TJVS Turkish Journal of Vascular Surgery

Turk J Vasc Surg 2024;33(2):78-83
DOI: 10.9739/tjvs.2024.05.019

Available online at www.turkishjournalofvascularsurgery.org

Original Article

The impact of aneurysm volume on midterm Post-EVAR outcomes

Mehmet Ali Turkcu[1], Osman Eren Karpuzoglu[2], Bahadir Aytekin[3], Ferit Cetinkaya[4], Mustafa Dagli[5], Hakki Zafer Iscan[3]

[1]Elbistan State Hospital, Department of Cardiovascular Surgery, Kahramanmaraş, Türkiye
[2]İstanbul Siyami Ersek Hospital, Department of Cardiovascular Surgery, İstanbul, Türkiye
[3]Ankara City Hospital, Department of Cardiovascular Surgery, Ankara, Türkiye
[4]Ağrı Training and Research Hospital, Department of Cardiovascular Surgery, Ağrı, Türkiye
[5]Ankara City Hospital, Department of Radiology, Ankara, Türkiye

Received: May 04, 2024 Accepted: June 04, 2024 Published online: July 01, 2024

Content of this journal is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

Abstract

Aim: We examined the impact of preoperative three-dimensional aortic volume on outcomes following Endovascular Aortic Repair (EVAR).
Material and Methods: A total of 146 patients who underwent elective EVAR at our hospital between January 2018 and January 2023, and who had preoperative and postoperative multislice Computed Tomographic Angiography (CTA), were included in the study. The effects of aneurysm sac volumetric measurements on post-EVAR endoleak, reintervention, and late mortality were evaluated. Since there is no definite cut-off value for aneurysm volume and EVAR results in the literature, we compared patients with aneurysm volumes above and below 231.7 cm³ obtained by roc analysis.
Results: During the follow-up period, the rate of secondary intervention was higher if the preoperative aneurysm volume was greater than 231.7 cm³ ($p=0.001$) or if the preoperative thrombus volume was greater than 206.1 cm³ ($p=0.002$). There was no notable difference in terms of endoleak ($p=0.5$) and during follow-up mortality rate ($p=0.8$) between patients with sac volumes above and below 231.7 cm³. After EVAR, when morphological changes were examined, it was noted that there was a dilatation of the neck (preoperative 23±4 mm and postoperative 26±4 mm) ($p<0.001$) and a decrease in neck (infrarenal) angulation (preoperative 39 degrees and postoperative 31.5 degrees) ($p<0.001$).
Conclusion: This study demonstrates that aneurysms with high volume are prone to secondary intervention. However, it is not correlated with early or midterm mortality and outcomes. Volumetric analysis of the aneurysms preoperatively may be an indicator of surveillance protocols and treatment choices. Lifetime follow-up and volumetric analysis of aneurysms seem crucial for effective and reliable surveillance.

Keywords: Aneurysm volume, secondary intervention, endovascular aortic repair

INTRODUCTION

Since its introduction, EVAR has revolutionized the treatment of infrarenal abdominal aortic aneurysms (iAAA), particularly in high-risk patients, by significantly reducing perioperative morbidity and mortality compared to open surgical repair [1,2]. However, EVAR has faced criticism compared to open surgery due to the occurrence of late reinterventions and the risk of persistent rupture [3]. Despite advancements in stent technology, the need for reintervention still exists even though the outcomes get better due to growing experience [4,5]. The consideration of various anatomical features as indicators of perioperative and long-term failure after EVAR suggests a robust relationship between morphological characteristics and outcomes [6,7]. Routine post-EVAR imaging is considered mandatory to detect graft-related complications and prevent rupture due to potential sac expansion.

In clinical practice, the most common used measurement is maximum diameter (D max) measurement. Some studies

CITATION
Turkcu MA, Karpuzoglu OE, Aytekin B, Cetinkaya F, Dagli M, Iscan HZ. The impact of aneurysm volume on midterm Post-EVAR outcomes. Turk J Vasc Surg. 2024;33(2):78-83.

