IMR Press

Original Research

Endovascular repair of traumatic aortic dissection: a single-center experience

Yingliang Wang[1,2,†], Tongqiang Li[1,2,†], Jiacheng Liu[1,2,†], Qin Shi[1,2], Chen Zhou[1,2], Chongtu Yang[1,2], Songjiang Huang[1,2], Yang Chen[1,2], Bin Xiong[1,2,*]

[1] *Department of Radiology, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, 430022 Wuhan, Hubei, China*

[2] *Hubei Key Laboratory of Molecular Imaging, 430022 Wuhan, Hubei, China*

*Correspondence: herr_xiong@126.com (Bin Xiong)

† These authors contributed equally.

DOI:10.31083/j.rcm2203112

Submitted: 19 June 2021 Revised: 16 August 2021 Accepted: 17 August 2021 Published: 24 September 2021

The data on endovascular aortic repair (EVAR) for traumatic aortic dissection (TAD) are lacking. Hence, this study aimed to evaluate the efficacy of EVAR for TAD and report our experience based on patients from our medical center with a relatively long follow-up. A total of 25 consecutive patients with TAD underwent EVAR from October 2015 to October 2020. The demographics, imaging characteristics, clinical features, treatment details, and follow-up results were reviewed. Urgent EVAR was performed in 3 patients (12%), while the remaining 22 patients (88%) underwent delayed EVAR. Systematic heparinization was used in all patients during the endovascular procedure. The EVAR was technically successful in all patients, with no cases converted into open surgery. No death occurred during the perioperative period. One patient presented with a type II endoleak on postoperative 1-month CT images during a mean follow-up of 42.3 $\pm$ 17.7 months (5–67.5 months) and showed spontaneous regression of the endoleak without any intervention during the subsequent follow-up. All the patients survived until the time of writing, and none of them showed late endoleak, stent migration, paraplegia, and reintervention. The patients with left subclavian artery covered (n = 8) had no obvious ischemia of the arm and brain. The study results demonstrated that EVAR for TAD proved to be safe and effective, and most patients could undergo delayed EVAR. Systematically heparinization during EVAR under the setting of multi-trauma was safe.

Keywords

Aortic dissection; Endovascular aortic repair; Stent; Trauma

1. Introduction

Traumatic aortic injury (TAI), including traumatic aortic dissection (TAD) is a potentially lethal clinical event usually seen in high-speed vehicle accidents and falls from heights. It is the second leading common cause of trauma-related death. Less than 25% of patients with such an injury could reach the hospital, and up to 50% of patients who arrived at the hospital might die within 24 h [1–3]. The injuries to the thoracic aorta are mostly located at the aortic isthmus due to the specific anatomy of the relative fixation of the descending aorta and mobility of the aortic arch, followed by the ascending aorta, aortic arch, distal descending aorta, and abdominal aorta [4].

Endovascular aortic repair (EVAR) offers lower perioperative mortality and provides satisfactory outcomes compared with open repair in patients with TAI [5, 6]. It has been recommended as the first-line treatment by the 2011 Society for Vascular Surgery clinical practice guidelines and the 2017 European Society for Vascular Surgery Guidelines [1, 2]. However, the recommendation is mostly based on retrospective cohorts with a small sample size limited by its low incidence. Thus, the mid- and long-term outcomes of EVAR for TAI remain unclear. In particular, reports on TAD treated by EVAR are limited, which poses a specific concern for its management [7].

Given the lack of data on endovascular repair of TAD, we aimed to evaluate the efficacy of EVAR for TAD and report our experience based on patients from our medical center with a relatively long follow-up.

2. Methods

2.1 Study population

This was an observational study following the STROBE guidelines [8].

From October 2015 to October 2020, consecutive patients with computed tomography angiography (CTA)-confirmed TAD were included in this study. The exclusion criteria were patients with type A aortic dissection, death before repair or refusal to repair, and insufficient medical records. The demographics, clinical features, imaging characteristics, treatment details, and follow-up results of the patients were reviewed.

2.2 Endovascular procedure

In our center, EVAR is the preferred treatment for non-type A TAD if available. All patients admitted to the hospital were initially managed with aggressive blood pressure control and pain management. An urgent EVAR (<24 h) was indicated if patients had aortic rupture or impending rupture, hemodynamic instability, malperfusion, or severe pericardial effusion; otherwise, a delayed EVAR was performed. Aortic CTA was preliminarily used to identify the anatomical condi-

