Aortoiliac angulation and the need for secondary procedures to secure stent graft fixation: which angle is important?

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Background. The purpose of this study was to quantify the degree of aortoiliac tortuosity and determine the relationship between aortoiliac angulation and the need for a secondary procedure following endovascular repair.

Methods. Among 206 patients treated with the AneuRx stent graft, 3-year follow up data were available in 71 patients. Twenty eight patients without duplex and CT angiograms (CT angiography) on follow-up were excluded. The anatomy of the prooperative proximal aortic neck was evaluated using 3D-CT angiography reconstructed images in: a) Group I: 15 patients who required secondary procedures and b) Group II: 18 patients without any endovascular leak during follow up. The groups did not differ in age (72.9±6.1 versus 73.3±9.1) or aneurysm diameter (60.1±9.1 versus 60.5±10.1). In order to determine the aortoiliac tortuosity, we measured: a) the suprarenal aorta-infrarenal aortic neck angle: angle of the aorta at the level of the renal arteries, b) infrarenal aortic neck-aneurysm angle: angle of the aorta at the start of aneurysm, c) right iliac angle, d) left iliac angle, e) aortic neck length, f) aortic neck diameter.

Results. Computer-based measurements on 3D-CT angiography reconstructed images were: a) suprarenal aorta-infrarenal aortic neck angle: group I: (22.6±16.2), group II: (11.9±6.9), p<0.05; b) infrarenal aortic neck-aneurysm angle: group I: 17.6±12.4, group II: 18.8±9.4, p=NS; c) right iliac angle: group I: 22.9±12.6, group II: 20.4±9.5, p=NS; d) left iliac angle: group I: 22.4±10.5, group II: 19.1±12.2, p=NS; e) aortic neck length: group I: 18.9±5.3 mm, group II: 20.4±5.3 mm, p=NS; f) aortic neck diameter: group I: 24.1±1.0 mm, group II: 23.3±1.6, p=NS.

Conclusions. Aortoiliac angulation can be defined and quantified. In patients requiring secondary procedures, there is an increased angulation at the proximal aortic neck angle.

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Key words: Aorta, abdominal, radiography - Tomography, emission computed - Iliac artery, radiography.

Endovascular grafts offer the potential to alter treatment of patients with an abdominal aortic aneurysm (AAA) by reducing the perioperative risk of death, shortening the hospital stay, and decreasing recovery time compared to standard surgical repair.1 While the short- and medium-term results of endografting are encouraging, future guidelines for treatment will depend on the long-term results. Late complications, including migrations and late type I endovascular leaks, can occur during the follow-up surveillance and have been reported.2 The presence of type I leaks are important, as they represent a failure to exclude the aneurysm from the arterial circulation with a continuing risk of rupture.2 Late type I leaks are accompanied with a rapid increase in aneurysm diameter and require intervention.3 However, these leaks are often asymptomatic and untreated until the patient returns for scheduled surveillance, putting the patient at potential risk during this interval.

Morphologic assessment of abdominal aortic aneurysms is based on anatomic guidelines to determine anatomic eligibility for endovascular treatment with the AneuRx (Medtronic AVE, Santa Rosa, CA) stent graft.4 In this report we evaluated anatomic features of aortoiliac tortuosity using computerized measurements of spiral CT angiograms in 2 groups of patients (group I: patients that required secondary procedures to repair late type I leaks and group II: patients with no secondary procedures), after endovascular treatment for AAA with the AneuRx stent graft during a 5-year period and a minimum of 3-year follow-up. The aim was to define aortoiliac angulation and to determine if the need of secondary procedures after endovascular repair are related to the angles that define this angulation.

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Materials and methods

During a 5-year period (1996-2001), 206 patients with abdominal aortic aneurysms were treated with the AneuRx stent graft. All patients with non-ruptured infrarenal aortic or aortoiliac aneurysms were considered candidates for endovascular treatment if the aneurysm met one of following criteria: larger than 5 cm in diameter, between 4 and 5 cm in diameter with a documented increase of 0.5 cm in the previous 6 months or twice the diameter of the infrarenal aorta. Anatomic requirements included an infrarenal neck between 18 and 26 mm in diameter with a minimum length below the most inferior renal artery of 10 mm. Iliac arteries had to be of adequate size to allow access with a 21F delivery catheter on one side and a 16F on the contralateral side with a maximum distal iliac artery diameter of 16 mm. All measurements had been performed by 2 vascular surgeons and 1 radiologist based on preoperative spiral CT angiography.