OPEN ACCESS

Corresponding Author: Mehmet Ali Turkcu, Elbistan State Hospital, Department of Cardiovascular Surgery, Kahramanmaraş, Türkiye
Email: mali.dev_@hotmail.com

DOI: 10.9739/tjvs.2024.05.019

support that diameter measurements may not accurately reflect the changes in the shape of the aorta or changes in aneurysms with an amorphous structure [8,9]. Recent studies suggest that three-dimensional volumetric analysis is more valuable than two-dimensional diameter measurements [10-12]. However, the question remains whether volumetric measurements will replace diameter measurement in identifying rupture risk and determining clinically significant sac growth in abdominal aortic aneurysms or will be used as a complementary technique as it takes a little bit longer time. The true benefit of EVAR may only be achieved by proper patient selection. 5-year reintervention rates, early and late mortality rates were higher for large (≥65 mm) iAAA patients when compared to smaller ones [13]. There is a robust relationship between morphological characteristics and EVAR outcomes. For today, morphovolumetric analysis of the aneurysms are in evaluation and in this study, we aimed to determine the impact of aneurysm volume, instead of maximum diameter for midterm EVAR outcomes and tried to place morphovolumetric analysis in our surveillance strategy.

MATERIAL AND METHODS

Our study was conducted prospectively in our hospital after receiving ethical approval from our hospital's Clinical Research Ethics Committee Institutional Review Board (Approval No: 1428). A total of 146 patients who underwent elective EVAR in our hospital between January 2018 and January 2023 and who had preoperative and postoperative CTA with a section thickness of 0.625 mm were included in the study. Emergency cases without pre- and postoperative control CTAs and cases with data loss were excluded from the study. EVAR was performed on all patients by the same team in the angiography room. The data were collected by dividing them into preoperative, intraoperative, postoperative, and follow-up periods. Preoperative data included patients' demographic information, ejection fraction, history of abdominal surgery, characteristic details, and preoperative CTA diameter measurements. Aneurysm neck diameter (infrarenal diameter and pre-sac diameter), preoperative and postoperative 3D aneurysm sac total volume measurement, thrombus volume measurement, and infrarenal angulation were recorded. Intraoperative data comprised graft measurements, procedural times, fluoroscopy and contrast amounts, and Type 1 endoleaks occurring during or after the procedure. Postoperative data consisted of intensive care unit (ICU) and ward admission durations and incurred complications. Follow-up data encompassed CTA diameter measurements, 3D total aneurysm volume, thrombus volume, endoleaks, secondary interventions, and during follow-up mortality data. Mortality was defined as mortality during follow-up rate. The endpoints of our study were determined as follows: the relationship between aneurysm volume over post-EVAR mortality, morbidity, endoleak and non-endoleak complications, rates and reasons for secondary interventions, and their effects on mortality. Operational success was defined as no conversion to open surgery, no intraoperative mortality, no Type 1 or Type 3 endoleak, no stent migration, and no occlusion on complementary angiography. In the study, Endurant II (Medtronic, Santa Rosa, CA, USA) and Ankura (Lifetech Scientific, Shenzen, China) stent grafts were used for the EVAR procedure.

Computed Tomographic Angiography (CTA) Measurements

Patients' preoperative and postoperative morphovolumetric measurements were obtained using the Sarus Workstation program by a cardiovascular surgeon and a radiologist with 10 years of experience. Three-dimensional images were acquired and volumes were measured in cubic centimeters (cm^3), while densities were measured in Hounsfield units (HU) from the proximal, distal, and mid (middle) regions of the aneurysm. The average of these three measurements was calculated and the numerical data were transferred to an Excel format. Measurements were conducted using preoperative and postoperative thoracoabdominal computed tomographic angiography with 128 and 512 detector computed tomography (CT) devices (GE Healthcare), administering 120 ml of contrast at a rate of 4 ml/s, during the arterial phase (20th second), and with a slice thickness of 0.625 mm. Images were evaluated in axial, coronal, and sagittal planes, and using customized three-dimensional volumetric software (Advantage Workstation 4.2, GE Healthcare Technologies), the total aortic volume and open lumen volume were semi-automatically measured. The diameter and volume of the aneurysm sac were calculated using a semi-automatic method by drawing the outer wall of the aneurysm sac in a circular manner, taking the widest distance as the reference. The thrombus volume was calculated by subtracting the patent lumen volume from the total aortic volume. Preoperative and postoperative CTA measurements were performed using the same method.

Since there is no definite cut-off value for aneurysm volume and EVAR results in the literature, we compared patients with aneurysm volumes above and below 231.7 cm^3 obtained by roc analysis.

