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Four Different Pathologic Conditions of the Descending Aorta – One Hybrid Solution: Thoracic Endovascular Aortic Repair with Partial Debranching of the Aortic Arch. A Series of 6 Cases

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Rezumat

Patru afecțiuni aortice complexe – o soluție hibridă: repararea endovasculară toracică a aortei cu debranșare parțială a arcului aortic. O serie de 6 cazuri

Introducere: În acest articol prezentăm experiența noastră cu şase pacienți internați în spital în perioada ianuarie - iulie 2023, cu afecțiuni aortice complexe, tratați printr-o procedură hibridă în două etape, constând în debranşarea chirurgicală – realizarea de bypass – a ramurilor supraaortice fără oprirea inimii şi plasarea unei endoproteze pentru repararea endovasculară toracică a aortei (TEVAR).
Prezentare de caz: Cazurile clinice prezentate evidențiază utilizarea TEVAR atât în afecțiuni cronice (disecții aortice de tip B, pseudoanevrisme şi ulcere penetrante ale aortei), cât şi în situații acute (secționări traumatice ale aortei şi anevrisme aortice rupte). TEVAR reprezintă o procedură intervențională care asociată cu debranşarea trunchiurilor arteriale supraortice devine hibridă. TEVAR oferă avantaje precum incizii mai mici, evitarea riscurilor asociate cu procedura clasica, timp de recuperare mai scurt după intervenție şi costuri mai reduse de spitalizare.
Concluzii: TEVAR reprezintă o alternativă la chirurgia deschisă, oferind rezultate mai bune pe termen imediat şi mediu, precum şi posibilitatea de a trata o varietate de cazuri, atât cronice cât şi acute, care altfel ar fi considerate cu un risc prea mare pentru chirurgia clasică.

Cuvinte cheie: reparare endovasculară a aortei toracice (TEVAR), debranşare chirurgicală distală, leziune toracică aortică traumatică închisă, ruptură traumatică a istmului aortic, pseudoanevrism, disecție aortică de tip B, ulcere penetrante ale aortei.

Abstract

Introduction: We report our experience of six patients admitted to our hospital during January - July 2023 with complex aortic conditions treated with a two-stage hybrid procedure, consisting of surgical debranching - bypass grafting - of the supra-aortic branches off-pump and stent graft placement for Thoracic Endovascular Aortic Repair (TEVAR).

Clinical features: The clinical cases we present highlight the use of TEVAR in both chronic (Type B aortic dissections, pseudoaneurysms, and penetrating aortic ulcers) and acute conditions (traumatic aortic transections and ruptured aortic aneurysms). TEVAR is a less invasive surgical approach for management of these critical patients, having as benefits: smaller incisions, avoiding operative risks associated with the classical procedure, shorter recovery time after the intervention and lower hospitalization costs.

Conclusions: TEVAR offers an alternative to open surgery, showing better immediate and mid-term results, as well as providing the chance to solve a variety of both chronic and acute cases that would be otherwise classified as too high risk for classic open surgery.

Keywords: Thoracic Endovascular Aortic Repair (TEVAR), distal surgical debranching, blunt traumatic thoracic aortic injury, traumatic rupture of aortic isthmus; pseudoaneurysm, type B aortic dissection, penetrating aortic ulcers

Introduction

Blunt traumatic thoracic aortic injury (BTAI) following car accidents in association with blunt thoracic trauma is a surgical emergency. High mortality rate in BTAI patients leads to a narrow time for surgical treatment, frequently patients not being able to survive long enough to receive specialized care (1,2). Traumatic injury of the aortic isthmus is reported to be the second most common cause of death following blunt thoracic trauma (3). The two main options of treatment are open thoracic surgery or TEVAR, the later continues to develop its applications, including as the primary line of treatment for life-threatening injury of the thoracic aorta (4-6). Current guidelines support this technique as the first-line repair method for traumatic isthmic ruptures (7-9).

