

## Short-term results of chimney stent revascularization of left subclavian artery and Zone 2 thoracic endovascular aortic repair for patients with aortic dissection or transection

*Aort diseksiyonlu veya transeksiyonlu Zone 2 torasik endovasküler aort tamiri yapılan hastalarda sol subklaviyan arterin baca stent ile revaskülarizasyonunun kısa dönem sonuçları*

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### ABSTRACT

**Background:** In this study, we present the short-term results of revascularization of left subclavian artery with the chimney technique in patients with aortic dissection or transection who underwent Zone 2 thoracic endovascular aortic repair.

**Methods:** A total of 11 patients (6 males, 5 females; mean age: 56.4±11.5 years; range, 38 to 76 years) who underwent Zone 2 thoracic endovascular aortic repair procedure and left subclavian artery revascularization with the chimney technique between April 2017 and January 2020 in our clinic were retrospectively analyzed. All patients were followed at one, three, six months and one year with computed tomography angiography.

**Results:** The mean follow-up was 19.7±14.5 (range, 6.3 to 45.8) months. Endoleak occurred in one (9%) patient and gutter leak occurred in three (27%) patients. The mean endoleak-free (including gutter leak) time was 19.9±5.4 (95% confidence interval: 9.36-30.34) months. No mortality occurred in any of the patients. No occlusion occurred in the chimney grafts.

**Conclusion:** The chimney revascularization technique is an alternative to other revascularization techniques of the left subclavian artery during thoracic endovascular aortic repair.

**Keywords:** Aortic transection, endoleak, left subclavian revascularization; subclavian chimney; thoracic endovascular aortic repair, zone 2.

### ÖZ

**Amaç:** Bu çalışmada Zone 2 torasik endovasküler aort tamiri uygulanan aort diseksiyonu ve transeksiyonu hastalarında sol subklaviyan arterin baca tekniği ile revaskülarizasyonunun kısa dönem sonuçları sunuldu.

**Çalışma planı:** Nisan 2017 - Ocak 2020 tarihleri arasında kliniğimizde Zone 2 torasik endovasküler aort tamiri yapılan ve baca tekniği ile sol subklaviyan arterin revaskülarize edildiği toplam 11 hasta (6 erkek, 5 kadın; ort. yaş: 56.4±11.5 yıl; dağılım, 38-76 yıl) retrospektif olarak incelendi. Hastaların tümü bir, üç, altı ay ve birinci yılda bilgisayarlı tomografi anjiyografi ile takip edildi.

**Bulgular:** Ortalama takip süresi 19.7±14.5 (dağılım, 6.3-45.8) ay idi. Bir (%9) hastada endoleak, üç (%27) hastada gutter leak görüldü. Endoleak dahil kaçak görülmeden geçen ortalama süre 19.9±5.4 (%95 güven aralığı: 9.36-30.34) ay idi. Hiçbir hastada mortalite görülmedi. Baca greftlerinde tıkanma izlenmedi.

**Sonuç:** Baca revaskülarizasyon tekniği, torasik endovasküler aort tamiri sırasında sol subklaviyan arterin diğer revaskülarizasyon tekniklerine alternatif bir tekniktir.

**Anahtar sözcükler:** Aort transeksiyonu, endoleak, sol subklaviyan arter revaskülarizasyonu; subklaviyan baca; torasik endovasküler aort tamiri; Zone 2.

Received: July 29, 2021 Accepted: December 16, 2021 Published online: January 28, 2022

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### Cite this article as:

Altınay L, İnce İ, Bayyurt C, Şenkal Zobu M, Şahin E, Sürer S, et al. Short-term results of chimney stent revascularization of left subclavian artery and Zone 2 thoracic endovascular aortic repair for patients with aortic dissection or transection. Turk Gogus Kalp Dama 2022;30(1):51-56

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The thoracic endovascular aortic repair (TEVAR) technique has gained worldwide acceptance in the treatment of aortic pathologies since 1988, when the first case was published by Volodos et al.<sup>[1]</sup> There have been many improvements in the technique and technological advancements in stent graft materials since then.

There must be a healthy aortic wall in the proximal and the distal parts of the aortic pathology for a successful TEVAR intervention to provide proper landing zones for the aortic stent graft. The length of the landing zone varies between stent graft brands, but minimally it should be at least 15 mm in length. The length of the landing zone can be extended by covering the ostia of the supra-aortic arteries. Freezor et al.<sup>[2]</sup> showed that the aortic pathology included the left subclavian artery (LSA) in 35% of patients in their cohort of 196 TEVAR patients.<sup>[2]</sup> If the LSA is not revascularized, vertebrobasilar insufficiency in 2%, upper extremity ischemia in 6%, medulla spinalis ischemia in 4%, anterior cerebral stroke in 5%, and death in 6% of patients may occur.<sup>[2]</sup>

The chimney technique was described and first performed by Greenberg et al.<sup>[3]</sup> in 2003 for the revascularization of a renal artery that was occluded during an endovascular aortic aneurysm repair. The main reasons for revascularization of the renal and subclavian arteries with the chimney technique in endovascular aortic repair interventions are to prevent a type 1A endoleak and gain a sufficient proximal landing zone to increase endograft durability.

