

Evaluation of Long-term Outcomes, Complications, and Treatment Efficiency in Abdominal Aortic Aneurysm

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Abstract

Objective: The primary goal in the treatment of abdominal aortic aneurysms (AAA) is to reduce long-term morbidity and mortality by preventing aneurysm rupture. This study aimed to evaluate the effect of aneurysm morphology before endovascular aneurysm repair (EVAR) in AAA on prognosis, compare the changes in aneurysm morphology after mid- and long-term follow-up after EVAR with extensive randomized studies, and evaluate the treatment efficacy.

Methods: A total of 75 patients who were evaluated with pre-operative computed tomography angiography (CTA) with a preliminary diagnosis of AAA in our institution and had a perioperative digital subtraction angiography examination and at least one post-operative follow-up CTA examination >12 months were included in the study. Additional interventions were recorded during the procedure, complications, endoleak types, demographic data, and changes in aneurysm morphology. The results were compared with the data in the literature.

Results: The mean follow-up period was calculated as 37 months. A mean decrease of 4.5 mm was detected in AAA diameter. A mean reduction of 4 mm in thickness was observed in accompanying common iliac artery (CIA) aneurysms ($p=0.016$). Complications were observed in 32% of the patients. The most common complication was Type 2 endoleak, which was observed in 25% of the patients. We did not observe a significant difference in pre-operative and post-operative mean thrombus thickness ($p=0.588$). Endoleak rate was increased in patients with bilateral CIA aneurysms accompanying AAA ($p=0.044$). While there was no significant effect of changing the AAA diameter in those with increasing thrombus diameter, it was observed that the aortic diameter decreased in those with decreasing thrombus diameter ($p=0.012$).

Conclusion: Our 10-year experience with EVAR shows that many complications may occur after stent grafting. Caution should be exercised regarding Type 2 endoleaks. Lifelong follow-up is necessary to prevent aneurysm rupture after EVAR.

Keywords: Abdominal aortic aneurysms; computed tomography angiography; digital subtraction angiography; endoleak; endovascular aneurysm repair treatment.

Abdominal Aort Anevrizmasında Uzun Dönem Sonuçlarının, Komplikasyonların ve Tedavi Etkinliğinin Değerlendirilmesi

Özet

Amaç: Abdominal aort anevrizmalarının (AAA) tedavisindeki temel amaç, rüptürü önlemek ve uzun vadeli morbidite ve mortaliteyi azaltmaktır. Abdominal aort anevrizmalarda endovasküler tedaviden (EVAR) önceki anevrizma morfolojisinin prognoza etkisi, EVAR sonrası orta-uzun dönem takipler sonucu anevrizma morfolojisinde meydana gelen değişikliklerin çok merkezli büyük randomize çalışmalarla karşılaştırılarak tedavi etkinliğinin değerlendirilmesi amaçlanmıştır.

Yöntem: Kurumumuzda abdominal aort anevrizması ön tanısı ile preoperatif bilgisayarlı tomografi anjiyografi (BTA) ile değerlendirilen ve peroperatif Dijital Subtraksiyon Anjiyografi (DSA) incelemesi ve en az bir postop-

Cite This Article: Özgür E, Sevinç Özgür D, Acunaş B. Evaluation of Long-term Outcomes, Complications, and Treatment Efficiency in Abdominal Aortic Aneurysm. Koşuyolu Heart J 2026;29(1):43–48

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Submitted: December 01, 2025

Revised: January 11, 2026

Accepted: January 13, 2026

Available Online: March 18, 2026



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eratif takip BTA incelemesi >12 ay olan yetmiş beş hasta çalışmaya dahil edildi. İşlem sırasında ek müdahaleler, komplikasyonlar, endoleak tipleri, demografik veriler ve anevrizma morfolojisindeki değişiklikler kaydedildi. Sonuçlar literatürdeki verilerle karşılaştırıldı.

