Implications of aortic neck dilation following thoracic endovascular aortic repair

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ABSTRACT

Objective: This article reports on a retrospective observational study designed to evaluate the incidence, etiology, and clinical implications of aortic neck dilation following thoracic endovascular aortic repair (TEVAR) for aneurysms with landing zones II and III.

Methods: The study included 37 patients who underwent TEVAR and had postoperative computed tomography angiography available within 30 days and at least one computed tomography angiography at 1 year postoperatively. The primary end point was proximal aortic dilation (defined as growth ≥5 mm or ≥10% of the original diameter), and secondary end points included annual growth of the aneurysmal sac, device migration, endoleak, and reintervention with additional neck-related adverse events. The measurements taken during follow-up included the maximum diameter of the aneurysm and aortic diameter at various locations relative to the stent graft.

Results: During follow-up, a significant increase in aortic diameter was observed at the proximal edge of TEVAR. The estimated freedom from 5 mm or 10% proximal aortic neck growth at 1, 2, and 3 years was 81%, 70%, and 65%, respectively. At the proximal edge of TEVAR the type III aortic arch was significantly associated with 5 mm growth during follow-up ($P = .047$) and this growth (5 mm or 10%) as well as a 10% increase at +20 mm were significantly associated with more aortic-related reinterventions. Moreover, an aortic diameter at the start <36 mm was associated with a greater increase during follow-up (area under curve in receiver operating characteristic >80%; $P < .05$).

Conclusions: The study concludes that proximal aortic dilation after TEVAR is a common and progressive phenomenon, and the management strategies for aortic neck dilation, including surveillance, secondary interventions, and open conversion, should be considered carefully to optimize patient outcomes and improve the long-term success of the procedure.

Keywords: Thoracic aorta; Thoracic endovascular aortic repair; Aneurysm; Aortic neck dilation; Stent migration

Although thoracic endovascular aortic repair (TEVAR) has been shown to be an effective treatment option, aortic neck dilation (AND) remains a significant concern, which can lead to endoleak and stent graft migration.

AND after TEVAR is a complex phenomenon influenced by various factors such as patient-specific anatomical characteristics, device-specific design, and the extent of the aortic pathology. The extent of AND after TEVAR can vary widely, ranging from mild dilation to severe anatomical changes. Therefore, it is essential to evaluate the incidence, risk factors, and clinical significance of AND after TEVAR to optimize patient outcomes.

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Few studies have reported the incidence of AND and the fate of aortas that developed an AND after TEVAR used to treat thoracic aortic aneurysm[1-3]; only two have reported on multiple measurements of the aorta after TEVAR in the literature.[1,3] A significant low number of patients in the last one[3] (15 patients treated owing to aneurysm) and a limited follow-up period as well as a missing three-dimensional reconstruction of the computed tomography (CT) scan (neck size was defined as the minor diameter of the best-fit ellipse of the aortic neck) in the second[1] have reduced the robustness of their results. However, the exact etiology and mechanism of AND remain unclear. Some studies have suggested that it may be due to the biomechanical stresses on the aortic wall caused by the stent graft,[4] and others have proposed that it may be related to the underlying aortic pathology.[3]

The purpose of this article is to evaluate the incidence, etiology, and clinical implications of AND after TEVAR of an aortic aneurysm. We review our single-center TEVAR data bank on this topic and discuss the implications of AND for patient outcomes. Additionally, we discuss potential management strategies for AND, including surveillance, secondary interventions, and conversion to open surgery. Overall, understanding the risk factors and management strategies for AND after TEVAR is critical for optimizing patient outcomes and improving the long-term success of this minimally invasive procedure.

METHODS

Study design. In a retrospective observational study for the period 2007 to 2018, patients who underwent TEVAR for degenerative aneurysms with landing zones (LZ) II and III were included.

Inclusion criteria. The inclusion criteria for this study include patients who underwent TEVAR (inside the instructions for use of the used stent grafts) for aneurysms with LZ II and III, had no perioperative type I or III endoleak, had postoperative contrast enhanced CT angiography (500- to 625-μm slice thickness) available within 30 days, and had at least one CT angiography at 1 year postoperatively. The patients should not have undergone supra-aortic debranching beyond the left subclavian artery.

