longitudinal studies with longer term follow-up.

**Keywords:** abdominal aortic aneurysm, endovascular aneurysm repair, 3D imaging, stents, aneurysm neck
Introduction

Endovascular aneurysm repair (EVAR) is the preferred treatment for most patients with an abdominal aortic aneurysm (AAA).\(^1\) Adequate apposition between the endograft fabric and the infrarenal aortic wall is essential for sustainable outcome.\(^2\) The absence of endoleak and ≥10 mm apposition length on the early (<90 days) post-EVAR computed tomography angiography (CTA) scan has been associated with a lower risk of adverse outcomes.\(^3,4\)

Apposition decrease during follow-up has been associated with a higher incidence of late type 1a endoleak and device migration.\(^2,5\)

Aortic neck dilatation is one of the causes of apposition loss during follow-up, and has been associated with type 1a endoleak, endograft migration, aneurysm sac repressurization and aortic rupture.\(^6,7\) Neck enlargement (NE) is the dilatation of the aortic neck that occurs immediately during implantation of the endograft and is influenced by the radial force of the endograft to the aortic wall.\(^8\) NE can be determined on the first post-EVAR CTA scan. NE is known to increase with larger preoperative aortic neck diameter (>28 mm), and treatment with a self-expanding endograft.\(^9,10\)

Endograft assessment on the early post-EVAR CTA scan may be beneficial to classify EVAR patients into low- or high-risk patients for future complications such as type 1a endoleak and device migration. Risk-stratified imaging surveillance has the potential to lower costs and decrease exposure to radiation and nephrotoxic contrast in low-risk patients, while high-risk patients could benefit from more frequent duplex or CTA image follow-up.\(^11\) Assessment of the endograft apposition within the infrarenal aortic neck, position of the fabric edge relative to the renal arteries and NE are however not included in current guidelines for EVAR surveillance.\(^12,13\)
In this study, endograft position, apposition and NE on the first post-EVAR CTA scan of a consecutive series of elective EVAR patients were analyzed and associated with supra- and infrarenal aortic neck morphology.

**Patients and methods**

A retrospective observational imaging study was performed to determine the aortic neck morphology on the pre-EVAR CTA scan and to assess the endograft position and apposition on the first post-EVAR CTA scan. Aortic diameters were measured in the supra-, juxta- and infrarenal neck on the pre- and post-EVAR CTA scan to determine NE. The patient files have been reviewed from the primary EVAR procedure until June 2021 for the occurrence of a type 1a endoleak any time during follow-up.

**Study population**

All patients who were treated with the Endurant II or IIs device (Medtronic Inc., Santa Rosa, CA, USA) by primary standard elective EVAR between January 2014 and December 2017 in the St. Antonius Hospital, Nieuwegein, the Netherlands and the Royal Oldham Hospital, Greater Manchester, United Kingdom were included in the study. Further inclusion criteria were availability of a CTA scan within 1 year pre-EVAR, and a CTA scan within 6 months post-EVAR. Exclusion criteria were treatment of a symptomatic or ruptured AAA in an urgent or emergency setting, complex endovascular procedures (e.g. chimney technique), the use of additional proximal fixation (e.g. endoanchors, proximal extension cuffs) or intentional targeting of the endograft main body lower than the lowermost (eventual accessory) renal artery. The study was approved by the institutional review board of both hospitals according
to the Declaration of Helsinki. Informed consent was waived according to institutional policy on retrospective research.

**Scan protocol**

In the St. Antonius Hospital and Royal Oldham hospital, images were acquired on a 256-slice CT scanner (Philips, Best, The Netherlands) and 640-slice CT scanner (Cannon, Acquilion One Genesis, Tokyo, Japan), respectively. Scan parameters of the St. Antonius Hospital CTA protocol were: 120 kV tube voltage, 180 mAs tube current time product, 0.9 mm pitch and 128×0.63 mm collimation. Per CTA scan, 100 mL (4 mL per second) diluted contrast (Xenetrix 300; Guerbet, Sulzbach, Germany) was administered intravenously in the arterial phase. Scan parameters of the Royal Oldham Hospital CTA protocol were 100 kV tube voltage with variable mAs upto a maximum of 600 mAs tube current time product, 0.8 mm pitch and 80×0.5 mm collimation. Per CTA scan, 100 mL (3.5 mL per second) contrast (Omnipaque 300; GE healthcare, Oslo, Norway) was administered intravenously in the arterial phase.