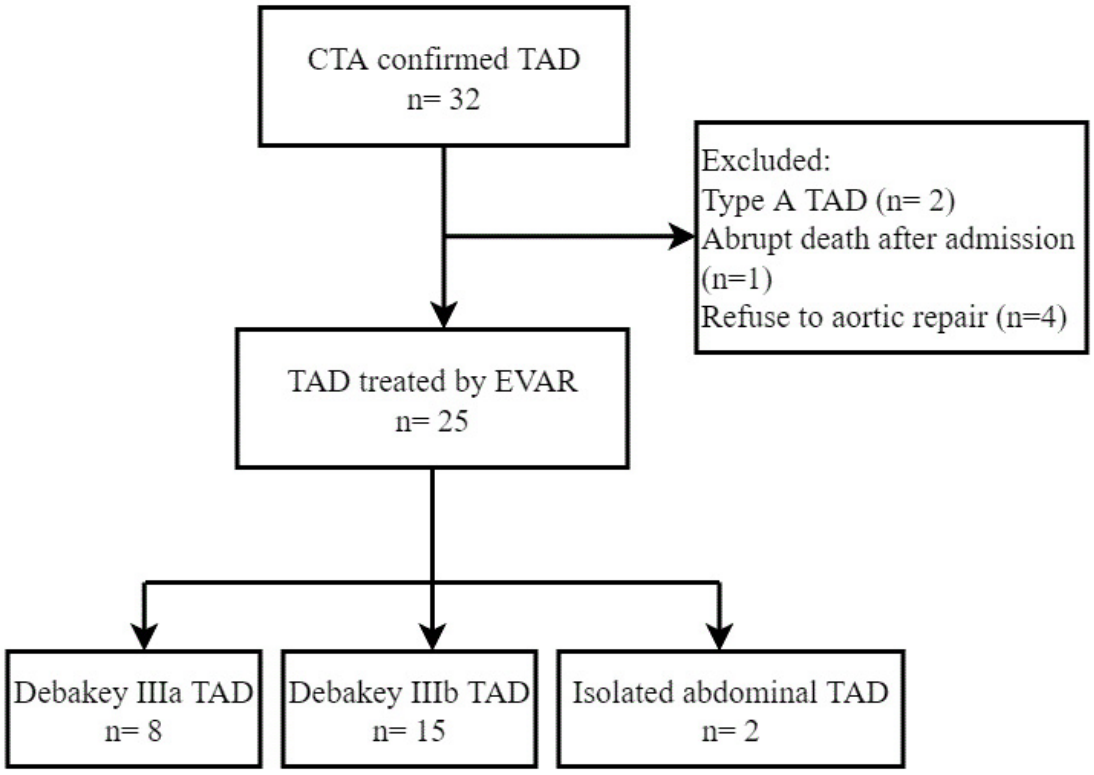

Fig. 1. Flowchart of inclusion of patients. From October 2015 to October 2020, there were 32 consecutive patients with computed tomography angiography (CTA) confirmed traumatic aortic dissection (TAD). Patients with type A aortic dissection (n = 2), abrupt death after admission (n = 1) and refused to aortic repair (n = 4) were excluded. Finally, 25 TAD patients who underwent EVAR procedure were included in the present study. There were 15 patients with Debakey IIIb dissection, 8 patients with Debakey IIIa dissection occurred, and 2 patients with isolated infrarenal abdominal aortic dissection.

tions, such as the location of intimal tear, extent of dissection involvement, landing zone diameter, and so forth.

All the patients underwent EVAR by experienced doctors under local/general anesthesia in the interventional operation room/hybrid operating room after obtaining the written informed consent from the patients or relatives. The treatment goal of EVAR was to cover the primary intimal tear. The intraoperative blood pressure was maintained at less than 120/80 mmHg. Heparin with a dose of 3000–5000 units was routinely used during the surgery, and patients with concomitant injuries who had a high risk of bleeding received a low dose of heparin. A 5-F calibrated pigtail catheter (Cook) was introduced into the aorta via a 6-F vascular sheath (Terumo Corporation, Tokyo, Japan) inserted into the brachial artery. Then, digital subtraction angiography (DSA) (Siemens Artis Zee DSA system, Munich, Germany) of the ascending aorta, aortic arch, and descending aorta were performed. The true and false lumens, as well as the intimal tear, were evaluated. A 0.035-inch wire with an angiographic catheter was subsequently introduced into the aortic root via an 8-F vascular sheath (Terumo Corporation, Tokyo, Japan) inserted into the incised femoral artery. Then, a stiff wire was exchanged with a 0.035-inch wire, and an appropriate stent was selected to cover the primary intimal tear. After deployment of the stent, angiography was performed again to check the endoleak, stent position, and blood supply of aortic branches.

