

One-stage supraclavicular hybrid procedure for type B aortic dissection involving three rare anatomical anomalies: a case report and literature review

Journal of International Medical Research

49(6) 1–10

© The Author(s) 2021

Article reuse guidelines:

sagepub.com/journals-permissions

DOI: 10.1177/03000605211020241

journals.sagepub.com/home/imr

Junhang Chen* , Xiangchen Dai ,
Jiechang Zhu, Fanguo Hu, Peng Li* ,
Yudong Luo, Hailun Fan, Zhou Feng and
Yiwei Zhang

Abstract

Managing type B aortic dissection (TBAD) involving Kommerell's diverticulum (KD), aberrant right subclavian artery (ARSA), and isolated left vertebral artery (ILVA), is extremely challenging. As treatment, we described a one-stage hybrid technique combined with thoracic endovascular aortic repair (TEVAR) with open surgery through a supraclavicular incision. A 57-year-old man with TBAD and the three anomalies successfully underwent hybrid TEVAR. A side-to-side artificial bypass between the ARSA and the right common carotid artery was established through a right supraclavicular incision before TEVAR. The release of the stent-graft was designed from the distal aortic ostium to the left common carotid artery (LCCA) to cover the ILVA, ARSA, and left subclavian artery (LSA). Then, the ILVA and LSA were transposed to the LCCA through a left supraclavicular incision. Intraoperative angiography confirmed complete false lumen exclusion and KD, with all branches patent and without endoleaks. Computed tomography angiography 7 days and 1 year postoperatively demonstrated well-perfused ARSA, LSA, and ILVA, and a fully expanded stent-graft with no endoleaks, migration, disconnection, or stenosis. TBAD involving KD, ARSA, and ILVA in one case is rare. This is the first report to treat this pathology with a one-stage supraclavicular hybrid procedure.

*These authors contributed equally to this work.

Corresponding author:

Xiangchen Dai, Tianjin Medical University General Hospital, No. 154 Anshan Rd., Heping District, Tianjin, 300052 China.

Email: 13302165917@163.com

Tianjin Medical University General Hospital, Tianjin, China



Creative Commons Non Commercial CC BY-NC: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 License (<https://creativecommons.org/licenses/by-nc/4.0/>) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (<https://us.sagepub.com/en-us/nam/open-access-at-sage>).

Keywords

Aberrant right subclavian artery, isolated left vertebral artery, Kommerell's diverticulum, type B aortic dissection, hybrid surgery, thoracic endovascular aortic repair, supraclavicular transposition

Date received: 25 January 2021; accepted: 4 May 2021

Introduction

Aberrant right subclavian artery (ARSA), Kommerell's diverticulum (KD), and isolated left vertebral artery (ILVA) are three aortic arch anomalies that seldom exist together. Moreover, people with these aortic arch anomalies are usually susceptible to aortic dissection that could benefit from surgery under certain conditions. The reported incidences of ARSA and ILVA are 0.6% and 3.4% in the general population, and 1.8% and 6.3% in patients with thoracic aortic disease, respectively.¹ KD has also been found in 60% of patients with ARSA.² The high morbidity and mortality rates with open surgery with total aortic arch replacement limit the scope of this approach. Conventional thoracic endovascular aortic repair (TEVAR) is also a challenging approach because the proximal landing zone may be insufficient for the endograft owing to involvement of the ostia of the left subclavian artery (LSA) and ILVA because of dissection. This report demonstrates a hybrid approach involving TEVAR, double supraclavicular transposition, and single bypass to treat type B aortic dissection (TBAD) involving the three anomalies.

Case report

A 57-year-old male patient with a long history of hypertension was admitted to our hospital with acute chest and back pain for 12 hours. Computed tomography

angiography (CTA) demonstrated TBAD combined with ILVA, ARSA, and KD, and that the ILVA was dominant (Figure 1a–d). The maximum KD diameter was 32.8 mm (Figure 1c), and the entry tear was located around KD and ARSA (Figure 1e). The distances between the ostia of the LSA and ILVA and the entry tear were 3.0 mm and 13.0 mm, respectively (Figure 1f and 1g). If traditional TEVAR were performed to treat the TBAD, the ARSA, ILVA, and LSA would have to have been covered to achieve an adequate landing distance, and, to ensure cerebral perfusion, the ILVA, LSA, and ARSA would have to have been revascularized. Because the fenestrated TEVAR (fTEVAR) and chimney TEVAR (chTEVAR) techniques are complicated, expensive, and prone to complications, a hybrid TEVAR with concomitant double supraclavicular transposition of the LSA and ILVA to the LCCA as well as single artificial bypass of the ARSA to the RCCA was performed through bilateral supraclavicular incisions.

