PREVALENCE, ASSOCIATED FACTORS AND REINTERVENTION RATE OF ENDOLEAKS AFTER THORACIC ENDOVASCULAR AORTIC REPAIR AMONG PATIENTS WITH THORACIC AORTIC ANEURYSMS, PHRAMONGKUTKLAO HOSPITAL, BANGKOK, THAILAND

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Abstract

Background: Endoleaks are one of the complications seen after endovascular repair of thoracic aortic aneurysms (TAA). The study evaluated the prevalence, associated factors and reintervention rate, the classified type of endoleaks and the outcomes of secondary interventions among patients with endoleaks.

Methods: Between 2010 and 2020, medical and radiologic data of all patients receiving a diagnosis of TAA treated by thoracic endovascular aortic repair (TEVAR) and undergoing postoperative CT angiogram at Phramongkutklao Hospital were retrospectively reviewed and analyzed.

Results: Over a median follow-up of 569 days (IQR=93-1256), 6 of 26 (23.08%) patients developed endoleaks, of which 50% (3 of 6) were type I, 16% (1 of 6) were type II, IV and V each and none were type III. The median aneurysm diameter was 62 mm (IQR=52.5-75.5). Endoleaks were associated with younger age ($p<0.05$) and a higher percentage of graft oversizing over the aorta distal to the aneurysm ($p=0.014$). All patients with endoleaks underwent reintervention (100%) with good outcomes.

Conclusion: Endoleaks were detected in one of the four patients treated with TEVAR during follow-up, particularly when they were young or exhibited a too oversized graft over the aorta distal to the aneurysm. All patients with endoleaks underwent reintervention with good outcomes.

Keywords: Endoleaks, Thoracic aortic aneurysm, Thoracic endovascular aortic repair, Stent-graft
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Introduction

Conventional open repair of a thoracic aortic aneurysm (TAA) remains a major invasive surgical procedure with significant inherent risk. These operations require a thoracotomy, aortic clamping, partial aortic bypass to support circulation and considerable blood loss with associated transfusions.[1] The surgical mortality rate may approach 12% even when performed by experienced surgeons among patients with a good cardiac reserve and deemed excellent surgical candidates.[2] Perioperative morbidities in this referenced cohort included spinal cord ischemia among 14%, respiratory failure among 20% and renal insufficiency among 13% of patients undergoing open repair.(2)

Endovascular techniques are now used to treat thoracic aortic aneurysms (TAAs). This endovascular approach (TEVAR) offers a subset of patients with TAA a less invasive procedure to exclude their aneurysms.(3) It has also altered how patients follow up after TAA repair.(2)

Endoleaks have been pointed out as adverse events causing migration of the stent-graft and rupture of the aneurysm; and therefore, need to be detected during follow-up.(4)

Although detecting and managing endoleaks after EVAR have been well described, less is known about endoleaks after TEVAR.(3) This investigation evaluated the prevalence and determinants of endoleaks and the outcomes of secondary interventions among patients with endoleaks after endovascular repair of TAAs.

Methods

Study design and subjects

This study was approved by the Institutional Review Board Royal Thai Army Medical Department (No. IRBRTA 1431/2563). Permission to Access Medical Records and ICD-10 was approved. Regarding using secondary data, a waiver of informed consent was granted.

Phramongkutklao Hospital is a 1200-bed tertiary hospital in Bangkok, Thailand, where TEVAR cases have been performed since 2010. Nonetheless, studies about endoleaks have not been conducted at this center. Between 2010 and 2020, medical and radiologic data of all patients receiving a diagnosis of thoracic aortic aneurysms treated by TEVAR and undergoing postoperative CT angiogram were retrospectively reviewed, as shown in **Table 4**. Patients not following up CTA study were excluded. All TEVAR were performed in the context of Food and Drug Administration trials with the Medtronic Valiant (Medtronic AVE; Santa Rosa, CA, USA), the Cook TX2 & Cook alpha (Cook Medical; Bloomington, IN, USA), the E-vita OPEN PLUS (JOTEC GmbH; Lotzenäcker, Hechingen, Germany) and the Terumo aortic (Bolton Medical; Sunrise, FL, USA) devices. After aneurysmal repair, imaging using triple-phase computed tomographic angiography (CTA) was performed at 1, 6 and 12 months after stent-graft implantation and annually after that. More frequent examinations were performed when clinically indicated. CTA was performed using a multidetector scanners (64-slice or 160-slice CT). The three-phase CTA consisted of a noncontrasted scan through the chest and upper abdomen, followed by a chest and abdominal CTA using 120 mL of nonionic contrast. A 2-minute delayed computed tomographic scan was performed through the chest and upper abdomen. (4)

Data collection

Preoperative clinical data of each patient, i.e., demographics, comorbidities, preoperative condition and radiologic data, such as TAA morphologic measurements, were reviewed by a diagnostic radiology resident under the supervision of an interventional radiologist. The radiologic data were reviewed at two different times and compared with the official report's data. The high intra- and interobserver agreement levels were exhibited in the data regarding diameter, length, morphology, nature and site of the aneurysm. A level of almost perfect was obtained for intra- and interobserver agreement of morphology and nature of the aneurysm as well as the interobserver agreement of the site of the aneurysm.(5) Additionally, a substantial level was exhibited in the intraobserver agreement of the site of the aneurysm.(5) The data are shown in the supplementary table.