**Measurement protocol**

Measurements were performed on a 3mensio vascular workstation (Version 9.1 SP2, Pie Medical Imaging BV, Maastricht, The Netherlands) by an experienced researcher using a standardized and previously validated protocol. Position and apposition of the endograft in the aortic neck were assessed with Vascular Imaging Analysis (VIA) prototype software (Endovascular Diagnostics BV, Utrecht, the Netherlands).
First, the lumen of the aortoiliac trajectory was segmented and a center lumen line (centerline) of the abdominal aorta was created semi-automatically. The baseline for anatomic measurements was positioned at the inferior border of the orifice of the lowermost renal artery.

Reference markers were placed at the inferior border of the orifices of both left and right renal arteries, at the end of the aortic neck (at 10% diameter increase relative to the diameter at the lowest renal artery baseline) and on the post-EVAR CTA scan at the four radiopaque endomarkers that are located at 1.3 mm below the proximal edge of the Endurant II(s) endograft fabric. The segmentation of the aortic lumen, the centerline and the 3-dimensional (3D) coordinates of the reference markers were exported from 3mensio and loaded into VIA prototype software for assessment of the endograft position and apposition.

**Aortic anatomy and morphologic measures pre-EVAR**

Measurements in 3mensio included aortic neck baseline diameter, neck length, neck shape, presence of neck thrombus and calcification, supra- and infrarenal angulation and maximum aneurysm diameter. Distances were measured along the centerline. Aortic diameters were measured as the average of two orthogonal diameters from adventitia to adventitia. The aortic diameter was measured at eight levels relative to the lowest renal artery baseline: +40, +30, +20, +15, +10, 0, -5 and -10 mm (Figure 1).

Neck shape (straight, conical or dumbbell, reversed conical), neck thrombus (absent, mild, moderate) and calcification (absent, mild, moderate) were categorized according to the reporting standards.\(^{15}\) Subsequently, mild and moderate calcification and/or thrombus were defined as ‘present’. Reversed conical shape was merged with straight shape, and conical and dumbbell shape were defined as ‘hostile shape’. The curvature was calculated by VIA
prototype software and has been described in detail in previous publications.\textsuperscript{16, 17} The maximum value of curvature was calculated over the segments of the suprarenal aorta (between +50 mm and the baseline), the aortic neck (between the baseline and the end of the aortic neck) and the aneurysm sac (between the aortic neck and the aortic bifurcation).

Additional information including the endograft main body diameter, procedural details, and complications on the first post-EVAR CTA scan were retrieved from electronic patient records.

\textit{Endograft position and apposition}

The methodology for defining endograft position and apposition on post-EVAR CTA scans with the VIA prototype software has been described in detail and validated in previous publications.\textsuperscript{4, 14} The software calculates the following variables automatically from the 3D coordinates (Figure 2): 1) Shortest fabric distance (SFD) – shortest distance between the inferior border of the lowest renal artery orifice and the proximal edge of the fabric; 2) Contralateral fabric distance (CFD) – shortest distance between the highest renal artery orifice and the edge of the fabric; 3) Shortest apposition length (SAL) – shortest distance over the circumference of the aorta between the fabric edge and the end of circumferential apposition; 4) SAL/neck length ratio - the ratio of the SAL and neck length was used to determine the postoperative utilization of the preoperative available neck length. A ratio of 1 equals a neck length which was completely utilized, whereas a ratio <1 indicates inadequate utilization of the preoperative neck length. The SFD, CFD and SAL are corrected for the location of the endomarkers at 1.3 mm below the proximal edge of the endograft fabric, which has been verified by Medtronic as the exact position of the center of the endomarkers.
Neck enlargement and oversizing

Pre- and post-EVAR aortic diameters at the eight levels relative to the baseline were compared to define the NE after endograft implantation. Patients in whom the endograft was positioned too caudal to the baseline (SFD ≥5 mm) were excluded for this sub-analysis. These patients were not excluded for the assessment of the anatomical and endograft characteristics.