The patient underwent standard drug therapy after admission, which lasted for 1 month. Symptoms of chest and back pain persisted. The hybrid procedure was then performed under general anesthesia in a hybrid operating room. The right common femoral artery was punctured, and a gold-marked pigtail catheter (Cook Medical Inc., Bloomington, IN, USA) was inserted into the ascending aorta to perform

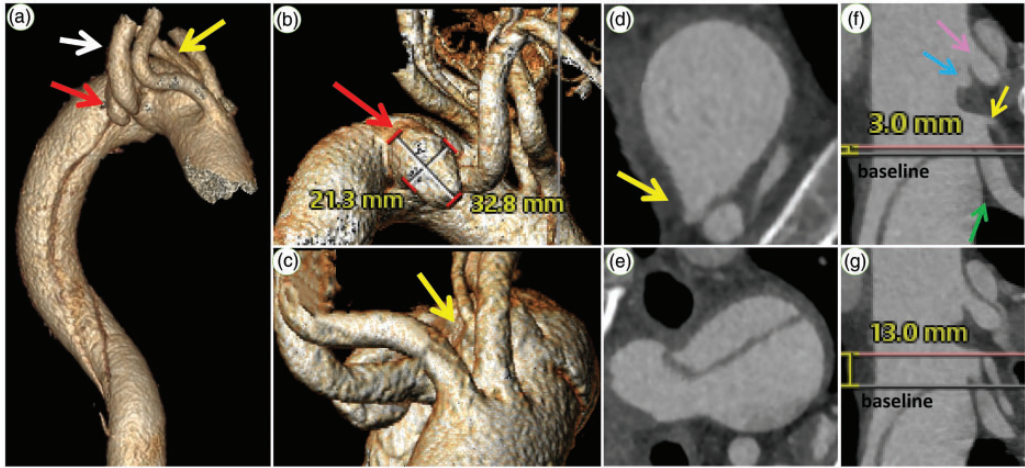


Figure 1. CTA findings confirming type B aortic dissection involving three rare anatomical anomalies. (a) 3D image showing type B aortic dissection involving anatomical anomalies, namely KD (red arrow), ARSA (white arrow), and ILVA (yellow arrow). (b) 3D image showing the ARSA and KD (red arrow), with a maximum KD diameter of 21.3×32.8 mm. (c) 3D image showing the ILVA (yellow arrow). (d) 2D image showing the ILVA directly arising from the aortic arch (yellow arrow). (e) The KD and ARSA were involved owing to dissection. (f) The distance between the entry tear and the LSA ostium (green arrow) on 2D imaging is 3.0 mm. This image shows the four supra-arch branches: RCCA (pink arrow), LCCA (blue arrow), ILVA (yellow arrow), and LSA (green arrow). (g) The distance between the entry tear and the ILVA ostium on 2D imaging is 13.0 mm

CTA, computed tomography angiography; 3D, three-dimensional; KD, Kommerell's diverticulum; ARSA, aberrant right subclavian artery; ILVA, isolated left vertebral artery; 2D, two-dimensional; LSA, left subclavian artery; RCCA, right common carotid artery; LCCA, left common carotid artery.