Endografts were implanted under general anesthesia in the operating room with portable fluoroscopy equipment. After completion of the procedure, an angiogram was performed to evaluate graft position and the presence of endovascular leaks. Type I or III leaks were promptly treated in the operating room with additional endovascular techniques. Type II leaks and transgraft flow were observed and treated expectantly.

Postoperative follow up included clinical examination, plain abdominal radiographs, color duplex ultrasound and spiral CT angiography, at hospital discharge, 1-, 6-, and 12-months and then bi-annually. Of 206 patients studied, long term (over 3 years) follow up was available in 71 patients. Of these 71 patients, 28 were excluded as a result of incomplete imaging including duplex scanning and CT angiography on all follow-up visits. Thus, 15 patients who required a secondary procedure (including placement of proximal or distal extender cuffs to secure stent graft fixation, treatment of late type I endovascular leaks and surgical conversions) (Table I) were compared to 18 patients without any leak or graft related complications at any time (group II). Mean follow-up in these patients was 39.5±2.7 months. Groups I and II were similar in age (72.9±6.1 versus 73.3±9.1), aneurysm maximum diameter (60.1±9.1 versus 60.5±10.1) and gender (86% male versus 94% males, respectively).

<table>
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<th>Presence of type I</th>
<th>Secondary procedure</th>
<th>Time of secondary procedure (months)</th>
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<tr>
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<td>Proximal extender cuff</td>
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Methods and definitions

All computer-based measurements were made at Stanford’s 3D imaging laboratory and were based on construction of the median luminal centerline (MLC) (Figure 1). After extraction of the contrast enhanced flow channel from spiral CT angiographic data, we manually selected the limits of calculation. This was done by scrolling on the computed loaded CT images and clicking on the anatomic points that defined the angle or the length to be measured. Following the definition of these points, the MLC was computed. Orthogonal cross sections were created at 1 mm intervals. Evaluation of aortoiliac tortuosity was measured as: a) Suprarenal aorta-infrarenal aortic neck angle. b) Infrarenal aortic neck-aneurysm angle. c) Right iliac angle, d) Left iliac angle. e) Aortic neck length. f) Aortic neck diameter.

Aortic neck angulation.—Aortic neck angulation was defined at 2 points: the proximal and the distal ends of the infrarenal aortic neck. The proximal aortic neck angle was defined as the angle between the axis of the suprarenal aorta and the axis of the aortic neck (Figure 2). Both axes were defined as the lines between the 2 points. The axis of the suprarenal aorta was defined as: the straight line between the median luminal centerline point (MLCP) of the aorta at the level of the orifice of the lower renal artery and that of the aorta at the level of the orifice of the superior mesenteric artery. The axis of the aortic neck was defined as the straight
angle was defined as the angle between the axis of the aortic neck (already described) and the axis of the lumen of the aneurysm (Figure 2). The axis of the lumen of the aneurysm was defined as the straight line between the MLCP at the start of the aneurysm and that at the end. When the lumen of the aneurysm was not straight, the first 2.0 cm at its proximal end were used to determine its axis.

**Angles at the iliac arteries.**—The angle between the axis of each iliac artery (c: right, d: left) and the axis of the lumen of the aneurysm (Figure 2). The axis of each iliac artery was defined as the straight line between the MLCP at the level of aortic bifurcation and that of each iliac artery at 2.0 cm distally. The axis of the aneurysm is described earlier, but when its lumen was not straight, the last 2 cm at its distal end were used to determine the axis.

**Aortic neck length and aortic neck diameter.**—e) The aortic neck length was measured between the MLCP at the level of the lower renal artery and that at the level of the start of the aneurysm and f) the aortic neck diameter was measured as the maximum of the diameters of the orthonormal cross section of the aorta at the level of the lower renal artery.

All patients were entered prospectively into a comprehensive database. The above measurements were performed in a retrospective analysis of the preoperative CT angiograms in order to objectively quantify aortoiliac tortuosity. The measurements were performed by investigators who were unaware of the identity and outcome of each patient in order to conduct an unbiased assessment.

