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Outcomes of Chimney Technique for Preservation of the Left Subclavian Artery in Type B Aortic Dissection

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WHAT THIS PAPER ADDS

This is a single centre study of the chimney technique for preservation of the left subclavian artery (LSA) in type B aortic dissection (TBAD). Several studies have reported outcomes of the chimney technique in aortic arch disease, but the long-term efficacy remains unclear. Previous studies are heterogeneous in that they include various pathologies and supra-aortic branches. To the authors' knowledge, the present study may be the largest series about the chimney technique for LSA revascularisation in TBAD. The findings demonstrate that the technique is feasible to preserve LSA flow in TBAD, without significant complications in the mid-term.

Objective: To report outcomes of the chimney technique for preservation of the left subclavian artery (LSA) in patients with type B aortic dissection (TBAD).

Methods: A retrospective analysis was performed of a prospectively maintained database from August 2012 to October 2017. Primary endpoints were 30 day and overall mortality. Secondary endpoints were technical success, type Ia endoleak, chimney stent occlusion, aortic rupture, stroke, spinal cord ischaemia, and re-intervention rate.

Results: A total of 159 patients (mean age 54 ± 11 years; 141 men) with TBAD were treated using the chimney technique for LSA revascularisation. Acute, subacute, and chronic TBAD accounted for 64%, 28%, and 8% of cases, respectively. One hundred and six cases (67%) were complicated TBAD. One hundred and fifty-six patients (98%) were treated electively, while three (2%) were treated urgently because of intestinal or lower extremity ischaemia. The 30 day mortality and morbidity rates were 2% (3/159) and 4% (7/159), respectively. The technical success rate was 81% (129/159) and immediate type Ia endoleak occurred in 30 (19%) patients. Three major strokes, two spinal cord ischaemia and one aortic rupture, occurred early on. During a mean follow up of 23 ± 16 months (range 1—65 months), three more patients died: from aortic rupture, cerebral haemorrhage, and rectal cancer, respectively. Chimney stent occlusions were observed in four patients and all these chimney stents were self expanding. During follow up, two major strokes, one late type Ia endoleak and one re-intervention, occurred. According to the Kaplan—Meier curve, the estimated one and three year survival rates were 98.1 ± 1.1% and 94.4 ± 2.4%, respectively.

Conclusion: Short and mid-term outcomes in the present study demonstrate that the chimney technique is safe and feasible for preservation of the LSA in patients with TBAD, but the durability of chimney stent needs to be evaluated carefully and immediate type Ia endoleak is a concern.

Keywords: Chimney, Endoleak, Left subclavian artery, Thoracic endovascular aortic repair, Type B aortic dissection
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INTRODUCTION

Thoracic endovascular aortic repair (TEVAR) is a valuable option for patients with descending thoracic aortic aneurysm or type B aortic dissection (TBAD).[1,2] However, endovascular management of lesions involving the aortic arch remains challenging because of its angulated morphology and involvement of the supra-aortic branches. Several strategies have been put forward in the literature to preserve the supra-aortic branches, such as chimney technique,[3—6] hybrid

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technique,[7] and fenestrated or branched stent graft technique.[8,9] The outcomes of the hybrid technique have been mixed, with morbidity and mortality rates of 0.8% to 18.8% and 2.0% to 23.7%, respectively.[10,11] Some studies have reported favourable results with the use of branched or fenestrated stent grafts in the aortic arch. However, these approaches were limited by the morphological diversity of the aortic arch, necessitating patient specific and tailor made devices. Moreover, such procedures are complex, time consuming, and often inapplicable in emergency situations, limiting their clinical usefulness.[12]

Another approach to maintain perfusion of the supra-aortic vessels is the chimney technique, which was first applied in the aortic arch to rescue an inadvertently covered left subclavian artery (LSA).[13] In recent years, the chimney technique has proliferated rapidly for the treatment of aortic arch disease, but the long-term efficacy remains unclear. Moreover, previous studies of this topic are heterogeneous in their pathologies and different supra-aortic branches.[14–17]

The aim of this study was to report experience with the chimney technique for LSA preservation in TBAD and to evaluate the short and mid-term outcomes in these patients.

MATERIALS AND METHODS

Study patients

A retrospective analysis of a prospectively maintained database was performed from August 2012 to October 2017. One hundred and fifty-nine consecutive patients (mean age 54 ± 11 years, range 28–78 years; 141 men) with TBAD underwent TEVAR combined with a LSA chimney stent at Guangdong Cardiovascular Institute, Guangdong General Hospital in China. The indication for the chimney stent was a proximal landing zone < 1.5 cm. Patients with Marfan syndrome or blunt traumatic thoracic aortic injury were not included in this study. Chimney stents used in a bailout setting were also excluded. All patients received computed tomography angiography (CTA) and were evaluated by an interdisciplinary board composed of cardiologists, endovascular surgeons, cardiovascular surgeons, radiologists, and anaesthetists. The size and location of primary entry tear, the maximum diameter of the aorta, the domination of the vertebral artery, and the involvement of visceral arteries were evaluated by dedicated Aquarius iNtuition software (Terarecon, San Mateo, CA, USA). The study institutional ethics board approved the study and the need for informed consent was waived because of the retrospective nature of the analysis.