The size of the stent used in the present cases was oversized 5%–20% larger than the maximum diameter of the aorta (from inner to inner) at the proximal landing zone. Tapered stents or overlapping tapered stents were used when the diameter of the distal landing zone was small. Meanwhile, the selection of stents was mainly based on the anatomical conditions, experience of the surgeons, and availability of devices. The proximal sealing length was at least 1.5 cm. Selective revascularization for preserving the left subclavian artery was performed if the patient had a hypoplastic right vertebral artery or a patent left internal mammary artery graft.

2.3 Follow-up protocol

All patients were prescribed to have a follow-up protocol including assessment of clinical symptoms and CTA images at 1, 3, 6, and 12 months and then annually thereafter. Follow-up data were obtained from reviewing medical records and a telephone interview with the patients and relatives.

2.4 Statistical analysis

The categorical variables were expressed as numbers (percentages), and the continuous variables as means ± standard deviation or median (interquartile range [IQR]). All statistical analyses were performed using SPSS 19.0 software (IBM

Table 1. Demographics of the traumatic aortic dissection patients.

Variables	Value
Age (years), mean ± SD	56.5 ± 8.3
Male/Female, n (%)	20/5 (80/20)
Hypertension, n (%)	7 (28)
Diabetes, n (%)	1 (4)
Trauma type, n (%)	
Traffic accident	17 (68)
Falling down	8 (32)
Concomitant injuries, n (%)	
Bone fractures	25 (100)
Brain injury	10 (40)
Pulmonary injury	14 (56)
Splenic injury	1 (4)
Pancreatic injury	1 (4)
Renal contusion	3 (12)

SD, standard deviation.

Corporation, Armonk, NY, USA).

3. Results

3.1 Patient characteristics

A total of 25 consecutive patients were included in this study (Fig. 1). Of these, 20 (80%) were men and 5 (20%) women, with a mean age of 56.5 ± 8.3 years (range 37–69 years). All (100%) patients presented with chest/back pain. Bilateral or unilateral pleural effusion was found in 14 (56%) patients. The symptoms and signs presented might have resulted from TAD and associated injuries such as rib fracture, lung contusion, or both of them. No severe fatal cases were reported.

Debakey IIIb dissection which with the false lumen expanding to the abdominal aorta occurred in 15 patients (60%), Debakey IIIa dissection occurred in 8 patients (32%), and isolated infrarenal abdominal aortic dissection occurred in 2 patients (8%). The primary intimal tear was located at the aortic isthmus in 23 patients (92%) and at the infrarenal abdominal aorta in 2 patients (8%). The mean length of Debakey IIIa dissection and isolated abdominal dissection were 3.2 ± 0.5 cm (2.5–3.8 cm). Twenty of the patients (80%) had only one single intimal tear (The detailed baseline and anatomical characteristics are shown in Table 1 and Table 2, respectively).

3.2 Treatment results

All patients initially underwent conservative treatment with antihypertensive and anti-pulse drugs. Urgent EVAR was performed in 3 patients (12%), while the remaining 22 patients (88%) underwent delayed EVAR. The median interval time between diagnosis and EVAR was 5 days (IQR: 4–7 days). The left subclavian artery was intentionally covered in eight patients (32%), and 2 of them (25%) received revascularization (one with a chimney stent and the other by bypass between the left cervical and left subclavian arteries before the EVAR procedure). The stents used in the present study included Aegis (MicroPort, Shanghai, China), Talent (Medtronic, Minneapolis, MN USA), E-vita (JOTEC, Hechingen, Germany), and Ankura (Lifetech, Shenzhen, China) (Table 3).

Table 2. Anatomical characteristics of the traumatic aortic dissection.

Variables	Value
Dissection type, n (%)	
Debakey IIIa	8 (32)
Debakey IIIb	15 (60)
Abdominal aortic dissection	2 (8)
D_{IT-LSA} (cm), mean ± SD	2.0 ± 1.0
Size of the primary intimal tear (cm), mean ± SD	1.0 ± 0.3
Diameter of proximal landing zone (cm)	25.9 ± 3.0

SD, standard deviation; D_{IT-LSA}, distance between the primary intimal tear and the ostium of the left subclavian artery in patients with Debakey III traumatic aortic dissection.

Table 3. Treatment details of the traumatic aortic dissection.

Variables	Value
Operation time (min), mean ± SD	57.8 ± 8.3
Stent type, n (%)	
Talent (Medtronic)	5 (20)
Ankura (Lifetech Scientific)	5 (20)
Aegis (Microport)	12 (48)
E-vita (JOTEC)	3 (12)
Stent length (mm), mean ± SD	158 ± 37.5
Oversizing (%), mean ± SD	10 ± 5
EVAR timing, n (%)	
Early	3 (12)
Delayed	22 (88)
LSA covered, n (%)	8 (32)
LSA reconstruction, n (%)	2 (8)

SD, standard deviation; EVAR, endovascular aortic repair; LSA, left subclavian artery.