Exclusion criteria. Patients with aortic dissection, CT angiography within <1 year, or emergent procedures were excluded from this study.

End points. The primary end point of this study is proximal aortic dilation (defined as growth ≥5 mm or ≥10% of the original diameter). The primary end point was determined analyzing the power of the study: Estimate power of one-sample proportion using a normal approximation, using a nondirectional (two-sided) analysis with a significance level of 0.05. The results of this analysis indicated a power of 82.7%.

Secondary end points include annual growth of the aneurysmal sac compared with the postoperative CT, determination of aneurysm sac growth, EL I or III, device migration in relation to neck-related adverse event, and reintervention with AND.

Measurements in CT angiography. Measurements were obtained on CT imaging by two investigators (W.A., P.W.) using a specialized program (IMPAX EE R20 2019 by AGFA HealthCare N.V, Mortsel, Belgium) from outer to outer aortic wall with high interobserver agree-ment achieved for the measurements of aortic diameter at the different defined sites. The CTs were reconstructed in three-dimensional and center lumen line.

The left common carotid artery and celiac axis were used as reference markers during follow-up.

Fig 1 demonstrates the different zones of the measurements. The measurements include.

- A. Maximum diameter of the aneurysm,
- B. Aortic diameter at 20 mm proximal to the stent graft proximal edge (+20) or A
- C. Aortic diameter at 10 mm proximal to the stent graft proximal edge (+10) or B
- D. Aortic diameter at the stent graft proximal edge (0) or C
- E. Aortic diameter at 10 mm distal to the stent graft proximal edge (−10) or D
- F. Aortic diameter at 20 mm distal to the stent graft proximal edge (−20) or E
- G. Calcification of the aortic neck, and thrombus in the aortic neck (in quartiles 1, 2, 3 and 4).

AND was defined as a 5 mm and/or 10% increase of aortic diameter at measurement sites C, D, and E, simultaneously.

We described the TEVAR procedure in details in one of our previous works.[5]

Statistical analyses. Data were collected from patient records and CT angiography images. We performed statistical analyses using the SPSS 29 package for Windows 10 (IBM SPSS Statistics Version 28.0.1.0, Armonk, NY, 2021). Data are expressed as median and min/max for nonparametric data and as mean with standard deviation for parametric data. Mann-Whitney test for independent and Wilcoxon signed rank test for dependent samples were used to compare the continuous variable and the χ^2 test to compare the categorical variable. A P value of <.05 was regarded as significant. An intraclass correlation coefficient with Fleiss-Kappa test analysis was used to evaluate the between-investigator measure variance. Kaplan-Meier curves were used to estimate the freedom of the 5 mm/10% aortic growth.