Statistical Analysis

All statistical analyses were conducted using the SPSS statistical software (SPSS for Windows 15.0, Inc., Chicago, IL, USA). Continuous variables were tested for normal distribution using the Kolmogorov-Smirnov test. Continuous variables conforming to a normal distribution were expressed as "mean±standard deviation (SD)", while those not conforming were expressed as "median and interquartile range". Categorical variables were expressed as numbers and percentages. The Wilcoxon test was used for continuous variables. Demographic characteristics, perioperative variables, and follow-up parameters were compared using the "independent samples t-test" or "Mann-Whitney U test" for continuous variables and the "chi-square test" or

"Fisher's exact test" for categorical variables. The relationship between variables was evaluated using Pearson's correlation test. The ROC curve (Receiver Operating Characteristic) method was used to determine the discriminative ability of variables.

Sensitivity and specificity rates were presented using ROC analysis to assess the relationship between preoperative CT findings and secondary interventions. The p-value <0.05 was considered statistically significant.

RESULTS

Operative success rate was 100%. Of the 146 patients followed, 91.8% were male (134 patients). The mean age was 70.1±6.8 years. Among the patients, the most associated comorbidities were Hypertension (HT) in 94 patients (64.4%) and Coronary Artery Disease (CAD) in 76 patients (52%), chronic obstructive pulmonary disease (COPD) in 49 patients (32%), Diabetes Mellitus in 32 patients (22%), and 82 patients had a history of smoking (56.2%) (Table 1).

Table 1. Comparison of characteristic features according to volume

	<231.7 cm³ aneursym volume (n=92)				≥231.7 cm³ aneurysm volume (n=54)				N=146 patients	
Parameters	**Mean**	**SD**	**Number (n)**	**(%)**	**Mean**	**SD**	**Number (n)**	**(%)**	**P* value**	**Total n (%)**
Age	71.81	7.59			69.55	7.42			0.51	
Male			82	89.1			52	96.2	0.57	134 (%91.8)
DM			21	22.8			11	20.3	0.35	32 (%22)
HT			53	57.6			41	75.9	0.86	94 (%64.4)
HL			34	36.9			22	40.7	0.53	56 (%38.3)
COPD			29	31.5			20	37	0.6	49 (%32)
CKD			8	8.62			5	9.2	0.36	13 (%8.9)
PVD			7	7.6			5	9.2	0.26	12 (%8.2)
CAD			47	51			29	53.7	0.49	76 (%52)
SVO			9	9.7			4	7.4	0.13	13 (%8.9)
Cancer			5	5.43			2	3.7	0.42	7 (%5.3)
Smoking			50	54.3			32	59.2	0.35	82 (%56.2)

* chi-square test
DM: diabetes mellitus, HT: hypertension, HL: hyperlipidemia, COPD: chronic obstructive pulmonary disease, CKD: chronic kidney disease, PVD: peripheral vascular disease, CAD: coronary artery disease, SVO: cerebrovascular event, SD: standard deviation

General anesthesia was administered to 87.7% of the patients (128 patients). The procedure duration was 120±46.3 minutes, while the fluoroscopy duration was 11.1±6.2 minutes. The mean contrast amount was 50.5±20.3 cc. The average length of stay in the ICU was 5 hours, and the hospital stay duration was 4 days. The mean follow-up duration was 29.8±14.1 months.

The mean preoperative aneurysm diameter was 64.5±12.8 mm. Aneurysm neck length was 26.2±11.1 mm. Preoperative aneurysm neck diameter was 23±4 mm and postoperative aneurysm neck diameter was 26±4 mm. The mean alpha angle (infrarenal angulation) was 39±21.3 degrees. Thrombus in the neck was present in 64.5% of patients. Postoperative aneurysm diameter was 62±16 mm. Preoperative neck angulation was 39 degrees and postoperative neck angulation was 31.5 degrees (p<0.001).

Preoperative total volume of the aneurysm sac was 223.2±144.7 cm³, and the preoperative thrombus volume was 105.6±86.3 cm³. Postoperative total aneurysm volume was 215±162 cm³. Postoperative thrombus volume was 157.2±87.4 cm³.During follow-up, endoleak was observed in 35 patients (24%). Among these, 7 patients (4.8%) had Type 1A endoleak, 7 patients (4.8%) had Type 1B endoleak, 15 patients (10.2%) had Type 2 endoleak, and 6 patients (4.1%) had Type 3 endoleak (Figure 1). Type 2 endoleaks seen in this study were seen only in patients with Polytetrafluoroethylene (e PTFE) endografts and this difference was statistically significant (p=0.035).

