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Original Article Open Access

Aortic remodeling following elective endovascular aortic repair

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ABSTRACT

Objectives: This study aimed to investigate the changes in the aneurysm morphology during mid-term follow-up after endovascular aortic repair (EVAR).

Patients and methods: A total of 192 patients (180 males, 12 females; mean age: 69±5.1 years; range, 46 to 88 years) with infrarenal abdominal aortic aneurysms, who underwent elective EVAR between June 2016 and July 2021, who had at least one year of follow-up, and who possessed preoperative and postoperative computed tomography angiography scans, were included in the retrospective study.

Results: The median aneurysm diameter decreased from 61.0 to 57.5 mm ($p<0.001$). The median upper neck diameter increased from 24.0 to 26.0 mm ($p<0.001$). The median lower neck diameter also increased from 24.0 to 26.0 mm ($p<0.001$). The median infrarenal neck angle decreased from 35.0^0 to 30.0^0 ($p<0.001$). The mean aneurysm length decreased from 131.6±18.5 to 130.5±18.6 mm ($p<0.001$).

Conclusion: This study suggests that the aneurysm sac contracts over the years following successful EVAR, while the infrarenal neck angle decreases, and the neck diameter expands due to the radial force of the endograft.

Keywords: Abdominal aort aneurysm; EVAR; neck, remodeling.

Abdominal aortic aneurysm is a frequently encountered condition, particularly in older individuals, and is associated with risk factors such as hypertension and atherosclerosis.[1] Endovascular aortic repair (EVAR) has gained increasing prominence in the treatment of infrarenal abdominal aortic aneurysms.[2] The 2019 European Society for Vascular Surgery guidelines recommend EVAR as the primary treatment option in suitable and elderly cases.[3]

Structural changes in the aneurysm morphology are crucial to monitor in post-EVAR surveillance.[4,5] Over the years, various alterations in the aneurysm sac and neck structure have been observed, attributed to the pressure exerted by the endograft and the thrombotic reduction of the sac in most patients.

The cessation of sac expansion is one of the primary objectives in EVAR treatment. Studies on post-EVAR sac morphology have demonstrated that EVAR effectively halts sac expansion in the majority of patients.[6,7] Additionally, the effects of aneurysm neck structure on success, its associations with type 1A endoleak risks, and post-EVAR alterations have also been among the researched topics in recent years.[8,9] This study aimed to elucidate the changes in aneurysm sac and neck structure during mid-term follow-up following EVAR.

PATIENTS AND METHODS

Patients who underwent elective EVAR at the Türkiye Yüksek İhtisas Hospital and Ankara Bilkent City Hospital between January 2016 and July 2021 were included in the retrospective study. Patients who presented with ruptured aortic aneurysms or required additional interventions during the

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same hospitalization, such as thoracic EVAR or percutaneous transluminal angioplasty, were excluded from the study. The patients were selected from our endovascular intervention database where comorbidities and pre-, peri-, and postoperative data were registered. Complementary clinical data were retrieved from patient records. Computed tomography angiography (CTA) measurements were conducted prospectively. Out of 262 patients, 192 patients (180 males, 12 females; mean age: 69±5.1 years; range, 46 to 88 years) with preoperative and postoperative CTAs, as well as recorded oversize rates, were included (Figure 1). All patients underwent EVAR under the same cardiovascular team. The endograft size was chosen to be 10% to 20% oversize for all patients. Computed tomography angiography measurements were performed by a single operator using the 3Mensio Vascular (3mensio Medical Imaging BV, Maastricht, Netherlands) program (Figure 2). The upper neck diameter was measured at the level just below the renal arteries, and the lower neck diameter was measured at the top of the aneurysm sac. All procedures were performed by the same endovascular team. The indication for EVAR intervention in abdominal aortic aneurysms was set for those with a sac diameter >55 mm. Additionally, patients with aneurysms with a diameter >40 mm that expanded >10 mm per year or those presenting with abdominal pain symptoms were also indicated for intervention. A written informed consent was obtained from each patient. The study protocol was approved by the Ankara City Hospital Ethics Committee (date: 1217, no: E1-20-1217). The study was conducted in accordance with the principles of the Declaration of Helsinki.