Procedures

The procedures were performed in a cardiac catheterisation room under local anaesthesia. In the urgent cases or for patients in pain, analgesic drugs such as morphine and fentanyl were used to alleviate pain. All thoracic stent grafts were deployed retrograde via percutaneous femoral artery access employing the pre-closing technique.[18] To control hypotension (systolic blood pressure < 90 mmHg), a rapid ventricular pacing technique was used during the deployment of aortic stent grafts.[19] The morphological features of the aortic lesions were measured with both CTA and angiography. Aortic stent graft diameters were generally oversized by 10–15% in TBAD with chimney stent.

For the LSA chimney stent, a sheath was introduced into the left radial artery (6 F) or left brachial artery (7–9 F) according to the size of chimney graft, through which a stiff guide wire was inserted into the ascending thoracic aorta. Aortic arch angiography was performed to confirm the deployment position through the catheter inserted into the femoral artery. After the aortic stent graft was introduced into the aortic arch, the chimney stent was delivered into the LSA through the arterial sheath. Under controlled hypotension (systolic blood pressure < 90 mmHg) and fluoroscopy, the aortic stent graft was firstly deployed, and then the chimney stent was deployed as soon as possible. For the majority of patients (n = 155, 97%) without an isolated left vertebral artery, the overlap between the chimney and the thoracic stent graft was at least 2.0 cm. But for the other four patients with an isolated left vertebral artery, the overlap was typically minimised (the minimum could reach to 1.0 cm) to avoid covering the ostium of the left vertebral artery.

Angiography was performed to evaluate the positions of the stent graft and the chimney stent, as well as to detect immediate type Ia endoleak (ELIa). Post-operatively, patients were placed on clopidogrel 75 mg/day for one month and aspirin 100 mg/day indefinitely.

Follow up

Patients were followed up regularly. Assessment of survival and clinical manifestations were completed by outpatient clinic visit or telephone interview. Contrast CTA was performed to evaluate aortic morphology and the patency of the chimney stent. For patients with immediate endoleak, aortic growth > 5 mm/year or aortic diameter > 50 mm, CTA was performed at 1, 3, 6, and 12 months post-operatively, and annually thereafter. For other patients CTA was performed at three months and annually thereafter. If the patient was in a stable condition after three years, the interval was extended to 2–3 years. Additional CTA examinations were performed if patients demonstrated new symptoms or signs of adverse events. While the CTA could be performed in any hospital, all images were evaluated by at least two physicians involved in this study.

Definition

Complicated TBAD was defined as persistent or recurrent pain, uncontrolled hypertension despite full medication, early aortic expansion, malperfusion, and signs of rupture (haemothorax, increasing peri-aortic and mediastinal haematoma).[1] Primary technical success was defined on an intention to treat basis requiring the successful introduction and deployment of the device in the absence of surgical

conversion to open repair, death in < 24 h, type I or III endoleaks seen on procedural angiography, or graft obstruction. Spinal cord ischaemia was graded according to the reporting standards for TEVAR.[20] Late ELIa was defined as an endoleak that was detected by CTA during follow up, which had not been found on angiography at the end of the procedure. Major adverse events included all cause death, aortic rupture, stroke, spinal cord ischaemia, and re-intervention. Early outcomes are presented as 30 day mortality and morbidity.

Statistical analysis

Continuous data are presented as the mean ± standard deviation; categorical data are given as the counts (percentage). A Kaplan-Meier analysis was used to estimate the freedom from all cause death, aortic specific death, major adverse events, and chimney stent occlusion. The differences between groups were assessed with the log rank tests. All statistical tests were two sided and p values <.05 were considered to be statistically significant. All statistical analyses were performed using SPSS software, version 19.0 (IBM Inc., Chicago, IL, USA).

RESULTS

Demographics and coexisting medical conditions

From August 2012 to October 2017, 159 consecutive patients with TBAD underwent TEVAR combined with LSA chimney stent at Guangdong Cardiovascular Institute, Guangdong General Hospital in China. The majority of patients were male (89%; $n = 141$), with a mean age of 54 ± 11 years (range 28—78 years). Hypertension was confirmed in 130 (82%) patients and was the most common coexisting medical condition. Forty-eight (30%) patients had a history of smoking and two (1%) patients had a medical history of previous aortic surgery. Additional details of comorbidities are presented in Table 1. In this series, acute, subacute, and chronic TBAD accounted for 64%, 28%, and 8% of cases, respectively. One hundred and six (67%) patients had complicated TBAD and 53 (33%) uncomplicated TBAD. The uncomplicated acute TBAD patients received TEVAR with chimney stent because the true lumen was severely compressed.