Bulgular: Ortalama takip süresi 37 ay hesaplandı. AAA çapında ortalama 4,5 mm azalma saptandı. Eşlik eden CİA anevrizmalarında ortalama 4 mm kalınlık azalması izlendi ($p=0,016$). Hastaların %32'sinde komplikasyon izlendi. En sık görülen komplikasyon Tip 2 endoleak olup hastaların %25'inde izlendi. Preoperatif ve postoperatif ortalama tromboz kalınlığında anlamlı farklılık izlenmedi ($p=0,588$). AAA'ya eşlik eden bilateral CİA anevrizması olan hastalarda endoleak görülme oranında artış izlendi ($p=0,044$). Tromboz çapı artanlarda AAA çapının değişiminin belirgin etkisi yokken tromboz çapı azalanlarda aort çapının azaldığı görüldü ($p=0,012$).

Sonuç: AAA'nın endovasküler tedavisi ile ilgili 10 yıllık deneyimimiz, stent-greftlemeden sonra birçok komplikasyonun olabileceğini göstermektedir. Tip 2 Endoleakler açısından dikkatli olunmalıdır. EVAR sonrası anevrizma rüptürünü önlemek için ömür boyu takip gereklidir.

Anahtar sözcükler: Abdominal aort anevrizmaları; bilgisayarlı tomografi anjiyografisi; dijital çıkarma anjiyografisi; endoleak; endovasküler tedavi.

Introduction

An abdominal aortic aneurysm (AAA) is defined as a 50% increase in the subdiaphragmatic aortic diameter or an infrarenal aortic diameter >3 cm.^[1] The prevalence of an abdominal aortic diameter >3 cm in individuals over the age of 50 ranges from 3% to 10%. AAA is most commonly observed in older men with a history of smoking, hypertension, hypercholesterolemia, peripheral artery disease, and coronary artery disease.^[1] The enlargement of an aneurysm is directly associated with the progressive weakening of the aortic wall. The risk of rupture increases with aneurysm diameter; estimated at 1–3% per year for aneurysms measuring 4–5 cm, 6–11% per year for those measuring 5–7 cm, and approximately 20% per year for aneurysms exceeding 7 cm in diameter.^[2]

The primary objective of aneurysm treatment is to reduce long-term morbidity and mortality by preventing rupture. Endovascular aneurysm repair (EVAR), first reported by Parodi et al. in 1991, has become widely used as a less invasive alternative to conventional open surgery for the management of AAAs.^[3] Today, EVAR is employed as the first-line treatment option in many centers. According to the UK National Vascular Registry report, the preference for EVAR as the initial treatment increased from 54% in 2009 to 69% in 2015.^[4] Since it is less invasive than open surgery and can be performed under regional anesthesia in patients with significant comorbidities, perioperative mortality is significantly lower compared to open surgical repair.^[5] The early outcomes of EVAR for AAA repair, which demonstrate superiority over open surgery has been supported by large randomized controlled trials, including the Dutch randomized endovascular aneurysm management, EVAR I, EVAR 2, the endovascular versus open repair of ruptured abdominal aortic aneurysm trial (IMPROVE), and the open versus endovascular repair trial for AAAs.^[6] Within the scope of this study, we aimed to investigate the long-term complications associated with stent-grafts following EVAR and to assess the overall effectiveness of the treatment.^[6] This study aimed to elucidate the long-term complications associated with stent-grafts following EVAR and to evaluate the overall effectiveness of the treatment.

Materials and Methods

We evaluated a total of 343 patients who were diagnosed with AAA by computed tomography angiography (CTA) and underwent endovascular aortic repair using the Medtronic Endurant II stent-graft (CE) over the last 10 years. The evaluation was conducted in three stages: Pre-operative, post-operative, and follow-up. Of

these, 75 patients with both pre-operative and post-operative (≥ 12 months) follow-up CTA images available in the picture archiving and communication system (PACS) were included in the study. We excluded patients with <12 months of follow-up, those without pre-operative CTA, those followed by magnetic resonance angiography, those who had only pre-operative CTA, and those whose DSA images were not available in the PACS.

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. This study was approved by the İstanbul University İstanbul Faculty of Medicine (Date: 18.10.2019, Decision no: 1254), and informed consent has been obtained from all participants.

