Supra-aortic debranching as a preliminary surgery prior to aortic endografting in patients with type B aortic dissection: immediate-term and short-term outcomes

Mahmoud M. Nasser, Beshoy S. Nassif, Mohamed H. Eldessoki, Ayman Elsamadoni, Ahmed M. Balboula

Vascular Surgery Unit, Faculty of Medicine, Cairo University Hospitals, Cairo, Egypt

Correspondence to Mahmoud M Nasser, MSC, MD, MRCS, FEBVS, Department of Vascular and Endovascular Surgery, Faculty of Medicine, Cairo University, Al-Saray st., El Manial, Cairo 11956, Egypt. Tel: +2025729584; e-mail: mahmoud.nasser@kasralainy.edu.eg

Received: 27 January 2023
Revised: 27 February 2023
Accepted: 13 March 2023
Published: 9 June 2023

The Egyptian Journal of Surgery 2023, 42:192–199

Background
Hybrid techniques have been mainly planned for the management of complex aortic lesions to deal with the critical arch and renovisceral branches. The debranching of these aortic segments offers new landing zones suitable for endograft. The current work aims to investigate the immediate-term and short-term outcomes of supra-aortic debranching through hybrid repair in patients with type B aortic dissection.
Patients and methods
This is a retrospective study that included patients with type B aortic dissection, in whom an effective proximal seal zone necessitates coverage of one or more supra-aortic branch vessels. The patients underwent supra-aortic debranching through open surgery, after which endovascular repair was performed. Patients were followed up at 1 and 6 months.
Results
The study included 40 patients. Initial technical success was achieved for all patients. No cases of endoleaks were encountered. Two cases had postoperative strokes due to intracerebral hemorrhage. Overall, the mortality rate was 7.5%. Primary patency was maintained in 37/40 (92.5%) cases.
Conclusion
Hybrid repair was shown to be feasible for the management of patients with Stanford B dissection who required supra-aortic debranching, and could alternate with conventional aortic arch surgery. Stroke is still an issue of concern that should elicit more efforts to prevent it.

Keywords:
Stanford B aortic dissection, supra-aortic debranching, thoracic endovascular aortic repair

Egyptian J Surgery 42:192–199

1110-1121

Introduction

Acute aortic dissection (AD) is the progressive separation of the aorta's layers by a blood column as a result of aortic medial deterioration, which is a fatal cardiovascular emergency [1].

For an accurate diagnosis and appropriate treatment decision, anatomical classification methods of AD were adopted, in which AD was classified according to the intimal tear location (DeBakey classification) [2] or the ascending aorta involvement (Stanford) [3]. In the type I DeBakey classification, the intimal tear begins in the ascending aorta, and the dissection continues to the aortic arch and descending aorta. In type II, the dissection is confined to the ascending aorta, while in type III, the tear begins in the descending aorta and continues distally [2]. In Stanford classification, AD is categorized as type A (any dissection involves the ascending aorta) or type B (descending aorta only-involving dissections) [3]. The Stanford classification is particularly important in the triage setting, where cases are categorized according to the need for emergent intervention [4].

More than one-quarter of ADs (25–40%) are type B dissections [5]. Aortic rupture is the primary cause of death in individuals with type B dissection, followed by malperfusion [6]. When such complications occur, thoracic endovascular aortic repair (TEVAR) is regarded as a life-saving option [7–10]. However, there are some TEVAR-related pitfalls, such as the anatomical variations of the proximal aorta, the distribution of axial stress and radial force across the true lumen, distal landing zones, endograft positioning, and the true lumen straightening proximal to the abdominal aorta. The hybrid techniques overcome

 DOI: 10.4103/ejs.ejs_41_23

these shortcomings of TEVAR for Stanford B ADs [11].

The hybrid technique has been mainly planned for the management of complex aortic lesions, including aneurysmal dilatation and dissections to deal with the critical arch and renovisceral branches. The debranching of these aortic segments offers new landing zones suitable for endograft [12].

Over time, supra-aortic debranching techniques have been established. This includes carotid–carotid bypass, left common carotid artery (LCCA) to left subclavian artery (LSA) bypass or total arch debranching [12].