Table 1. Demographic characteristics and coexisting medical conditions in 159 patients with TBAD

Parameter	Mean ± SD or *n* (%)
Age, years	54 ± 11
Male	141 (89)
Coexisting medical conditions	
Hypertension	130 (82)
Coronary artery disease	25 (16)
Diabetes mellitus	12 (8)
Hyperlipidaemia	42 (26)
Stroke	7 (4)
Chronic obstructive pulmonary disease	4 (3)
Chronic kidney disease	19 (12)
Acute kidney injury	8 (5)
Peripheral arterial disease	6 (4)
Abdominal aortic aneurysm	3 (2)
Smoke	48 (30)
Prior aortic surgery	2 (1)
Stage	
Acute TBAD	101 (64)
Subacute TBAD	45 (28)
Chronic TBAD	13 (8)
Complicated TBAD	106 (67)
Uncomplicated TBAD	53 (33)

TBAD = type B aortic dissection; SD = standard deviation.

Details of the operation

TEVAR was performed in emergency settings in three acute TBAD patients with intestinal or lower extremity ischaemia. Thirteen patients received two aortic stent grafts. A total of 159 chimney stents were deployed in this patient series. The majority ($n = 103$, 65%) of chimney stents were bare self expandable stents. The bare balloon expandable stents and covered self expanding stents account for 21% and 13%, respectively. Immediately chimney stent compression or occlusion was not observed, so no cases needed re-lining with a self expandable stent. Procedural details can be found in Table 2.

Short-term outcomes

The mean post-operative hospital stay was 7 ± 5 days (median six days; range 1—44 days), and the technical success rate was 81% (129/159). Angiography after chimney stent placement showed that all supra-aortic branches were patent and immediate ELIa occurred in 30 (19%) patients. These endoleaks were treated conservatively with close surveillance. Four (2%) access related complications occurred, including femoral artery stenosis or occlusion which required implantation of a peripheral vascular stent ($n = 3$) and brachial artery infection requiring antibiotic therapy ($n = 1$).

The 30 day mortality rate was 2% (3/159). The reasons for deaths were aortic rupture in one case, ventricular fibrillation in one case, and major stroke in one case. Three major strokes were recorded in the short term. Two of these patients gradually recovered at discharge, while the other one ultimately died in hospital. Spinal cord ischaemia occurred in two cases, one case was transient (Grade 2) and the other was permanent (Grade 3a). Minor stroke, transient ischaemic attack, or re-intervention was not recorded. Therefore, the major adverse events rate was 4% (7/159) in the short term.

Follow up outcomes

Notably, 98% (153/156) of patients were successfully followed up by outpatient clinic visits or telephone interviews to assess survival and clinical findings. The mean duration of clinical follow up was 23 ± 16 months (range 1—65 months), during which time deaths were recorded in three

Table 2. Operative Details of 159 patients with TBAD managed interventionally

Interventional detail	Mean ± SD or *n* (%)
Emergency setting	3 (2)
Restrictive bare stent	12 (8)
Stent graft details	
More than one aortic stent graft	13 (8)
Brand of aortic stent graft	
Valiant (Medtronic, MN, USA)	63 (40)
Zenith TX2 (Cook, IN, USA)	6 (4)
TAG (Gore, AZ, USA)	2 (1)
cTAG (Gore, AZ, USA)	30 (19)
Ankura (Lifetech, Shenzhen, China)	47 (30)
Hercules-T (Microport, Shanghai, China)	10 (6)
Aortec (YTH, Beijing, China)	14 (9)
Details of chimney stent grafts	
Bare self expanding	103 (65)
Bare balloon expandable	33 (21)
Covered self expanding	23 (14)
Brand of chimney stent grafts	
Complete SE (Medtronic, MN, USA)	47 (30)
Express LD (Boston Scientific, MA, USA)	33 (21)
Wallstent Monorail (Boston Scientific, MA, USA)	1 (1)
Fluency Plus (Bard Tempe, AZ, USA)	12 (8)
E. Luminexx (Bard Tempe, AZ, USA)	42 (26)
Maris (Invatec, Brescia, Italy)	13 (8)
Viabahn (Gore, AZ, USA)	11 (7)

SD = standard deviation.

cases. One was caused by aortic rupture, one by cerebral haemorrhage, and another to rectal cancer. Major stroke occurred in two cases; one had cerebral haemorrhage and eventually died, and the other had cerebral infarction 13 months after the procedure and recovered gradually. Minor stroke or transient ischaemic attack was not recorded during follow up. One patient received re-intervention because of distal expansion. The details of the early and mid-term outcomes are listed in Table 3.