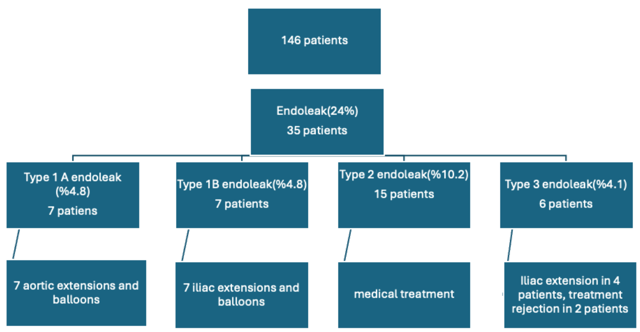

Figure 1. Endoleaks and reinterventions

There was no early mortality. 23 patients (15.8%) experienced mortality during the follow-up period. The most common cause of mortality was cardiac-related. Aneurysm-related mortality occurred in 2 frail patients (1.37%) who had Type 3 endoleak and refused treatment. Postoperatively, secondary interventions were performed in 20 patients (13.7%), with endoleak being the cause in 18 patients (12.3%) out of these.

Preoperative aneurysm volume above 231.7 cm³ was associated with secondary intervention (p=0.001) (Figure 2). Preoperative thrombus volume above 206.1 cm³ was associated with secondary intervention (chi-square test) (p=0.002). There was no difference in endoleak (p=0.546) and mortality (p=0.822) regarding aneurysm sac volume above 231.7 cm³ for patients. There was no difference in terms of demographic characteristics between an aneurysm volume above or below 231.7 cm³ (Table 1).

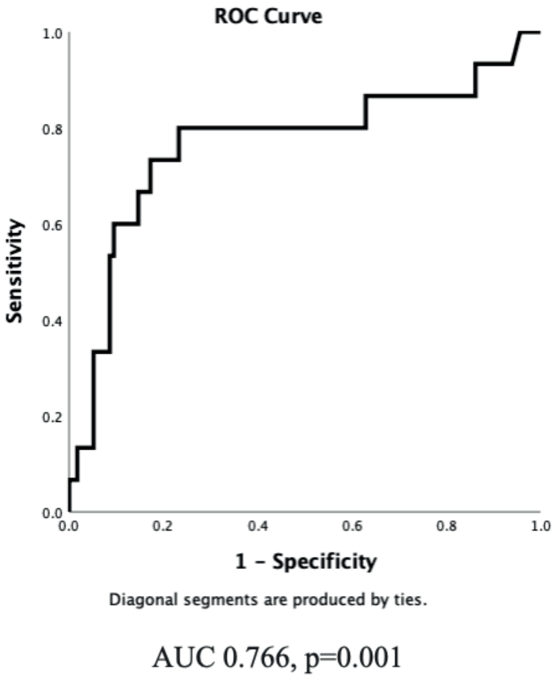

Figure 2. Relationship between preoperative sac volume and secondary intervention

DISCUSSION

The dominant treatment modality for iAAA is EVAR for today and accounts for nearly 80% of all repairs [14,15]. İşcan et al, in their study comparing EVAR and open surgery, showed that EVAR is becoming more popular day by day and successful results are obtained with the right patient selection [16]. However, continuous surveillance necessity, secondary interventions, and cost remain as criticisms of EVAR. In fact, up to 30% of patients will undergo reintervention at 10 years after their primary EVAR procedure [17,18]. In our study, it was observed that the preoperative sac volume of ≥231.7 cm³ and the thrombus volume of ≥206.1 cm³ were prone to higher secondary interventions, affecting EVAR outcomes at the midterm. However, it was not directly in relation with late mortality. There were only two cases of Aneurysm Related Mortality (ARM) who did not accept secondary intervention.

EVAR is an increasingly common procedure for open abdominal aortic aneurysm repair. Recent data confirm the benefits of EVAR in the early period, but show higher rates of reintervention compared to open surgery in the long term [3]. It is assumed that the risk of secondary intervention is likely to be associated with the specific morphological characteristics of the aneurysm rather than other factors such as the implanted device [19,20]. In the present study of volumetric analysis, we found that the preoperative volume of the aortic aneurysm was a statistically significant factor influencing higher secondary interventions for midterm follow-up. It was not in relation with mid or late term mortality.

Morphological characteristics, still considered risk factors today, are primarily evaluated by clinicians using two-dimensional diameter measurements. It is known that aneurysm size affects EVAR outcomes, with Brown et al. showing that aneurysms larger than 62 mm are at risk for complications and secondary interventions [4]. Similarly, Keith et al. demonstrated that EVAR yields better results for small-diameter abdominal aortic aneurysms compared to larger ones [7]. However, data on volumetric analysis are limited. Diameter measurement is a two-dimensional measurement and is influenced by the patient's position in the CT scan and hemodynamics [10]. Recent studies suggest that three-dimensional volumetric analysis of the aneurysm sac is safer than two-dimensional diameter measurements and provides a more reliable assessment of intra-sac morphology [10,21].