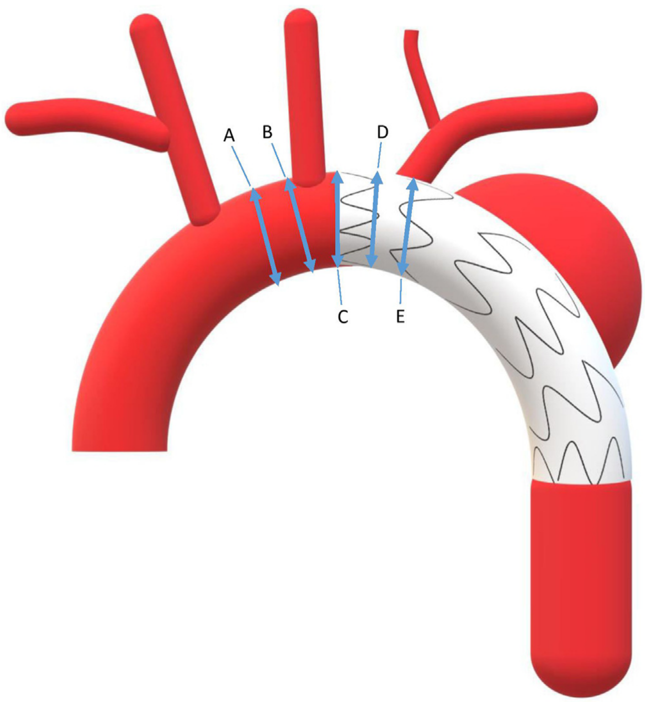

Fig 1. Zones of the measurements. **(A)** Aortic diameter at 20 mm proximal to the stent graft proximal edge (+20). **(B)** Aortic diameter at 10 mm proximal to the stent graft proximal edge (+10). **(C)** Aortic diameter at the stent graft proximal edge (0) - or C. **(D)** Aortic diameter at 10 mm distal to the stent graft proximal edge (−10). **(E)** Aortic diameter at 20 mm distal to the stent graft proximal edge (−20).

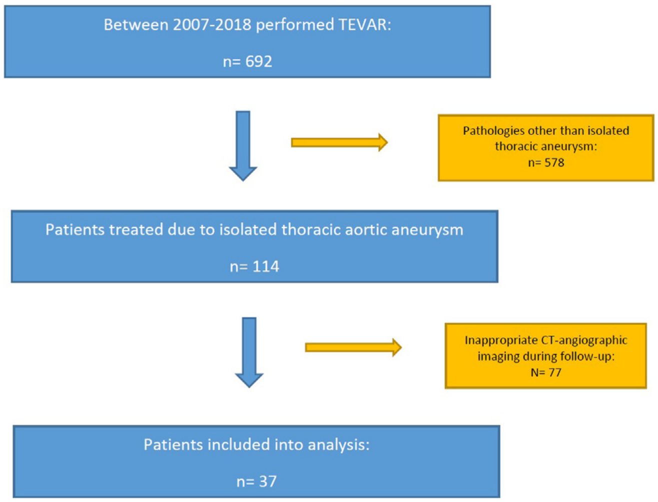

Fig 2. A flow chart of the number of included and excluded patients. *CT*, computed tomography; *TEVAR*, thoracic endovascular aortic repair.

Ethical considerations. The institutional review board approved this study, and patient confidentiality was maintained throughout the study. Informed consent was waived owing to the retrospective nature of the study.

RESULTS

In the study period, 114 patients (68 male) with a mean age of 72 ± 9 years underwent TEVAR owing to a thoracic aortic aneurysm. Only 37 patients fulfilled the inclusion criteria with appropriate CT angiographic imaging during follow-up (patients not showing up for their scheduled appointments to get the CT scan). A flow chart of the number of included and excluded patients is shown in Fig 2. To determine the differences between the two groups (patients with follow-up scans vs those without), we examined various demographic and clinical variables, including age, gender, comorbidities, initial presentation, aortic geometry, and LZs. Our analysis did not reveal any statistically significant differences between these groups in terms of these variables.

The median follow-up was 47 months (range, 12-117 months). The incidence of AND during the completely follow-up period was 27.5%. The patients' characteristics, divided into two groups with and without AND, are demonstrated in Table I. An intraclass correlation (average measures) of >0.81 to 0.89 between the two investigators who performed the measurements with a *P* value of <.001 was found.

During follow-up, a significant increase in aortic diameter was observed at the proximal edge of TEVAR (location C): 36.6 mm ±6.9 mm vs 38.6 mm ±5.9 mm (*P*= .038), as well as at location D: 36.5 mm ±6.9 mm vs 39.5 mm ±6.6 mm (*P*= .006). At location E, there was a tendency for the diameter to increase (*P* = .062), although no significant increase in aortic diameter was seen at locations A and B at the end of the follow-up period. The difference in diameter at the measured zones during follow-up compared with the postoperative measurements are shown in Table II.

Table III demonstrates an extensive overview comparing the aortic size at the different plans between AND and non-AND groups of patients. No significant difference was observed between LZs II and III with respect to growth (5 mm or 10%) at 20, 10, 0, −10, or −20 proximal. Moreover, no correlation was observed between growth and aortic arch type, except for type III aortic arch, which was significantly associated with 5 mm growth at the proximal edge of TEVAR during follow-up (*P* = .047).