3.3 Outcomes

The EVAR was technically successful in all patients, with no cases converted into open surgery (Figs. 2,3). No death occurred during the perioperative period. During a mean follow-up of 42.3 ± 17.7 months (5–67.5 months), one patient presented with a type II endoleak on postoperative 1-month CTA images and showed spontaneous regression of the endoleak without any intervention during the subsequent follow-up. All the patients survived until the time of writing, and none of them showed late endoleak, stent migration, paraplegia, and reintervention. The patients with the left subclavian artery covered had no obvious ischemia of the arm and brain. A significant enlargement of the true lumen and regression of the false lumen were observed on the latest CTA images in all patients. Complete aortic remodeling was observed in all patients with Debakey IIIa aortic dissection and isolated abdominal aortic dissection. For patients with Debakey IIIb aortic dissection, complete thoracic descending

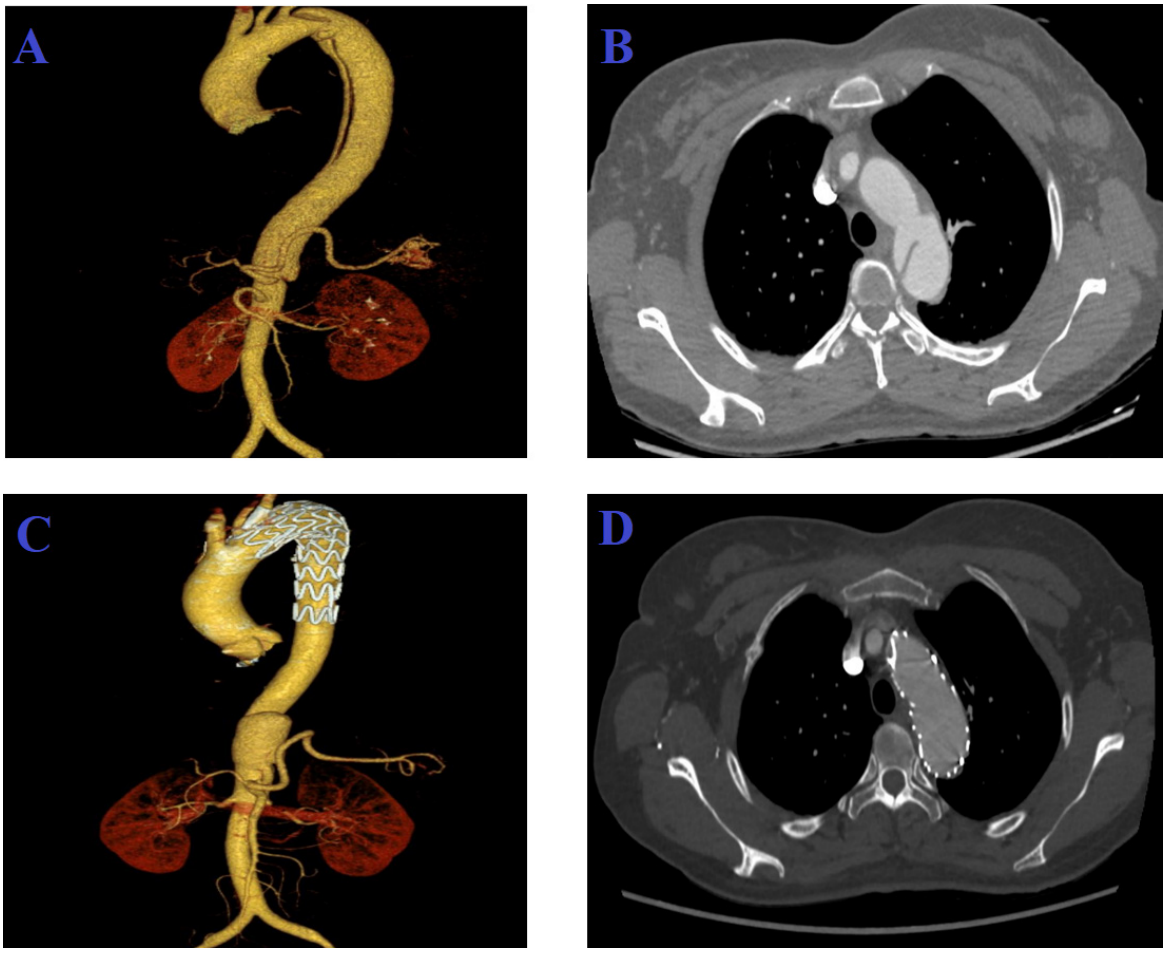

Fig. 2. Endovascular aortic repair of a Debakey III traumatic aortic dissection. (A,B) Computed tomography angiography images (including volume-rendering technique) of a patient demonstrating a Debakey III traumatic aortic dissection and an intimal tear distal to the left subclavian artery (namely, aortic isthmus). The distance between the primary intimal tear and the ostium of the left subclavian artery was 0.8 cm. (C,D) Computed tomography angiography images (including volume-rendering technique) 6 months after the endovascular aortic repair, demonstrating that the stents were in good shape, the true lumen was unobstructed, no endoleak occurred, and the thoracic aorta and left subclavian artery were well reconstructed.

aortic remodeling were observed in all patients, five patients (33.3%) had complete abdominal aortic remodeling and ten patients (66.7%) had partial thrombotic false lumen in the abdominal aorta.