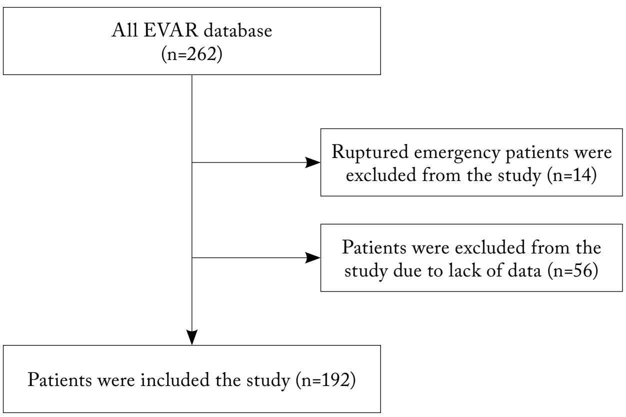

Figure 1. Flowchart of the study.

EVAR: Endovascular aortic repair.

Statistical analyses

Data were analyzed using IBM SPSS version 19.0 software (IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was used to assess the fit of numeric variables to the normal distribution. Descriptive statistics were reported as frequency and percentage. Normally distributed data were reported as mean ± standard deviation (SD), and data not conforming to normal distribution were presented as median (min-max). To assess statistical significance, the chi-square test was used to determine the difference and relationship between categorical data. The Mann-Whitney U test and Student's t-test were used to assess the relationship between nominal data and numerical values. A p-value <0.05 was considered statistically significant.

RESULTS

The patients' characteristics are presented in Table 1. Thirty-nine percent of the patients had coronary artery disease. The perioperative characteristics of the patients are provided in Table 2. General anesthesia was administered to 89.2% of the patients. Modular endografts

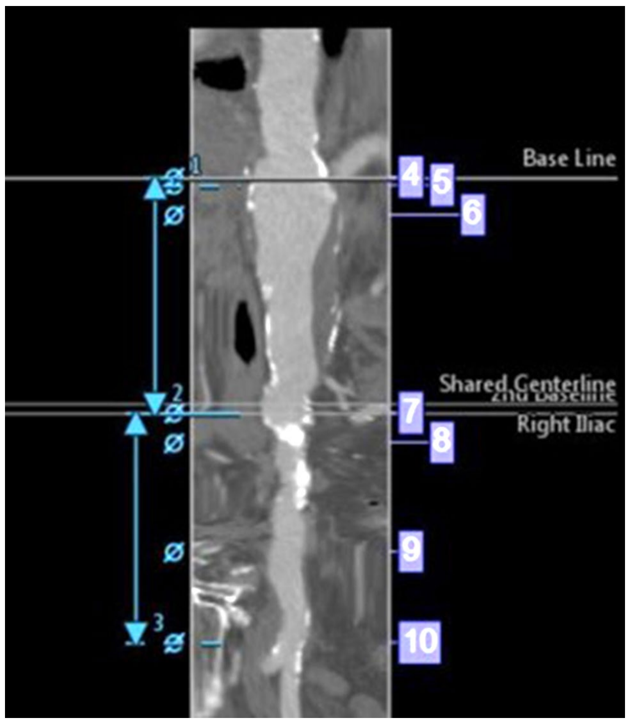

Figure 2. An example of diameter measurements from the 3MensioVascular program.

Table 1
Baseline characteristics of the patients (n=192)

	n	%	Mean±SD	Median	Min-Max
Age (year)			69.4±5.1	69.0	46.0-88.0
Ejection fraction			48.5±7.4	50.0	20.0-67.0
Sex					
Male	180	93.7			
Diyabetes mellitus	24	12.5			
Hypertension	135	70.0			
Hyperlipidemia	55	28.6			
Chronic obstructive pulmonary disease	44	22.9			
Chronic kidney disease	18	9.3			
Peripheral artery disease	12	6.2			
Coronary artery disease	75	39.0			
Coronary artery bypass graft	29	15.1			
Congestive heart disease	5	2.8			
Transient ischemic attact/cerebrovascular disease	11	5.7			
Cancer	6	3.1			
Symptomatic patient	84	43.7			
History of abdominal surgery	6	3.1			
Smoking	102	53.1			

SD: Standard deviation.

were used in 95.4% of the cases, while unibody (AFX, Endologix; Irvine, CA, USA) endografts were used in 4.6%. The median duration of intensive care unit stay was 6.4 (1-120) h, and the median hospital stay was 2.9 (1-19) days.