angiography, which confirmed the CTA results (Figure 2). Two transverse incisions were made in bilateral supraclavicular fossae. The clavicular end points of the sternocleidomastoid muscle and anterior scalene muscle were transected to expose the LCCA, LSA, ILVA, RCCA, and ARSA (Figure 2). A side-to-side bypass between the ARSA and RCCA was established using an 8- to 40-mm artificial vessel (W. L. Gore & Associates, Inc., Flagstaff, AZ, USA) (Figure 2). The proximal ARSA was not transected during the bypass procedure. Next, a 0.035-inch Lunderquist guidewire (Cook Medical Inc.) was advanced into the ascending aorta via right common femoral artery access. A $38 \times 32 \times 180$ -mm thoracic aortic stent-graft (DiNova Medtech, Hangzhou, China) was

introduced into the aortic arch through the Lunderquist guidewire and then deployed to cover the entry tear as well as the ostia of the LSA, ILVA, and ARSA. A $40 \times 34 \times 180$ -mm bare stent (DiNova Medtech) and a $34 \times 34 \times 120$ -mm bare stent (DiNova Medtech) were sequentially deployed in the distal descending aorta. Angiography showed that the first entry tear, LSA, and ILVA resolved, and the true lumen was fully expanded. Both the proximal ILVA and LSA were transected and ligated, and the distal arteries were anastomosed to the LCCA end-to-side (Figure 2). Completion angiography demonstrated that the artificial bypass and all of the supra-arch branches were patent (Figure 2). The procedure required 6.5 hours, including 7 minutes of X-ray

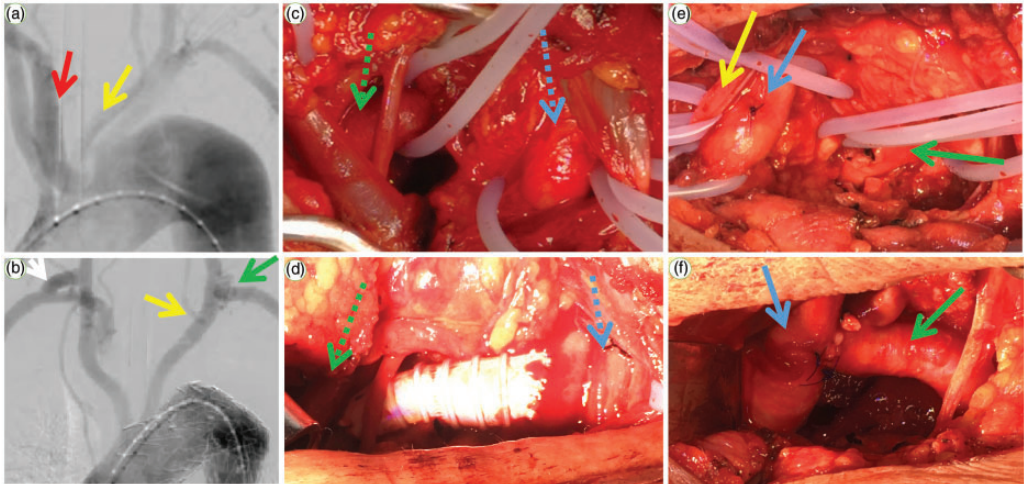


Figure 2. Intraoperative images. (a) Angiography before constructing the artificial bypass showing the ARSA (red arrow) and ILVA (yellow arrow) directly originating from the aortic arch. (b) Completion angiogram demonstrating that the artificial bypass (white arrow), ILVA-LCCA transposition (yellow arrow), and LSA-LCCA transposition (green arrow) were patent, with the initial part of the ARSA not developed. (c) Intraoperative photograph of the ARSA (green dotted arrow) and RCCA (blue dotted arrow). (d) The side-to-side artificial bypass established between the distal RSA (dotted green arrow) and RCCA (dotted blue arrow). (e) Intraoperative photograph of the ILVA (yellow arrow), LCCA (blue arrow), and LSA (green arrow). (f) End-to-side transposition of the LSA (green arrow) to the LCCA (blue arrow). ARSA, aberrant right subclavian artery; ILVA, isolated left vertebral artery; LCCA, left common carotid artery; LSA, left subclavian artery; RSA, right subclavian artery; RCCA, right common carotid artery.

exposure time. The total fluoroscopy dose was 56 K mGy, and the iodine contrast dose was 100 mL.

The patient experienced no complications of stroke, dizziness, upper limb claudication, abnormal neck movement, or poor wound healing perioperatively. He spent 1 day in the intensive care unit (ICU), with stable vital signs. CTA on postoperative day 7 showed that the stent-graft was fully expanded, with no endoleak, migration, disconnection, or stenosis, and that the false lumen was completely excluded (Figure 3a and 3g). The artificial bypass and all of the supra-arch branches were patent (Figure 3b–d). Contrast agent was not found in the proximal ARSA and KD (Figure 3e and 3f), suggesting complete exclusion of KD. The patient was discharged on postoperative day 14.