There were two endograft oversizing parameters defined: the planned pre-EVAR endograft oversizing (1) and the effective post-EVAR endograft oversizing (2). The planned endograft oversizing was defined as the intended oversizing based on the preoperative neck diameter and was calculated as:

\[
\left( \frac{\text{nominal endograft diameter}}{\text{preEVAR neck diameter}} - 1 \right) \times 100\% 
\] (1)

The effective endograft oversizing was calculated from the nominal endograft diameter and the postoperative neck diameter where the endograft is circumferentially apposed and was calculated as:

\[
\left( \frac{\text{nominal endograft diameter}}{\text{postEVAR neck diameter}} - 1 \right) \times 100\% 
\] (2)

Statistics

Data were analyzed using SPSS version 23 statistical software (IBM, Armonk, NY, USA). P-values with two tailed alpha <0.05 were considered statistically significant. Data was visually inspected; most variables were considered not-normally distributed. Therefore, medians (interquartile ranges) were provided. Differences in continuous variables between subgroups were tested with the nonparametric Mann-Whitney U test. Preoperative aortic neck characteristics have been tested for patients with SAL <10 and ≥10 mm, respectively. The
aortic neck diameter and preoperative oversizing were correlated to NE with the Pearson’s correlation coefficient, where \( r \geq 0.5 \) indicates a strong relationship.

**Results**

*Study population*

In total, 75 patients from the St. Antonius Hospital and 49 patients from the Royal Oldham Hospital met the inclusion criteria. Twenty-six out of these 124 patients were excluded from the analysis due to missing pre-EVAR CTA scan (n-2), pre-EVAR CTA scan >1 year (n-1), CTA scan not suitable for 3mensio analysis (e.g. unable to segment, too short scan window or only longitudinal coupes, n-11), adjunct proximal fixation applied (n-7), and endograft main body not targeted at the lowermost (accessory) renal artery (n-5).

A total of 97 patients were included in the current analysis. Ninety-three patients (96%) were treated within instructions for use (IFU) of the Endurant II(s) endograft, patients who were treated outside IFU had a neck length of 7, 8 or 9 mm. The median time between the pre- and post-EVAR CTA scan and the EVAR procedure was 40 (25, 71) days and 36 (30, 46) days, respectively. The median slice thicknesses of the studied CT scans were 1.0 (1.0, 2.0) mm and 2.0 (1.0, 2.0) mm for the pre-and post-EVAR CTA scans, respectively. Eight patients had a physician reported type 1a endoleak on the completion angiogram. The type 1a endoleak persisted on the 30-day CTA scan in one patient, this patient was excluded. The pre-EVAR infrarenal anatomic and morphologic measures of the included patients are presented in Table I.

*Endograft position and apposition*
The endograft dimensions calculated with the VIA prototype software at the first post-EVAR CTA are presented in Table II. In patients with an accessory renal artery (n=7) that was preserved during EVAR, this was considered the baseline. The median SFD (distance from baseline to the proximal edge of the fabric) was 1.0 (0.0, 3.0) mm and the distribution is shown in Figure 3. In one patient the main lowest renal artery was entirely obstructed by the fabric, and partial coverage (1-2 mm) of the main lowest renal artery occurred in 19 patients. None of these patients needed hemodialysis. The accessory right renal artery was covered in one patient which resulted in a lower pole infarct of the right kidney.

The median SAL (shortest distance from the proximal edge of the fabric to the level of the infrarenal neck where circumferential apposition was lost) was 21.0 (15.0, 27.0) mm with a median pre-EVAR infrarenal neck length of 23.5 (13.0, 34.8) mm as shown in Figure 4. Patients who were treated outside IFU had a median SAL of 16 (7, 24) mm due to endograft oversizing. The post-EVAR SAL and the pre-EVAR neck length differed significantly (p=0.004) with a median of -5.0 (-12.0, 2.8) mm (Figure 5), which means that the obtained SAL is significantly shorter than the pre-EVAR calculated neck length.

In nine patients the SAL at the early post-EVAR CTA was <10 mm, seven patients of them had a pre-EVAR neck length >10 mm. The patients with a SAL <10 mm were compared to 88 patients with a SAL ≥10 mm (Table III). Patients with a SAL <10 mm had significantly shorter aortic necks, more hostile neck shapes, and a larger maximum curvature in the suprarenal aorta.

*Neck enlargement and oversizing*

Nine patients were excluded for the analysis of NE due to a SFD >5 mm (n-7) or unknown nominal endograft diameters (n-2). Median diameter changes at the eight aortic levels are
shown in Figure 6. In the presence of circumferential calcification (n=1), the inner diameter over the entire length of the aorta was measured instead. Proximal to the bare stent (+20 to +40 mm), there was no significant diameter change observed between pre- and post-EVAR measurements. At the level of the bare stent (+10 mm), the median NE of 1.0 (0.4, 1.6) mm was significant (p=0.007). At the levels of the endograft fabric (-5 and -10 mm) the NE was also significantly (p=<0.001) with a median of 1.7 (0.9, 2.5) mm and 1.6 (1.0, 2.7) mm, respectively. No correlation was found between NE and aortic neck diameter or the amount of oversizing of the endograft. At the baseline, the correlation between NE and the aortic diameter was not significant (r = -0.08; p = 0.47), and between NE and endograft oversizing was also not significant (r = -0.12; p = 0.28).