No correlation was found between oversizing and growth (5 mm or 10%) at 20, 10, −10, or −20 proximal. However, a cut-off value of ≤36.3 mm of the aortic diameter at location C was found to predict a 10% or 5 mm increase in diameter during follow-up with a sensitivity of 85% and 75%, respectively. The same value has a sensitivity and specificity of 88% and 70%, respectively with an area under curve of 80% to predict AND.

Table I. Basic characteristics of patients

	No AND (n = 29)	AND (n = 8)	*P* value
Female/male	12 (41)/17	3 (38)/5	.588
Diabetes	3 (10)	0	.470
Hypertension	25 (86)	6 (75)	.387
Prior coronary artery disease	8 (28)	3 (38)	.444
Chronic obstructive pulmonary disease	5 (17)	2 (25)	.479
Cerebrovascular disease	3 (10)	0	.470
Smoking	11 (38)	2 (25)	.790
ASA			.351
II	6 (21)	0	
III	19 (66)	7 (88)	
IV	4 (14)	1 (13)	
eGFR <60 mL/min	4 (14)	2 (25)	.344
Proximal LZ			.171
II	18 (62)	2 (25)	
III	10 (34)	6 (75)	
Type of aortic arch			.732
I	6 (21)	1 (13)	
II	12 (41)	3 (38)	
III	10 (34)	4 (50)	
Presence of calcification	0	2 (25)	**.025**
Need for reintervention	5 (17)	5 (61)	**.021**
Oversizing of the stent graft	23 ±14%	31 ±15%	.096
Diameter of the proximal LZ, mm	30.0 ±3.9	28 ±4	.251
Type of stent graft			.850
Gore[a] (cTAG)	20 (69)	6 (75)	
Cook[b] (TX2, Alpha)	8 (22)	2 (25)	
Medtronic[c] (Valiant)	1 (3)		

AND, Aortic neck dilation; *ASA*, American Society of Anesthesiologists; *eGFR*, estimated glomerular filtration rate; *LZ*, landing zone.
AND is defined as 5 mm and/or 10% increase of aortic diameter at measurement sites: C, D and E.
Values are number (%) or mean ± standard deviation. Boldface entries indicate statistical significance.
[a]W. L. Gore & Associate (Flagstaff, AZ).
[b]Cook medical llc (Bloomington, IN).
[c]Medtronic (Minneapolis, MN).

At locations A, B, and C, a smaller aortic diameter at the start was associated with a greater increase during follow-up (area under curve in receiver operating characteristic = 82%, 85%, and 83% with $P < .05$, respectively). Additionally, at location D, a cut-off value of ≤36 mm of the aortic diameter was found to predict a 10% increase in diameter during follow-up with a sensitivity of 70% and specificity of 75%.

A 10% increase at location A and 5 mm or 10% increase at location C were associated with more aortic-related reinterventions (P = .012, .02, and .017, respectively), whereas a tendency toward more reintervention was seen with a 5-mm increase at locations D and E (P = .052 both) and with the presence of calcification at the proximal LZ (P = .064). A detailed description of the reintervention during the follow-up period is shown in Table IV.

Freedom of a 5-mm or 10% increase of aortic diameter at the different measured zone is analyzed using Kaplan-Meier curves (Supplementary Fig, online only). The estimated freedom from 5 mm/10% aortic growth at the proximal TEVAR edge (location C) at 1, 2, and 3 years was 81%, 70%, and 65%, respectively.

Interestingly, calcification of the aortic neck and the presence of a thrombus were not significantly associated with any of the other outcomes of interest. However, the maximum aneurysm diameter showed a significant reduction during follow-up, with a median (minimum, maximum) preoperative diameter of 67.5 mm (38, 119) and 60.9 mm (35, 120) at the end of the follow-up period (P = .017). Additionally, the proximal LZ II was significantly associated with increased aneurysmal diameter (P = .034) when compared with zone III.

DISCUSSION

Our results showed a significant increase in aortic diameter at the proximal edge of the TEVAR (location C) and location D during follow-up. Moreover, smaller aortic diameter at locations A, B, and C at the start of the follow-up period were associated with a greater increase in diameter during follow-up as well as the development of AND. A phenomenon found similar for infrarenal aortic aneurysm repairs.[6] In our study, a cut-off value of ≤36.3 mm of the aortic diameter at location C predicted a 10% or 5-mm increase in diameter during follow-up with a sensitivity of 85% and 75%, respectively.