The median follow-up duration was 28 months (interquartile range, 37 to 21 months). Endoleaks were observed in 18.3% (n=33) of the patients during follow-up. Type 1A endoleaks were detected in 3.8% (n=7) of cases, all of which underwent secondary interventions. Type 1B, type 2, and type 3 endoleaks were observed in 3.3% (n=6), 6.6% (n=12), and 4.1% (n=8) of cases, respectively. All patients with type 2 endoleaks had a benign course and were managed medically. For other patients with endoleaks, treatments included nine aortic extensions, nine iliac extensions, three balloon dilations, two crossover procedures, one iliac extension with embolectomy, one iliac extension with crossover, and two open surgeries. The frequency of endoleak-independent complications was 3.9%, with iliac graft thrombosis

Table 2
Perioperative features

Parameters	Median	Min-Max
Procedure time (min)	120.0	30.0-360.0
Scopy time (min)	12.0	4.0-52.0
Opaque amount (mL)	50.0	0-140.0
Length of stay in intensive care (h)	4.0	1.0-120.0
Length of stay in the hospital (day)	2.0	1.0-19.0

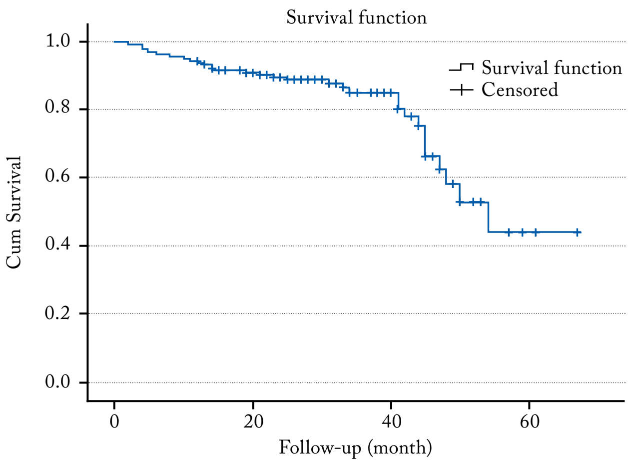

Figure 3. Kaplan-Meier survival analysis.

being the most common (n=5). These five patients underwent embolectomy and additional iliac extension graft placement. The mortality rate was determined to be 18.3% (n=33) during follow-up (Figure 3). Among these, 17 were of cardiac origin, seven were aortic-related mortalities, eight were due to noncardiac causes, and one was of unknown etiology.

Morphological changes in patients' aneurysms, both preoperatively and postoperatively, are detailed in Table 3. In 6.3% (n=12) of patients, the aneurysm sac was enlarged by >5 mm during mid-term follow-up. In 81.7% (n=157) of cases, the aneurysm sac diameter remained stable or decreased. When considering all patients, the median aneurysm diameter reduced significantly from 61.0 to 57.5 mm (p<0.001). The median upper neck diameter (diameter at the lowest renal artery level) increased from 24.0 to 26.0 mm (p<0.001). The median lower neck diameter (before the aneurysm sac level) also increased from 24.0 to 26.0 mm (p<0.001). The median infrarenal neck angle decreased from 35.0° to 30.0° (p<0.001). The mean aneurysm length decreased from 131.6±18.5 to 130.5±18.6 mm (p<0.001).

DISCUSSION

Coronary tomography angiography measurements play a critical role in the monitoring

Table 3
Morphological changes in aneurysm after EVAR

	Mean±SD	Median	Min-Max	Test value	*p*
Aneurysm sac diameter (mm)					
Preoperative		61.0	54.0-118.0	-7.867	**<0.001**
Postoperative		57.5	31.0-113.0		
Upper neck diameter (mm)					
Preoperative		24.0	16.0-34.0	-11.193	**<0.001**
Postoperative		26.0	20.0-60.0		
Lower neck diameter (mm)					
Preoperative		24.0	15.0-38.0	-9.734	**<0.001**
Postoperative		26.0	18.0-38.0		
Neck length (mm)					
Preoperative		28.0	8.0-72.0	-0.581	0.56
Postoperative		28.0	8.0-74.0		
Infrarenal neck angulation (degree)					
Preoperative		35.0	0.0-90.0	-6.229	**<0.001**
Postoperative		30.0	0.0-110.0		
Aneurysm length (mm)					
Preoperative	131.6±18.5			4.25	**<0.001**
Postoperative	130.5±18.6				

SD: Standard deviation; EVAR: Endovascular aortic repair.

of patients following EVAR treatment to detect morphological changes in aneurysm sacs and necks.[10] This study focused on the mid-term follow-up of EVAR patients who received oversizing in the range of 10 to 20%. As expected, in this study, among patients with a stable or decreasing sac diameter (n=157, 81.7%), the average aneurysm sac diameter statistically significantly decreased by 3.5 mm after EVAR treatment. Soler et al.[4] reported that, during an mean follow-up of 24.6±4.1 months, over 51.8% of patients experienced a reduction of 10 mm or more in aneurysm sac diameter following EVAR.