The current work aimed to investigate immediate and short-term outcomes of supra-aortic debranching through open techniques followed by aortic endograft in patients with Stanford B AD, in whom effective proximal seal zone necessitates covering of one or more of supra-aortic branch vessels.

Patients and methods

This is a retrospective analysis of prospectively collected data of patients with type B dissection who were treated with TEVAR at the Vascular Surgery Department at Cairo University hospitals and Nasser Institute from January 2019 through July 2022. The study was approved by the research ethics committee and conducted per the Declaration of Helsinki.

Patients who indicated extension of the proximal endograft attachment into the aortic zones 0–2 were eligible for the study. Patients with incomplete follow-up data were excluded. Informed written consent was obtained from each included patient.

All patients underwent preprocedural aortic computed tomography angiography (CTA). Based on these studies, stents with appropriate diameters and lengths were selected. Devices were oversized by 0–10% larger than the aortic neck diameter to allow adequate radial force for sufficient fixation.

Prior to deploying the selected stent-grafts, debranching procedures were performed. This was performed in the same setting as the endovascular repair procedure, or 2 days before, according to the acuity of the clinical presentation.

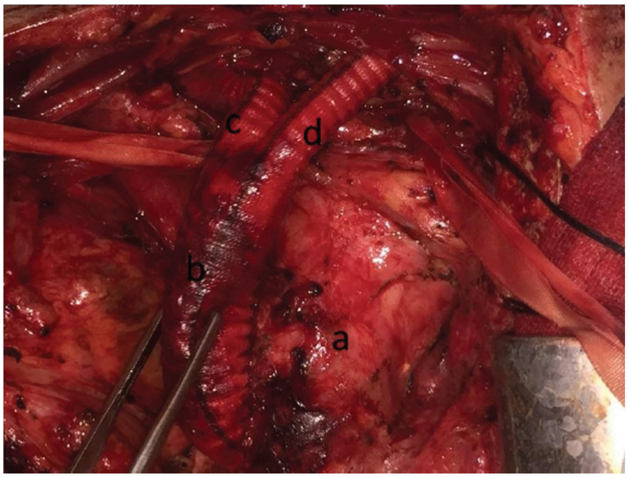
All procedures were performed under general anesthesia. Drainage of the cerebrospinal fluid (CSF) was performed prior to TEVAR procedure.

Surgical approach

When coverage of the aortic arch in zone 2 was deemed necessary, a carotid–subclavian bypass was performed. The subclavian artery stump was occluded through ligation whenever feasible, proximal to the origin of the vertebral artery or embolized with coils after TEVAR procedure.

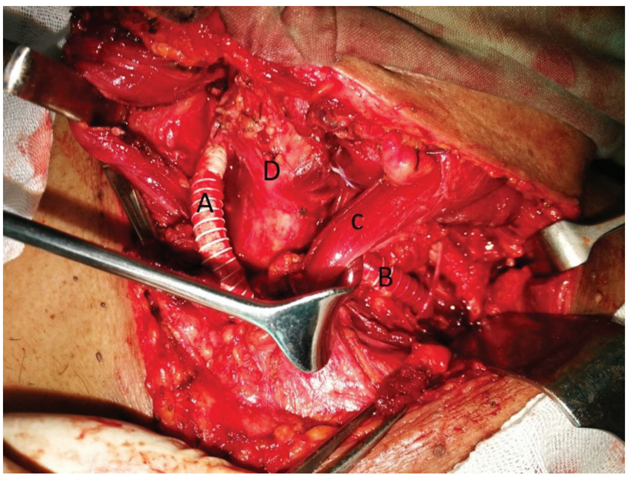
If coverage in zone 1 was indicated, a carotid–carotid bypass was performed using a retropharyngeal tunnel or pretracheal tunnel, according to surgeon preference, in association with LSA revascularization by left carotid-to-subclavian bypass.

Figure 1



Median sternotomy showing: (a) ascending aorta, (b) aortic graft anastomosis with Dacron bifurcated graft, (c) right graft limb with anastomosis to brachio-cephalic artery, (d) left graft limb (complete arch debranching).

Figure 2



(a) Carotid–carotid bypass (using PTFE graft), (b) carotid–subclavian bypass, (C) left sternomastoid muscle, and (D) trachea.