Previous studies have reported varying degrees of AND after TEVAR, ranging from 1.3 to 6.2 mm at the proximal end of the stent graft, depending on the follow-up period and the definition of aortic dilation.[3] Our study showed an increase of 2.0 mm and 3.5 mm at locations C and D, respectively, during follow-up, which is within the range reported by previous studies.

By analyzing the patients with AND (27.5%), defined as a 5-mm/10% enlargement of the aortic diameter at the proximal edge of TEVAR, at −10 mm and −20 mm simultaneously, we found the calcification was only seen in this group of patients and, as expected, the reinterventions were significantly more needed in the AND group. Interestingly, only a tendency to have a higher oversized stent graft in AND group (P = .096) was seen compared with the group of patients who did not develop a neck dilation (Table I). In the cases where a reintervention during follow-up was needed the mean stent graft oversizing was 27% with a standard deviation of 18%. However, given the small cohort size of our study, we

Table II. Difference in diameter at the measured zones compared with the postoperative computed tomography (CT) scan

Location	One year (n = 26)	Two years (n = 24)	Three years (n = 20)	Maximum follow-up (n = 37)	>5 mm[a]	>10%[b]
A. Aortic diameter at 20 mm proximal to the stent graft proximal edge	−1 mm (−6, 5) 1% (−17, 16)	−2 mm (−5, 6) 3% (−12, 19)	1 mm (−3, 6) 1% (−9, 14)	1 mm (−5, 14) 1% (−13, 41)	8 (21%)	10 (27%)
B. Aortic diameter at 10 mm proximal to the stent graft proximal edge	0 mm (−4, 8) 1% (−12, 27)	1 mm (−8, 9) 1% (−18, 31)	1 mm (10, 8) 1% (−22, 27)	1 mm (−10, 20) 1% (−22, 68)	3 (8%)	9 (24%)
C. Aortic diameter at the stent graft proximal edge	2 mm (−7, 8) 4% (−16, 32)	1 mm (−9.0, 8.5) 1% (−20, 33)	2 mm (−6, 11.6) 5% (−13, 39)	2 mm (−7, 13) 6% (−16, 51)	8 (21%)	13 (43%)
D. Aortic diameter at the stent graft proximal edge	2 mm (−3, 8) 3% (−9, 27)	4 mm (−8, 12) 10% (−18, 33)	3 mm (−8, 14) 8% (−23, 43)	3 mm (−9, 14) 9% (−23, 43)	16 (43%)	17 (46%)
E. Aortic diameter at the stent graft proximal edge	1 mm (−16, 9) 2% (−30, 31)	3 mm (−11, 14) 6% (−21, 45)	0 mm (−8, 35) 0% (−21, 67)	2 mm (−11, 16) 6% (−23, 49)	16 (43%)	17 (46%)

Values are median (minimum, maximum) during follow-up.
[a]Number of patients with >5 mm enlargement.
[b]Number of patients with >10% enlargement.

Table III. Difference in diameter at the measured zones-compared with the postoperative computed tomography (CT) scan

Location	AND difference, mm	Non-AND difference, mm	AND difference, %	Non-AND difference, %	*P* value (5 mm)[a]	*P* value (10%)[b]
F. Aortic diameter at 20 mm proximal to the stent graft proximal edge	3 (−1, 6)	1 (−5, 14)	9 (−4, 19)	1 (−13, 41)	.118	.094
G. Aortic diameter at 10 mm proximal to the stent graft proximal edge	3 (0, 9)	1 (−10, 20)	8 (0, 28)	1 (−22, 68)	**.002**	**.002**
H. Aortic diameter at the stent graft proximal edge	7 (5, 13)	1 (−7, 13)	24 (12, 51)	1 (−16, 34)	**<.001**	**<.001**
I. Aortic diameter at 10 mm distal to the stent graft proximal edge	9 (6, 14)	2 (−9, 8)	30 (19, 43)	3 (−23, 24)	**<.001**	**<.001**
J. Aortic diameter at 20 mm distal to the stent graft proximal edge	8 (6, 16)	1 (−11, 12)	24 (15, 49)	3 (−23, 34)	**<.001**	**<.001**