Stent Application

The Endurant II stent-graft was used in cases of infrarenal AAAs, or aortoiliac aneurysms. It can be deployed in aorto-bi-iliac, aorto-uni-iliac, or tubular configurations.^[7,8] Aortouni-iliac stent-grafts are reserved for anatomies unsuitable for bifurcated or standard aortic stents. In our study, we evaluated patients who received aortic stent-grafts and had more than 12 months of follow-up. Parameters assessed included changes in the aneurysmal sac diameter, iliac artery aneurysm diameter (if present), thrombus diameter, aneurysm morphology, and the stent-graft components used. In addition, endoleak incidence rates, stent-graft stenosis, graft migration, and total complication incidence rates were examined proportionally, and the effects of aneurysm morphology and time-dependent impact were investigated. Additional intervention incidence rates, aneurysm diameter, and thrombus morphology changes were examined retrospectively. Aneurysm morphology was evaluated in sagittal, coronal, and axial planes using the multiplanar reformation technique on images retrieved from the PACS system. The maximum aneurysm diameters were measured and recorded twice by a single investigator. In addition, the temporal changes of complications in follow-up images and the treatment effectiveness as the follow-up period increased were compared with literature data.

Statistical Analysis

Descriptive statistics were presented as mean \pm standard deviation, median (minimum-maximum), and frequency (percentage) where appropriate. The normality of data distribution was assessed using the Kolmogorov–Smirnov test.

Table 1. Frequencies of demographic data findings before and after the procedure

	n (%)		n (%)
Gender		AAA diameter stable	10 (13.30)
Female	13 (17.30)	Thrombosis diameter	29 (38.70)
Male	62 (82.70)	Thrombosis diameter	41 (54.70)
Aortic-bi-iliac		Main body >%30 stenosis	
(+)	73 (97.33)	(+)	5 (6.7)
Aortic-uni-iliac		Complication	
(+)	2 (2.66)	(-)	51 (68)
Migration		(+)	24 (32)
(+)	5 (6.70)	Endoleak total	
I	3 (4)	(+)	22 (29.30)
II	2 (2.70)	Type 1A endoleak	0
Stent graft kink		Type 1B endoleak	4 (5)
(+)	0	Type 2 endoleak	19 (25.30)
Stent leg occlusion		Type 3 endoleak	0
(+)	6 (8)	Type 4 endoleak	1 (1.30)
Single CIA aneurysm		Type 5 endoleak	0
(+)	13 (17.30)	Second operation	
Double CIA aneurysm		(+)	8 (10.7)
(+)	11 (14.70)	Second operation post	
AAA diameter increasing	17 (22.70)	(+)	3 (4.00)
AAA diameter decreasing	48 (64)		

CIA: Common iliac artery, AAA: Abdominal aortic aneurysms.

Table 2. Mean values of aneurysm diameter changes and complications

	Mean±standard deviation	Median	Minimum	Maximum
Age	70.70±9	72.00	42.00	89.00
Follow-up (ay)	37.80±24.3	32.00	12.00	109.00
Leg migration (mm)	21±8.5	21	9	33
Main body migration (mm)	19.5±9.2	19.5	13	26
CIA aneurysm initial diameter (mm)	36±15.8	30	22	91
CIA aneurysm final diameter (mm)	32.2±16	27	20	76
AAA initial diameter (mm)	61.4±15.9	57	37	128
AAA final diameter (mm)	57±19.1	53	24	124
Thrombosis thickness initial (mm)	26±14.9	25	0	80
Thrombosis thickness final (mm)	26.6±15.7	23	0	74

CIA: Common iliac artery; AAA: Abdominal aortic aneurysms.

Comparisons between independent quantitative variables were performed using the Mann–Whitney U test. Paired quantitative variables were analyzed using the Wilcoxon signed-rank test.

For the analysis of categorical variables, the chi-square test was applied; when the assumptions for the chi-square test were not met, Fisher's exact test was used.

Correlation between variables was evaluated using Spearman's rank correlation coefficient.

