From the Canadian Society for Vascular Surgery

Explaining endograft shortening during endovascular repair of abdominal aortic aneurysms in severe aortoiliac tortuosity

Kevin Lee, MD, Sajjid Hossain, MD, Maher Sabalbal, MD, Luc Dubois, MD, MSc, Audra Duncan, MD, Guy DeRose, MD, *and* Adam H. Power, MD, MPhil (Cantab), *London, Ontario, Canada*

ABSTRACT

Objective: During endovascular aneurysm repair (EVAR), severely tortuous aortoiliac anatomy can alter the deployment and conformability of the endograft. The accuracy of treatment length measurements is commonly recognized to be affected by severe tortuosity. However, the exact mechanism of the postintervention length discrepancy is poorly understood. The objective of this study was to determine the mechanism of how severe aortoiliac tortuosity influences the endograft and native aorta during EVAR and its impact on the distal sealing zone.

Methods: A prospectively collected vascular surgery database was retrospectively reviewed at a university-affiliated medical center to identify the study patients. Patients who underwent EVAR with the main body device deployed on the side of the severely tortuous iliac artery were selected. Severe aortoiliac tortuosity was defined as having either aortoiliac or common iliac angulation <90 degrees.

Results: A total of 469 patients between 2008 and 2014 underwent EVAR using the Endurant endograft (Medtronic Cardiovascular, Santa Rosa, Calif). Severe aortoiliac tortuosity was observed in 36% of patients; 17 patients were found to have the main body placed on the side of severe tortuosity without an extension limb. There was a significant shortening of the main body endograft length from 169 mm before EVAR to 147 mm after EVAR ($P < .001$). The treatment length of the main body, measured from the lowest renal artery to hypogastric artery, also significantly shortened from 179 mm to 170 mm ($P < .001$). There was a decrease in tortuosity at the most angulated portion of the aneurysm after EVAR, in which angulation changed from 86 degrees to 114 degrees ($P < .001$). There was no significant change in treatment length ($P = .859$) and angulation ($P = .195$) on the nontortuous side of the aneurysm.

Conclusions: The study observed significant shortening of endografts and native aorta and iliac arteries in patients with severe aortoiliac tortuosity during EVAR. This shortening effect can have a negative impact on the distal sealing zone during EVAR. A longer main body or an extension limb should be considered when one is faced with severely tortuous aneurysms. (J Vasc Surg 2016;■:1-8.)

Advanced preoperative imaging and three-dimensional (3D) reconstruction software have allowed accurate anatomic measurements for endovascular aneurysm repair (EVAR). Center lumen line measurement using 3D software can accurately predict the treatment length (from the lowest renal artery to the hypogastric artery) that is within 5 mm of actual length.[1-3] However, the accuracy of treatment length measurement decreases with an increase in aneurysm tortuosity.[1-3] Increased tortuosity of aneurysms has also been shown to increase graft-related complications, such as type I endoleak, migration, limb thrombosis, and kinking.[4-7] The treatment length shortening in tortuous anatomy is a commonly recognized phenomenon; a previous study by Lee et al demonstrated shortening by >15 mm after EVAR in aneurysms with severe aortoiliac tortuosity.[3] Whether the native aneurysm is shortened alone or in conjunction with or without change in endograft length is unclear. If the aneurysm is shortened alone, there is a risk of hypogastric artery coverage because of overestimation of the endograft length. On the other hand, if the endograft also is shortened, it may lead to an inadequate length for complete distal sealing. The objective of this study was to better understand the mechanism of treatment length shortening in aneurysms with severe aortoiliac tortuosity and its effect on endograft length.

METHODS

A retrospective review of a prospectively collected database was performed to identify all consecutive patients who underwent elective EVAR for infrarenal abdominal aortic aneurysm using Endurant I or II endograft (Medtronic Cardiovascular, Santa Rosa, Calif) from 2008 to 2014. The study did not anticipate a difference in endograft-specific conformability between Endurant I and Endurant II, given identical designs with nitinol

From the Division of Vascular Surgery, Western University.

Author conflict of interest: none.

Presented at the Thirty-seventh Annual Meeting of the Canadian Society for Vascular Surgery, Victoria, British Columbia, September 25-26, 2015.

Correspondence: Sajjid Hossain, MD, 800 Commissioners Rd E, Rm E2-121, London, Ontario N6A 5W9, Canada (e-mail: shossa27@uwo.ca).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

0741-5214

http://dx.doi.org/10.1016/j.jvs.2016.09.041

stents in both models. The Society for Vascular Surgery standard reporting practices were used for determining iliac and aortic angles.[8] Severe aortoiliac tortuosity was defined as having either the aortic bifurcation angle or the common iliac artery (CIA) angle <90 degrees. Because the Endurant endograft can be used as a two-piece system, the study isolated patients with or without the use of extension on the main body side. An iliac extension to the main endograft would preclude accurate measurement of the total endograft length because of the overlap between the endografts.