In zone 0 coverage, all supra-aortic vessels were revascularized by using total debranching through a median sternotomy (Fig. 1).

Carotid–subclavian bypass

Both the neck and the sternal areas were prepped for the field. A short transverse supraclavicular cervical incision was performed. After raising subplatysmal flaps, the surgical dissection was carried out lateral to the sternomastoid muscle (Figs 2–5).

Figure 3

Arch angiogram showing patent carotid–carotid and carotid–subclavian bypass with deployed TEVAR stent. TEVAR, thoracic endovascular aortic repair.

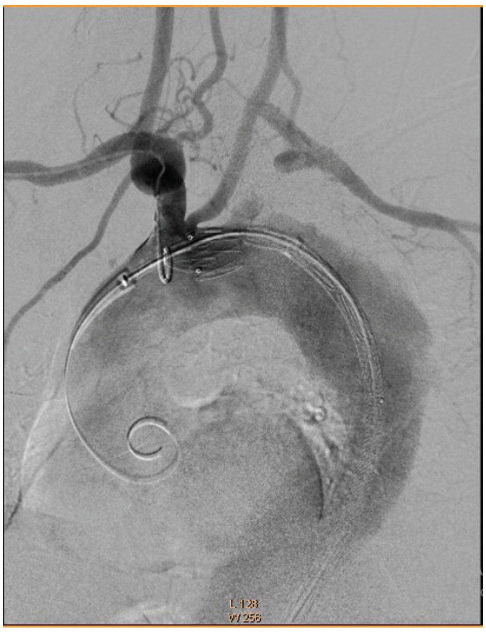
The jugular vein was redirected medially to uncover the CCA. The vagus nerve was encountered and protected. The scalene pad of fat was divided with clamps and ligatures to prevent lymphatic leakage. The anterior scalene muscle was divided to identify the subclavian artery. Systemic heparinization followed. Clamping of the LCCA proximal and distal followed. Lateral arteriotomy in the LCCA was performed, followed by end-to-side anastomosis with an 8-mm polytetrafluoroethylene (PTFE)-ringed graft to the LSA with 5/0 prolene sutures.

Declamping of the LCCA followed, and a clamp was applied to the graft just after the anastomosis. The LSA was clamped in the same order, anastomosis was done, and flushing of the graft was done prior to declamping. Proper hemostasis was ensured, and closure of the platysma by continuous vicryl 3/0 and of the skin by monocryl 3/0 was performed. Drains were inserted.

Carotid–carotid bypass

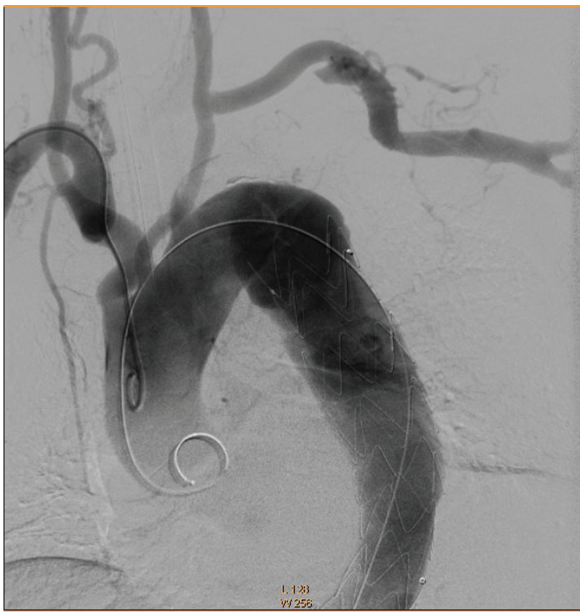
A collar neck incision (or bilateral transverse supraclavicular incision) was done to expose the proximal common carotid bilaterally. The midline was crossed using a retropharyngeal path. The space for the tunnel was created by passing a finger medial to

Figure 4



Arch angiogram showing patent carotid–subclavian bypass prior to TEVAR deployment. TEVAR, thoracic endovascular aortic repair.