4. Discussion

EVAR has been the first-line treatment for TAI according to the guidelines of the Society for Vascular Surgery (SVS) [2], the European Society of Cardiology [9], the Eastern Association for the Surgery of Trauma [10], and the European Society for Vascular Surgery (ESVS) [1], considering previously published reports of the low mortality and morbidity of EVAR compared with open surgery. Several studies including a relatively large number of cases with a long follow-up showed satisfactory outcomes of EVAR for TAI and superiority of EVAR over open surgery [3, 5, 6, 11–13]. However, EVAR for TAD was scarcely reported, and the characteristics of TAD were not thoroughly known. The satisfactory mid- and long- term outcomes of the patients in the present study demonstrated that EVAR was safe and effective for TAD. In addition, 40% of patients had a localized dissection (Debakey IIIa and isolated abdominal aortic dissection) with a mean length of 3.2 $\pm$ 0.5 cm (2.5–3.8 cm) and 80% of patients had only one single intimal tear, which seemed to be a prominent characteristic of TAD and made it easier to perform EVAR. The aforementioned study results were also confirmed in Li's study cohort [7].

The most used classification scheme for grading the severity of TAI was from SVS guidelines: type I (intimal tear), type II (intramural hematoma), type III (pseudoaneurysm), and type IV (rupture) [2]. According to the definition, the TAD could be easily classified as type I and the definition is broad (from slightly intimal injury to dissection). The Debakey classification which is mostly used in describing aortic dissection could indicate some anatomical characteristics of the lesion such as the extent of the lesion. Thus, we used the Debakey classification in the present study. The timing for performing EVAR for TAI remains controversial. The SVS guidelines