The median planned oversizing of the endografts on the pre-EVAR measurements was 18% (12, 26), whereas the effective oversizing on the first post-EVAR CTA appeared to be 11% (5,18). In 43% of patients NE resulted in effective oversizing <10% at the early post-EVAR CTA.

Follow-up

The median duration of CTA or DUS surveillance was 3.4 (1.4, 5.1) years. A type 1a endoleak occurred in three patients during follow-up at 3.5 (#1), 5.5 (#2), and 6.3 (#3) years after the primary EVAR procedure, respectively. Baseline aortic neck characteristics of patient #1 were not hostile except for a conical shape. The initial SAL was 11 mm with effective endograft oversizing of 14%. Patient #2 also had a conical aortic neck with an initial SAL of 11 mm and effective oversizing of 6%. The baseline aortic neck criteria of patient #3 included a 90° suprarenal angulation combined with a diameter >29 mm. The postoperative SAL was 18 mm and the effective endograft oversizing 20%. In all three patients the type 1a
endoleak occurred during late follow-up and at that time the aortic diameter exceeded the nominal diameter of the endograft due to persistent neck dilation.

Discussion

In this retrospective study of 97 patients electively treated for infrarenal abdominal aortic aneurysms with an Endurant II(s) endograft, changes in aortic neck morphology and endograft apposition were determined on the early post-EVAR CTA with dedicated software. The Endurant II(s) endograft was deployed with high accuracy in the majority of this bi-center consecutive group of elective EVAR patients, regardless of underlying anatomy. Accurate determination of the endograft apposition and neck morphology at the first post-EVAR CT scan showed less than the recommended 10 mm apposition length in 9% of the patients. Moreover, NE at the infrarenal neck was significant, which resulted in less effective oversizing relative to the nominal endograft diameter. NE at the suprarenal neck was also significant, but not clinically relevant given the measurement error.\(^{18}\)

A properly oversized endograft (15-20%) provides radial force onto the aortic wall for sustainable infrarenal seal and fixation.\(^ {19}\) In only one patient a persistent type 1a endoleak was diagnosed on the post-EVAR CT-scan. This may increase NE because of continuous pressure on the aortic wall. However, due to the small number this cannot be proven in the current study design. The effective postoperative endograft oversizing in the current study group was reduced to <10% on the first post-EVAR CTA scan in 43% of the patients. As the aortic neck baseline diameter may change during the cardiac cycle and increases over time after EVAR, patients with effective oversizing of <10% due to NE may be of higher risk for migration or seal failures during follow-up, although this couldn’t be proven in the current analysis.\(^ {20-22}\)

In this study, the amount of NE was not associated to the pre-EVAR neck morphology like
nominal diameter, nor to the amount of endograft oversizing. As NE seems to be substantial and unpredictable it should be determined on the first post-EVAR CTA scan.

In our opinion it is recommended to determine all the endograft and aortic neck morphology characteristics as described in this study on the first post-EVAR CTA which can serve as a baseline for the parameters, and to compare eventual differences in follow-up imaging. Endograft apposition and NE are rarely set by default in standard CTA reports post-EVAR, but may be of influence on effective seal. It may be argued that patients with SAL <10 mm or insufficient effective post-EVAR endograft oversizing due to NE may benefit from stricter CT or duplex ultrasound surveillance than patients with sufficient apposition and stable necks. Follow-up imaging however remains necessary to evaluate eventual further decrease of SAL or persistent neck dilatation, which cannot be predicted on the first post-EVAR CTA. All three type 1a endoleaks in the studied patients occurred during late follow-up, which is in line with a recent publication of Oliveira et al. who concluded that persistent aortic neck dilatation is associated with type 1a endoleak.