All statistical analyses were conducted using the Statistical Package for the Social Sciences software version 22.0. A value of $p < 0.05$ was considered statistically significant.

Results

We included seventy-five patients who underwent AAA repair with the Endurant II stent-graft in this study.

Among the 24 patients who experienced complications, endoleak was identified in 22 cases. Among the 13 patients with isolated common iliac artery (CIA) aneurysms, eight were endoleak-negative, and five were endoleak-positive, with no significant difference in the occurrence of isolated CIA aneurysms between the two groups. No significant difference in the incidence of stent-graft limb occlusion was observed between the endoleak-positive and endoleak-negative groups (Table 1, 2).

Table 3. Comparison of secondary complications in patients with endoleak following first versus second EVAR procedures

EVAR	Complication (-)		Complication (+)		p m
	Mean±SD	Median	Mean±SD	Median	
CIA aneurysm diameter (mm)					
Before	38.7±19.0	30.0	33.1±11.4	29.5	0.892
After	32.2±17.5	24.0	32.3±14.9	28.0	0.156
AAA diameter (mm)					
Before	61.7±16.3	57.5	61.1±15.6	56.0	0.523
After	53.8±18.1	50.5	63.3±19.6	62.0	0.280
Thrombosis thickness (mm)					
Before	26.1±13.9	25.5	25.8±17.1	25.0	0.773
After	25.1±13.9	22.5	29.5±18.7	25.0	0.620
Patients with increased thrombus thickness (%)	15 (30)		14 (56)		0.019
Patients with decreased thrombus thickness (%)	31 (62.0)		10 (40.0)		0.071

m: Mann–Whitney U test. SD: Standard deviation; CIA: Common iliac artery; AAA: Abdominal aortic aneurysms; EVAR: Endovascular aneurysm repair.

The mean diameter of the CIA aneurysm before EVAR was 36.0 ± 15.8 mm, which decreased to 32.2 ± 16.0 mm following the procedure. This reduction was statistically significant ($p=0.016$). The final measured AAA diameter (57.0 ± 19.1 mm) showed a significant decrease compared to the initial measurement (61.4 ± 15.9 mm) ($p=0.001$). No significant correlation was found between the follow-up duration, the initial thrombus thickness, and the final thrombus thickness.

There were no significant differences in age (70.6 ± 8.4 vs. 70.7 ± 10.2 years, $p=0.95$) or male sex distribution (84.0% vs. 80.0%, $p=0.66$) between patients with and without complications. Although the follow-up period was longer in patients with complications compared to those without (46.7 ± 28.9 vs. 33.4 ± 20.5 months), the difference was not statistically significant ($p=0.21$). The mean initial CIA aneurysm diameter was 33.1 mm in the group with complications and 38.7 mm in the group without complications. However, this difference was not statistically significant ($p=0.892$) (Table 3).

The second operation rate was significantly higher ($p=0.001$) in the group with complications than in the group without complications. After the second operation, the endoleak rate was significantly ($p=0.023$) higher in the group with complications.

The first measured thrombus thickness mean was 24.6 mm in the endoleak group and 26.5 mm in the non-endoleak group, and there was no statistically significant difference ($p=0.089$) between them.

There was no significant difference between the last measured thrombus thicknesses in the endoleak and non-endoleak groups ($p=0.239$). Of the 29 patients whose thrombus diameter increased, 15 had endoleak (-), 14 had endoleak (+), and the diameter increase was significantly ($p=0.008$) higher in the endoleak positive group (Table 4).

No significant correlation was observed between the follow-up period, the first measured thrombus thickness, and the final thrombus thickness (Table 2).