Intraoperative data collected consisted of the size, number and type of stent-graft used, the left subclavian artery (LSA) coverage, section of aorta coverage by stent-graft, proximal & distal landing zone, oversizing and the presence of immediate endoleak on completion of the arteriogram.

Postoperative clinical events, such as secondary endovascular or surgical interventions, major complications and mortality were reported. In addition, radiologic data, including TAA diameter, aneurysmal sac expansion, and types of the endoleak were also recorded during follow-up. The diagnosis of the endoleak and its type was performed on CTA examinations evaluated on the picture archiving and communication system (PACS) workstations with multiplanar reformatting capabilities to classify the endoleak type. Endoleaks were classified as type I based on their location in contiguity with the proximal or distal sealing zone, as well as early filling of the TAA sac. Endoleaks were classified as type II if they could not be seen communicating with either the distal or the proximal sealing zones or, in the case of delayed enhancement of the sac. Type III endoleak was classified based on association with a disjunction of two stent grafts.(6) Changes in TAA diameters were evaluated using standardized maximal aortic sac diameter measurements. The mean changes in maximal aortic diameter were calculated by comparing the baseline aortic diameter with the maximal diameter at the last follow-up in the sagittal plane on CTA, irrespective of endoleak treatment.

Definition

Oversizing was defined as the percent difference between the stent graft diameter and the diameter of the aorta deployed.(7) Results of patients undergoing reintervention were described as good outcomes or successful in the case of the endoleak being totally resolved in the intraoperative angiography without any acute intraoperative complications.

Statistical analysis

Data were analyzed using SPSS Statistics for Windows, Version 23.0 (IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp). Continuous data between non-parametric distribution continuous data were assessed using the Mann-Whitney U test or independent t-test. In addition, Fisher's exact test was used to analyze categorical data. All statistical analyses were two-tailed, and a significance level of 0.05 was used to calculate the proportion.

Results

Baseline characteristics and preoperative conditions

The study included 26 patients treated consecutively for a TAA by TEVAR during the observation period; 16 were male and 10 were female. Ages ranged from 27 to 87 years, with a mean of 68.73 ± 12.85 and a median of 71 (IQR = 63.5 to 78.5). No patients were excluded due to poor image qualities. The median follow-up period was 569 days; IQR = 93- 1256. The following data are shown in **Table 1**. A total of 95 CTA studies were reviewed. Six endoleaks were detected in 6 of 26 (23.08%), as described in **Table 2.** Among these aneurysms, 22 were degenerative ones; two were dissecting aneurysms, one was postdissecting aneurysm, and one was a pseudoaneurysm developed on the penetrating ulcer of the thoracic aorta. At the time of TEVAR, the median TAA diameter was 62 mm (IQR = 52.5-75.5), and the median TAA length was 67.5 mm (IQR = 43.5-85), as described in Table 3. A total of 34 stent-grafts (16 Cook TX2, 3 Cook alpha, 4 Medtronic Valiant, 2 E-vita OPEN PLUS and 1 Terumo aortic) were used for TAA exclusion (1.31 per patient) for a median length of aortic coverage of 166 (IQR = 150-216) as described in **Table 4**. In the endoleak group, 50% (3 of 6) exhibited endoleak type I as shown in **Figure 1**, 16.67% (1 of 6) type II, as shown in **Figure 2**, none of type III, 16.67% (1 of 6) type IV as shown in **Figure 3** and 16.67% (1 of 6) type V (**Figure 4**). Three endoleaks (50%) were diagnosed on the first postoperative CTA within the first month, and the rest (50%) were detected during follow-up. Patients with endoleaks and their management after diagnosis are described in **Table 5.**