Follow-up CTA 1 year postoperatively showed that the main graft was fully expanded, with all branches patent (Figure 4). Moreover, no complications occurred during the follow-up.

Discussion

ARSA was first described by Hunauld in 1735.³ ARSA is one of the most common congenital aortic arch anatomical anomalies reported worldwide, and it is located distal to the LSA ostium on the aortic arch and passes through the posterior mediastinum to the right upper limb. Over 60% of patients have a wider attachment between the ARSA and the aortic arch, which was described and named Kommerell's diverticulum by Kommerell⁴ in 1936. As another congenital aortic arch

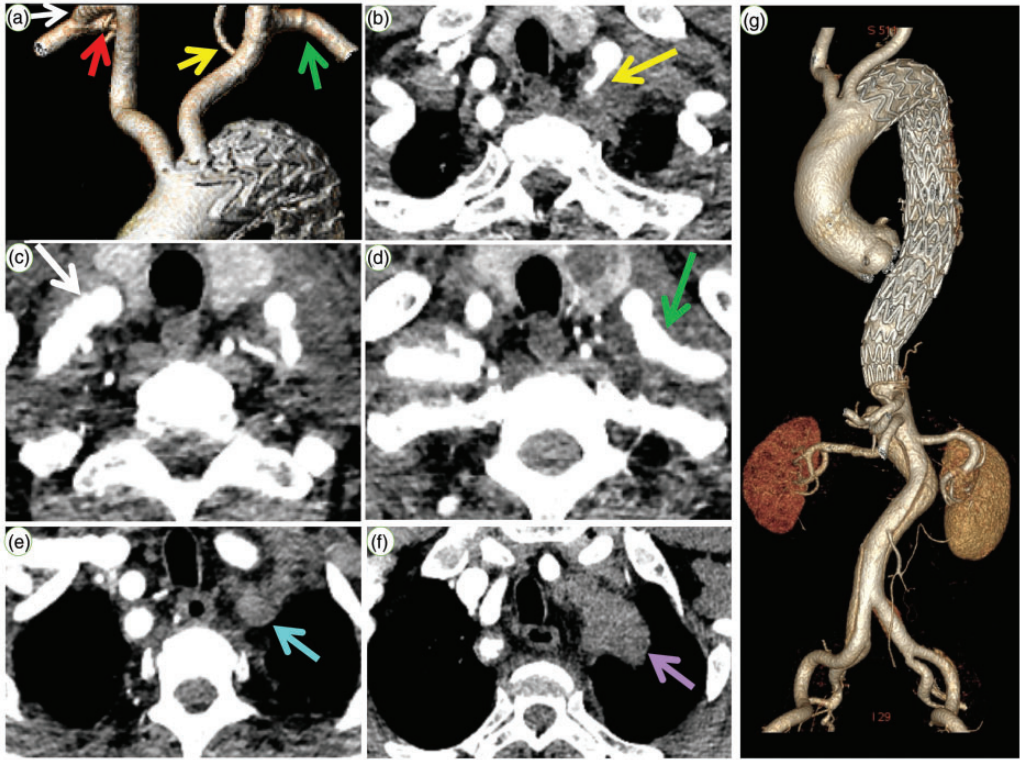


Figure 3. CTA on postoperative day 7. **(a)** ARSA-RCCA artificial bypass (white arrow). The ILVA (yellow arrow) and LSA (green arrow) were patent, and a small amount of blood flowed back from the distal RSA (red arrow) on 3D imaging, with the false lumen of the aortic arch completely excluded. **(b)** ILVA-LCCA transposition (yellow arrow) on 2D imaging. **(c)** ARSA-RCCA artificial bypass (white arrow) on 2D imaging. **(d)** LSA-LCCA transposition (green arrow) on 2D imaging. **(e)** No contrast agent was found in the proximal ARSA (blue arrow) on 2D imaging. **(f)** No contrast agent was found in the KD (purple arrow) on 2D imaging. **(g)** General view of the aorta under 3D reconstruction.