A limitation of this study is its retrospective design. Second, the short pre-EVAR neck length of the patients who were treated outside IFU could however represent a small selection bias. Neck length in this study was measured at the pre-EVAR CT scan according to core lab definitions, where the neck ends at a 10% diameter increase compared to the level at the lowest renal artery. Third, in the current sub-analysis specific hostile anatomical measures, such as hostile neck shape, and greater suprarenal curvature were of influence on short-term SAL <10 mm. These results may be underpowered, because of the relatively small number of patients in the subgroup SAL <10 mm. In addition, the numbers however were too small to prove their clinical impact on type 1a endoleak and/or migration. Early detection of late complications based on apposition and NE measurements should be verified in longitudinal studies including a larger group of patients with long-term follow-up.
Another limitation is the fact that the VIA software is not CE/FDA marked yet, and replication of the endograft apposition and position calculations by other groups is therefore not possible. As an alternative to the VIA prototype software, apposition length can be measured over the centerline in a dedicated vascular workstation. This would however not represent the shortest length of apposition over the full circumference, which is important in angulated aortic necks were the endograft is tilted.

The study included specifically the Endurant endograft with suprarenal fixation, which is the first-choice endograft of the participating centers of this study. NE may be different for infrarenal sealing devices or other commercially available suprarenal fixating endografts.

**Conclusions**

Circumferential apposition between an endograft and the infrarenal aortic neck, SAL, and NE can be derived from standard postoperative CT scans. These variables provide essential information about the post-procedural endograft and aortic neck morphology regardless of the preoperative measurements. Patients with SAL <10 mm or effective oversizing <10% due to NE may benefit from intensified follow-up, but clinical consequences of SAL and NE should be evaluated in future longitudinal studies with longer term follow-up.
Figure 1: Schematic presentation of eight diameter measurement levels: +40, +30, +20, +15, and +10 mm proximal to the baseline, one at the baseline and -5, and -10 mm distal to the baseline. (A) Pre-endovascular aneurysm repair (EVAR). (B) Post-EVAR.
Figure 2: Postoperative infrarenal endograft position and apposition calculation in Vascular Image Analysis prototype software. (A) Aortic lumen segmentation with centerline, highest and lowest renal artery, and 3D coordinates of the 4 reference markers of the Endurant endograft from a postoperative CTA scan exported from 3mensio. (B) The shortest and contralateral fabric distance (SFD and CFD) between the lowest and highest renal arteries respectively and the edge of the fabric. (C) Circumferential apposition surface (white) of the endograft with the aortic wall and the shortest apposition length (SAL) between the fabric edge and the end of circumferential apposition.
Figure 3: Shortest fabric distance (SFD) distribution; Distribution of shortest fabric distances relative to the inferior border of the orifice of the lowest renal artery on the first postoperative CTA scan.
Figure 4: EVAR, endovascular aneurysm repair; Pre-EVAR infrarenal neck length and post-EVAR shortest apposition length
Figure 5: EVAR, endovascular aneurysm repair; Difference between post-EVAR shortest apposition length and pre-EVAR infrarenal neck length
Figure 6: Neck enlargement on the first computed tomography angiography (CTA) scan after endovascular aneurysm repair (EVAR).
Tables

Table I: Abdominal aortic anatomic and morphologic measures on the preoperative CTA scan

<table>
<thead>
<tr>
<th>Variable</th>
<th>All patients (n = 97)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic neck baseline diameter (mm)</td>
<td>24.3 (22.6, 25.7)</td>
</tr>
<tr>
<td>Neck length (mm)</td>
<td>23.5 (13.0, 34.8)</td>
</tr>
<tr>
<td>Neck shape&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Straight</td>
<td>59 (61)</td>
</tr>
<tr>
<td>Hostile</td>
<td>38 (39)</td>
</tr>
<tr>
<td>Thrombus&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>45 (46)</td>
</tr>
<tr>
<td>Present</td>
<td>52 (54)</td>
</tr>
<tr>
<td>Calcification&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>63 (65)</td>
</tr>
<tr>
<td>Present</td>
<td>34 (35)</td>
</tr>
<tr>
<td>Angulation (°)</td>
<td></td>
</tr>
<tr>
<td>Suprarenal</td>
<td>30 (19, 44)</td>
</tr>
<tr>
<td>Infrarenal</td>
<td>51 (38, 66)</td>
</tr>
<tr>
<td>Maximum curvature (m&lt;sup&gt;1&lt;/sup&gt;)</td>
<td></td>
</tr>
<tr>
<td>Suprarenal aorta</td>
<td>28 (15, 41)</td>
</tr>
<tr>
<td>Aortic neck</td>
<td>35 (27, 59)</td>
</tr>
<tr>
<td>Aneurysm sac</td>
<td>56 (44, 73)</td>
</tr>
<tr>
<td>Maximum aneurysm diameter (mm)</td>
<td>59.0 (55.0, 64.9)</td>
</tr>
<tr>
<td>Planned pre-EVAR endograft oversizing at baseline (%)</td>
<td>18 (12, 26)</td>
</tr>
</tbody>
</table>