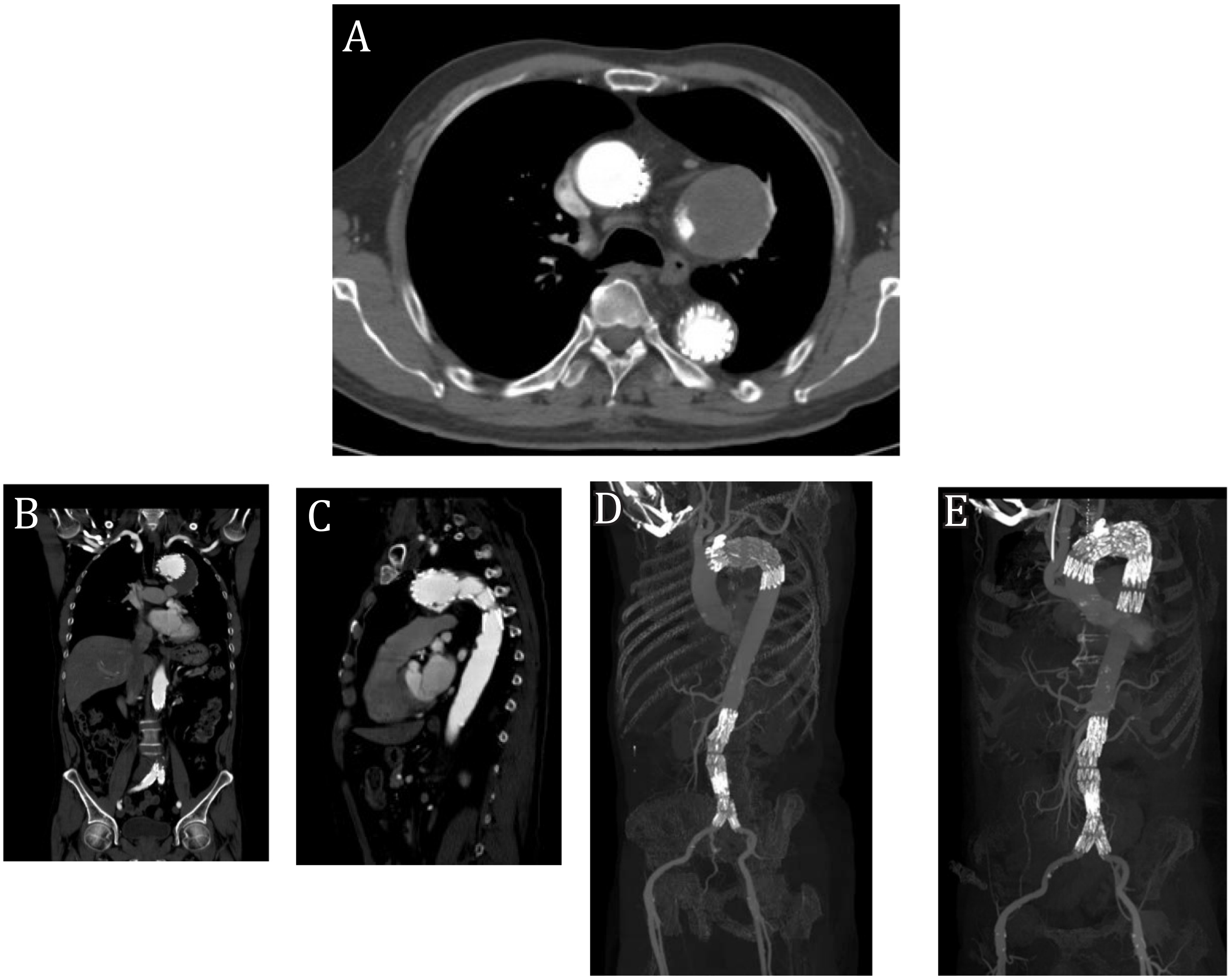

Figure 1. Radiographic feature of endoleak type IA, A., B., C. CTA shows contrast leakage at the proximal aortic stent. D. CTA with 3D reconstruction shows an endovascular aortic stent- graft at the aortic arch, just at the level of the origin of the left common carotid artery cover to the mid-descending thoracic aorta. E. CTA with the 3D reconstruction of the same patient, posttreatment for 6 months, demonstrated a new stent-graft at the aortic arch, inner to the previous stent, and covering more on the descending thoracic aorta. Note the stent-graft at the abdominal aorta.

Table 1. Demographic data and comorbid conditions of patients

	N (n=26)	**%**
Age		
Mean ± SD	68.73 ± 12.85	
Median (IQR)	71 (63.5 – 78.5)	
Sex		
Male	16	61.54
Female	10	38.46
Hypertension	18	69.23
Diabetes mellitus	6	23.08
Dyslipidemia	10	38.46

Table 1. Demographic data and comorbid conditions of patients (Cont.)

	N (n=26)	%
Coronary artery disease	5	19.23
Renal insufficiency	5	19.23
Abdominal aortic aneurysm	4	15.38
length of follow up (day)		
Mean ± SD	767.81 ± 736.66	
Median (IQR)	569 (93 - 1256)	