CTA, computed tomography angiography; ARSA, aberrant right subclavian artery; ILVA, isolated left vertebral artery; LSA, left subclavian artery; RSA, right subclavian artery; LCCA, left common carotid artery; RCCA, right common carotid artery; KD, Kommerell's diverticulum; 2D, two-dimensional; 3D, three-dimensional.

anatomical anomaly, the ILVA arises directly from the aortic arch and is located proximal or distal to the LSA. Affected patients with all of the common aortic arch anomalies, such as ARSA, ILVA, and a bovine arch usually have higher morbidity related to aortic dissection than does the general population.¹ The formation of ARSA and ILVA is associated with involution of the right dorsal aorta and abnormal

development of the seventh intersegmental artery during fetal development.^{5,6}

Cases combining all three anomalies (ARSA, ILVA, and KD) with aortic dissection or aneurysm have been reported rarely. We reviewed previous cases with one or more anomalies (Table 1).^{2,7-20} Nonami et al.⁷ reported that a patient with ARSA and ILVA with aortic aneurysm successfully underwent aortic arch replacement with

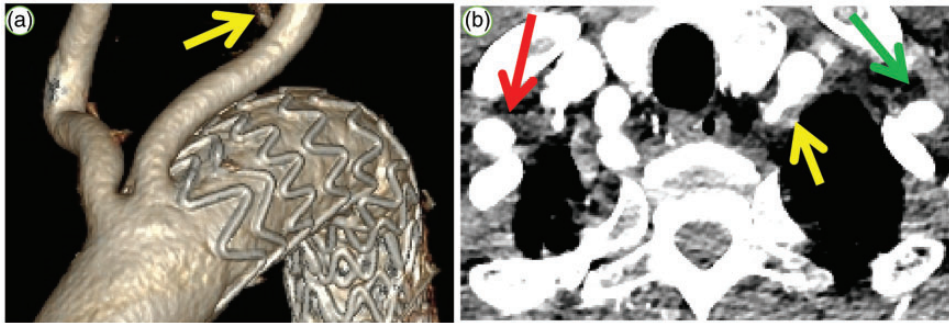


Figure 4. CTA findings 1 year postoperatively. **(a)** Aortic arch on 3D imaging showing that the ILVA-LCCA transposition (yellow arrow) was patent. **(b)** The ILVA-LCCA transposition (yellow arrow), distal LSA (green arrow), and distal RSA (red arrow) were patent on 2D imaging. CTA, computed tomography angiography; 3D, three-dimensional; ILVA, isolated left vertebral artery; LCCA, left common carotid artery; LSA, left subclavian artery; RSA, right subclavian artery; 2D, two-dimensional.

five branches, in 1998. Before the development of TEVAR, traditional treatment was accompanied by a high risk of complications and injuries. Compared with open surgery, endovascular therapy has the advantages of lower mortality and morbidity, and operation duration and length of hospital stay.^{21,22} Elghoneimy et al.⁸ reported a patient with all three anomalies with TBAD who successfully underwent traditional TEVAR without reconstruction of any aortic arch branches because the entry point was 2 cm distal to the ARSA, and the landing distance was adequate. The patient recovered without morbidity during the postoperative follow-up. However, traditional TEVAR is unsuitable for all patients because of landing zone limitations. Other surgeons have reported aortic dissection or aneurysm with ARSA or ILVA occurring alone, treated with total endovascular repair,⁹⁻¹² hybrid procedure,¹²⁻¹⁷ or open surgery.¹⁸⁻²⁰