Results are reported as the mean ± standard deviation. Comparison between groups was analyzed using Student’s “t”-test. A p-value less than 0.05 was considered significant.

**Results**

Of 206 patients undergoing endovascular treatment, we identified 15 patients with greater than 3 year follow-up who required secondary procedures. Secondary procedures were performed to increase proximal or distal fixation (n=5), treat late endovascular leaks (n=4), treat migration (n=3), and type II endoleaks with increased aneurysm diameter (n=3). Of 206 patients undergoing endo-
vascular repair the presence of a new onset type I endovascular leaks occurred in 4 (1.9%). In 3 cases the leak was associated with the proximal fixation of the graft and in 1 case it was associated with the distal fixation of the graft. All patients in group I required a secondary procedure with 14 patients treated with endovascular extender cuff placement and 1 patient converted to open surgical repair. Secondary procedures were performed at 1.4 to 37.6 months after endovascular graft placement (mean 20.5±12.2 months). No patient in group II (n=18) had an endovascular leak or required a secondary procedure.

Aortic neck angulation.—Patients in group I had a twofold greater proximal aortic neck angle (suprarenal aorta-infrarenal aortic neck angle) compared to patients of group II (22.6±16.2 versus 11.9±6.9, p=0.019). The variability of angles was greater in group I (min: 5.7, max: 61.9) compared to group II (min: 2.8, max: 25.1). Five of 15 patients (33%) in group I had an angle greater than 25 degrees compared to only one patient in group II (5%) who had an angle of 25.1 degrees. However, there was no difference in the distal aortic neck angle (infrarenal aortic neck-aneurysm angle) between the 2 groups (group I: 17.6±12.4, group II: 18.8±9.4, p=0.756). The distal aortic neck angle was less than 30 degrees in 14/15 patients in group I and in 17/18 patients of group II.

Angles at the iliac arteries.—There was no difference in the right iliaca angle (group I: 22.4±10.5, group II: 19.1±6.9, p=0.518) or the left iliac angle (group I: 22.9±12.6, group II: 20.4±9.5, p=0.428).

Aortic neck length and aortic neck diameter.—Aortic neck length was not different between groups (group I: 18.9±5.3, group II: 20.4±5.3,
Additionally, aortic neck diameter was not different between the 2 groups (group I: 24.1±1.0, group II: 23.3±2.4, p=0.105).

All measurements and comparisons between the 2 groups are presented in Tables II, III and IV.

Discussion and conclusions

Endovascular aneurysm repair has had a dramatic effect in the treatment of infrarenal abdominal aortic aneurysm repair. Short- and medium-term results have been encouraging. However, longer-term data regarding endovascular repair is scant, and recently there have been reports of adverse events of rupture, migrations, and late onset endovascular leaks especially in patients with increased angulation of the proximal aortic neck. While this observation may be true, the definition and quantification of neck angulation is poorly defined.

Currently, the literature contains a number of recommendations regarding angulation and patient selection for endovascular repair of abdominal aortic aneurysms. The presence of greater than 60 degrees neck angulation is often regarded as a contraindication for endovascular repair. However, this angle is poorly defined. Albertini et al. showed that patients with migration or type I endoleak had a greater aortic neck angulation compared to those without migration or type I endoleak. In the Eurostar trial, among 2146 endovascular AAA repairs, 3.3% of patients were noted to have a proximal type I leak unrelated to aortic neck angle. Recently, Sternberg et al. published their results on the relation of aortic neck angulation and adverse outcomes after endovascular repair. They demonstrated that a distal aortic neck angle greater than 40 degrees was a significant predictor for adverse outcomes. Furthermore, they demonstrated that the proximal neck angle was related to adverse outcome following endovascular AAA repair, but felt this angle had no significant role for devices with infrarenal fixation. Petrik et al. found no significant difference in neck angulation between patients with type I leak and those without. However, no patient with a greater than 60 degree distal aortic neck angle was treated in that study as well as in our own study.