In this study, there were 36 patients without imaging follow up for various reasons (lost contact, $n = 3$; economic reasons, $n = 4$; receiving CTA in other hospitals but could not provide imaging data, $n = 25$; patient refusal, $n = 4$). Only 77% of patients (120/156) received at least one CTA to evaluate aortic morphology and patency of the chimney stent. Accordingly, 69% of patients (108/156) had complete imaging follow up. The mean duration of imaging follow up was 20 ± 16 months (range 1–64 months). There was no significant difference in the maximum aortic diameters between those patients with and without immediate type Ia endoleak (36.4 ± 2.8 mm vs. 37.2 ± 2.8 mm, $p = .264$). Of the cohort, 91% (109/120) had complete false lumen occlusion during follow up. Among the 30 cases with immediate ELIa, four (13%) original ELIa persisted, 19 (64%) original ELIa disappeared, and seven (23%) patients were lost to CTA follow up. For the four cases with persistent ELIa, no re-interventions were needed because enlargement of the aorta was not detected, and the patients remain under close surveillance. Late ELIa was detected in one patient with a partially thrombosed false lumen. Occlusion of the LSA chimney stent was recorded in four (3%) patients and all were self expanding. The details of pre-operative CTA and follow up CTA outcomes are described in Table 4.

Survival statistic

According to Kaplan–Meier analysis, the estimated survival at one and three years was 98.1 ± 1.1% and 94.4 ± 2.4%, respectively. Similarly, the estimated freedom from chimney stent occlusion at one and three years was 98.6 ± 1.0% and 96.5 ± 1.8%, respectively (Fig. 1). Comparisons of outcomes for patients with or without immediate ELIa are presented in Fig. 2. The log rank test revealed that there was no significant difference between the survival curves examining all cause death, aorta specific death, major adverse events, or chimney stent occlusion.

DISCUSSION

The chimney technique, which serves as a way to restore blood flow in the aortic arch branches and to extend the length of the proximal landing zone, is an increasingly popular option. In 1999, Greenberg et al. implanted a renal stent parallel to the aortic stent graft to rescue the renal artery in endovascular treatment of an abdominal aortic aneurysm.[21] In 2007, Criado comprehensively introduced

Table 3. Short and mid-term outcomes of LSA chimney technique for TBAD in 159 patients

Outcome	Mean ± SD or *n* (%)
Short-term up to 30 days (n=159)	
Duration of post-operative hospital stay (days)	7 ± 5
Immediate type Ia endoleak	30 (19)
Puncture site complications	4 (3)
Femoral artery stenosis or occlusion	3 (2)
Brachial artery local infection	1 (1)
Major adverse events	7 (4)
All cause death	3 (2)
Aortic rupture	1 (1)
Major stroke	3 (2)
Minor stoke/TIA	0 (0)
Spinal cord ischaemia	2 (1)
Re-intervention	0 (0)
Mid-term outcomes 30 days to 23 ± 16 months (n=156)	
Clinical follow up	153 (98)
Clinical follow up time (months)	23 ± 16
Imaging follow up	120 (77)
Imaging follow up time (months)	20 ± 16
Late type Ia endoleak	1 (1)
Chimney stent occlusion	4 (3)
Major adverse events	5 (3)
All cause death	3 (2)
Aortic rupture	1 (1)
Major stroke	2 (1)
Minor stoke/TIA	0 (0)
Spinal cord ischaemia	0 (0)
Re-intervention	1 (1)

LSA = left subclavian artery; TBAD = type B aortic dissection; TIA = transient ischaemic attack; SD = standard deviation.

Table 4. Details of pre-operative CTA and follow up CTA

CTA features	Mean ± SD or *n* (%)
Pre-operative CTA (n=159)	
Maximum diameter of aorta, mm	38.2 ± 2.8
Size of primary entry tear, mm	10.3 ± 2.9
Blood supply of visceral arteries	
Coeliac artery (TL/FL/TF)	72 (45)/44 (28)/43 (27)
Superior mesenteric artery (TL/FL/TF)	67 (42)/41 (26)/51 (32)
Left renal artery (TL/FL/TF)	59 (37)/44 (28)/56 (35)
Right renal artery (TL/FL/TF)	66 (41)/54 (34)/39 (25)
False lumen status	
Patent	109 (69)
Partially thrombosed	37 (23)
Completely thrombosed	13 (8)
Dominance of vertebral artery	
Left dominant	66 (41)
Equality dominant	63 (40)
Right dominant	30 (19)
Follow up CTA (n=120)	
Maximum diameter of aorta (mm)	37.0 ± 2.8
Original type Ia endoleak (n = 30)	
Persistent	4 (13)
Disappeared	19 (64)
Lost follow up	7 (23)
Late type Ia endoleak	1 (1)
Type Ib endoleak	6 (5)
False lumen status	
Patent	0 (0)
Partially thrombosed	11 (9)
Completely thrombosed	109 (91)
Chimney stent occlusion	4 (3)

CTA = computed tomography angiogram; SD = standard deviation; FL = false lumen; TF = true lumen and false lumen; TL = true lumen.

this technique for endovascular aortic arch repair.[22] Considering the parallel relationship between the aortic stent graft and the branch vessel stent, the branch vessel stent was defined as the chimney stent, and this technique was renamed the chimney technique.[23] In the past few years, the chimney technique has been used increasingly in TEVAR. To the authors' knowledge, this study may be the largest to examine the chimney technique for preservation of the LSA in TBAD at a single centre including mid-term outcomes.