In our patient, TEVAR was beneficial in slowing the progression of TBAD and reducing continuous pain. Performing TEVAR 1 month after admission may improve clinical outcomes owing to satisfactory vascular conditions in the subacute phase.²³ The distances between the ostia of

the ILVA and LSA, and the entry tear were 13.0 mm and 3.0 mm, respectively. As the landing distance was inadequate, it was necessary to cover the ILVA and LSA to provide a sufficient landing zone. To prevent ischemia of the left upper limb, LSA revascularization was unavoidable. CTA showed that both vertebral arteries were dominant, ensuring cerebral perfusion and suggesting that the ARSA and ILVA should also be revascularized.⁹ Although fTEVAR or chTEVAR techniques could extend the landing distance, these procedures are complicated, expensive, and prone to complications when revascularizing two or more branches. Furthermore, the chimney and periscope techniques could lead to higher incidences of endoleak and retrograde dissection.^{2,9,24,25} Branched endografts or physician-modified fenestrated endografts were considered difficult to design and deploy accurately in this case owing to the complicated anatomical structure with the three rare anomalies.^{9,10,26} Open surgery with total aortic arch replacement was not considered because of the high risk of complications and injury. Although all of the above methods were achievable in our center, none was considered the best solution. Thus, a hybrid approach constituting

Table 1. Recent cases of aortic dissection or aneurysm with ARSA, ILVA, or KD.

No.	Author (year)	Number of case(s)	Sex (n)	Age (years)	Follow-up (months)	Anomaly	Treatment	Outcome (n)
1	Zhou et al. ² (2017)	13	M (8) F (5)	58 (mean)	36 (mean)	ARSA (13)	TEVAR (6) TEVAR + chimney (3) TEVAR + periscope (4) Aortic arch replacement TEVAR	Alive (13)
2	Nonami et al. ⁷ (1998)	1	F	54	60	ARSA & ILVA		Alive
3	Eighoneimy et al. ⁸ (2019)	1	M	51	6	ARSA & ILVA & KD		Alive
4	Zhang et al. ⁹ (2019)	15	M (13) F (2)	55 (mean)	33 (mean)	ARSA (13) ARSA & KD (2)	TEVAR (6) TEVAR + fenestration (1) TEVAR + chimney (7) TEVAR + chimney + periscope (1) TEVAR with unibody branched stent-graft	Alive (15)
5	Sun et al. ¹⁰ (2018)	1	M	57	12	ARSA & KD		Alive
6	Fan et al. ¹¹ (2019)	1	M	65	6	ILVA	TEVAR + fenestration	Alive
7	Ding et al. ¹² (2019)	31	M (27) F (4)	55 (mean)	33 (mean)	ILVA (31)	TEVAR (12) TEVAR + chimney (9)	Alive (30) 1 dead of cancer
8	Son et al. ¹³ (2018)	1	F	32	-	ARSA	TEVAR + bypass (10)	Alive
9	Abuharb et al. ¹⁴ (2019)	1	M	54	1	ARSA	TEVAR + bypass	Alive
10	Piffaretti et al. ¹⁵ (2019)	9	M (8)	76 (mean)	15 (mean)	ILVA (9)	TEVAR (3) TEVAR + bypass (2) TEVAR + transposition + bypass (4) TEVAR + transposition + bypass TEVAR + bypass Stented elephant trunk technique (2) Stented elephant trunk technique + bypass (1)	Alive (9)
11	Blumberg et al. ¹⁶ (2016)	1	M	61	12	ILVA		Alive
12	Lee et al. ¹⁷ (2017)	1	M	63	-	ILVA		Alive
13	Zhu et al. ¹⁸ (2016)	7	M (7)	53 (mean)	44 (mean)	ILVA (7)		Alive (7)

(continued)

Table 1. Continued.

No.	Author (year)	Number of case(s)	Sex (n)	Age (years)	Follow-up (months)	Anomaly	Treatment	Outcome (n)
14	Huang et al. ¹⁹ (2019)	1	F	39	16	ARSA	Stented elephant trunk technique + transposition (4)	Alive
15	Van der Weijde et al. ²⁰ (2019)	1	M	79	3	ILVA	Stented elephant trunk technique + transposition	Alive
16	Our case	1	M	57	12	ARSA & ILVA & KD	Interposition graft through a left thoracotomy TEVAR + transposition + bypass	Alive

ARSA, aberrant right subclavian artery; ILVA, isolated left vertebral artery; KD, Kommerell's diverticulum; M, male; F, female; TEVAR, thoracic endovascular aortic repair.

TEVAR, double supraclavicular transposition, and single bypass was designed.