If the aortic pathology contains the aortic arch and its branches, treatment strategies include hybrid procedures (open surgical and endovascular interventions), surgeon-modified fenestrated and branched endovascular graft implantations, and combined endovascular techniques such as the chimney and periscope.<sup>[4]</sup> In the present study, we aimed to present short-term results of revascularization of the LSA with the chimney technique in patients who underwent TEVAR procedures.

## PATIENTS AND METHODS

This single-center, retrospective study was conducted at University of Health Sciences, Dışkapı Yıldırım Beyazıt Training and Research Hospital, Department of Cardiovascular Surgery between April 2017 and January 2020. A total of 11 patients (6 males, 5 females; mean age: 56.4±11.5 years; range, 38 to 76 years) who underwent combined LSA revascularization with the chimney technique and TEVAR were included. The main indication for the

chimney technique was the presence of an inadequate proximal landing zone. Other indications included emergency interventions or being an inappropriate candidate for an open surgical carotid-subclavian bypass due to the risks for general anesthesia, such as severe chronic obstructive pulmonary disease and previous radiotherapy in the neck region. Hypertension was defined as a systemic arterial blood pressure of >130/80 mmHg. Any patient with serum creatinine level of >2 mg/dL or under routine hemodialysis program was considered a chronic renal insufficiency patient. A body mass index of ≥30 kg/m<sup>2</sup> was accepted as obesity. A serum low-density lipoprotein (LDL) cholesterol level of >130 mg/dL was accepted as hyperlipidemia.

The multiplanar reconstruction (MPR) computed tomography angiographies (CTAs) of the patients with a 1-mm scan slice thickness and slice increment were evaluated by the endovascular team, which consisted of a cardiovascular surgeon and an anesthesiologist. The site of the primary intimal tear of the aortic dissection, diameters of the aorta and the LSA, length of the LSA, anatomy and dominance of the vertebral arteries and other supra-aortic branches were evaluated. A written informed consent was obtained from each patient. The study protocol was approved by the University of Health Sciences, Dışkapı Yıldırım Beyazıt Training and Research Hospital Ethics Committee (17/05/2021, 111/06). The study was conducted in accordance with the principles of the Declaration of Helsinki.

## Surgical procedure

All of the procedures were performed in the hybrid surgery room under local anesthesia. After proper disinfection of the surgical site and electrocardiographic monitoring of the patient, a vascular access sheath was introduced into the left brachial artery which was exposed with an open surgical technique. Femoral access sheaths were placed into both common femoral arteries using the percutaneous technique in seven patients. In the other four patients, the access sheaths were placed percutaneously into one of the femoral arteries and with an open technique into the other femoral artery. A vascular closure device (ProGlide®, 6 Fr, Abbott Vascular Inc., CA, USA) was utilized in all of the patients, if the femoral access sheath was placed percutaneously. A long sheath was introduced into the left brachial artery. The chimney stent graft was parked in the proper proximal landing zone in the aorta through the long sheath before aortic stent implantation. Then, the thoracic aortic stent graft was placed through the femoral access (Figure 1). A 10 to 15% oversized thoracic aortic stent graft was



**Figure 1.** Multiplanar sections of the TEVAR graft in thoracic aorta and chimney graft in left subclavian artery (arrows); (a) coronal; (b) sagittal; (c) axial; (d) three-dimensional image.  
TEVAR: Thoracic endovascular aortic repair.

used along with the chimney stent. Systemic arterial blood pressure was maintained below 80 mmHg during aortic stent graft implantation. An oral dose of clopidogrel 300 mg was administered to all of the patients postoperatively. The patients were discharged on the postoperative second day with a prescription for oral clopidogrel 75 mg a day for a month and oral acetylsalicylic acid 300 mg a day indefinitely. All patients were followed at one, three, six months and one year with CTA.

### Statistical analysis

Statistical analysis was performed using the SPSS version 13.0 software (SPSS Inc., Chicago, IL, USA). Quantitative data were expressed in mean  $\pm$  standard deviation (SD) or median (min-max), while qualitative data were expressed in number and percentage (%). The

Kaplan-Meier curves were calculated for cumulative survival analysis. A  $p$  value of  $<0.05$  was considered statistically significant.