For patients with zone 2 TBAD, the LSA chimney technique was a total endovascular repair method, and it was conducted under local anaesthesia. There has been considerable evidence demonstrating a higher risk of vertebrobasilar ischaemia and left upper extremity ischaemia after LSA coverage, which was associated with an increased risk of stroke and paraplegia.[24] Therefore, the Society for Vascular Surgery practice guidelines suggested that revascularisation of the LSA should be one routinely in all elective cases.[25] According to these guidelines, the chimney technique was used to reconstruct LSA in zone 2 aortic arch disease. If patient anatomy was not suitable, left common carotid artery (LCCA) to LSA bypass/transposition was performed when the patient had an incomplete Circle of Willis, dominant LSA, or aberrant right subclavian artery. However, complications of LCCA-LSA bypass/transposition include haemorrhage, wound infection, local nerve injury, etc. Compared with the hybrid technique, the chimney technique is more advantageous in terms of immediacy, reduced invasiveness, and improved safety. Therefore, the present authors prefer use of the LSA chimney stent over LCCA-LSA bypass/transposition.

The main concern of the chimney technique is the risk of ELIa from the gutters alongside the aortic stent graft, chimney stent, and thoracic aortic wall. To decrease the incidence of ELIa, different approaches have been reported. Theoretically, a covered stent may be helpful because it can decrease the blood flow through the mesh of the bare stent into the gutter. Beyond that, Wang et al. recommend at least 2 cm overlap between the aortic stent graft and the chimney stent to promote thrombosis in the gutter.[14] Furthermore, adequate oversizing of the aortic stent graft

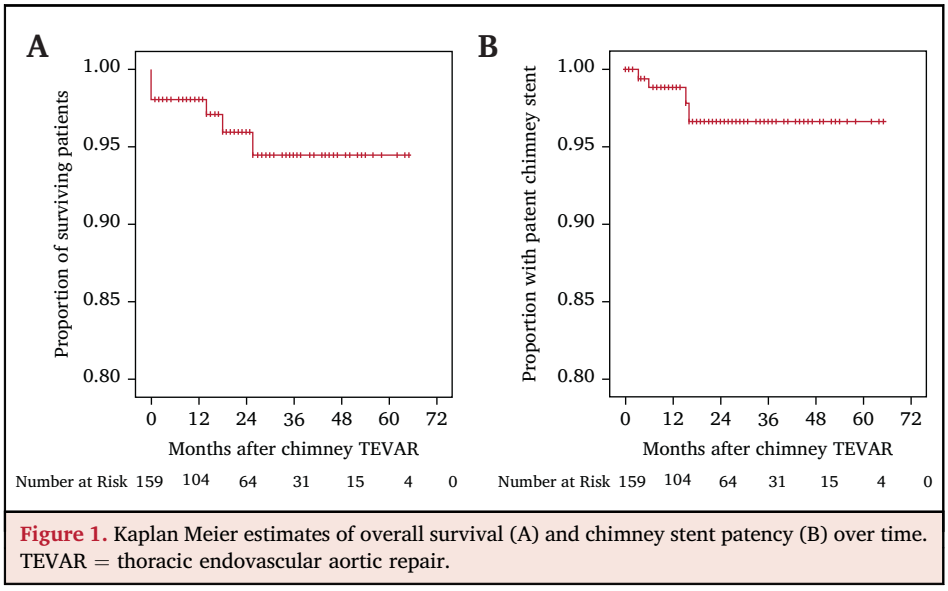

Figure 1. Kaplan Meier estimates of overall survival (A) and chimney stent patency (B) over time. TEVAR = thoracic endovascular aortic repair.