Some cases of TBAD with ARSA or ILVA have been treated successfully with a supraclavicular hybrid operation.^{12–17} Supraclavicular hybrid TEVAR has the advantages of less invasiveness, and better efficacy and cost compared with open surgery with total arch replacement and total endovascular treatment, such as with multiple fTEVAR or chTEVAR. Thus, we designed a hybrid TEVAR with concomitant double transposition of the LSA and ILVA to the LCCA and single artificial bypass of the ARSA to the RCCA through bilateral supraclavicular incisions. The reason for using artificial bypass to revascularize the ARSA was that the dissection had formed in the proximal ARSA. We deployed a bare metal stent distally because it was favorable in the short-term.^{27,28} This is the first report describing supraclavicular hybrid TEVAR for a patient with TBAD combined with three rare anomalies.

Three anomalies combined with TBAD is rare in a single patient. Supraclavicular hybrid TEVAR can decrease the risk of open surgery with total arch replacement as well as total endovascular treatment, such as multiple fTEVAR or chTEVAR. The hybrid approach is an effective, safe, and economical treatment for TBAD involving aortic arch anomalies.

Ethics statement

This study was granted written approval from the Ethics Committee from Tianjin Medical University General Hospital (approval number: No. IRB2021-WZ-021). Because the patient had already been discharged and lived far from the hospital at the time of writing of this report, verbal informed consent by telephone was obtained from the patient for publication of this case report and accompanying images.

Declaration of conflicting interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.


Authors' contributions

All data generated or analyzed during this study are included in this article. Junhang Chen collected the case data and made substantial contributions to the writing of the manuscript. Yudong Luo, Hailun Fan, Zhou Feng, and Yiwei Zhang contributed substantially to the analysis of the case. Xiangchen Dai, Jiechang Zhu, Fanguo Hu, and Peng Li performed the operation and assisted in preparing the manuscript. All authors read and approved the final manuscript.

ORCID iDs

Junhang Chen  <https://orcid.org/0000-0002-9744-6118>

Xiangchen Dai  <https://orcid.org/0000-0001-9074-6452>

Peng Li  <https://orcid.org/0000-0002-2878-2169>

References

- Dumfarth J, Chou AS, Ziganshin BA, et al. Atypical aortic arch branching variants: a novel marker for thoracic aortic disease. *J Thorac Cardiovasc Surg* 2015; 149: 1586–1592.
- Zhou M, Bai X, Ding Y, et al. Morphology and outcomes of total endovascular treatment of type B aortic dissection with aberrant right subclavian artery. *Eur J Vasc Endovasc Surg* 2017; 54: 722–728.
- Hunauld PM. Examen de quelques parties d'un singe. *J Hist Acad Roy Sci* 1735; 2: 516–523.
- Kommerell BF. Verlagerung des oesophagus durch eine abnorm verlaufende arteria subclavia dextra (arteria lusoria). *J Forstsch Geb Roetgenstr* 1936; 54: 590–595.
- Nelson ML and Sparks CD. Unusual aortic arch variation: distal origin of common carotid arteries. *Clin Anat* 2001; 14: 62–65.
- Stone WM, Ricotta JJ 2nd, Fowl RJ, et al. Contemporary management of aberrant right subclavian arteries. *Ann Vasc Surg* 2011; 25: 508–514.
- Nonami Y, Tomosawa N, Nishida K, et al. Dissecting aortic aneurysm involving an anomalous right subclavian artery and isolated left vertebral artery: case report and review of the literature. *J Cardiovasc Surg (Torino)* 1998; 39: 743–746.
- Elghoneimy YF, Nashy MR, Mahmoud AE, et al. Three rare structural anomalies: right aberrant subclavian artery, Kommerell's diverticulum, and isolated left vertebral artery all associated with type B aortic dissection. *Case Rep Surg* 2019; 2019: 7927613.
- Zhang W, Li X, Cai W, et al. Midterm outcomes of endovascular repair for Stanford type B aortic dissection with aberrant right subclavian artery. *J Vasc Interv Radiol* 2019; 30: 1378–1385.
- Sun GY, Guo W, Liu XP, et al. Total endovascular repair of aberrant right subclavian artery using castor branched stent-graft. *J Geriatr Cardiol* 2018; 15: 751–754.
- Fan W, Li C, Zheng G, et al. Thoracic endovascular aortic repair in penetrating aortic ulcer combined with isolated left vertebral artery: a case report. *Medicine (Baltimore)* 2019; 98: e17159.
- Ding H, Zhu Y, Wang H, et al. Management of type B aortic dissection with an isolated left vertebral artery. *J Vasc Surg* 2019; 70: 1065–1071.
- Son SA, Lim KH and Kim GJ. Hybrid approach of ruptured type B aortic dissection with an aberrant subclavian artery in a single patient with Turner syndrome: a case report. *Vasc Specialist Int* 2018; 34: 121–126.
- Abuharb MYI, Ming BX and Jian H. Repair of a type B aortic dissection with a re-vascularization of the aberrant right subclavian artery in an adult patient. *J Cardiothorac Surg* 2019; 14: 201.
- Piffaretti G, Gelpi G, Tadiello M, et al. Transposition of the left vertebral artery during endovascular stent-graft repair of