In our study, 146 patients were evaluated with both preoperative and postoperative CTA diameter measurements as well as sac volume. Preoperative aneurysm volume above 231.7 cm³ was associated with secondary intervention (p=0.001). Montelione et al. also showed that aneurysm sac volume above 159 cm³ is a risk factor for secondary intervention [20]. The high volume value in our study cohort may be attributed to the application of EVAR to patients with larger aneurysms in terms of diameter and volume, considering the average age and comorbid factors of the cohort. If some of these patients underwent EVAR due to being unsuitable for open surgery because of comorbidities, it could have affected the average aneurysm volume value and outcomes of the cohort. There was no difference in mortality among patients with sac volume above 231.7 cm³. The lack of difference in mortality between patients with sac volume over 231.7 cm³ and others does not eliminate the risk and cost of secondary intervention. Our study has shown us that aneurysm volume measurement can be effective in treatment selection and that open surgery should be considered in high-volume aneurysms. If EVAR is to be performed within the indication for high-volume aneurysms, knowing that the risk of secondary intervention is high, close postoperative follow-up of these patients is mandatory and the use of 3D volumetric analysis should be taken into consideration.

In our study, preoperative thrombus volume above 206.1 cm^3 was associated with secondary intervention ($p=0.002$). This can likely be explained by the high thrombus volume secondary to high aneurysm volume. Yeung et al. demonstrated that thrombus burden on preoperative BTA is an independent predictor of sac regression [22]. However, there is no definitive threshold value for preoperative thrombus volume that would significantly impact outcomes. In our study, the localization of thrombus within the sac was not evaluated, which may have prevented some endoleaks requiring secondary intervention by ensuring thrombosis of peri-aortic side branches.

Studies have shown that neck angle and type 1A endoleak are associated with the volume of the sac not shrinking due to high pressure in the proximal aorta, and that they negatively affect sac regression [10]. In our study, sac volume above 231.7 cm^3 did not affect type 1A endoleak rates, nor did it affect early mortality or procedure success.

In our study, endoleak was observed in 35 patients (24%), and in 10 patients (6.85%), an increase in sac volume was observed despite a decrease or no change in diameter. This indicates that some negative pathologies causing endoleak, which are not reflected in diameter changes, contribute to volume changes. Particularly in the diagnosis and monitoring of slow-flow endoleaks such as Type 2 endoleaks, diameter measurements, which are commonly used to detect minimal pathological changes, should be supplemented with volumetric analysis. Despite the high correlation between diameter and volume shown in the study, the increase in volume in these endoleak patients demonstrated the reliability of volumetric analysis.

Limitations

Our study has several limitations. These include the majority of the follow-up period coinciding with the COVID-19 pandemic and the lack of serial contrast-enhanced CTA data. If serial CTA data were available, we could have made assumptions about the timing of intrasac pathological changes. The study was conducted independently of graft brands, which could be a factor affecting the results due to different radial strengths of the grafts. Another limitation was the small cohort size of 146 patients from a single center in our study. Obtaining stronger results may be possible with larger patient cohorts and serial imaging.

CONCLUSION

This study has demonstrated that aneurysms with high preoperative volume have a high rate of secondary intervention after EVAR, and safe monitoring is only possible with volumetric analysis in addition to diameter measurement. It has also highlighted the need for different treatment and follow-up protocols for large aneurysms. For patients with high aneurysm volume if physically fitness is present, open surgical repair may be considered.

In the future, prospective, multicenter studies involving a larger number of patients will provide clinicians with more information regarding the effectiveness and threshold values of volumetric analysis.

Ethics Committee Approval: Our study was conducted prospectively in our hospital after obtaining ethical approval from the Institutional Review Board (Approval No: 1428) of Ankara City hospital's Clinical Research Ethics Committee.

Patient Consent for Publication: Consent was obtained from all of the patients.