Figure 5



Arch angiogram showing patent carotid–subclavian bypass with deployed TEVAR stent. TEVAR, thoracic endovascular aortic repair.

the common carotid artery and behind the esophagus (retroesophageal) or pretracheal (Figs 2 and 3).

Total debranching

In supine position, arms by the side, with a roll or bump placed vertically between the scapulae and the head extended and supported, the head was prepared to be rotated in either direction. The operative field included the neck, chest, and upper abdomen. Standard methods for skin preparation and draping were used.

A midline incision and complete or partial sternotomy were performed. A hockey stick extension of this incision a short distance along the anterior border of the right sternomastoid muscle allows for exposure of the innominate artery bifurcation. The sternal attachments of the sternomastoid muscle were divided and retracted laterally to improve exposure.

Division of the thymus gland and pericardial fat was performed. The left innominate vein was identified anterior to the arch and origins of the great vessels and was mobilized with ligation and division of the tributaries to the vein.

Dissection past the bifurcation to the right subclavian artery and CCA in order to facilitate distal clamp placement was performed. The vagus nerve within the carotid sheath and the recurrent laryngeal nerve was identified as it sweeps inferior to the subclavian artery and preserved.

A partial occluding clamp was placed on the ascending aorta in the most lateral position possible. A vertical aortotomy was made. The proximal end of a bifurcated graft was spatulated appropriately to fit the aortotomy and 3-0 polypropylene was used to fashion the anastomosis as a running suture.

Once complete, the graft was clamped more distally and the aortic clamp was gently released to verify hemostasis. At this point, the patient was heparinized systemically, clamps were placed on the right subclavian and CCAs, and proximal innominate. The innominate artery was divided distally and spatulated to accept the graft.

The distal anastomosis was completed end-to-end with a branched graft to the innominate artery and to the LCCA as well, and both antegrade and retrograde flushing was performed before completion of the anastomosis.

Protamine was given for the reversal of the effects of systemic heparin. Chest and mediastinal drains were placed. Wire re-approximation of the sternum was performed, and the subcutaneous tissue and skin were closed in layers in the standard fashion.

Endovascular repair

E-Vita thoracic 3G stent graft Jotec Evita (Jotec, Hechingen, Germany) or the Zenith TX2 Dissection Endovascular Graft (ZDEG, Cook Medical, Bjaeverskov, Denmark) were used. The endovascular access was via the common femoral artery. A 0.035-inch guide wire (Terumo Medical Corporation, Tokyo, Japan) was introduced under fluoroscopic guidance to the ascending aorta, over which a 5-F calibrated pigtail catheter proceeded into the ascending aorta. After the advancement of the catheter, the guide wire was exchanged for another stiffer one (Lunderquist; Cook Medical, West Lafayette, Indiana, USA). The deployment of the stent graft was performed under fluoroscopic guidance.

Controlled hypotension was used in landing zones 1 and 2 for precise deployment. Transesophageal echocardiography and intravascular ultrasound was implemented in complicated dissections.

An angiogram study was performed before and after deploying the graft to ensure the appropriate placement of the stent graft and the absence of the lesion.

A completion angiogram was performed to evaluate for endoleaks. Postoperatively, care for the surgical site was ensured with daily dressings until the removal of stitches 2 weeks later. Patients' follow-up visits were planned at 1 and 6 months after the procedure.

Sample size calculation

The power of the study was estimated using an online software for sample size calculation supported by the National Center for Advancing Translational Sciences, National Institutes of Health, through UCSF-CTSI Grant Numbers UL1 TR000004 and UL1 TR001872 [Kohn MA, Senyak J. Sample Size Calculators (website)]. UCSF-CTSI. December 20, 2021. Available at https://www.sample-size.net/. With a 95% confidence level, and a margin of error of 0.05, and based on the previous study of Bünger *et al.* [13] that assessed the outcome of patients who underwent hybrid repair for type B AD and found success rate of 86.7%, sample size calculation necessitated inclusion of 40 patients.

Study outcomes

The outcome criteria were defined according to the standards for TEVAR as reported by Fillinger *et al.* [14]. The study outcomes were the procedure's technical success and operation-related mortality and morbidity.