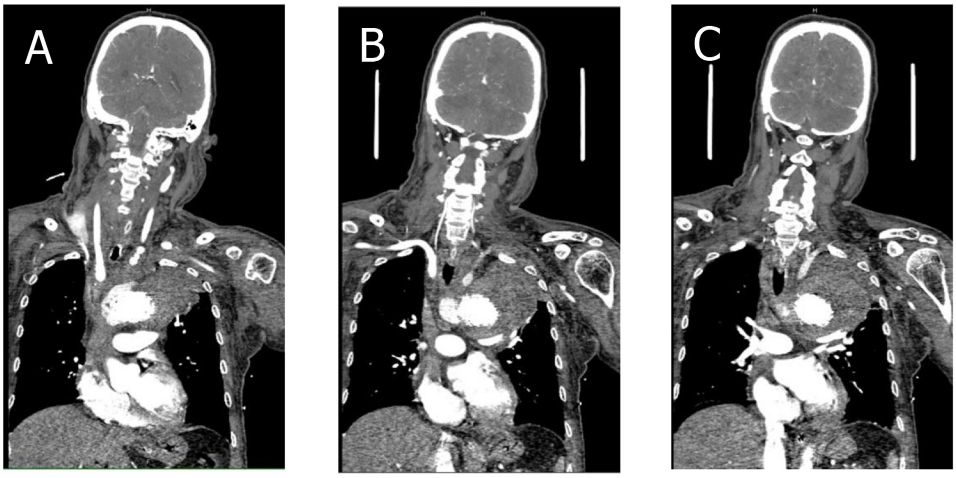

Figure 2. The radiographic appearance of endoleak type II, A., B., C. Computed tomographic angiography demonstrated contrast enhancement in the periphery of the aneurysmal sac. Blood flow retrograded from the residual proximal left subclavian artery and left vertebral artery.

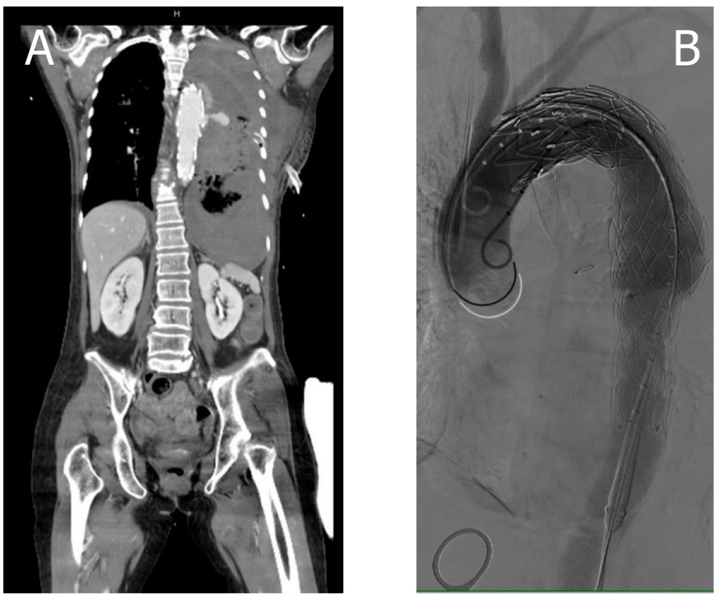

Figure 3. Radiologic appzearance of endoleak type IV, A. computed tomographic angiography shows peri-graft hematoma and contrast leakage at the mid-graft level. B. angiography on the same day shows no graft kink, narrowing, collapse or migration.