The purpose of this study was to define aortoiliac angulation and determine whether it plays a role in the need for secondary procedures. While angulation and tortuosity is easy to understand conceptually it is difficult to define and measure quantitatively. We defined aortoiliac tortuosity using 4 separate angles and showed that the proximal aortic neck angulation is one parameter that appears related to secondary procedures. This angle was twofold greater (23 degrees) in patients who required secondary interventions for leakage or to improve fixation than in patients who never had a leak or required secondary interventions (12 degrees). Certainly this study did not define a threshold size for the proximal aortic neck angle as a guideline for prevention of complications. However, the increased angulation of the proximal aortic neck angle was accompanied by the need for secondary procedures to treat complications.

We used spiral CT angiography to evaluate the morphologic characteristics of the aneurysm and iliac arteries. This technique allows 3D reconstruction of cross-sectional images and objective computational analysis of angulation. The only subjective aspect of this method of measurement is the selection of the points on the median lumen centerline that determine the position of the proximal and the distal limits of the aortic neck. This was done on pre-operative CT scans by a vascular surgeon trained in endovascular techniques but blinded to patient outcome, as well as whether a secondary procedure was required at any time during follow-up.

We quantified aortic neck tortuosity by measuring 2 different angles, the neck length and the neck diameter. Aortic neck angulation was quantified by measuring the angulation at the proximal and distal end of the infrarenal aortic neck. The aortic neck was assumed to be a true cylinder in order to simplify calculations. The actual variation in diameter of the aortic neck was small ranging from 0.4 mm. By assuming the neck to be a cylinder, we were able to divide the infrarenal aorta from the level of the superior mesenteric artery (SMA) origin to the aortic bifurcation into 3 segments. The first segment is the aorta above the renal arteries, the second is the cylindrical neck, and the third segment the aneurysm. Between these 3 segments were the 2 angles used to determine aortic neck tortuosity.

In order to complete the anatomic measurements of the aortic neck, for the aortic neck length we measured the length of the MLC from the lower
renal artery to the start of the aneurysm, and for
the aortic neck diameter we measured the maxi-
mum diameter of the orthonormal cross section
just below the lower renal artery, as others.11, 12

The proximal aortic neck angle appears to be
related to the need for secondary procedures. In
this study, we defined a method to define and
measure the proximal and the distal aortic neck
angles. Both of them have to be measured as they
contribute to a secure fixation during time. In
those patients who required a secondary proce-
dure there was a twofold greater angulation of
the proximal neck compared to those who did not.

Iliac tortuosity in this study was estimated by
measuring the angles of the right and left com-
mon iliac arteries at their junction with the aorta.
This, however, does not fully describe the tortu-
osity of the iliac arteries since they can be vari-
ably tortuous throughout their length. However,
a detailed analysis of iliac tortuosity is beyond the
scope of this study. Others have suggested that
the proximal iliac angles may be important param-
eters of aortoiliac tortuosity that may play a role
in postoperative clinical outcome.8 With tech-
niques currently available, it may be difficult to
define iliac angles in a way so as to eliminate inter-
observer variability. Angulation may change along
the length of the iliac arteries and may be differ-
en in the common and external iliac arteries.

The long-term follow up of these patients encom-
passes a period of time when both the stiff and
the flexible AneuRx grafts were implanted. It has
previously been demonstrated that patients with
the stiff bifurcated device had an increased risk
of secondary procedures.13 Therefore, whether it
was the increased angle of the proximal neck or
the stiffness of the graft that resulted in the need
for secondary procedures will need to be further
studied. This will require longer follow up and
evaluation of those patients who had only the flex-
ible bifurcation graft. Furthermore, the small num-
ber of patients in this study may have led to the
presence of a type II statistical error. However,
this study suggests that proximal neck angle is
important and is related to the need for sec-
ondary procedures. These patients can be continued
to be treated if they are prohibitive risks, but will
require a more rigorous postoperative surveil-
lance. Improvements in technique and device
design may limit these difficulties in the future.

Improvements in device design have included
the increased flexibility of the graft. Improved
imaging and placement of the grafts with appro-
priate angles may also improve their initial place-
ment and reduce the need for secondary proce-
dures in patients with angled necks.

In conclusion, we have defined aortoiliac angu-
luation. There appears to be a relationship of pro-
ximal aortic angulation and the requirement for
secondary procedures.

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