AND, Aortic neck dilation.
Values are median (minimum, maximum) at the end of the follow-up period between the AND and non-AND groups of patients. Boldface entries indicate statistical significance.
[a]Significance of >5 mm enlargement.
[b]Significance of >10% enlargement.

acknowledge the need for caution in drawing definitive conclusions from this finding because many studies have reported an increased risk of AND with greater degrees of stent graft oversizing. The dilation can occur because of the radial forces exerted by the oversized stent graft on the aortic wall. This mechanical stress can lead to chronic remodeling and expansion of the aortic neck, potentially causing long-term complications.

Yau et al[3] found in their collective of 30 patient (15 patients with dissection and 15 with aneurysm) a significant correlation between the oversizing and the neck growth in thoracic aortic aneurysm patients. Other studies that examined the aortic biomechanical mechanisms by coupling ex vivo and in silico analyses showed that oversizing contributes heavily to the shear wall stress,[4] which in turn could explain the observed dilatation in aorta corresponding with the oversizing.

Additionally, the authors stated that the implantation of a TEVAR leads to aortic stiffening, changes in the aortic pressure curves, especially regarding the pulse wave velocity, change in the aortic wall shear stress, increases tortuosity, and other aspects that lead to aortic and cardiac remodeling.[4]

The AND was seen as a progression of the aneurysmatic disease itself, but that would not explain the aortic dilation seen in trauma patients. In these cases, the aortic segments that are covered by the stent graft tend to dilate, but not the native aorta proximal or distal to the stent graft itself. In addition, as in our study, the dilation in trauma patients showed no direct significant relation

Table IV. Detailed description of the re-interventions during the follow-up period

Patient	Complication	Management	Time after surgery	Outcome	Neck dilation, mm	Oversizing, %
1	Type Ia endoleak	Proximal extension into LZII	Postoperative	Endoleak disappeared	2	10
2[a]	Stent migration + EL Ia	Proximal extension in LZ II	23 months	No migration/EL during further FU	9	32
3[a]	Stent-migration	Proximal extension with chimneys	126 months	No migration during further FU	21	27
4[a]	Type Ia endoleak	Coiling and proximal extension in LZI (carotid-carotid Bp)	23 months	Endoleak disappeared	15	27
5	Type Ia endoleak	Proximal extension into LZII	15 months	Endoleak disappeared	7	12
6	Type Ia endoleak	Coiling and proximal extension	12 months	Endoleak disappeared	5	24
7	Aortic rupture owing to Ia EL	Proximal extension in LZI (carotid-carotid Bp)	12 months	Discharged in rehabilitation center	5	21
8[a]	Migration and aortoesophageal fistula	Open repair	115 months	Discharged home	16	42
9[a]	Type Ic endoleak	Distal extension	12 months	Open conversion in 12 months	15	3
10	Migration and EL III	Proximal extension	24 months	No migration/EL during further FU	14	15

Bp, Bypass; *EL*, endoleak; *FU*, follow-up; *LZ*, landing zone.
A detailed description of the reinterventions performed during follow-up period.
[a]Patients with aortic neck dilation.

to oversizing.[7,8] Moreover, different studies for infrarenal aortic repair showed that choosing different stent graft designs had no impact on aortic neck changes.[6,9] We have encountered the same observation in our study.

There are hints that the evolution of AND depends on the condition of the treated aorta itself. Accordingly, patients with aortic dissection show higher rates of AND.[3] Although older studies[1] did not find an association between the neck dilation and the stent migration and endoleaks, the recent works showed a significant graft migration, but no endoleak or need for aortic reintervention.[3] In contrast, we found that the patients who develop a neck dilation after TEVAR are more prone to aortic reinterventions owing to endoleak and graft migration.