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

Author Contributions: All authors contributed equally to the article.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Parodi JC, Palmaz JC, Barone HD. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. Ann Vasc Surg. 1991;5:491-9.
2. EVAR trial participants. Endovascular aneurysm repair versus open repair in patients with abdominal aortic aneurysm (EVAR trial 1): randomised controlled trial. Lancet. 2005;365:2179-86.
3. Patel R, Sweeting MJ, Powell JT, Greenhalgh RM; EVAR trial investigators. Endovascular versus open repair of abdominal aortic aneurysm in 15-years' follow-up of the UK endovascular aneurysm repair trial 1 (EVAR trial 1): a randomised controlled trial. Lancet. 2016;388:2366-74.
4. Brown LC, Greenhalgh RM, Powell JT, Thompson SG; EVAR Trial Participants. Use of baseline factors to predict complications and reinterventions after endovascular repair of abdominal aortic aneurysm. Br J Surg. 2010;97:1207-17. Erratum in: Br J Surg. 2011;98:162.
5. Karthikesalingam A, Holt PJ, Hinchliffe RJ, Nordon IM, Loftus IM, Thompson MM. Risk of reintervention after endovascular aortic aneurysm repair. Br J Surg. 2010;97:657-63.
6. 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.
7. Keith CJ Jr, Passman MA, Gaffud MJ, Novak Z, Pearce BJ, Matthews TC, et al. Comparison of outcomes following endovascular repair of abdominal aortic aneurysms based on size threshold. J Vasc Surg. 2013;58:1458-66.

8. Nana P, Spanos K, Dakis K, Brodis A, Kouvelos G. Imaging predictive factors of abdominal aortic aneurysm growth. J Clin Med. 2021;10:1917.

9. Spanos K, Eckstein HH, Giannoukas AD. Small abdominal aortic aneurysms are not all the same. Angiology. 2020;71:205-7.

10. Quan C, Oh YK, Park SC, Won YS, Yun SS, Suh YJ, Kim JY. Efficacy of volumetric analysis of aorta as surveillance tool after EVAR. Asian J Surg. 2019;42:746-54.

11. van Keulen JW, van Prehn J, Prokop M, Moll FL, van Herwaarden JA. Potential value of aneurysm sac volume measurements in addition to diameter measurements after endovascular aneurysm repair. J Endovasc Ther. 2009;16:506-13.

12. 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.

13. de Guerre LEVM, Dansey K, Li C, Lu J, Patel PB, van Herwaarden JA, et al. Late outcomes after endovascular and open repair of large abdominal aortic aneurysms. J Vasc Surg. 2021;74:1152-60.

14. Dua A, Kuy S, Lee CJ, Upchurch GR Jr, Desai SS. Epidemiology of aortic aneurysm repair in the United States from 2000 to 2010. J Vasc Surg. 2014;59:1512-7.

15. National Institute for Health and Care Excellence: Guidelines, in Abdominal aortic aneurysm: diagnosis and management. London: National Institute for Health and Care Excellence (NICE); 2020.

16. İşcan H, Unal E, Sarıcaoğlu M, Aytekin B, Türkcan B, Akkaya B, Yigit G, et al. Our clinical approach to the last five-year elective infrarenal abdominal aortic aneurysm: short-term results. Turk J Vasc Surg. 2018;27:1-7.

17. Kansal V, Nagpal S, Jetty P. Editor's choice - late open surgical conversion after endovascular abdominal aortic aneurysm repair. Eur J Vasc Endovasc Surg. 2018;55:163-9.

18. Wanken ZJ, Barnes JA, Trooboff SW, Columbo JA, Jella TK, Kim DJ, et al. A systematic review and meta-analysis of long-term reintervention after endovascular abdominal aortic aneurysm repair. J Vasc Surg. 2020;72:1122-31.

19. Mehta M, Sternbach Y, Taggert JB, Kreienberg PB, Roddy SP, Paty PS, et al. Long-term outcomes of secondary procedures after endovascular aneurysm repair. J Vasc Surg. 2010;52:1442-9.

20. Montelione N, Sirignano P, d'Adamo A, Stilo F, Mansour W, Capoccia L, et al. Comparison of outcomes following EVAR based on aneurysm diameter and volume and their postoperative variations. Ann Vasc Surg. 2021;74:183-93.

21. Renapurkar RD, Setser RM, O'Donnell TP, Egger J, Lieber ML, Desai MY, et al. Aortic volume as an indicator of disease progression in patients with untreated infrarenal abdominal aneurysm. Eur J Radiol. 2012;81:e87-93.

22. Yeung JJ, Hernandez-Boussard TM, Song TK, Dalman RL, Lee JT. Preoperative thrombus volume predicts sac regression after endovascular aneurysm repair. J Endovasc Ther. 2009;16:380-8.