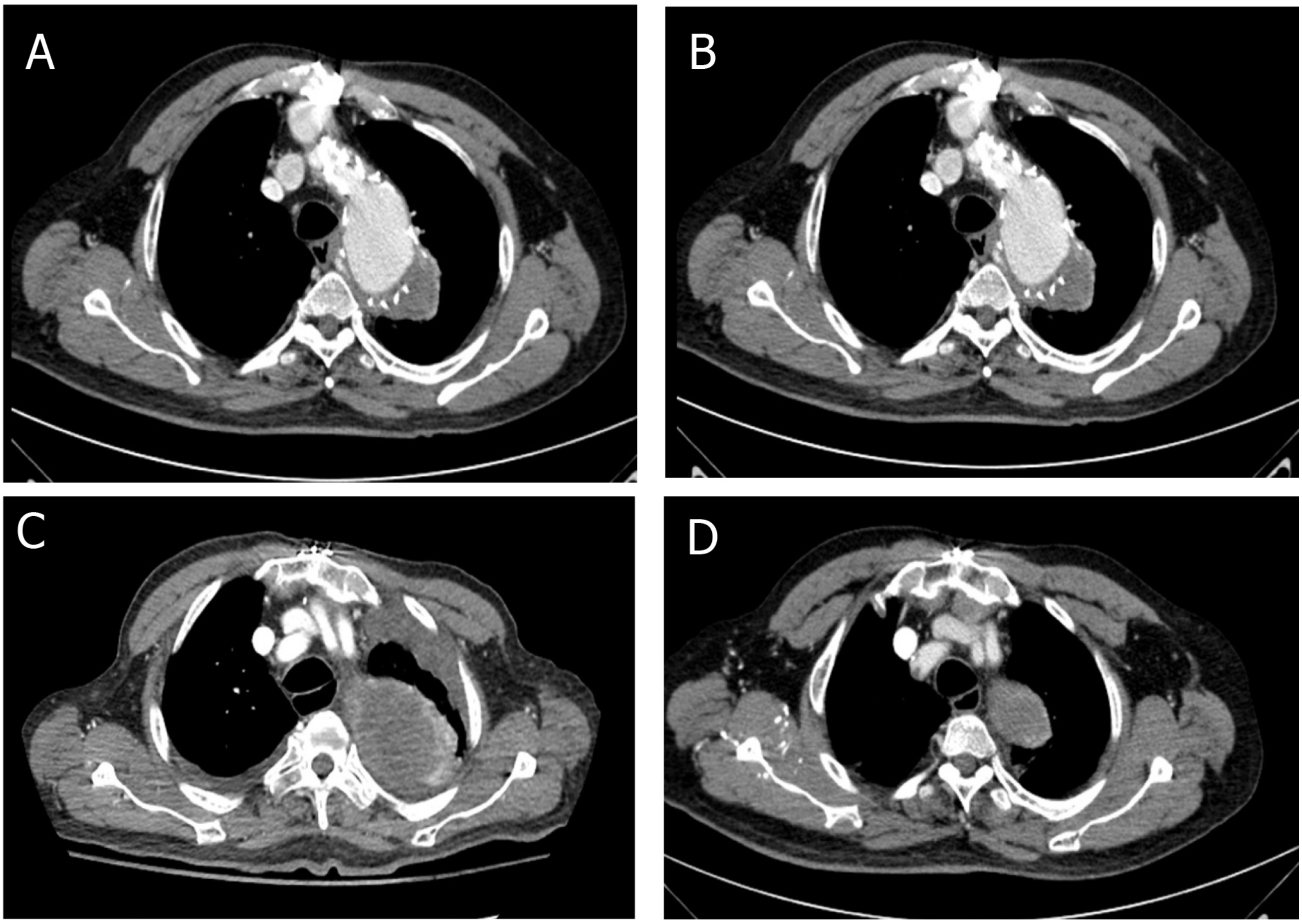

Figure 4. Endoleak type V, A., B. computed tomographic angiography shows a thrombosed fusiform aneurysm at the proximal descending thoracic aorta. C., D. CTA of the whole aorta in the next 4 years of the same patient demonstrated a significant increase in the size of the thrombosed aneurysmal sac at the proximal descending aorta and new left hemothorax.

Patients who developed endoleaks were younger than those who did not (64.17± 5.78 vs. 70.10 ± 14.14 years old; p=0.041) but a wider range of age was noted in the nonendoleak group than in the endoleak group (range 27 to 87 vs. 56 to 74 years old). However, the sex ratio and prevalence of comorbidities showed no statistical difference (**Table 2**). In addition, days of follow-up among patients with endoleaks were more than those without endoleaks (1337 vs. 536 days).

Morphologic characteristics of TAA at the time of interventions are shown in **Table 3**. The extension of TAAs was comparable at the time of intervention, with similar diameter and length among both groups. The nature and morphology of aneurysms did not differ between the two groups. In addition, the location of the aneurysm along the thoracic aorta, including ascending, arch and descending parts, showed similarity in both groups (p=0.999).

Peroperative conditions

Peroperative conditions and technical considerations are shown in **Table 4**. The percentage of graft oversizing over the aorta distal to the aneurysm among patients with endoleaks was higher among those in the nonendoleaks group (49 vs. 29%; p=0.014). The percentage of proximal graft oversizing in the endoleak group was also more than in the non-endoleak group (40 vs. 27%; p=0.055). No differences were observed in the mean diameter of proximal and distal sites, length and the number of stent grafts used for TEVAR in the two groups. The mean length of proximal and distal landing zones and the section of the aorta treated by stent-grafts showed no difference in the two groups (p=0.748, p=0.077

and *p*=0.737, respectively). Intentional coverage of the LSA to extend the proximal landing zone of the stent-graft (*p*=0.16) and the urgent character of TEVAR (10 of 26; *p*=0.644) did not affect the occurrence of endoleaks during follow-up. More patients in the endoleak group received a Cook TX2 device (4 of 6; 66.67%) compared with other devices, one (16.67%) of Cook alpha and one (16.67%) of Medtronic Valiant. No patients receiving E-vita OPEN PLUS or the Terumo aortic developed endoleaks.

Table 2. Compared characteristics of the patients in both groups

	Endoleaks (n=6) (%)	**No endoleaks (n=20) (%)**
Prevalence	6/26 (23.08)	20/26 (76.92)
Age		
Mean ± SD	64.17 ± 5.78	70.10 ± 14.14
Median (IQR)*	63.5 (59.5 – 69.5)	73.5 (65 - 79)
Sex		
Male	4 (25.00)	12 (75.00)
Female	2 (20.00)	8 (80.00)
Hypertension	3 (16.67)	15 (83.33)
Diabetes mellitus	1 (16.67)	5 (83.33)
Dyslipidemia	3 (30.00)	7 (70.00)
Coronary artery disease	2 (40.00)	3 (60.00)
Renal insufficiency	1 (20.00)	4 (80.00)
Abdominal aortic aneurysm	1 (25.00)	3 (75.00)
length of follow-up (day)		
Mean ± SD	1251 ± 1069.36	622.85 ± 568.22
Median (IQR)	1337 (87 - 2329)	536 (45 - 141)

*p< 0.05 ; Mann-Whitney U test.