Statistical analysis

The patients' data was analyzed using version SPSS statistical software (IBM Corp., Armonk, New York, USA), version 26. Numerical values were presented as a range, mean, and SD. Categorical values were presented as counts and percentages. Regression analysis was performed to assess potential predictors of patients' mortality. A *P* value less than 0.05 was considered statistically significant.

Results

This study included 40 patients who indicated TEVAR with planned coverage of one or more arch vessels. The age of the study patients ranged from 38 to 74 years, with a mean of 58.11±12.46. The majority were males (34 patients, 85%). Twenty-eight (70%) patients had hypertension, 23 (57.5%) patients had dyslipidemia, and 16 (40%) patients had ischemic heart disease. Twenty-three (57.5%) patients were smokers (Table 1).

The indications for intervention were the occurrence of the aneurysm on top of dissection (22 patients, 55%), persistent chest pain (eight patients, 20%), and a false lumen diameter of more than 22 mm (10 patients, 25%).

Postprocedural CTA revealed luminal thrombosis in 18 (45%) patients. The descending aorta diameter ranged from 4.7 to 9.6 cm, with a mean of 6.14±1.58.

Spinal drainage was used in all patients, with a mean CSF pressure of 10.3 mmHg.

Table 1 Sociodemographic data of the study patients

	Study patients (*N*=40) Mean±SD (minimum–maximum)
Age (years)	58.11±12.46 (38–74)
	n (%)
Sex	
Female	6 (15)
Male	34 (85)
Comorbidities	
Dyslipidemia	23 (57.5)
Hypertension	28 (70)
Ischemic heart disease	16 (40)
Smoking	23 (57.5)

Concerning the type of conduit, this was 8 mm ringed PTFE in 34 (85%) cases and bifurcated dacron graft in six (15%) cases. The used stents were the E-Vita thoracic 3G stent graft (Jotec) in seven (17.5%) patients and the Zenith TX2 in 33 (82.5%) patients.

Endografts were deployed into zone 0 in six (15%) patients, zone 1 in 10 (25%) patients, and zone 2 in the remaining 24 (60%) patients. The distal landing zone was above the celiac trunk in six (15%) patients and at the distal thoracic aorta in 34 (85%) patients. The mean length of the covered area was 23.22±4.60 cm.

Ten (25%) patients required right-to-left common carotid artery surgical bypass combined with LCCA to left LSA bypass, 24 (60%) patients required isolated LCAA to LSA bypass, and six (15%) patients required total arch debranching (three bypasses).

Cauda balloon dilatation was indicated in eight (20%) patients, and intraoperative blood transfusion was required in 12 (30%) patients.

Initial technical success was obtained in all patients. There were no cases of endoleaks.

Two cases had postoperative strokes due to intracerebral hemorrhage. One of them developed a disturbance of consciousness on the fourth postoperative day. Brain CT showed temporoparietal hemorrhage. Glasgow's coma scale rapidly dropped to 3, and the patient was not a candidate for evacuation or shunting. The patient died on the ninth postoperative day. The second case developed thrombosis of the carotid–subclavian graft, heparin was administered, and the patient developed thrombocytopenia (a drop in the platelet count from 250 000 to 120 000), which was diagnosed as heparin-induced thrombocytopenia. Therapeutic anticoagulation was shifted into Hirudin (thrombex). Two days later, the patient developed a stroke. Brain CT showed intraventricular hemorrhage. The patient died on the fifth postoperative day.

A third mortality case occurred on day 5 due to acute myocardial infarction. Overall, the mortality rate was 7.5%. No variable was found to be significantly predicting mortality in the study cases ($P>0.05$).

The follow-up period ranged from 6 to 25 months, with a median of 9 months. Primary patency was maintained in 37/40 cases (92.5%). All the patients who survived the early postoperative period had false lumen thrombosis and true lumen expansion; as evidenced in follow-up CT scans, and there was no