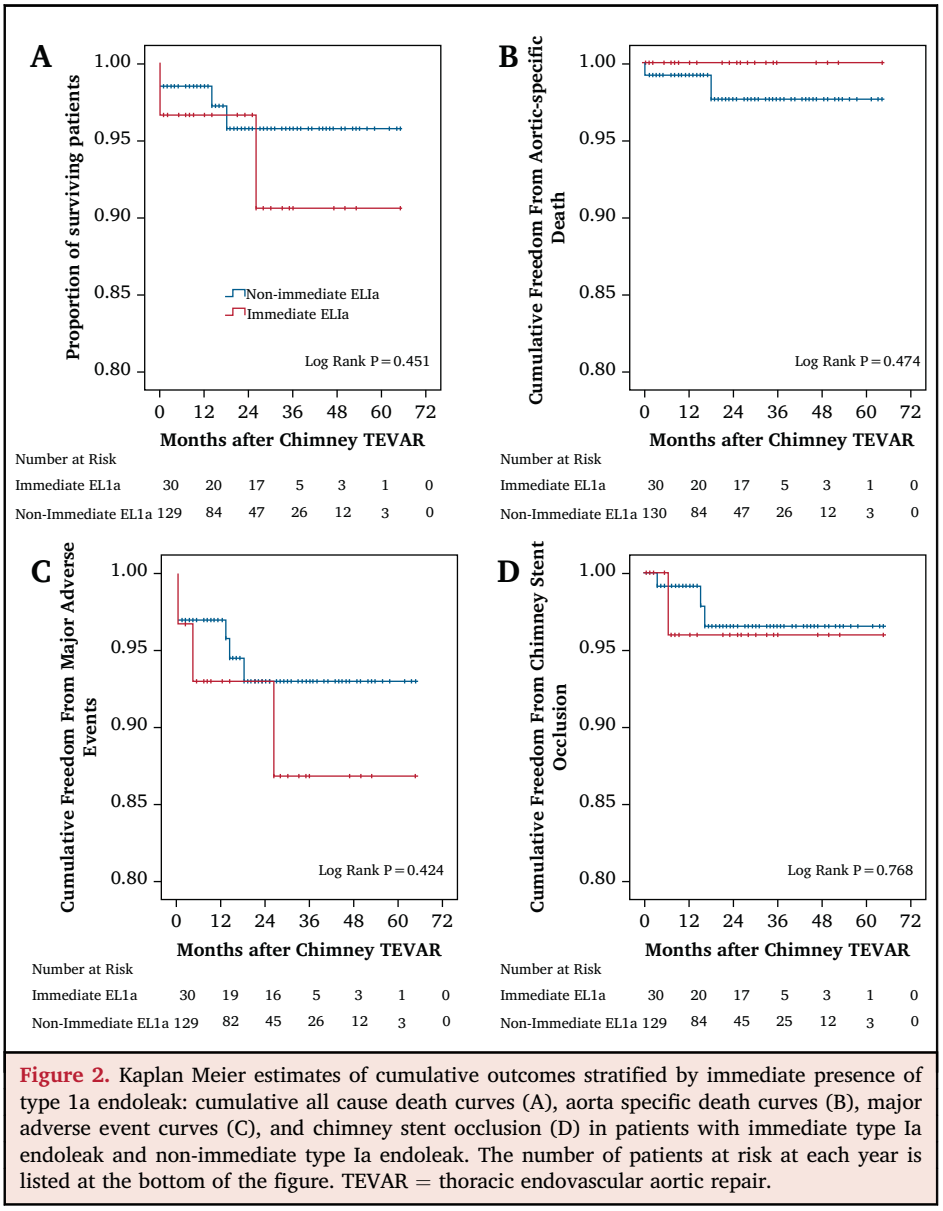

Figure 2. Kaplan Meier estimates of cumulative outcomes stratified by immediate presence of type 1a endoleak: cumulative all cause death curves (A), aorta specific death curves (B), major adverse event curves (C), and chimney stent occlusion (D) in patients with immediate type Ia endoleak and non-immediate type Ia endoleak. The number of patients at risk at each year is listed at the bottom of the figure. TEVAR = thoracic endovascular aortic repair.

can narrow the gutter and reduce the risk of ELIa. For patients with TBAD, Huang et al. suggest that the gutter should be formed as far away from the entry tear as possible.[26] The kissing balloon technique should be used with extreme caution as excessive angioplasties may cause retrograde type A aortic dissection, especially in cases of acute TBAD with a highly fragile aortic wall. Another promising technique to handle the ELIa is to selectively catheterise and embolise the gutter with coils.[27] In the present study, 30 (19%) cases of immediate ELIa were recorded. Given that the ELIa were low flow, additional treatment was not required. There were no significant differences between the immediate ELIa and non-immediate ELIa groups for all cause death, aorta specific death, major adverse events, or chimney stent occlusion (Fig. 2); findings which are similar to previous studies.[15,26]

The ideal configuration for chimney grafts remains a controversial topic. Both covered and bare stents have been used, but a consensus has not been reached about which is more suitable.[14,15,26,28] For cases of supra-arch branch dissection, or a tear near the supra-arch branch ostium, the present authors prefer use of a covered stent because it might be more helpful in establishing a blind channel to decrease the risk of endoleak around the chimney stent. However, some of the covered stents had to be implanted by surgical access because of their large delivery system; whereas, with a thin delivery system, the bare stent can be implanted by percutaneous radial artery access. It should be noted that 31% of patients did not have adequate imaging follow up in the study cohort, which made assessment of outcomes between covered and bare stents unreliable. The choice between stents requires further research.