Discussion

The aneurysmal segment is defined as an abdominal aortic diameter >30 mm or a region with a diameter increase of $>50\%$ from the regular diameter segment.^[9] Most AAAs are asymptomatic and are mainly detected incidentally.^[10,11] Management of AAAs depends on the aneurysm diameter. The most important long-term prognostic factor for the success of AAA treatment is the decrease in aneurysm diameter. However, some aneurysms continue to increase in diameter.^[11,12]

Changes in aneurysm morphology over time following treatment may reduce the effectiveness of the intervention and can even contribute to treatment failure.^[13,14]

In our study, we investigated the complication rates and their relationship with follow-up duration in patients who underwent EVAR for AAA and were monitored for more than 12 months. We also evaluated the association between the initial aneurysm diameter, baseline thrombus thickness, and treatment efficacy; assessed how complications varied according to aneurysm morphology; and examined the effects of concomitant iliac artery aneurysms and aneurysm diameter on prognosis.

Tsuyuki et al.^[15] claimed that a high thrombotic area/patent lumen ratio is more effective in aneurysm shrinkage.^[16] In our study, the thrombotic area/patent lumen ratio was not studied. In our study, we observed a decrease in aortic diameter in 33 of 41 patients with reduced thrombus thickness. There was no significant effect of the change in AAA diameter in those with increased thrombus diameter. While the follow-up periods in our study varied, we did not observe a clear relationship between follow-up period and thrombus thickness. However, in our study, complications developed in 14 of 29 (48.2%) patients with increased thrombus diameter and 10 of 41 (24.3%) patients with decreased thrombus diameter. These data show that developing complications rates are relatively lower in individuals with reduced thrombus diameter.

In the ENGAGE study, the total number of patients with endoleak at the end of 3 years was 277, and the rate was calcu-

Table 4. Comparison of complications based on the presence or absence of endoleak

Complication	Endoleak (-)	Endoleak (+)	p	Complication	Endoleak (-)	Endoleak (+)	p
	n (%)	n (%)			n (%)	n (%)	
Single CIA aneurysm				Stent-graft kink			
(-)	44 (86.30)	18 (75.00)	0.229	(-)	53 (100)	22 (100.00)	0.172
(+)	7 (13.70)	6 (25.00)		(+)	0	0	
Double CIA aneurysm				Stent-graft leg occlusion			
(-)	46 (90.20)	18 (75.00)	0.083	(-)	50 (94.30)	19 (86.40)	0.351
(+)	5 (9.80)	6 (25.00)		(+)	3 (5.70)	3 (13.60)	
AAA				Single CIA aneurysm			
(-)	0	0	0.550	(-)	45 (84.90)	17 (77.30)	0.507
(+)	51 (100)	24 (100.00)		(+)	8 (15.10)	5 (22.70)	
AAA diameter				Double CIA aneurysm			
Increasing	5 (8.00)	13 (56.00)	0.002	(-)	46 (91.20)	18 (75)	0.044
Decreasing	39 (76.00)	8 (36.00)	0.001	(+)	5 (9.80)	6 (25)	
Stable	9 (16.00)	1 (8.00)	0.337	Total CIA aneurysm			
Thrombosis diameter				(-)	40 (75.50)	13 (44.20)	0.156
Increasing	15 (30.00)	14 (56.00)	0.008	(+)	13 (24.50)	11 (45.80)	
Decreasing	33 (62.00)	8 (40.00)	0.040	>30% Stenosis in main graft			
Second operation				(-)	50 (94.30)	20 (90.90)	0.605
(+)	2 (2.00)	6 (28.00)	0.001	(+)	3 (5.70)	2 (9.10)	
(-)	51 (98)	16 (72)		AAA			
Endoleak	Absent	Present	p	(-)	0	0	0.465
Migration				(+)	53 (100)	22 (100)	
(-)	51 (96.20)	19 (86.40)	0.147	Second operation			
(+)	2 (3.80)	3 (13.60)		(-)	51 (96.20)	16 (72.70)	0.007
				(+)	2 (3.80)	6 (27.30)	

Chi-square test. CIA: Common iliac artery, AAA: Abdominal aortic aneurysms.

lated as 27.7%.^[8] In the DREAM and EUROSTAR studies, the endoleak rates at the end of the 1st year were calculated as 20% and 15.5%, and the cumulative values in the follow-up years were similar to those in the ENGAGE study.^[17] In our research, endoleak was seen in 22 of 75 patients, and the rate was calculated as 29.3%, which is generally consistent with the literature.^[18,19] Still, it was thought that the difference was due to using a stent-graft outside the IFU criteria in our study.