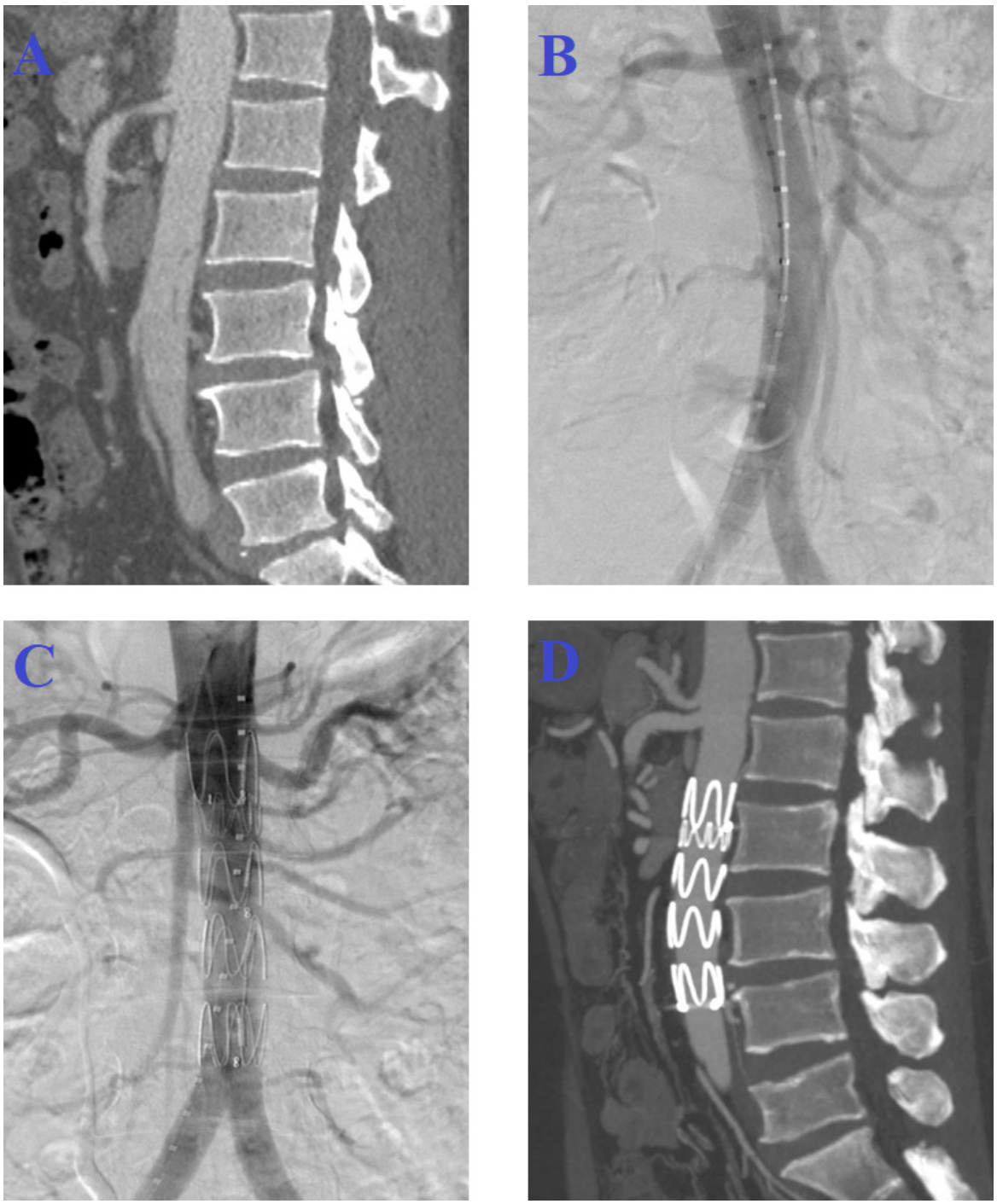

Fig. 3. Endovascular aortic repair of an isolated traumatic abdominal aortic dissection. (A–C) Computed tomography angiography and digital subtraction angiography images of a patient with localized isolated traumatic abdominal aortic dissection; a covered stent was implanted to cover the intimal tear. (D) Computed tomography angiography image 12 months after the endovascular aortic repair, demonstrating that the stent was in good shape, the true lumen was unobstructed, no endoleak occurred, and the abdominal artery was well reconstructed.

recommended urgent intervention when available to avoid aorta rupture [2], while the guidelines from the Eastern Association for the Surgery of Trauma suggested a delayed repair [10]. Several studies also demonstrated that delayed repair could improve mortality [14–16]. A 10-year study of EVAR for TAI, including 74 cases, showed that most deaths were unrelated to TAI and associated with the severity of associated injuries [17], indicating that it was important to treat associated life-threatening injuries before aortic repair. Also, it has been reported the aortic diameter could decrease by up to 30% in patients with a hypovolemic shock status [18], which led to selecting an inappropriate size during ur-

gent EVAR. In our center, we recommended a delayed EVAR with antihypertensive therapy and the management of associated fatal injuries for TAD. An urgent EVAR was reserved if patients had aortic rupture or impending rupture, hemodynamic instability, malperfusion, or severe pericardial effusion. The results of the present study supported the management strategy. However, no directed comparison between urgent EVAR and delayed EVAR for TAD in current published literature, and thus the appropriate timing for EVAR needs further exploration.

Appropriate stents are very important to prevent device-related complications, including endoleak, stent migration, stent collapse and so forth. However, no consensus exists in recent guidelines on the size of the stent for TAI and TAD. The oversizing of the stent ranged from 5%–60% in published reports [17, 19–22], and all of them were selected based on the operator's experience and device availability. On the one hand, the current stents were mostly designed for degenerative aneurysmal diseases, compared with the aorta in patients with TAD having normal pathophysiology, and often had a small diameter. On the other hand, the aortic diameter can increase and the aortic arch angulation can decrease with age in the young individuals [23], resulting in stent-related complications; however, no related reports were available. In the present study, the stent was oversized 5%–20% larger than the maximum diameter of the aorta (from inner to inner) at the proximal landing zone and it indeed achieved promising outcomes, indicating that the oversizing was appropriate in treating these patients. However, further studies with a large sample size should be performed to explore the optimal oversizing and more efforts should be made to design trauma-specific stents.

The left subclavian artery is often covered due to the intimal tear mostly located at the aortic isthmus. Thus, whether the left subclavian artery coverage is safe remains unclear. Some reports [24, 25] showed the left subclavian artery coverage increased the risk of stroke and claudication, while the results of other studies were contradictory [3, 26]. Our results were consistent with the later reports. In the present study, selective revascularization for preserving the left subclavian artery was performed if the patient had a hypoplastic right vertebral artery or a patent left internal mammary artery graft; none of the patients with the left subclavian artery coverage developed ischemic complications. Thus, the management strategy for the left subclavian artery seemed to be appropriate.

