

Changes in suprarenal and infrarenal aortic angles after endovascular aneurysm repair

Ho Kyun Lee, Sang Young Chung, Jea Kyu Kim¹, Sung Hee Yoo², Soo Jin Na Choi

Departments of Surgery and ¹Radiology, Chonnam National University Medical School, Gwangju, ²Chonnam National University Collage of Nursing, Gwangju, Korea

Purpose: We investigated whether suprarenal and infrarenal aortic angles change after the endovascular aneurysm repair (EVAR) procedure and during follow-up, and investigated the correlation between infrarenal aortic angle after EVAR and type Ia endoleaks.

Methods: Data collected on 70 EVAR procedures for a fusiform infrarenal aortic aneurysm performed between May 2006 and December 2012 were supplemented with a retrospective review of charts and radiographs.

Results: The greater the preoperative infrarenal aortic angle, the greater the suprarenal aortic angle ($r = 0.72$, $P < 0.001$). The infrarenal aortic angle decreased after the EVAR procedure and continued to decrease slowly thereafter (all $P < 0.001$). Suprarenal aortic angle decreased immediately after the EVAR procedure and continued to decrease during the first month ($P < 0.001$). No differences in angulation were observed based on stent graft type. Type Ia endoleaks occurred with significantly greater incidence in patients with a larger post EVAR infrarenal angle ($P = 0.037$).

Conclusion: The infrarenal aortic angle decreased significantly immediately after the EVAR procedure and continued to decrease slowly thereafter. Suprarenal aortic angle decreased immediately after the EVAR procedure and continued to decrease during the first month. We found a correlation between infrarenal and suprarenal aortic angle. Type Ia endoleaks occurred with greater incidence in patients with a larger infrarenal angle immediately after EVAR.

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Key Words: Aortic aneurysm, Endovascular procedures, Endoleak

INTRODUCTION

Endovascular repair compares favorably to open aneurysm repair with a significant reduction in morbidity, reduced blood loss, shorter hospital stay, and earlier return to function [1]. Thus, endovascular aneurysm repair (EVAR) has become the preferred treatment for abdominal aortic aneurysms (AAAs) and as an alternate treatment for traditional open aneurysm repair. However, EAVR results in complications, such as endoleaks and stent migration. Hence, EVAR requires long-term follow-up and frequent imaging studies [2].

Aneurysm neck anatomy is considered a major anatomical

limitation. Neck angle, neck length, neck diameter, and thrombus or calcification lining the aneurysm neck are determinants of a successful procedure. In particular, neck angle is possibly the most important anatomical factor of the aneurysm neck [3,4]. In generally, an aortic neck angle $>60^\circ$ is limited in the instructions for use of most commercially available stent grafts. These limitations resolve as the operator gains experience with the many new devices.

The influence of EVAR on aneurysm morphology is changing. During or post-EVAR, it is possible that an angulated aneurysm neck can be straightened under the influence of the guidewire, the delivery system, and the stent-graft, and the aneurysm sac

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Corresponding Author: Soo Jin Na Choi

Department of Surgery, Chonnam National University Hospital, Chonnam National University Medical School, 42 Jebong-ro, Dong-gu, Gwangju 501-757, Korea

Tel: +82-62-220-6456, Fax: +82-62-227-1635

E-mail: choisjn@chonnam.ac.kr

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shrinks as a result [5]. Nevertheless, it is rare for the change in suprarenal aortic angle to result in an endoleak after EVAR.

The aim of this study was to investigate the change in suprarenal and infrarenal aortic angles after the EVAR procedure and during follow-up, as well as investigate the correlation between infrarenal aortic angle after EVAR and the incidence of type Ia endoleaks.

METHODS

Patients

A total of 177 patients underwent EVAR for a fusiform infrarenal AAA between March 2006 and December 2012 at Chonnam National University Hospital. Of these, 70 patients were followed up for at least 1 year and underwent an abdominal computed tomography (CT) scan according to the follow-up protocol (within 1 week and at 1, 3, 6, and 12 months after EVAR). These 70 patients were included in this retrospective review study.