The patency of the chimney stent is another momentous topic. In a systematic review, Lindblad et al. revealed that the primary patency of the chimney stents in aortic arch pathologies was 99% (361/364).[4] Similarly, the results from a European multicentre registry study showed that the primary patency of chimney stents was 98% (100/102).[5] Two

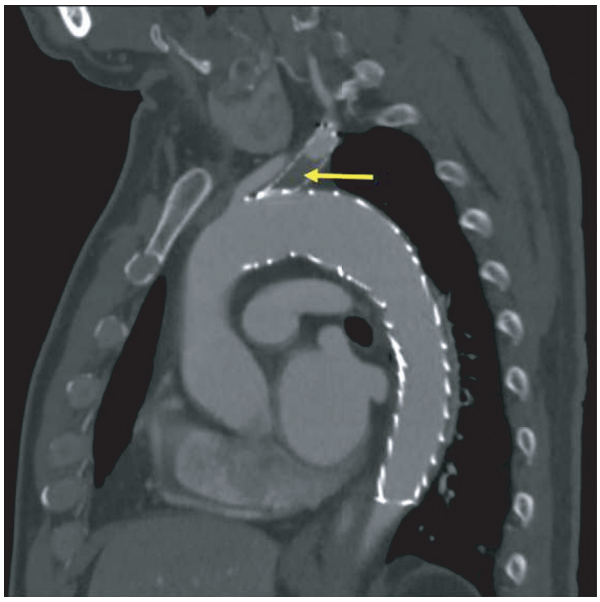

Figure 3. Chimney stent occlusion was confirmed by CTA during follow up. The LSA chimney stent was occluded (yellow arrow) at three months' follow up.

patients with occluded self expandable covered stents in the LSA were asymptomatic. In the present study, there were four patients (3%) with occluded self expandable chimney stent in the LSA during follow up (Fig. 3). These patients received close surveillance but no re-intervention as there were no vertebrobasilar ischaemia or left upper extremity ischaemia symptoms. In the present authors' opinion, the speculative reason was that the self expandable stents have reduced radial force. As occlusions were only seen in self expanding chimney stents, balloon expandable chimney stents may be a more reasonable choice. This conclusion needs to be confirmed by future studies.

There are several limitations in this study that deserve mention. First, it was an observational and retrospective study, and the outcomes represented experience obtained at a single institution. Second, it was not possible to make a direct comparison of the therapeutic effect between the chimney technique, hybrid procedure, and fenestrated or branched stent grafts. Third, there were 31% of patients without adequate imaging follow up in the cohort, so it was not possible to assess chimney patency and endoleak rate accurately. Therefore more cases need to be accumulated and long-term follow up is required before a more comprehensive and accurate conclusion can be reached.

Short and mid-term outcomes from the present study have demonstrated that the chimney technique is safe and feasible for preservation of the LSA in TBAD, but the durability of chimney stent needs to be evaluated carefully and immediate ELIas remain a concern as these patients have uncertain long-term outcomes.

CONFLICT OF INTEREST

None.

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REFERENCES

1 Erbel R, Aboyans V, Boileau C, Bossone E, Bartolomeo RD, Eggebrecht H, et al. 2014 ESC guidelines on the diagnosis and treatment of aortic diseases: document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult. The task force for the diagnosis and treatment of aortic diseases of the European Society of Cardiology (ESC). *Eur Heart J* 2014;**35**:2873–926.

2 Riambau V, Bockler D, Brunkwall J, Cao P, Chiesa R, Coppi G, et al. Editor's choice – management of descending thoracic aorta diseases: clinical practice guidelines of the European Society for Vascular Surgery (ESVS). *Eur J Vasc Endovasc Surg* 2017;**53**:4–52.

3 Zhu Y, Guo W, Liu X, Jia X, Xiong J, Wang L. The single-centre experience of the supra–arch chimney technique in endovascular repair of type B aortic dissections. *Eur J Vasc Endovasc Surg* 2013;**45**:633–8.

4 Lindblad B, Bin JA, Holst J, Malina M. Chimney grafts in aortic stent grafting: hazardous or useful technique? Systematic review of current data. *Eur J Vasc Endovasc Surg* 2015;**50**:722–31.

5 Bosiers MJ, Donas KP, Mangialardi N, Torsello G, Riambau V, Criado FJ, et al. European multicenter registry for the performance of the Chimney/Snorkel technique in the treatment of aortic arch pathologic conditions. *Ann Thorac Surg* 2016;**101**:2224–30.

6 Voskresensky I, Scali ST, Feezor RJ, Fatima J, Giles KA, Tricarico R, et al. Outcomes of thoracic endovascular aortic repair using aortic arch chimney stents in high–risk patients. *J Vasc Surg* 2017;**66**:9–20.

7 Benrashid E, Wang H, Keenan JE, Andersen ND, Meza JM, McCann RL, et al. Evolving practice pattern changes and outcomes in the era of hybrid aortic arch repair. *J Vasc Surg* 2016;**63**:323–31.