The upper and lower neck diameters exhibited statistically significant expansion (2 mm), while no significant changes were observed in neck length. In patients with observed aortic neck dilatation, no complications related to the neck dilatation were observed. Kret et al.[11] noted that the average neck diameter expanded by 1 to 3 mm following EVAR and found it to be associated with oversizing regardless of the endograft brand. Oliveira et al.[12] reported an average aortic neck dilatation of 3 to 4 mm after EVAR. In our study, all oversizing ratios fell within the 10 to 20% range. These similar findings validate and elaborate on the specific measurements supported by our study.

The present study also revealed a statistically significant decrease of approximately 5° in infrarenal neck angulation. Ishibashi et al.[13] found that infrarenal neck angles >60° decreased by 20% in a two-year follow-up study.

The significant 1-mm reduction in aneurysm length is presumed to be due to the upward movement of the aneurysm related to its shrinkage. Wever et al.[14] found that in 14 patients with shrinking aneurysm sacs following EVAR, the average aneurysm length between the renal arteries and aortic bifurcation reduced by 4 mm after one year of follow-up. The impact of endograft aneurysm shrinkage on aneurysm morphology is a noteworthy outcome of this study.

Endovascular aortic repair often involves selecting grafts oversized approximately 10 to 20%, as recommended by endograft companies. The median 2-mm expansion observed in the upper and lower limits of the aneurysm neck, as documented in the study's results, is primarily attributed to the radial strength of the oversized grafts. This neck expansion was observed in all patients during immediate post-EVAR follow-up angiographies. Additionally, no neck expansion due to endoleak was found in control CTAs among patients with endoleak.

Unibody (AFX, Endologix) endografts were used in the early years of this study, and these patients were included in the study. This may have increased our total endoleak rates due to type 3 endoleak.

Although the routine follow-up of EVAR patients is currently performed using two-dimensional CTA measurements, recent studies have demonstrated the increased value of three-dimensional volumetric monitoring.[15,16] We believe that with advancing technology and artificial intelligence in the coming years, volumetric monitoring will become more convenient and is likely to replace diameter measurements in routine follow-ups. On the other hand, open surgery will stay as a good alternative to EVAR, both in cases of EVAR complications and in patients who are anatomically unsuitable for endovascular treatment.[16]

There are some limitations to this study. This study is a retrospective and single-center investigation. Given the precise CTA measurements in this study, there may be a margin of error in the measurements. Measurements were conducted by a single expert. The study included multiple endograft brands to mitigate bias risk. However, this may have introduced graft variety since different endograft brands may have varying radial strength. The study was conducted with a relatively small sample size and short follow-up due to limitations. Larger sample sizes and longer follow-up durations may provide more conclusive results.

In conclusion, in the mid-term follow-up after EVAR (median of 28 months), a median expansion of 2 mm in the aneurysm neck diameter was observed due to the radial force of the endograft. The infrarenal aneurysm neck angle decreased by a median of 5°, the aneurysm sac diameter reduced by a median of 3.5 mm, and the aneurysm length shortened by approximately 1 mm. While changes in neck morphology were associated with endograft dimensions and radial strength, alterations in sac morphology were directly linked to the success of EVAR treatment.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Writing: F.Ç.; Analysis and idea: H.Z.İ.; Critical review: E.U.Ü.; Data collection: M.A.T., B.A.