EVAR, endovascular aneurysm repair;

<sup>a</sup>Continuous variables are shown as the median (interquartile range) and categorical variables as n (%)  

<sup>b</sup>Straight necks included reversed conical shapes, whereas hostile necks included conical and dumbbell shapes  

<sup>c</sup>Absent was defined as <25% coverage of the circumference, present as ≥25% coverage.
Table II: Endograft dimensions on the first postoperative CTA scan\textsuperscript{a}

<table>
<thead>
<tr>
<th>Variable</th>
<th>All patients (n = 97)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortest fabric distance (mm)</td>
<td>1.0 (0.0, 3.0)</td>
</tr>
<tr>
<td>Contralateral fabric distance (mm)</td>
<td>6.0 (3.0, 9.0)</td>
</tr>
<tr>
<td>Shortest apposition length (mm)</td>
<td>21.0 (15.0, 27.0)</td>
</tr>
<tr>
<td>SAL/neck length ratio</td>
<td>0.8 (0.6, 1.1)</td>
</tr>
<tr>
<td>Effective post-EVAR endograft oversizing at baseline (%)</td>
<td>11 (5, 18)</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Data are shown as the median (interquartile range)
Table III: Preoperative aortic neck morphology of 9 patients with SAL <10 mm vs 88 patients with SAL ≥10 mm at the early post-EVAR computed tomography angiography.

<table>
<thead>
<tr>
<th>Variable</th>
<th>SAL &lt;10 mm</th>
<th>SAL ≥10 mm</th>
<th>p-value</th>
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<tbody>
<tr>
<td></td>
<td>(n = 9)</td>
<td>(n = 88)</td>
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<tr>
<td>Shortest apposition length (mm)</td>
<td>8.7 (4.5, 9.6)</td>
<td>22.1 (15.0, 31.7)</td>
<td>.002</td>
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<tr>
<td>Aortic neck baseline diameter (mm)</td>
<td>25.5 (22.0, 26.0)</td>
<td>24.2 (22.5, 25.6)</td>
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<tr>
<td>Neck length (mm)</td>
<td>13 (10, 17)</td>
<td>25 (15, 35)</td>
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<td>Neck shapeᵇ</td>
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<tr>
<td>Straight</td>
<td>4 (44)</td>
<td>73 (83)</td>
<td>.017</td>
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<tr>
<td>Hostile</td>
<td>5 (56)</td>
<td>15 (17)</td>
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<tr>
<td>Thrombusᶜ</td>
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<td></td>
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</tr>
<tr>
<td>Absent</td>
<td>2 (22)</td>
<td>43 (49)</td>
<td>.170</td>
</tr>
<tr>
<td>Present</td>
<td>7 (78)</td>
<td>45 (51)</td>
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<tr>
<td>Calcificationᶜ</td>
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<tr>
<td>Absent</td>
<td>3 (33)</td>
<td>60 (68)</td>
<td>.062</td>
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<tr>
<td>Present</td>
<td>6 (67)</td>
<td>28 (32)</td>
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<td>Angulation (°)</td>
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<tr>
<td>Suprarenal</td>
<td>30 (26, 50)</td>
<td>31 (18, 43)</td>
<td>.538</td>
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<tr>
<td>Infrarenal</td>
<td>52 (39, 65)</td>
<td>49 (38, 66)</td>
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<td>Maximum curvature (m⁻¹)</td>
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<td>Suprarenal aorta</td>
<td>40 (33, 43)</td>
<td>25 (14, 40)</td>
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<td>Aortic neck</td>
<td>35 (35, 59)</td>
<td>35 (25, 60)</td>
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<td>Aneurysm sac</td>
<td>69 (43, 83)</td>
<td>56 (44, 72)</td>
<td>.490</td>
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<td>Maximum aneurysm diameter (mm)</td>
<td>60.5 (55.5, 76.2)</td>
<td>58.7 (55.0, 64.4)</td>
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SAL, shortest apposition length;

ᵃContinuous variables are shown as the median (interquartile ranges) and categorical variables as n (%) 

ᵇStraight included reversed conical necks and hostile included conical and dumbbell shaped necks.

ᶜAbsent was defined as <25% coverage of the circumference, present as ≥25% coverage.
References


Notes

Conflicts of interest
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Authors’ contribution
All authors read and approved the final version of the manuscript.

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<th>2 Manuscript Development</th>
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