8 Tsilimparis N, Debus ES, von Kodolitsch Y, Wipper S, Rohlffs F, Detter C, et al. Branched versus fenestrated endografts for endovascular repair of aortic arch lesions. *J Vasc Surg* 2016;**64**:592–9.

9 Spanos K, Tsilimparis N, Rohlffs F, Wipper S, Detter C, Behrendt CA, et al. Total endovascular arch repair is the procedure of the future. Part I. *J Cardiovasc Surg (Torino)* 2018;**59**:559–71.

10 Cao P, De Rango P, Czerny M, Evangelista A, Fattori R, Nienaber C, et al. Systematic review of clinical outcomes in hybrid procedures for aortic arch dissections and other arch diseases. *J Thorac Cardiovasc Surg* 2012;**144**:1300–1.

11 Hiraoka A, Chikazawa G, Tamura K, Totsugawa T, Sakaguchi T, Yoshitaka H. Clinical outcomes of different approaches to aortic arch disease. *J Vasc Surg* 2015;**61**:88–95.

12 Hongku K, Dias N, Sonesson B, Resch T. Techniques for aortic arch endovascular repair. *J Cardiovasc Surg (Torino)* 2016;**57**:421–36.

13 Criado FJ, Barnatan MF, Rizk Y, Clark NS, Wang CF. Technical strategies to expand stent–graft applicability in the aortic arch and proximal descending thoracic aorta. *J Endovasc Ther* 2002;**9**:I32–8.

14 Wang T, Shu C, Li M, Li QM, Li X, Qiu J, et al. Thoracic endovascular aortic repair with Single/Double chimney technique for aortic arch pathologies. *J Endovasc Ther* 2017;**24**:383–93.

15 Zou J, Jiao Y, Zhang X, Jiang J, Yang H, Ma H. Early- and mid-term results of the chimney technique in the repair of aortic arch pathologies. *Cardiovasc Intervent Radiol* 2016;**39**:1550–6.

16 Li Y, Hu Z, Wang J, Zhang Y, Chen Z, Zhang H. Endovascular chimney technique for aortic arch pathologies treatment: a systematic review and meta−analysis. *Ann Vasc Surg* 2018;**47**:305−15.
17 Ahmad W, Mylonas S, Majd P, Brunkwall JS. A current systematic evaluation and meta−analysis of chimney graft technology in aortic arch diseases. *J Vasc Surg* 2017;**66**:1602−10.
18 Ni ZH, Luo JF, Huang WH, Liu Y, Xue L, Fan RX, et al. Totally percutaneous thoracic endovascular aortic repair with the preclosing technique: a case−control study. *Chin Med J (Engl)* 2011;**124**:851−5.
19 Chen J, Huang W, Luo S, Yang D, Xu Z, Luo J. Application of rapid artificial cardiac pacing in thoracic endovascular aortic repair in aged patients. *Clin Interv Aging* 2014;**9**:73−8.
20 Fillinger MF, Greenberg RK, McKinsey JF, Chaikof EL. Reporting standards for thoracic endovascular aortic repair (TEVAR). *J Vasc Surg* 2010;**52**:1015−33.
21 Greenberg RK, Clair D, Srivastava S, Bhandari G, Turc A, Hampton J, et al. Should patients with challenging anatomy be offered endovascular aneurysm repair? *J Vasc Surg* 2003;**38**:990−6.
22 Criado FJ. A percutaneous technique for preservation of arch branch patency during thoracic endovascular aortic repair (TEVAR): retrograde catheterization and stenting. *J Endovasc Ther* 2007;**14**:54−8.
23 Criado FJ. Chimney grafts and bare stents: aortic branch preservation revisited. *J Endovasc Ther* 2007;**14**:823−4.
24 Rizvi AZ, Murad MH, Fairman RM, Erwin PJ, Montori VM. The effect of left subclavian artery coverage on morbidity and mortality in patients undergoing endovascular thoracic aortic interventions: a systematic review and meta−analysis. *J Vasc Surg* 2009;**50**:1159−69.
25 Matsumura JS, Lee WA, Mitchell RS, Farber MA, Murad MH, Lumsden AB, et al. The society for vascular surgery practice guidelines: management of the left subclavian artery with thoracic endovascular aortic repair. *J Vasc Surg* 2009;**50**:1155−8.
26 Huang C, Tang H, Qiao T, Liu C, Zhou M. Early results of chimney technique for type b aortic dissections extending to the aortic arch. *Cardiovasc Intervent Radiol* 2016;**39**:28−35.
27 Mangialardi N, Serrao E, Kasemi H, Alberti V, Fazzini S, Ronchey S. Chimney technique for aortic arch pathologies: an 11-year single-center experience. *J Endovasc Ther* 2014;**21**:312−23.
28 Xue Y, Sun L, Zheng J, Huang X, Guo X, Li T, et al. The chimney technique for preserving the left subclavian artery in thoracic endovascular aortic repair. *Eur J Cardiothorac Surg* 2015;**47**:623−9.