Table 3. Morphological characteristics of the aneurysm

	Total (n=26) (%)	**Endoleaks (n=6) (%)**	**No endoleaks (n=20) (%)**	***p*-value**
Morphology of aneurysm				0.999[a]
Saccular	16 (61.54)	4 (25.00)	12 (75.00)	
Fusiform	10 (38.46)	2 (20.00)	8 (80.00)	
Diameter of aneurysm(mm)				
Mean ± SD	61.69 ± 19.35	59.67 ± 20.99	62.3 ± 19.37	0.777[b]
Median (IQR)	62 (52.5 – 75.5)	60 (56 - 76)	62.5 (40 - 79)	
Length of the aneurysm (mm)				
Mean ± SD	72.62 ± 37.52	49.17 ± 16.29	79.65 ± 39.45	0.080[b]
Median (IQR)	67.5 (43.5 - 85.0)	53 (30.5 - 64.0)	76.5 (58 - 89)	

Table 3. Morphological characteristics of the aneurysm (Cont.)

	Total (n=26) (%)	Endoleaks (n=6) (%)	No endoleaks (n=20) (%)	*p*-value
Nature of aneurysm				0.999[(a)]
Pseudoaneurysm	1 (3.85)	-	1 (100.00)	
Post dissection	1 (3.85)	-	1 (100.00)	
Dissecting	2 (7.69)	-	2 (100.00)	
Degenerative	22 (84.62)	6 (27.27)	16 (72.73)	
Site of aortic aneurysm				0.999[(a)]
Descending	19 (73.08)	4 (21.05)	15 (78.95)	
Arch to descending	3 (11.54)	1 (33.33)	2 (66.67)	
Arch	4 (15.38)	1 (25.00)	3 (75.00)	

[(a)] Fisher's exact test. [(b)] Independent t-test. [(c)] Mann-Whitney U test.

Table 4. Peroperative conditions and technical considerations of TEVAR procedures

	Total (n=26) (%)	Endoleaks (n=6) (%)	No endoleaks (n=20) (%)	*p*-value
Type of procedure				0.644[(a)]
urgent	10 (38.46)	3 (30.00)	7 (70.00)	
elective	16 (61.54)	3 (18.75)	13 (81.25)	
LSA coverage	13 (50.00)	5 (38.46)	8 (61.54)	0.160[(a)]
Percent of oversizing proximal				
Mean ± SD	28.19 ± 11.81	35.17 ± 13.04	26.1 ± 10.90	
Median (IQR)	29.5 (19 - 39)	40 (21.5 - 44)	27 (17 - 33)	0.055[(c)]
Percent of oversizing distal				
Mean ± SD	33.69 ± 14.4	46.00 ± 16.26	30.00 ± 11.89	0.014[(b)]
Median (IQR)	33 (19.5 – 45.5)	49 (27.5 – 61.5)	29 (19 - 40)	
length of aortic coverage (mm)				
Mean ± SD	189.88 ± 85.68	193.33 ± 81.52	188.85 ± 88.91	
Median (IQR)	166 (150 - 216)	167.5 (137.5 - 275.0)	164.5 (150 - 216)	0.737[(c)]
Number of stent graft				0.697[(a)]
1	19 (73.08)	4 (21.05)	15 (78.95)	
2	6 (23.08)	2 (33.33)	4 (66.67)	
3	1 (3.85)	-	1 (100.00)	

Table 4. Peroperative conditions and technical considerations of TEVAR procedures (Cont.)

	Total (n=26) (%)	Endoleaks (n=6) (%)	No endoleaks (n=20) (%)	*p*-value
Type of stent graft				0.999 [(a)]
Cook TX2	16 (61.54)	4 (25.00)	12 (75.00)	
Cook alpha	3 (11.54)	1 (33.33)	2 (66.67)	
Medtronic Valiant	4 (15.38)	1 (25.00)	3 (75.00)	
E-vita OPEN PLUS	2 (7.69)	-	2 (100.00)	
Terumo aortic	1 (3.85)	-	1 (100.00)	
Proximal landing zone (mm)				
Mean ± SD	50.12 ± 19.28	47.83 ± 17.49	50.8 ± 20.17	0.748 [(b)]
Median (IQR)	51 (32.0 – 65.5)	46 (31.0 – 66.5)	52.5 (30 - 66)	
Distal landing zone (mm)				
Mean ± SD	53.73 ± 25.48	69.83 ± 35.93	48.9 ± 20.21	0.077 [(b)]
Median (IQR)	49.5 (33.5 – 64.5)	57.5 (40.5 – 111.5)	47.5 (33 - 61)	