Pre-EVAR evaluation

A pretreatment angio CT scan was performed with SOMATOM Sensation 64 (Siemens Medical Systems, Forchheim, Germany), a SOMATOM Definition Flash (Siemens Medical Systems) or a LightSpeed VCT instrument (GE Healthcare, Milwaukee, WI, USA).

We measured maximum aneurysm diameter and neck as well as iliac and common femoral maximal diameter in all axial slices. We measured aneurysm neck length and the iliac and common femoral artery in a volume-rendered three dimensional (3D) image of the aneurysm reconstructed with a Maroview image viewer (Marotech, Inc., Seoul, Korea). A center lumen line (CLL) of the aorta was made, and a 3D aortic reconstruction was obtained to measure the suprarenal and infrarenal aortic angles. The 3D reconstruction was turned 360° perpendicular to the CLL in the middle of the flexure. The sharpest angle of the CLL was considered the true angle of the aortic axis [6].

EVAR procedure

The procedures were performed in an angiography room with an Allura Xper FD20 instrument (Philips Medical Systems, Amsterdam, the Netherlands). All patients underwent ultrasonography-guided percutaneous femoral access with local anesthesia.

A pig-tail catheter (Super Torque MB, Cordis, Tipperary, Ireland), placed above the abdominal aneurysm, was used for digital subtraction angiography to identify aneurysm morphology. If the AAA extended into the iliac artery, internal iliac artery embolization was performed using an Interlock coil (Boston Scientific, Tipperary, Ireland) or an Amplatzer

vascular plug (AGA Medical, Golden Valley, MN, USA). The main body and contralateral limb were deployed at a suitable place, and angiography was conducted to detect an endoleak or stent migration. The final angiography confirmed successful exclusion of an aneurysm, femoral access was removed, and Perclose Proglide was applied (Abbott, Green Oaks, IL, USA). When bleeding was absent, additional manual compression with gel pad compression was applied for 15 minutes and absolute bed rest was instructed for 8 hours.

Post-EVAR evaluation and follow-up

The follow-up protocol required a patient assessment by contrast-enhanced abdominal CT scan after the EVAR at 1 week and at 1, 3, 6, and 12 months.

The CLL of the aorta was made to measure suprarenal and infrarenal aortic angles, and a 3D aortic reconstruction was obtained. The 3D reconstruction was turned 360° perpendicular to the CLL in the middle of the flexure. We defined the supra- and infrarenal angles immediately after EVAR as the measured angles on CT scan at 1 week.

Endoleaks were defined as persistent perfusion of the aneurysmal sac after EVAR as detected by CT scan or final angiography.

There are five different types of endoleaks, which are classified based on the source vessels, and cause inflow into the aneurysm sac. Type I endoleaks are leaks at the proximal (Ia) or distal (Ib) attachment sites. Type II endoleaks are caused by retrograde flow through collateral vessels into the aneurysm sac. Type III endoleaks are holes, defects, or separations in the stent-graft material. Type IV endoleaks represent porous graft walls. Type V endoleaks are due to endotension with an enlarging aneurysm sac without a visible endoleak [7].

We defined graft migration as stent movement ≥ 5 mm. Technical success required the successful introduction and deployment of the device in the absence of surgical conversion or graft limb obstruction without an unplanned endovascular or surgical procedure. Clinical success was defined as no mortality during the 30 days after the procedure, aneurysm dilatation (>5 mm), infection of stent graft or thrombosis into graft, or aneurysmal rupture.

Data analysis

General and disease specific characteristics are presented as numbers (%) or means \pm standard deviations (SD). The Kolmogorov-Smirnov test was used to test for normality. The Friedman test was used to assess the significance of serial changes in the infrarenal and suprarenal aortic angles. The Wilcoxon signed-rank test was used to compare two consecutive periods. Spearman rho test was used to identify the correlation between the infrarenal and suprarenal aortic angles. Repeated-measures analysis of variance was used to compare serial

changes in the infrarenal aortic angle according to stent type, and the P-value was presented by Huynh-Feldt correction after Mauchly sphericity test. The relationship between infrarenal aortic angle and endoleaks was examined by the Mann-Whitney test and the independent t-test. All statistical analyses were performed with IBM SPSS Statistics ver. 20.0 (IBM Co., Armonk, NY, USA). A P-value <0.05 was considered significant.