Preoperative and postoperative contrast-enhanced computed tomography (CT) images were processed in Digital Imaging and Communications in Medicine format and imported to Aquarius 3D Workstation (TeraRecon, San Mateo, Calif). Subsequently, all anatomic measurements were performed using the 3D reconstruction images and automatically generated center lumen line. When the automatic generation of center lumen line led to significant errors at certain points, these points were manually edited. The treatment length was measured from the lowest renal artery to origin of hypogastric artery. All the endografts were then preselected by the operating surgeon. All EVAR procedures were performed by vascular surgeons, and digital subtraction angiography was used intraoperatively to confirm patency of iliac vessels and to exclude the presence of endoleak. The positions of the renal and internal iliac arteries were noted by roadmapping after the initial digital subtraction angiography run. The study did not use a marker catheter during EVAR to measure treatment length because it has been shown to be less accurate than using the centerline measurements.[9,10] In fact, marker catheters tend to travel along the lesser curve of tortuosity and take a shorter path compared with the endograft device.[11]

All the anatomic measurements for this study were performed by one author (K.L.). Patients underwent postoperative CT imaging follow-up with intravenous administration of contrast material at 1 month, at 6 months, and annually thereafter. Post-EVAR treatment lengths were measured at the first postoperative CT scan.

Information relating to patient demographics, including comorbidities, secondary procedures, and postoperative complications and mortality, was gathered from hospital and clinic charts. Given the retrospective nature of our study, patient consent was not obtained as many were deceased and lost to follow-up. The study was submitted for ethics and approved by the local Institutional Review Board.

Statistical analysis for categorical variables was carried out with Fisher exact test and continuous variables were compared using *t*-tests, with a $P < .05$ indicating statistical significance. All statistical tests were performed with IBM SPSS Statistics (version 20.0; IBM Corp, Armonk, NY).

ARTICLE HIGHLIGHTS

- **Significance:** The mechanism of endograft shortening after endovascular aneurysm repair in patients with severe aortoiliac tortuosity is not well known.
- **Type of Research:** Retrospective analysis of prospectively collected single-center registry data
- **Take Home Message:** In 17 patients with severe aortoiliac tortuosity, the length of the main body endograft shortened by 2.2 cm after endovascular aneurysm repair ($P = .001$). The maximum angulation of the tortuosity lessened by 28 degrees ($P < .01$).
- **Recommendation:** The authors propose that severe aortoiliac tortuosity shortens the endograft by overlapping of fabric between the metal struts and suggest using a main body or limb that is 5 to 10 mm longer than measured preoperatively.
- **Strength of Recommendation:** 2. Weak
- **Level of Evidence:** C. Low or very low

RESULTS

As shown in Fig 1, we identified 469 patients who underwent EVAR with the Endurant graft, and 171 patients (37%) were found to have severe aortoiliac tortuosity. After exclusion of patients who had the main body placed in a nontortuous side and those with iliac extension on the main body side, a total of 28 patients were identified. The study then further excluded 11 patients for the lack of preoperative contrast-enhanced CT (4), for no follow-up CT (3), or with ballerina configuration (4). Ballerina configuration was defined as crossing of the limbs of the bifurcated abdominal aortic endograft.

Ballerina configuration grafts were excluded as all preoperative measurements were based on non-ballerina configuration, and changing the orientation of the short limb leads to length that is unaccounted for in the aneurysm sac. Fig 2 shows an example of severe tortuosity at the aortic bifurcation and CIA.

Most of the study patients were male (94%) with a mean age of 75 ± 6 years (Table I). The mean abdominal aortic aneurysm diameter was 56 ± 4 mm (Table II). The majority of patients (88%) had severe angulation in the CIA and the rest had severe tortuosity at the aortic bifurcation. There was only one patient who could have achieved a minimum seal in the CIA proximal to the area of severe tortuosity with a landing zone of 26.6 mm. That patient had a total left CIA length of 57 mm. The mean distance from the iliac bifurcation to the area of tortuosity was 13 ± 6 mm. The mean angulation for severe tortuosity was 86 ± 7 degrees and 87 ± 6 degrees in the CIA and aortic bifurcation, respectively.

A summarized comparison of the endograft length, treatment length, and angulation before and after EVAR is presented in Table III. The mean length of the