### RESULTS

The mean follow-up was  $19.7 \pm 14.5$  (range, 6.3 to 45.8) months. No mortality occurred and one patient was lost to follow-up. Type 1A endoleak occurred in one patient in the first postoperative month which was treated with stent graft and TEVAR graft extension. In this patient, the TEVAR graft landed closer to the LSA than intended and, therefore, there was a loss of the proximal landing zone. The TEVAR extension was placed using the entire length of the proximal landing zone, avoiding the left common carotid artery (CCA) ostium closure. In addition, a second balloon

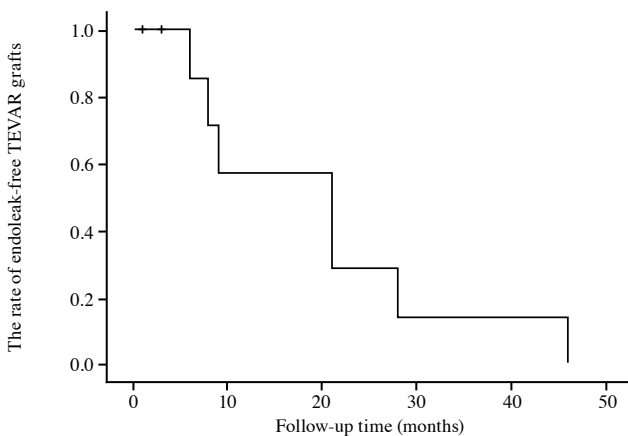
**Table 1. Preoperative data (n=11)**

	n	%	Mean±SD
Age (year)			56.4±11.5
Sex			
Male	6	55	
Hypertension	9	81	
Diabetes	2	18	
Chronic renal insufficiency	1	9	
Hyperlipidemia	3	27	
COPD	4	36	
Obesity	3	27	
Diagnosis			
Type 3 aortic dissection	7	64	
Aortic transection	2	18	
Type 1 aortic dissection	2	18	

SD: Standard deviation; COPD: Chronic obstructive pulmonary disease.

expandable stent graft was placed into the first chimney stent graft to avoid narrowing and collapse of the first stent graft by the radial force of the TEVAR extension graft. Preoperative data are presented in Table 1.

Gutter leak occurred in three patients (27%). It was seen in the first postoperative month in one patient and in the third postoperative month in two patients. It was treated with in-stent extension in one patient and with kissing balloon remodeling in two patients. The mean endoleak-free (including gutter leak) time was 19.9±5.4 months (Figure 2). No occlusion occurred in the chimney grafts. No access site complication occurred. Postoperative data are presented in Table 2.



**Figure 2.** Survival curve related to TEVAR stent graft endoleak. TEVAR: Thoracic endovascular aortic repair.

**Table 2. Postoperative data (n=11)**

	n	%	Mean±SD
Follow-up time (month)			19.7±14.5
Stent types			
Balloon expandable	9	82	
Self-expandable	2	18	
Postoperative leak			
Type 1A endoleak	1	9	
Gutter leak	3	27	
Survival time (month)*			19.9±5.4

SD: Standard deviation; \* Survival from endoleak.

Aortic pathologies, endograft sizes, indications for the endovascular interventions, types of endoleaks and treatments are summarized in Table 3.

## DISCUSSION

The chimney technique is a popular technique that has been increasingly utilized to maintain the blood flow of the LSA in endovascular procedures for thoracic aortic pathologies. The risk of vertebrobasilar ischemia is high in the presence of left vertebral artery dominance and discontinued blood flow of the Willis polygon, if the LSA is occluded.<sup>[5]</sup> Rizvi et al.<sup>[6]</sup> reported in their meta-analysis that the risks of left upper extremity ischemia and vertebrobasilar insufficiency significantly increased, when the LSA was occluded and found a non-significant increase in the risk of medulla spinalis ischemia. In the 2009 Society for Vascular Surgery Practice Guidelines, LSA revascularization was suggested for all patients undergoing elective thoracic endovascular interventions due to the posterior cerebral blood flow impairment related to high stroke rates, high risk of left upper extremity ischemia and paraplegia related to medulla spinalis ischemia.<sup>[7]</sup> Therefore, we attempted to revascularize the LSA in all of our patients who underwent emergent or elective endovascular thoracic aortic procedures using the chimney technique, carotid-subclavian bypass or implanting a surgeon-modified fenestrated stent graft. İşcan and Ünal<sup>[8]</sup> also reported a successfully treated type B aortic dissection case with a surgeon-modified fenestrated stent graft.