RESULTS

The mean ± SD age of the study population was 69.0 ± 73 years (range, 45–82 years). The 70 patients consisted of five females (7.1%) and 65 males (92.9%). Of these, 20 were treated with Zenith (Cook, Bloomington, IN, USA), 30 with Excluder (W. L. Gore and Associates, Flagstaff, AZ, USA), 17 with Endurant (Medtronic Vascular, Santa Rosa, CA, USA), and three with SEAL stents (S&G Biotech, Seongnam, Korea).

No patient experienced stent graft migration, technical or clinical failure, or EVAR-related death.

An endoleak of any type was diagnosed in 34 patients (48.6%). A type Ia endoleak was diagnosed in 10 patients (14.3%), a type Ib endoleak in two patients (2.8%), and a type II endoleak in 22 patients (31.4%) (Table 1).

The type Ia endoleaks were detected on postoperative CT in the 10 patients after 1 week. The endoleak disappeared in nine of these patients, and one patient was treated 1 month later with a secondary intervention.

The type Ib endoleak in one patient disappeared, and the other patient was treated 2 weeks later with a secondary intervention. Three of the 22 patients with type II endoleaks underwent secondary interventions due to aneurismal dilatation.

We analyzed the relationship between infrarenal and suprarenal aortic angles; the greater the preoperative infrarenal aortic angle, the greater the suprarenal aortic angle ($r = 0.72$, $P < 0.001$).

Table 1. Patient general and disease characteristics (n = 70)

Characteristic	Value
Age (yr)	69.0 ± 7.3
Male sex	65 (92.9)
Body mass index (kg/m ²)	23.6 ± 7.5
Hypertension	39 (55.7)
Diabetes	10 (14.3)
Coronary arterial disease	13 (18.6)
Hyperlipidemia	11 (15.7)
Smoking	18 (25.7)
Antiplatelet medication	18 (25.7)
Neck length (mm)	39.1 ± 16.5
Neck diameter (mm)	24.2 ± 5.0
Abdomen aneurysm diameter (mm)	57.7 ± 13.8
Stent graft	
Seal	3 (4.3)
Zenith	20 (28.6)
Excluder	30 (42.9)
Endurant	17 (24.3)
Endoleak	34 (48.6)
Type Ia	10 (14.3)
Type Ib	2 (2.8)
Type II	22 (31.4)
Stent graft migration	0 (0)
EVAR related mortality	0 (0)

Values are presented as mean ± standard deviation or number (%).

EVAR, endovascular aneurysm repair.