Table 2 Clinical and surgical data of the study patients

	Study patients (*N*=20) Mean±SD
Descending aorta diameter (cm)	6.14±1.58
Length of covered area (cm)	23.22±4.60
	n (%)
Indication of intervention	
Aneurysm on top of dissection	22 (55)
Persistent chest pain	8 (20)
False lumen diameter of >22 mm	10 (25)
Postprocedural CTA revealed false luminal thrombosis	18 (45)
Type of conduit	
Ringed PTFE	34 (85)
Bifurcated dacron graft	6 (15)
Used stents	
E-Vita thoracic 3G stent	7 (17.5)
Zenith TX2	33 (82.5)
Proximal landing zone	
0	6 (15)
1	10 (25)
2	24 (60)
Distal landing zone	
Above celiac trunk	6 (15)
Distal thoracic aorta	34 (85)
Debranching bypasses	
Right-to-left common carotid artery+left CCA – left LSA bypass	10 (25)
Left common carotid-to-subclavian artery bypass	24 (60)
Total arch debranching	6 (15)
Cauda balloon dilatation	8 (20)
Intraoperative blood transfusion	12 (30)
Initial technical success	40 (100)
Stroke	2 (5)
Mortality	3 (7.5)
Primary patency	37 (92.5)

CCA, common carotid artery; CTA, computed tomography angiography.

need for re-intervention. There were neither cases of spinal cord ischemia nor local nerve injuries (Table 2).

Discussion

Recently, there has been evidence of the superiority of TEVAR over medical treatment for the management of Stanford B ADs [11].

Although TEVAR has been the primary managing procedure for complicated Stanford B dissections, hybrid repair may be essential in some situations. It is ideal to have at least 2 cm of the normal aorta proximal to the entry tear for the proximal seal zone in order to prevent retrograde dissection into the ascending aorta. In certain cases, this 2 cm landing zone is not feasible unless one or more of the aortic arch branches are partially or totally covered [15]. Thus, a hybrid repair would be a suitable choice.

This study presents our experience in the hybrid treatment of patients with Stanford B ADs whose cases necessitate coverage of one or more supra-aortic branch vessels to obtain effective proximal seal zones.

Prior to deploying the selected stent-grafts, debranching procedures were performed. This was performed as a single approach or staged procedure according to the acuity of the clinical presentation. A staged approach provides a number of advantages, including a shorter interventional time and a reduced incidence of hypothermia, blood loss, and postprocedure paraplegia. Instead, the one-approach procedure allows for monitoring the status of supra-aortic and/or renovisceral revascularization and reducing the risk of rupture while waiting for TEVAR [16].

In the present study, supra-aortic debranching was necessary to provide effective graft sealing. It has been well-established that when coverage of other aortic arch branches deems necessary, this should be preceded by revascularization. There is still a great deal of discussion and disagreement over the management of patients whose LSA is covered. The increased risk of upper limb ischemia, stroke, and spinal cord ischemia was linked to LSA coverage without revascularization by supporters of routine revascularization [17]. On the contrary, according to proponents of selective revascularization, LSA coverage may not necessarily confer an increased risk of the previously described side outcomes in all patients [18,19]. In the present study, we adopted routine vascularization for cases, with no encountered cases of upper limb ischemia.

Routine spinal drainage prior to TEVAR was performed in all patients to preclude spinal cord ischemia. Indeed, no cases had spinal cord ischemia in this work. In accordance with our study, CSF drainage has been shown to be efficient in preventing spinal cord ischemia in previous studies [20–22]. It is worth noting that in the study conducted by Xiang *et al.* [23] who did not perform a preoperative CSF drainage, nearly 5% of the included patients had postoperative neurological deficits referable to spinal cord ischemia that resolved after CSF drainage and systemic blood pressure elevation.

The advancement of endovascular devices is a mainstay to provide promising outcomes in long-term follow-up. In this study, Zenith TX2 or E-Vita thoracic 3G stent graft (Jotec) were used. It has been found that the stent graft proximal barbs make the patient more likely to develop retrograde type A aortic dissection (RTAD). Other factors implicated in the risk for RTAD are ballooning of the proximal landing zone, excessive oversizing of the proximal stent, and the presence of a proximal bare stent [24,25]. The Zenith TX2 Dissection Endovascular Graft addresses these tones, integrating a number of the tapered prosthesis without proximal barbs or bare stent, and hence reduces the RTAD risk. The E-Vita stent offers single-approach repair, with efficient false lumen thrombosis to the distal end of the stent [26].