The unwanted results of open carotid-subclavian bypass surgery such as hemorrhage, wound infection, lymphorrhea or local nerve injury are not seen in the chimney technique. Also, it does not require general anesthesia and can be done easily under emergent situations.<sup>[9]</sup>

**Table 3. Summary of the aortic pathologies and endovascular interventions**

Aortic pathology	n	TEVAR grafts (mm)	LSA Chimney grafts (mm)	*Indication for endovascular intervention	*Endoleak (treatment)	
Type 3 aortic dissection	7	32×32×200	10×59	COPD	4	Type 1A (1) (TEVAR extension, chimney graft extension)
		42×42×212	13.5×60	Obesity	3	
		40×40×212	10×38	IPL	5	
		30×30×200	10×38			Gutter leak (2) (kissing balloon)
		36×36×200	9×59			
		34×34×200	12×58			Gutter leak (1) (stent extension)
Aortic transection	2	30×30×150	9×59	EO	2	None
		30×30×100	8×38			
Type 1 aortic dissection	2	46×46×200	10×38	EO	2	None
		40×36×150	13.5×60			

\* Number of patients; TEVAR: Thoracic aortic endovascular repair; LSA: Left subclavian artery; COPD: Chronic obstructive pulmonary disease; IPL: Inadequate proximal landing zone; EO: Emergency operation.

Kanaoka et al.<sup>[10]</sup> reported a seven-year follow-up stroke rates 12.1% in the patients who underwent TEVAR procedures for aortic arch pathologies.<sup>[10]</sup> We had no case of stroke or any other cerebrovascular event in this study.

The main problems with the chimney technique are a type 1A endoleak: the leak caused by the gutters between the stent grafts which is called a “gutter leak”. The diameters of the grafts should be calculated precisely to avoid these problems. Chou et al.<sup>[11]</sup> suggested a formula ( $R' \geq \sqrt{(1.44R^2 - r^2)}$ ) to minimize gutter leak where  $R'$  is the radius of the main aortic graft,  $R$  is the radius of the native aorta, and  $r$  is the radius of chimney graft. Wang et al.<sup>[12]</sup> reported that maintaining an overlap at least 2-cm long between the aortic stent and the chimney stent would provoke thrombosis and reduce the risk of gutter leak between the grafts. In our practice, we use covered stents instead of bare metal stents and we believe that this may promote gutter thrombosis between the grafts. Additionally, using the kissing balloon technique while implanting the stents and deflating the chimney stent balloon after the aortic stent balloon would reduce the risk of gutter leak.

If the gutter leak occurred in the post-procedural follow-up period, remodeling the stent grafts using the kissing balloon technique can be curative. We had a gutter leak in three cases in this study. We treated the leaks by expanding the aortic and the chimney stents by using the kissing balloon technique in two of these patients. In one patient, the gutter leak was

treated by extension of the chimney stent and the TEVAR stent graft. In acute type B aortic dissections, the aortic wall can be very fragile and aggressive dilatations of the aortic wall can cause a retrograde type A dissection; therefore, the kissing balloon technique should be utilized very carefully in these pathologies.

The patency of the chimney stent grafts is an important subject. Zhang et al.<sup>[13]</sup> reported the results of 43 type B aortic dissection patients treated with TEVAR and revascularization of LSA with chimney stents and custom-made single-branched stent grafts (SBSG). They reported occlusion in two (9.1%) chimney stent patients and in one (4.8%) SBSG patient. They found no significant difference between the results of these two techniques. Lindblad et al.<sup>[14]</sup> reported the primary patency rate of chimney stents as 99% in their study. The primary patency rate of the chimney stents was 100% in the one-year follow-up period in our study.

Thoracic aortic aneurysm is the first approved indication and one of the main indications for the TEVAR procedure.<sup>[15,16]</sup> We had patients with aneurysms in aortic arch and descending thoracic aorta in whom we performed TEVAR procedures with surgeon-modified fenestrated aortic stent grafts and open surgical LSA - carotid artery bypass with synthetic grafts. However, the cohort in this study consisted of patients with aortic dissections and transections. We believe that this is coincidental and there is no selection bias.

The LSA chimney revascularization was performed simultaneously with the emergency TEVAR procedure due to the increase in diameter of the descending aorta in the follow-up of two patients who previously underwent ascending aorta replacement and innominate artery and left CCA debranching due to type I aortic dissection.

The limitations of this study are that it was conducted in a single center and it was retrospective.

In conclusion, the endovascular treatment of complex aortic pathologies is a reasonable alternative solution compared to more invasive surgical treatment techniques. The chimney technique is an alternative to other left subclavian artery revascularization techniques with reasonable results. Further studies should be conducted to draw firm conclusions on this subject.

#### **Declaration of conflicting interests**

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.

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