- the aortic arch. *J Thorac Cardiovasc Surg* 2020; 159: 2189–2198.e1.
16. Blumberg SN, Adelman MA and Maldonado TS. Aberrant left vertebral artery transposition and concomitant carotid-subclavian bypass for treatment of acute intramural hematoma with thoracic endovascular aortic repair. *J Vasc Surg* 2017; 65: 860–864.
 17. Lee KS, Kim GS, Jung Y, et al. Supraclavicular transposition of aberrant left vertebral artery for hybrid treatment of aortic arch aneurysm: a case report. *J Cardiothorac Surg* 2017; 12: 9.
 18. Zhu JM, Qi RD, Liu YM, et al. Repair of complicated type B dissection with an isolated left vertebral artery using the stented elephant trunk technique. *Eur J Cardiothorac Surg* 2016; 49: 778–782.
 19. Huang M, Piao H, Li B, et al. A new inclusion technique through an upper partial sternotomy for complicated Stanford B-type aortic dissection with an aberrant right subclavian artery: a case report. *Medicine (Baltimore)* 2019; 98: e14727.
 20. Van Der Weijde E, Bakker OJ, Sonker U, et al. Isolated left vertebral artery and its consequences for aortic arch repair. *J Vasc Surg Cases Innov Tech* 2019; 5: 369–371.
 21. Cheng D, Martin J, Shennib H, et al. Endovascular aortic repair versus open surgical repair for descending thoracic aortic disease a systematic review and meta-analysis of comparative studies. *J Am Coll Cardiol* 2010; 55: 986–1001.
 22. Harky A, Kai Chan JS, Ming Wong CH, et al. Open versus endovascular repair of descending thoracic aortic aneurysm disease: a systematic review and meta-analysis. *Ann Vasc Surg* 2019; 54: 304–315.e305.
 23. Kaji S. Update on the therapeutic strategy of type B aortic dissection. *J Atheroscler Thromb* 2018; 25: 203–212.
 24. Van Der Weijde E, Bakker OJ and Heijmen RH. A custom-made scalloped stentgraft to preserve left subclavian artery flow in descending thoracic aortic disease with a short neck. *Expert Rev Med Devices* 2016; 13: 487–496.
 25. Xue Y, Sun L, Zheng J, et al. The chimney technique for preserving the left subclavian artery in thoracic endovascular aortic repair. *Eur J Cardiothorac Surg* 2015; 47: 623–629.
 26. Zhu J, Dai X, Noiniyom P, et al. Fenestrated thoracic endovascular aortic repair using physician-modified stent grafts (PMSGs) in zone 0 and zone 1 for aortic arch diseases. *Cardiovasc Intervent Radiol* 2019; 42: 19–27.
 27. Rong D, Ge Y, Liu J, et al. Combined proximal descending aortic endografting plus distal bare metal stenting (PETTICOAT technique) versus conventional proximal descending aortic stent graft repair for complicated type B aortic dissections. *Cochrane Database Syst Rev* 2019; 2019: CD013149.
 28. Kong X, Peng L, Wu F, et al. Distal bare metal stent implantation during thoracic endovascular aortic repair is beneficial to treat complicated type B aortic dissection: a systematic review and meta-analysis. *Vascular* 2020; 1708538120968404.