The stroke rate reported in this study (5%) is in the range reported in previous studies (0–11%) [27–31]. However, comparing the rates of stroke is not reliable since some authors reported major strokes and others incorporated minor strokes. To minimize the incidence of stroke as far as possible, special strategies were followed in the present work including a detailed preoperative CTA examination, ultrasound guidance for percutaneous access, and when total debranching was indicated, clamps were placed on the right subclavian and common carotid arteries, and proximal innominate. This sequence of clamp placement was intended to prevent distal embolization.Our immediate technical success rate was comparable with the study of Harmon *et al.* [11] who achieved immediate success in 100% of the patients. Our reported high rate is likely attributable to the precise attention to characteristics of the dissection and the steps of the procedure.

The 30-day mortality of 7.5% that was shown in this study is lower than the rates reported by Dueppers *et al.* [32] (9%) and Bosiers *et al.* [27] (9.5%), and higher than the rate reported by two meta-analysis studies conducted by Lindblad *et al.* [29] and Li *et al.* [31] (4%).

This study is limited by the short period of follow-up, the retrospective design, and being a single-center experience.

Conclusion

The hybrid repair was shown to be feasible for the management of patients with Stanford B dissection who required supra-aortic debranching and could alternate with conventional aortic arch surgery. Stroke is still an issue of concern that should elicit more efforts to prevent it.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 LeMaire SA, Russell L. Epidemiology of thoracic aortic dissection. Nat Rev Cardiol 2011; 8:103–113.

2 Debakey ME, Henly WS, Cooley DA, Morris GC, Crawford ES, Beall AC. Surgical management of dissecting aneurysms of the aorta. J Thorac Cardiovasc Surg 1965; 49:130–149.

3 Daily PO, Trueblood HW, Stinson EB, Wuerflein RD, Shumway NE. Management of acute aortic dissections. Ann Thorac Surg 1970; 10:237–247.

4 Philip JL, De Oliveira NC, Akhter SA, Rademacher BL, Goodavish CB, DiMusto PD, Tang PC. Cluster analysis of acute ascending aortic dissection provides novel insight into mechanisms of distal progression. J Thorac Dis 2017; 9:2966–2973.

5 Hughes GC. Management of acute type B aortic dissection; ADSORB trial. J Thorac Cardiovasc Surg 2015; 149:S158–S162.

6 Ziganshin BA, Dumfarth J, Elefteriades JA. Natural history of type B aortic dissection: ten tips. Ann Cardiothorac Surg 2014; 3:247–254.

7 Dake MD, Kato N, Mitchell RS, Semba CP, Razavi MK, Shimono T, *et al.* Endovascular stent-graft placement for the treatment of acute aortic dissection. N Engl J Med 1999; 340:1546–1552.

8 Nienaber CA, Kische S, Ince H, Fattori R. TEVAR in complicated type B aortic dissection. J Vasc Surg 2011; 340:1529–1533.

9 Svensson LG, Kouchoukos NT, Miller DC, Bavaria JE, Coselli JS, Curi MA, *et al.* Society of Thoracic Surgeons Endovascular Surgery Task Force. Expert consensus document on the treatment of descending thoracic aortic

disease using endovascular stent-grafts. Ann Thorac Surg 2008; 85(1 suppl):S1–S41.

10 Fattori R, Tsai TT, Myrmel T, Evangelista A, Cooper JV, Trimarchi S, *et al.* Complicated acute type B dissection: is surgery still the best option?: a report from the International Registry of Acute Aortic Dissection. JACC Cardiovasc Interv 2008; 1:395–402.

11 Harmon TS, Ghannam A, Meyer TE, Concepcion C, Pirris J, Matteo J. Covered or not, here i come: Stanford type B aortic dissection repair with a covered and uncovered stent hybrid technique. Cureus 2020; 12: e11729.

12 Alonso Pérez M, Llaneza Coto JM, Del Castro Madrazo JA, Fernández Prendes C, González Gay M, Zanabili Al-Sibbai A. Debranching aortic surgery. J Thorac Dis 2017; 9(Suppl 6):S465–S477.

13 Bünger CM, Kische S, Liebold A, Leißner M, Glass A, Schareck W, *et al.* Hybrid aortic arch repair for complicated type B aortic dissection. J Vasc Surg 2013; 58:1490–1496.