There was no relationship between the abdominal or iliac artery aneurysm diameters of the patients and the occurrence of endoleaks. Still, our study observed that concomitant double iliac artery aneurysms increased endoleak incidence. Our findings are consistent with previously published data.^[20]

When we grouped the patients with AAAs as aneurysm diameters >60 mm and <60 mm, we did not observe an increase in the incidence of endoleaks. We also found that the initial diameter of the AAA did not significantly affect the complication rate and the number of complications. However, in the study conducted by Boulton et al.^[19] in 2006 with 961 patients, they reported that the frequency of sac expansion and the

second operation increased after EVAR in the patient group with aneurysm diameters >60 mm.

In our study, we thoroughly examined how the initial morphology of the aneurysm influenced treatment outcomes in patients who developed endoleaks or other procedure-related complications. Furthermore, we explored the relationship between endoleaks – the most frequent complication – and both stent deployment and aneurysm morphology. Overall, our findings align well with previously reported data in the literature.^[21] These results suggest that aneurysm morphology at baseline may play a critical role in determining both the risk and the type of post-procedural complications, highlighting the importance of individualized pre-procedural assessment and stent selection. The main limitation of our study is the relatively small sample size resulting from the strict patient selection criteria. A larger cohort might have increased the likelihood of detecting statistically significant differences. In addition, aneurysm diameters and wall thicknesses were measured at the widest point on axial sections, whereas the craniocaudal length of the aneurysm was not assessed. Approximately 30% of the patients underwent emer-

gency procedures for indications outside the device's instructions for use, which introduced heterogeneity to the study population. Finally, aneurysmal calcification and tortuosity indices were not incorporated into the analysis, which may have limited the comprehensiveness of morphological evaluation. Despite these limitations, our findings offer important insights into the relationship between aneurysm morphology, procedural characteristics, and post-treatment complications, providing a basis for future studies with larger and more homogeneous cohorts.

Conclusion

Our 10-year experience with endovascular repair of AAA demonstrates that a substantial number of complications may arise following stent-graft implantation. Among these, Type 2 endoleaks remain the most frequent and clinically significant issue, requiring careful monitoring and timely management.

Despite advances in device technology and operator experience, the long-term success of EVAR largely depends on exact pre-procedural planning, adherence to anatomical suitability criteria, and vigilant post-procedural surveillance.

Lifelong imaging follow-up is essential to identify late complications, prevent aneurysm rupture, and ensure durable treatment outcomes. These findings emphasize the need for individualized patient assessment and the continued optimization of stent design and procedural strategies in order to improve the safety and efficacy of EVAR further.

Disclosures

Ethics Committee Approval: The study was approved by the İstanbul University İstanbul Faculty of Medicine Ethics Committee (no: 1254, date: 18/10/2019).

Informed Consent: Informed consent was obtained from all participants.

Conflict of Interest Statement: All authors declared no conflict of interest.

Funding: The authors declared that this study received no financial support.

Use of AI for Writing Assistance: The authors used AI and AI-assisted Technologies (Grammarly and MS Word Editor) in the writing process. These technologies improved the readability and language of the work. Still, they did not replace key authoring tasks such as producing scientific or medical insights, drawing scientific conclusions, or providing clinical recommendations. The authors are ultimately responsible and accountable for the contents of the whole work.

Author Contributions: Concept – E.Ö.; Design – E.Ö.; Supervision – B.A., E.Ö.; Data collection and/or processing – E.Ö.; Analysis and/or interpretation – E.Ö., D.S.Ö.; Literature review – E.Ö., D.S.Ö.; Writing – E.Ö.; Critical review – B.A.

Acknowledgments: QA Executive Consultancy, Ozan Batigun MD, MBA in 2024, has conducted the editorial support of this article. www.QAexecutiveconsultancy.com Ozan.Batigun@outlook.com

Peer-review: Externally peer-reviewed.

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