In a recent meta-analysis of proximal aortic neck dilatation after endovascular abdominal aortic aneurysm repair, the risk of a type Ia endoleak was significantly higher in patients with AND compared with those without AND ($P = .030$). Endograft migration was also more common in the AND group compared with the non-AND group ($P = .004$). However, the combined incidence of secondary rupture and reintervention did not differ significantly between the two groups, even though the combined effect was in favor of the non-AND group.[10] The interpretation of these differences could be the small number of patients,[3] the inhomogeneous follow-up period.[1] and the large number of available studies on the EVAR and the abdominal AND.

The most aortic reinterventions in our group were performed during the first 2 years of follow-up, which is in line with the observation in the study of Oliveira et al,[11] who examined the AND after standard abdominal endovascular aortic repair and found that the neck enlargement was greater during the first postoperative year. In contrast with the findings of Dillavou et al,[6] the former work[11] suggested the cut-off value of >30 mm as neck diameter to be a relevant risk factor for excessive neck dilation and, therefore, recommended a longer sealing distance.

Despite the relatively small number of patients in our cohort, our results suggest minimizing the oversizing when the aortic neck diameter is <36 mm. A possible explanation could be the progressive loss of flexibility and increased stiffness of the aortic wall associated with the advancement of atherosclerotic disease in patients with a larger initial aortic diameter. Conversely, an aorta with a smaller diameter may have greater inherent flexibility, making it more susceptible to the mechanical stresses exerted by an oversized stent graft. Additionally, we recommend a close follow-up of the patients in the first 2 postoperative years, when the most graft-related complications could occur.

Although no significant difference was found in terms of the incidence of AND between the LZs, the higher occurrence of AND in LZ III (75%) highlights the need for a more progressive approach in these repairs. This process entails targeting more proximal LZs and using more complex techniques such as thoracic branched devices, in situ fenestration, and chimney TEVAR to address the increased risk in this particular zone. The presence of calcification at the proximal LZ should also raise the attention to identify and manage graft migration and the endoleaks caused by AND early.

Nonetheless, these results must be interpreted with caution and a number of limitations should be borne in mind. The first is the retrospective design and the second concerns a selection bias, which could not be excluded. Further, our study spanned a period of >10 years, during which several changes in procedures, devices, and surgeons occurred, which could have influenced the outcomes. Moreover, the small number of patients and the low rate of the performed CT angiographic imaging during follow-up limit the power of our analysis and did not allow a detailed analysis (like a logistic regression model) of the factors influencing AND.

CONCLUSIONS

Proximal aortic dilation after TEVAR is a progressive phenomenon with different possible risk factors. The close surveillance is essential for the detection and management of possible graft complications like endoleaks and migration to optimize patient outcomes and improve the long-term success of the procedure.

AUTHOR CONTRIBUTIONS

Conception and design: WA
Analysis and interpretation: WA, PW, UW, PM, BD
Data collection: WA, PW, OS
Writing the article: WA, UW
Critical revision of the article: WA, PW, OS, PM, BD
Final approval of the article: WA, PW, OS, UW, PM, BD
Statistical analysis: WA
Obtained funding: Not applicable
Overall responsibility: WA