14 Fillinger MF, Greenberg RK, McKinsey JF, Chaikof EL. Society for vascular surgery ad hoc committee on TEVAR reporting standards.Reporting standards for thoracic endovascular aortic repair (TEVAR). J Vasc Surg 2010; 52:1022–1033.

15 Wang GJ, Fairman RM. Endovascular repair of the thoracic aorta. Semin Intervent Radiol 2009; 26:17–24.

16 Sood V, Patel HJ, Williams DM, Dasika NL, Yang B, Deeb GM. Open and endovascular repair of the nontraumatic isolated aortic arch aneurysm. J Vasc Surg 2014; 60:57–63.

17 Riambau V, Capoccia L, Mestres G, Matute P. Spinal cord protection and related complications in endovascular management of B dissection: LSA revascularization and CSF drainage. Ann Cardiothorac Surg 2014; 3:336–338.

18 Hu J, Li F, Qiu P, Wu X, Pu H, Zhao Z, *et al.* Clinical validation of the impact of branch stent extension on hemodynamics in ISF-TEVAR involving LSA reconstruction. Front Cardiovasc Med 2022; 9:911934.

19 Youssef A, Ghazy T, Kersting S, Leip JL, Hoffmann RT, Kappert U, *et al.* Management of the left subclavian artery during TEVAR – complications and mid-term follow-up. Vasa 2018; 47:387–392.

20 Ferrero E, Ferri M, Viazzo A, Robaldo A, Zingarelli E, Sansone F, *et al.* Is total debranching a safe procedure for extensive aortic-arch disease? A single experience of 27 cases. Eur J Cardiothorac Surg 2012; 41:177–182.

21 van der Weijde E, Saouti N, Vos JA, Tromp SC, Heijmen RH. Surgical left subclavian artery revascularization for thoracic aortic stent grafting: a single-centre experience in 101 patients. Interact Cardiovasc Thorac Surg 2018; 27:284–289.

22 De Rango P, Cao P, Ferrer C, Simonte G, Coscarella C, Cieri E, *et al.* Aortic arch debranching and thoracic endovascular repair. J Vasc Surg 2014; 59:107–114.

23 Xiang Y, Huang B, Zhao J, Hu H, Yuan D, Yang Y. The strategies and outcomes of left subclavian artery revascularization during thoracic endovascular repair for type B aortic dissection. Sci Rep 2018; 8:9289.

24 Chen Y, Zhang S, Liu L, Lu Q, Zhang T, Jing Z. Retrograde type A aortic dissection after thoracic endovascular aortic repair: a systematic review and meta-analysis. J Am Heart Assoc 2017; 6:e004649.

25 Neuhauser B, Greiner A, Jaschke W, Chemelli A, Fraedrich G. Serious complications following endovascular thoracic aortic stent-graft repair for type B dissection. Eur J Cardiothorac Surg 2008; 33:58–63.

26 Varzaly J, Chaudhuri K, Crouch G, Edwards J. E-VITA Jotec open hybrid stent graft system for the treatment of complex thoracic aortic aneurysm and dissection – a four year experience. Heart Lung Circ 2014; 23: e77–e79.

27 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; 101:2224–2230.

28 Ahmad W, Liakopoulos OJ, Mylonas S, Wegner M, Brunkwall J, Dorweiler B. Long-term outcomes after thoracic endovascular aortic repair using chimney grafts for aortic arch pathologies: 10 years of single-center experience. Ann Vasc Surg 2021; 72:400–408.

29 Lindblad B, Bin Jabr A, 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; 50:722–731.

30 Zhang L, Wu MT, Zhu GL, Feng JX, Song C, Li HY, *et al.* Off-the-shelf devices for treatment of thoracic aortic diseases: midterm follow-up of TEVAR with chimneys or physician-made fenestrations. J Endovasc Ther 2020; 27:132–142.

31 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; 47:305–315.

32 Dueppers P, Reutersberg B, Rancic Z, Messmer F, Menges AL, Meuli L, *et al.* Long-term results of total endovascular repair of arch-involving aortic pathologies using parallel grafts for supra-aortic debranching. J Vasc Surg 2022; 75:813–823.