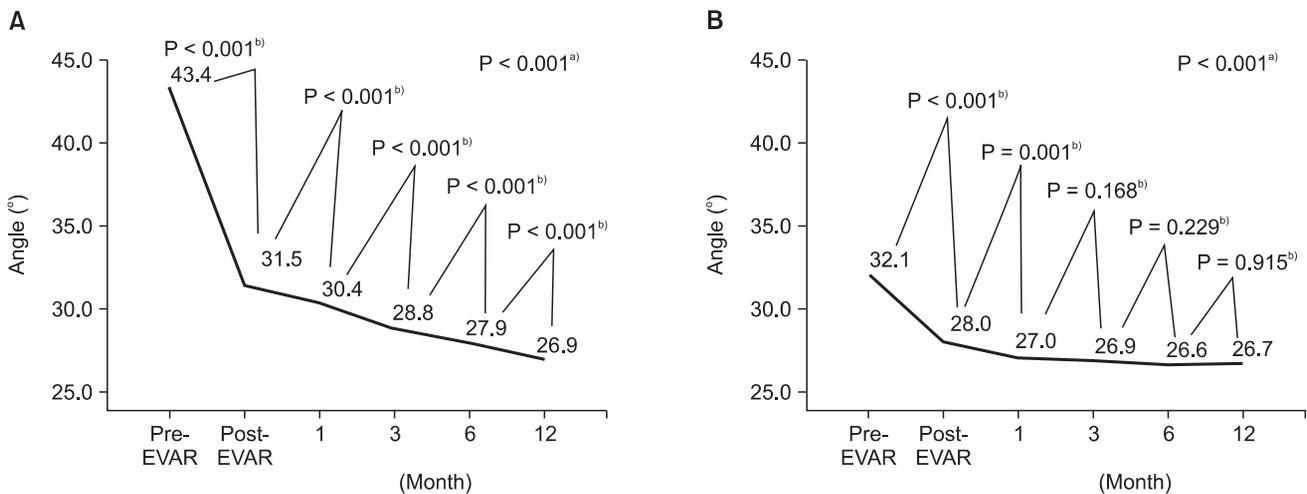


Fig. 1. The angle change of infrarenal (A) and suprarenal aorta (B). EVAR, endovascular aneurysm repair. ^{a)}P-values are presented to show the significance of serial change until 1 year follow-up by Friedman test. ^{b)}P-values are presented to show the significance of two consecutive periods by the Wilcoxon signed rank test.

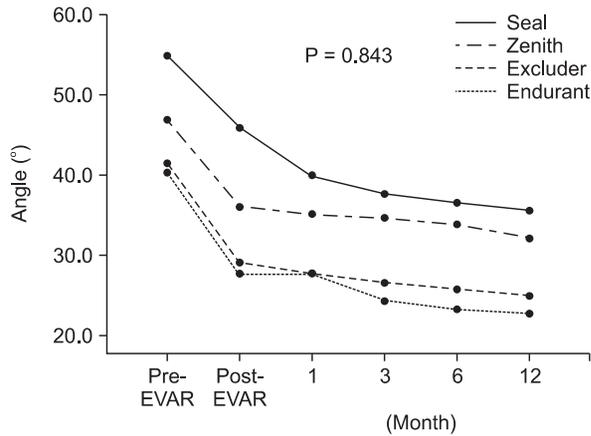


Fig. 2. The comparison of the serial change of infrarenal aortic angle according to stent types. EAVR, endovascular aneurysm repair.

The infrarenal aortic angles were $43.4^{\circ} \pm 25.0^{\circ}$ preoperatively, $31.5^{\circ} \pm 18.3^{\circ}$ within 1 week after EVAR, $30.4^{\circ} \pm 17.6^{\circ}$ at 1 month, $28.8^{\circ} \pm 17.6^{\circ}$ at 3 months, $27.9^{\circ} \pm 17.5^{\circ}$ at 6 months, and $26.9^{\circ} \pm 17.1^{\circ}$ at 1 year.

The Friedman test analysis found that compared with the preoperative infrarenal angle ($P < 0.01$), the early postoperative angle and the angle after 1, 3, 6 months, and 1 year decreased significantly (all $P < 0.01$) (Fig. 1A).

Suprarenal aortic angles were $32.1^{\circ} \pm 21.6^{\circ}$ preoperatively, $28.0^{\circ} \pm 18.8^{\circ}$ within 1 week after EVAR, $27.0^{\circ} \pm 18.8^{\circ}$ at 1 month, $26.9^{\circ} \pm 18.8^{\circ}$ at 3 months, $26.6^{\circ} \pm 18.7^{\circ}$ at 6 months, and $26.7^{\circ} \pm 18.2^{\circ}$ at 1 year.

The Friedman test analysis found that compared with the preoperative suprarenal angle ($P < 0.01$), the early postoperative angle and the angle after 1 month decreased significantly ($P < 0.01$) but the angle after 3 and 6 months and 1 year had not decreased (Fig. 1B).

Infrarenal aortic angles were compared in patients with the Zenith, Excluder, Seal, and Endurant stent grafts. No difference in angulation was observed based on stent graft types (Fig. 2).

We investigated the correlation between a type Ia endoleak and infrarenal angle before and immediately after EAVR. A type Ia endoleak was significantly associated with post-EVAR infrarenal angle ($P = 0.037$), but not pre-EVAR infrarenal angle ($P = 0.372$) (Table 2). Neck length ($P = 0.258$) and neck diameter ($P = 0.947$) were also not related with a type Ia endoleak.