[(a)] Fisher's exact test. [(b)] Independent t-test. [(c)] Mann-Whitney U test

Postoperative conditions

All patients with endoleaks underwent reintervention (reintervention rate=100%). In addition, the open surgical conversion was performed to treat two patients (33.33%), including patients with type II (n=1) and type V (n=1) endoleaks with good outcomes. Endovascular techniques were successful in treating endoleaks among the remaining patients (n=4; 66.67%), using proximal (n=2) and distal (n=1) extensions for patients with type I endoleak, and RE-TEVAR with stent-in-stent was performed in one patient with endoleak type IV (n=1). Details of these remedial procedures are shown in **Table 5**.

All patients' mean changes in maximal aortic diameter were calculated by comparing the baseline aortic diameter with the maximal diameter at the last follow-up, irrespective of endoleak treatment. During follow-up, the median decrease of maximum aneurysm diameter among all patients with endoleaks was 21.5 mm, compared with 12.5 mm for those without endoleak as shown in **Table 6**. The median maximum aneurysm diameter decreased by 12 mm among patients with type I endoleak.

Table 5. Description of six patients with endoleaks, management and results

Endoleak patients	Type of endoleaks (n=6)	Onset of diagnosis after TEVAR (day)	Type of treatment	Result*
1	II	5	Ligation proximal LSA with repair left brachiocephalic vein	Successful
2	V	1881	Repaired Endoleak type V, pulmonary toilet and evacuation blood clot	Successful
3	IA	27	Proximal stent graft extension	Successful

Table 5. Description of six patients with endoleaks, management and results (Cont.)

Endoleak patients	Type of endoleaks (n=6)	Onset of diagnosis after TEVAR (day)	Type of treatment	Result*
4	IV	0.08	Re-TEVAR with stent-in-stent	Successful
5	IB	211	Distal stent graft extension	Successful
6	IA	98	Proximal stent graft extension	Successful

*Successful - Case of the endoleak who was resolved in the intraoperative angiography without any acute intra-operative complication.

Table 6. Maximum aneurysm diameter variations during follow-up in different types of patients with endoleak

Endoleak type	Decrease in sac diameter (mm)	*p*-value
No endoleak (n=20)		
Mean ± SD	18.4 ± 20.12	
Median (IQR)	12.5 (0.5 – 33.0)	
Endoleak (n=6)		0.502 (*)
Mean ± SD	22.83 ± 18.73	
Median (IQR)	21.5 (5 – 32)	
I (n=3)		
Mean ± SD	16 ± 13.45	
Median	12	
II (n=1)	52	
IV (n=1)	32	
V (n=1)	5	

(*) Mann-Whitney U test

Discussion

Endoleaks observed after endovascular repair have been well-described in the published data after EVAR, but few articles document their incidence and the consequences after TEVAR.(3) This series reports the prevalence of 23.08% of all types of endoleaks, which matches the range from 5 to 29% described in earlier series involving stent-graft repair of TAAs[8], and which is also similar to the endoleak incidence after EVAR.(8, 9)

The published data has described predictive factors of sac expansion after EVAR. Still, more is needed regarding the factors that predict endoleak development, especially after TEVAR.(4, 6) Related studies show that endoleak is a possible risk factor for TAA sac expansion after TEVAR.(4, 9, 10) On the contrary, in our study, patients without endoleak experienced lesser aneurysm sac regression than those with endoleaks (12.5 mm vs. 21.5 mm), although this difference was not statistically significant (p=0.5015). We recognize that our sample size was relatively small.

In our series, patients with endoleaks were significantly younger than those without endoleaks (p=0.041). Still, they had a wider age range in endoleaks than those in the nonendoleak group (range 56 to 74 vs. 27 to 87). In contrast, the study of Alsac et al. revealed that older age significantly affected the occurrence of endoleaks. [4] Noisiri et al. and Belvroy et al. showed that mean ages were similar in the two groups.[10, 11] In other studies, the two groups were compared for age distribution; all patients with endoleaks presented a degenerative aneurysm.[8, 9] No difference was found in the prevalence of medical comorbidities between the two groups, compatible with prior studies.[8, 9] Corresponding with studies of Morales et al.[8] and Alsac et al.[4] the two groups did not differ in sex distribution, in contrast to Parmer et al.[6] showing that being male was a predictive factor of endoleaks.