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REFERENCES

1. Sakalihasan N, Limet R, Defawe OD. Abdominal aortic aneurysm. Lancet 2005;365:1577-89. doi: 10.1016/S0140-6736(05)66459-8.
2. Mani K, Lees T, Beiles B, Jensen LP, Venermo M, Simo G, et al. Treatment of abdominal aortic aneurysm in nine countries 2005-2009: A vascunet report. Eur J Vasc Endovasc Surg 2011;42:598-607. doi: 10.1016/j.ejvs.2011.06.043.
3. Wanhainen A, Verzini F, Van Herzeele I, Allaire E, Bown M, Cohnert T, et al. Editor's Choice - European Society for Vascular Surgery (ESVS) 2019 clinical practice guidelines on the management of abdominal aorto-iliac artery aneurysms. Eur J Vasc Endovasc Surg 2019;57:8-93. doi: 10.1016/j.ejvs.2018.09.020.
4. Soler RJ, Bartoli MA, Mancini J, Lerussi G, Thevenin B, Sarlon-Bartoli G, et al. Aneurysm sac shrinkage after endovascular repair: Predictive factors and long-term follow-up. Ann Vasc Surg 2015;29:770-9. doi: 10.1016/j.avsg.2014.12.016.
5. Antoniou GA, Alfahad A, Antoniou SA, Torella F. Prognostic significance of aneurysm sac shrinkage after endovascular aneurysm repair. J Endovasc Ther 2020;27:857-68. doi: 10.1177/1526602820937432.
6. Arko FR, Filis KA, Hill BB, Fogarty TJ, Zarins CK. Morphologic changes and outcome following endovascular abdominal aortic aneurysm repair as a function of aneurysm size. Arch Surg 2003;138:651-5. doi: 10.1001/archsurg.138.6.651.
7. İşcan HZ, Karahan M, Akkaya BB, Başar V, Aşkın G, Kubat E, et al. Long-term results of endovascular intervention with unibody bifurcation endograft for elective abdominal aortic aneurysm management. Rev Cardiovasc Med 2021;22:453-59. doi: 10.31083/j.rcm2202051.
8. Aytekin B, Deniz G, Çetinkaya F, Mola S, Tümer NB, Ünal EU, et al. The impact of large proximal aortic neck on endovascular aneurysm repair outcomes. Turk Gogus Kalp Dama 2023;31:489-97. doi: 10.5606/tgkdc.dergisi.2023.25255.
9. Çetinkaya F, İşcan HZ, Türkçü MA, Mavioğlu HL, Ünal EU. Predictive parameters of type 1A endoleak for elective endovascular aortic repair: A single-center experience. Ann Vasc Surg 2024;98:108-14. doi: 10.1016/j.avsg.2023.07.095.
10. Baderkhan H, Haller O, Wanhainen A, Björck M, Mani K. Follow-up after endovascular aortic aneurysm repair can be stratified based on first postoperative imaging. Br J Surg 2018;105:709-18. doi: 10.1002/bjs.10766.
11. Kret MR, Tran K, Lee JT. Change in aortic neck diameter after endovascular aortic aneurysm repair. Ann Vasc Surg 2017;43:115-20. doi: 10.1016/j.avsg.2016.11.013.
12. Oliveira NF, Bastos Gonçalves FM, de Vries JP, Ultee KH, Werson DA, Hoeks SE, et al. Mid-term results of EVAR in severe proximal aneurysm neck angulation. Eur J Vasc Endovasc Surg 2015;49:19-27. doi: 10.1016/j.ejvs.2014.10.001.
13. Ishibashi H, Ishiguchi T, Ohta T, Sugimoto I, Yamada T, Tadakoshi M, et al. Remodeling of proximal neck angulation after endovascular aneurysm repair. J Vasc Surg 2012;56:1201-5. doi: 10.1016/j.jvs.2012.04.014.
14. Wever JJ, Blankensteijn JD, Broeders IA, Eikelboom BC. Length measurements of the aorta after endovascular abdominal aortic aneurysm repair. Eur J Vasc Endovasc Surg 1999;18:481-6. doi: 10.1053/ejvs.1999.0882.
15. Franchin M, Serafini M, Tadiello M, Fontana F, Rivolta N, Venturini M, et al. A morphovolumetric analysis of aneurysm sac evolution after elective endovascular abdominal aortic repair. J Vasc Surg 2021;74:1222-31.e2. doi: 10.1016/j.jvs.2021.03.034.
16. Akansel S, Erdoğan BS, Sargın M, Sokullu O, Kurç E, Aka SA. Late surgical conversion after failed endovascular aortic repair: Our single-institutional experience. Cardiovasc Surg Int 2023;10:79-88. doi: 10.5606/e-cvsi.2023.1493.