DISCUSSION

Since first described by Parodi et al. [8] in 1991, EVAR has progressively and dramatically changed the approach to treat AAA. EVAR was historically developed to treat patients unfit for open repair but now represents the primary treatment by which infrarenal AAAs are managed [9,10].

Table 2. Relationship between infrarenal aortic angle and endoleak type Ia ($n = 70$)

	Endoleak type Ia		P-value ^{a)}
	Yes ($n = 10$)	No ($n = 60$)	
Pre-EVAR angle	49.9 ± 22.9	42.2 ± 25.1	0.372
Post-EVAR angle	39.9 ± 14.1	30.1 ± 18.6	0.037

Values are presented as mean \pm standard deviation.

^{a)}Mann-Whitney U-test.

EVAR, endovascular aneurysm repair.

Anatomic exclusion criteria used to reject patients for EVAR are: aortic neck diameter > 28 mm, aortic neck length < 15 mm, aortic neck angulation $> 60^{\circ}$, severe iliac tortuosity, extensive aortic neck thrombus, iliac artery diameter < 7 mm, aortic bifurcation diameter < 18 mm, bilateral common iliac aneurysm requiring coverage of both hypogastric arteries, and essential accessory renal artery [3,11].

Well-designed devices and experience has led to successful procedures and expanded the indications for EVAR.

Despite improvements in devices and techniques, significant anatomic constraints still preclude successful EVAR in a large number of patients, and selection must be careful to acquire appropriate patients [12,13]. Patients with hostile neck anatomy continue to have restricted widespread applicability of EVAR [14,15].

The anatomical features of aneurysms are changing during and after EVAR. An aneurysm exhibits a wide variety of morphological changes throughout the cardiac cycle during the procedure, and aortic diameter changes within and above the aneurysm neck just after EVAR [16,17].

Our study revealed that proximal neck angle decreased significantly immediately after the EVAR procedure and continued to decrease slowly.

The infrarenal aortic neck angle changed immediately during the EVAR procedure, due to multiple factors, such as passage of the guidewire, the stent graft delivery system, and radial force of the stent graft. Only radial force of the stent affected aortic angle slowly and continuously after the EVAR procedure.

Furthermore, the suprarenal angle decreased after EVAR without direct contact with the stent graft. van Keulen et al. [5] reported that suprarenal and infrarenal aortic neck angles decrease during the EVAR procedure, and that this decrease continues in the years after the procedure. However, we found that infrarenal aortic angle continued to decrease, and that the suprarenal aortic angle decreased for 1 month after EVAR and then did not change significantly thereafter.

The change in the infrarenal angle affected the suprarenal aorta for up to 1 month after the operation, but did not affect it after 1 month. This correlation seems relevant to the correlation between suprarenal angle and infrarenal angle. The suprarenal

angle had a strong correlation with infrarenal angle, which means that the change in infrarenal angle was related with the change in the suprarenal angle.

In this study, the infrarenal angle was large when the zenith was used unintentionally. However, no difference in the change in angle was observed according to stent type.

No research is available on the effect of the change in infrarenal angle on endoleak, particularly the largest change in the angle immediately after EVAR.

Type Ia endoleaks occurred immediately after the operation. Therefore, we compared the relationship between endoleaks and infrarenal angle immediately after the operation. Pre-EVAR and post-EVAR infrarenal angles were analyzed for type Ia endoleaks. As a result, type Ia endoleaks significantly affected the post-EVAR angle, but did not affect pre-EVAR angle, which was different from previous results [18]. This result may have occurred due to the small sample size of 70 patients.

In the future, multicenter and large prospective studies will be required to investigate predictors of type Ia endoleaks, considering the pre- and post-EVAR infrarenal angles.

In conclusion, the infrarenal aortic angle decreased significantly immediately after the EVAR procedure and continued to decrease slowly. Suprarenal aortic angle decreased immediately after the EVAR procedure and decreased continuously for 1 month. We found a correlation between infrarenal and suprarenal aortic angle. Type Ia endoleak occurred with a greater incidence in patients with a larger infrarenal angle immediately after EVAR.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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