Systematic heparinization during EVAR for patients with TAI remains controversial. Using heparin may increase the risk of bleeding in the setting of multi-trauma, while not using heparin may lead to thromboembolic events. Some studies investigated the safety of using heparin during EVAR for TAI and showed that systemic heparinization can be safe without increasing hemorrhagic events [27, 28]. In our center, systematic heparinization with a dose of 3000–5000 units was routinely used during the surgery, and patients with concomitant injuries who had a high risk of bleeding received a low dose of heparin. The promising results in the present study supported the use of heparin.

5. Limitations

The study had certain limitations. First, the results of this study should be viewed with an inherent bias due to the respective nature. Second, the study was conducted with a small sample size, and therefore further large-sample studies are warranted to evaluate the long-term outcomes. Finally, nearly two thirds of the cases had a CTA follow-up at the local hospital and therefore we could not evaluate the aortic remodeling exactly. Consequently, more studies with a strict radiographic follow-up are needed.

6. Conclusions

EVAR for TAD proved to be safe and effective, and most patients could undergo delayed EVAR. Systematically heparinization during EVAR under the setting of multi-trauma was safe.

Author contributions

Study conceptualization and design—YLW, TQL, JCL; Study supervision—BX; Data collection—QS, CZ, CTY; Data analysis and interpretation—SJH, YC, YLW, TQL, JCL; Draft writing—YLW; Draft revising—TQL, JCL; All authors contributed edits, read and approved the final manuscript version.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Wuhan union hospital (approval number: 20210701) and written informed consent was waived because of the retrospective nature.

Acknowledgment

We would like to express our gratitude to all those who helped us during the writing of this manuscript. Thanks to all the peer reviewers for their opinions and suggestions.

Funding

This research received no external funding.

Conflict of interest

The authors declare no conflict of interest.

References

[1] Riambau V, Böckler 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) European Journal of Vascular and Endovascular Surgery. 2017; 53: 4–52.

[2] Lee WA, Matsumura JS, Mitchell RS, Farber MA, Greenberg RK, Azizzadeh A, *et al.* Endovascular repair of traumatic thoracic aortic injury: Clinical practice guidelines of the Society for Vascular Surgery. Journal of Vascular Surgery. 2011; 53: 187–192.