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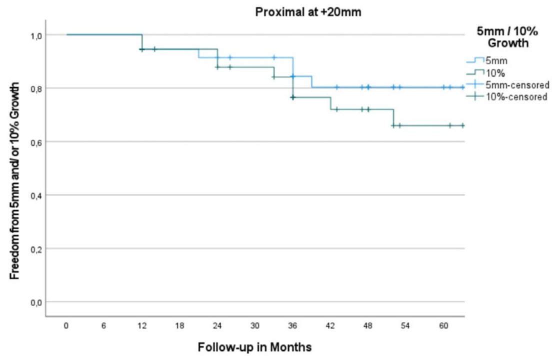
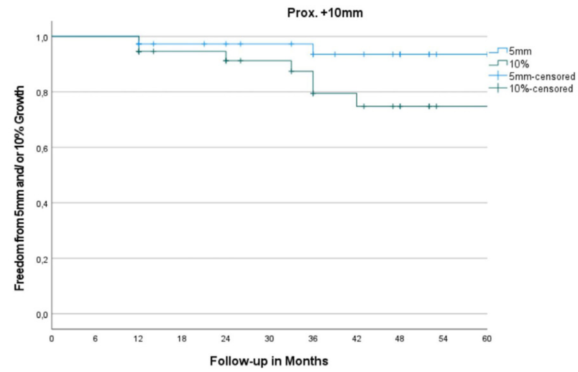
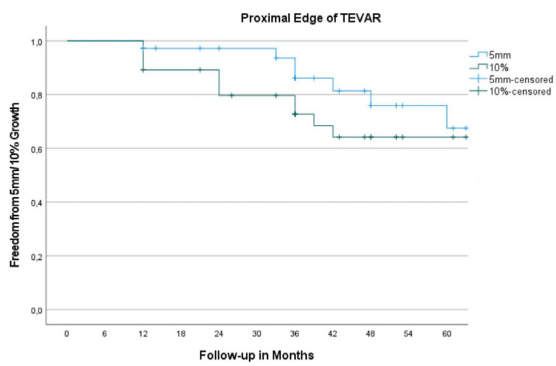


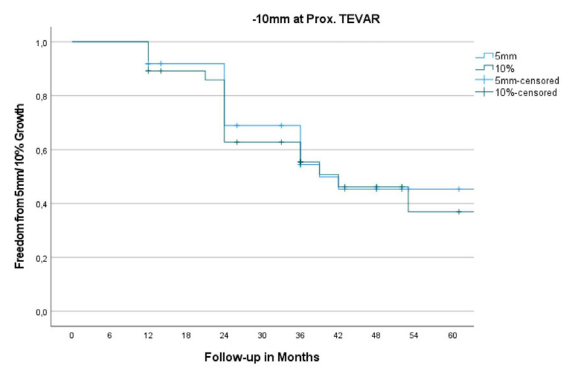
Month	0	12	24	36	48	60
5mm						
Nr. at Risk	37	31	28	21	14	10
St. Error		.037	.028	.065	.073	.073
10%						
Nr. at Risk	37	29	25	17	12	9
St. Error		.037	.058	.079	.086	.098



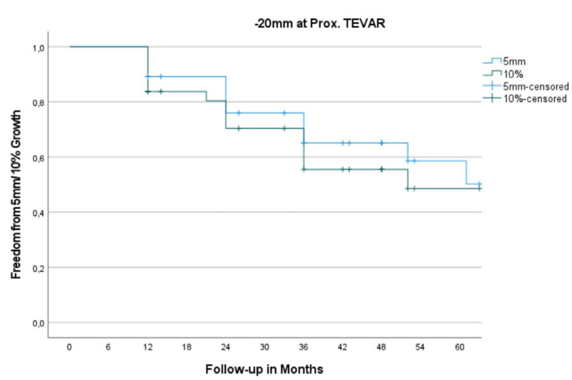
Month	0	12	24	36	48	60
5mm						
Nr. at Risk	37	36	28	21	14	20
St. Error		.027	.027	.045	.045	.045
10%						
Nr. at Risk	37	29	25	17	12	9
St. Error		.037	.049	.076	.085	.085



Month	0	12	24	36	48	60
5mm						
Nr. at Risk	37	30	27	19	12	8
St. Error		.027	.027	.065	.089	.112
10%						
Nr. at Risk	37	29	25	17	11	8
St. Error		.051	.069	.079	.090	.090



Month	0	12	24	36	48	60
5mm						
Nr. at Risk	37	29	21	12	8	3
St. Error		..045	.082	.095	.096	.096
10%						
Nr. at Risk	37	28	19	12	7	4
St. Error		.051	.059	.091	.096	.113



Month	0	12	24	36	48	60
5mm						
Nr. at Risk	37	28	23	16	10	7
St. Error		.051	.071	.087	.087	.099
10%						
Nr. at Risk	37	26	21	14	8	5
St. Error		.061	.067	.091	.091	.103

Supplementary Fig (online only). Kaplan-Meier freedom from 5 mm/10% growth. *Nr.*, number; *St.*, standard; *TEVAR*, thoracic endovascular aortic repair.