Concerning the morphologic data of TAAs, no differences were noted between the two groups regarding maximum aneurysm diameter & length, morphology and location of the aneurysm, corresponding to the study findings of Noisiri et al.[10] Conversely, the study by Parmer et al. was the only study that reported the size of aneurysm sac significantly related with endoleaks.[9] Alsac et al. suggested that fusiform morphology was a factor of endoleaks.[4]

The most relevant morphologic factor associated with the incidence of endoleaks was the length of the proximal neck, that is, the distance between the LSA and the beginning of the descending thoracic aortic aneurysm (DTAA). The short proximal landing zone reflects the proximal character of the treated DTAA, which usually develops from the distal aortic arch and the proximal portion of the descending aorta. This portion of the thoracic aorta is known to be the worst landing zone because of its curvature,[12] leading to frequent mispositioning of the stent-graft and its inefficient proximal sealing.[13] Although we considered 20 mm as a minimum distance of the proximal landing zone,[14] this represented a significant issue in our series of TEVAR that could explain the large majority of proximal type I endoleaks among the endoleaks observed. On the other hand, in our study, the distance between the proximal and distal landing zone showed no difference between the two groups. Moreover, the left subclavian artery coverage, the diameter of graft at the proximal and distal aneurysm neck, and the length of aortic coverage showed no statistical significance between the two groups.

Among clinical variables, the percentage of graft oversizing over the aorta distal to the aneurysm among patients with endoleaks was significantly more than those among patients without endoleaks. The percentage of proximal graft oversizing in the endoleak group was also more than that in the non-endoleak group without statistical significance. These findings are based on experiences of EVAR in the abdominal aorta; stent-graft oversizing is essential, as it enhances the radial force of the device against the aortic wall, improving fixation and sealing. [15,16] On the other hand, excessive oversizing in EVAR is associated with an increased risk of complications. It may lead to infolding of the graft or dilatation of the aortic neck.[17] A systematic review of the influence of oversizing on the outcomes and complications in EVAR demonstrated 10 to 20% oversizing, corresponding to the Instructions of Use (IFU) of most manufacturers, offering the best results. [16] In contrast, the study base on TEVAR by Tolenaar et al. found the percentage of oversizing did not significantly affect the incidence of device-related complications after TEVAR for TAA.[18]

The type and the number of stent-grafts used were similar in both groups. A related study [4] found that Gore TAG was associated with endoleaks, but no such device has been used in our center. Currently, many up-to-date devices are available, which is better than in the past.

The mean decrease in maximum aneurysm diameter between the two groups showed no significant difference. Nonetheless, the related studies of Alsac et al. and Parmer et al. found that the persistence of an endoleaks led to significant sac expansion.[4, 6]

Although endoleaks after TEVAR were common in our series, no type III endoleak was reported. This could be explained using commercially available longer stent-grafts of up to 250 mm, allowing the deploying of only one graft in most procedures to obtain DTAA exclusion (1.3 stent-graft/patient). Moreover, lessons learned by the early implantations of stent-grafts of the first generation allowed us to understand the importance of a long overlapping zone between stent-grafts (>80 mm) when more than one device was to be used to avoid later disconnection and type III endoleaks. [4] However, in a recent study, Noisiri et al. reported that the occurrence of endoleak type III was about 2.9%. [10]

All patients with endoleaks in our series underwent reintervention with successful results through type II endoleaks, which could be treated conservatively. In this study, the patient with unstable clinical history experienced type II endoleak repair. The result was similar to Noisiri et al. showing a success rate of 87.5%.[10]

The earlier series showed that predictive factors of endoleaks were bird beak configuration, landing zones 0 to 2, LSA coverage, large proximal neck and stent-graft diameters, excessive oversizing, aneurysm enlargement and length of the aneurysm. In the Thai population, factors that had statistically significant differences between patients with and without endoleaks were the landing zone and aortic arch for the aneurysm location.[10] In this study, younger age was also an associated factor of endoleaks, which was not a factor for predicting the decreased rate of aneurysm sac regression. The rate of reintervention and successful rate were also present in the study.

This study encountered limitations. The number of patients was relatively small, contributing to absolutely low numbers in each category. Regarding the small sample size; multivariable analysis to adjust the potential confounder was not performed. Additionally, the present study was conducted in only one hospital; the data may not represent the overall population. It will be interesting to perform a similar analysis on a cohort of patients in a multicenter study. Using CTA to diagnose and classify endoleaks in this study when diagnostic angiography is known to be more accurate [19] might have led to endoleak classification errors during radiologic follow-up.

Conclusion

Endoleaks after TEVAR is not a rare phenomenon, and their prevalence seems to be similar to that seen after EVAR. Patients at younger ages are at increased risk to develop endoleaks. The percentage of proximal graft oversizing over the aorta distal to the aneurysm among patients with endoleaks was significantly greater than those of patients without endoleak, corresponding to the IFU of most manufacturers, offering the best results. Type I endoleaks could be successfully treated using endovascular techniques with subsequent sac regression. The open surgical conversion was performed to treat patients with type II and type V endoleaks, and a hybrid procedure was successfully performed for type IV endoleaks. However, studies of higher sample sizes are further needed to assess the outcomes of other types of endoleaks.

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