[3] Hundersmarck D, van der Vliet QMJ, Winterink LM, Leenen LPH, van Herwaarden JA, Hazenberg CEVB, *et al.* Blunt thoracic aortic injury and TEVAR: long-term outcomes and health-related quality of life. European Journal of Trauma and Emergency Surgery. 2020. (in press)
[4] Kapoor H, Lee JT, Orr NT, Nisiewicz MJ, Pawley BK, Zagurovskaya M. Minimal Aortic Injury: Mechanisms, Imaging Manifestations, Natural History, and Management. RadioGraphics. 2020; 40: 1834–1847.
[5] Harky A, Bleetman D, Chan JSK, Eriksen P, Chaplin G, MacCarthy-Ofosu B, *et al.* A systematic review and meta-analysis of endovascular versus open surgical repair for the traumatic ruptured thoracic aorta. Journal of Vascular Surgery. 2020; 71: 270–282.
[6] Cheng Y, Cheng C, Wang S, Wu VC, Chu P, Chou A, *et al.* Long-term Outcomes of Endovascular and Open Repair for Traumatic Thoracic Aortic Injury. JAMA Network Open. 2019; 2: e187861.
[7] Li S, Cai W, Li X, Qiu J, Li Q, Shu C. Thoracic endovascular aortic repair for traumatic type B aortic dissection: a 5-year experience from a single center. International Angiology. 2017; 36: 316–321.
[8] von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. PLoS Medicine. 2007; 4: e296.
[9] 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). European Heart Journal. 2014; 35: 2873–2926.
[10] Fox N, Schwartz D, Salazar JH, Haut ER, Dahm P, Black JH, *et al.* Evaluation and management of blunt traumatic aortic injury: A practice management guideline from the Eastern Association for the Surgery of Trauma. Journal of Trauma and Acute Care Surgery. 2015; 78: 136–146.
[11] Pang D, Hildebrand D, Bachoo P. Thoracic endovascular repair (TEVAR) versus open surgery for blunt traumatic thoracic aortic injury. Cochrane Database of Systematic Reviews. 2019; 2: CD006642.
[12] Kaneyuki D, Asakura T, Iguchi A, Yoshitake A, Tokunaga C, Tochii M, *et al.* Early- and long-term results of thoracic endovascular aortic repair for blunt traumatic thoracic aortic injury: a single-centre experience. European Journal of Cardio-Thoracic Surgery. 2019; 56: 307–312.
[13] Prendes CF, Stana J, Schneidwind KD, Rantner B, Konstantinou N, Bruder J, *et al.* Blunt traumatic thoracic aortic injuries: a retrospective cohort analysis of 2 decades of experience. Interactive CardioVascular and Thoracic Surgery. 2021; 33: 293–300.
[14] Maggisano R, Nathens A, Alexandrova NA, Cina C, Boulanger B, McKenzie R, *et al.* Traumatic rupture of the thoracic aorta: should one always operate immediately? Annals of Vascular Surgery. 1995; 9: 44–52.
[15] Marcaccio CL, Dumas RP, Huang Y, Yang W, Wang GJ, Holena DN. Delayed endovascular aortic repair is associated with reduced in-hospital mortality in patients with blunt thoracic aortic injury. Journal of Vascular Surgery. 2018; 68: 64–73.
[16] Estrera AL, Miller CC, Guajardo-Salinas G, Coogan S, Charlton-Ouw K, Safi HJ, *et al.* Update on blunt thoracic aortic injury: fifteen-year single-institution experience. The Journal of Thoracic and Cardiovascular Surgery. 2013; 145: S154–S158.
[17] Steuer J, Björck M, Sonesson B, Resch T, Dias N, Hultgren R, *et al.* Editor's Choice – Durability of Endovascular Repair in Blunt Traumatic Thoracic Aortic Injury: Long-Term Outcome from Four Tertiary Referral Centers. European Journal of Vascular and Endovascular Surgery. 2015; 50: 460–465.
[18] van Prehn J, van Herwaarden JA, Muhs BE, Arnofsky A, Moll FL, Verhagen HJM. Difficulties with endograft sizing in a patient with traumatic rupture of the thoracic aorta: the possible influence of hypovolemic shock. Journal of Vascular Surgery. 2008; 47: 1333–1336.
[19] Bae M, Jeon CH, Kwon H, Kim JH, Choi SU, Song S. Evaluation of Zone 2 Thoracic Endovascular Aortic Repair Performed with and without Prophylactic Embolization of the Left Subclavian Artery in Patients with Traumatic Aortic Injury. Korean Journal of Radiology. 2021; 22: 577–583.
[20] Gennai S, Leone N, Andreoli F, Munari E, Berchiolli R, Arcuri L, *et al.* Influence of Thoracic Endovascular Repair on Aortic Morphology in Patients Treated for Blunt Traumatic Aortic Injuries: Long Term Outcomes in a Multicentre Study. European Journal of Vascular and Endovascular Surgery. 2020; 59: 428–436.
[21] Lee C, Huang J, Yang T. Experience of endovascular repair of thoracic aortic dissection after blunt trauma injury in a district general hospital. Journal of Thoracic Disease. 2016; 8: 1149–1154.
[22] Son S, Jung H, Cho JY, Oh T, Do YW, Lim KH, *et al.* Mid-term outcomes of endovascular repair for traumatic thoracic aortic injury: a single-center experience. European Journal of Trauma and Emergency Surgery. 2019; 45: 965–972.
[23] Yoon WJ, Mani K, Wanhainen A, Rodriguez VM, Mell MW. Anatomic feasibility of off-the-shelf thoracic single side-branched endograft in patients with blunt traumatic thoracic aortic injury. Journal of Vascular Surgery. 2021. (in press)
[24] Antonello M, Menegolo M, Maturi C, Dall'antonia A, Lepidi S, Frigo AC, *et al.* Intentional coverage of the left subclavian artery during endovascular repair of traumatic descending thoracic aortic transection. Journal of Vascular Surgery. 2013; 57: 684–690.e1.
[25] Sepehripour AH, Ahmed K, Vecht JA, Anagnostakou V, Suliman A, Ashrafian H, *et al.* Management of the left subclavian artery during endovascular stent grafting for traumatic aortic injury - a systematic review. European Journal of Vascular and Endovascular Surgery. 2011; 41: 758–769.
[26] Klocker J, Koell A, Erlmeier M, Goebel G, Jaschke W, Fraedrich G. Ischemia and functional status of the left arm and quality of life after left subclavian artery coverage during stent grafting of thoracic aortic diseases. Journal of Vascular Surgery. 2014; 60: 64–69.
[27] Makaloski V, Widenka H, Schönhoff F, Spanos K, Wyss TR, Schmidli J. Efficacy and Safety of Heparinization before Deployment of Endograft for Blunt Traumatic Aortic Injury in Severely Injured Patients. Annals of Vascular Surgery. 2021; 75: 341–348.
[28] Ho VT, George EL, Rothenberg KA, Lee JT, Garcia-Toca M, Stern JR. Intraoperative heparin use is associated with reduced mortality without increasing hemorrhagic complications after thoracic endovascular aortic repair for blunt aortic injury. Journal of Vascular Surgery. 2021; 74: 71–78.