Type B aortic dissection (TBAD) that is defined as a dissection involving the aorta distal to the left subclavian artery with the ascending aorta and the aortic arch not affected. Type B dissection accounts for 25% to 40% of all aortic dissections (10). The management of acute co-TBAD is a clinical challenge. Thoracic endovascular aortic repair (TEVAR) is now considered the gold standard with open surgery almost disappearing in these dramatic situations (11).

Penetrating aortic ulcers are characterized by an ulcerated atheromatous plaque that extends into the aortic media, whereas an intramural hematoma is characterized by hemorrhage within the aortic wall without a clear intimal disruption. Penetrating aortic ulcers with a depth greater than 10 mm or wider than 20 mm are at a higher risk of progression and should be considered for repair. Indications for intervention include rupture, presence of saccular aneurysm, symptoms such as hemoptysis (12).

Therefore, TEVAR procedure increased the intervention rates for patients who would previously have been considered having an exceeding high risk for surgery. Guidelines have identified general indications for both elective and emergency TEVAR, including acute and chronic descending thoracic aortic dissections, pseudoaneurysms, traumatic aortic transections, and penetrating aortic ulcers with or without associated embolizing lesions (13).

Clinical Features

This study presents six patients who were admitted to our department between January-July 2023 for TEVAR procedure treatment of traumatic aortic transection, ruptured aortic aneurysms, chronic type B aortic dissections and penetrating aortic ulcers using JOTEC (E-VITA), and MEDTRONIC stent-grafts implants (one female and five males). Two male patients were victims of motor vehicle accidents, one of whom required a hybrid technique of left carotid-subclavian bypass using a 7 mm PTFE vascular graft with follow-up TEVAR. For all the six cases, the vascular grafts and stent grafts were deployed successfully, there was no intraoperative complication and no post-operative deaths. The patients were discharged from hospital in good clinical condition. Periodical

follow-ups are required to further document long-term survival in both acute and chronic cases.

Case Report I

A 44-year-old male patient, victim of a car accident (backseat passenger) was diagnosed with poly-trauma, including - minor head trauma, traumatic lesions at the level of the vertebral column (L1 and L2 regions), intrathoracic lesions (type B dissection of descending thoracic aorta; intramural hematoma of the aortic arch, including the descending aorta; pseudoaneurysm of isthmic aorta), 1st degree dilaceration of spleen, 1st degree dilaceration of kidneys and blunt trauma of osteoarticular structures (displacement of medial 1/3 and diaphysis of the left femur; fractures of the left radius and ulna).

The patient is deemed at a high mortality risk and becomes candidate for cardiovascular surgical treatment using a hybrid TEVAR procedure.

Computer Tomography (CT) scans following surgical repair of fractures reveal an acute traumatic transection of the aorta at the level of the ductus arteriosus and a rupture located just at the takeoff of the left subclavian artery (LSA) that is presented in *Fig. 1 A,B*. Without a dissection fold at the lower level of the descending thoracic and abdominal portions of the aorta. Right hemothorax present with an increase in volume (from 10 mm at admission scan to 18-20mm in a 6-day interval post general surgery intervention) and an enlargement of the pseudoaneurysm (from ~25 mm / 18 mm / 27 mm to ~25 mm / 30 mm / 35 mm).

The first step of our approach consists of a left carotid-subclavian bypass. The LSA, with a below average length, is discovered in a post scalenus position, leading to the practice of an anterior scalene muscle section (with the protection of the phrenic nerve). The left common carotid artery (LCCA) is discovered using a retro jugular approach, then it is clamped and the proximal anastomosis of the reinforced PTFE graft is performed by suturing "en surjet". Confirmation of patency of the proximal graft allows for de-clamping of the LCCA and clamping of the left subclavian artery (LSA) to begin suturing of the terminal anastomosis, as seen in *Fig. 1 E*.

The second and final step of our approach begins after the confirmation of patency at both ends of the by-pass, while the patient is kept under sedation and orotracheal ventilation for TEVAR procedure. Using an self-expandable graft the pseudoaneurysm is sealed as identified on intraprocedural angiographic imaging showed in *Fig. 1 C,D*.

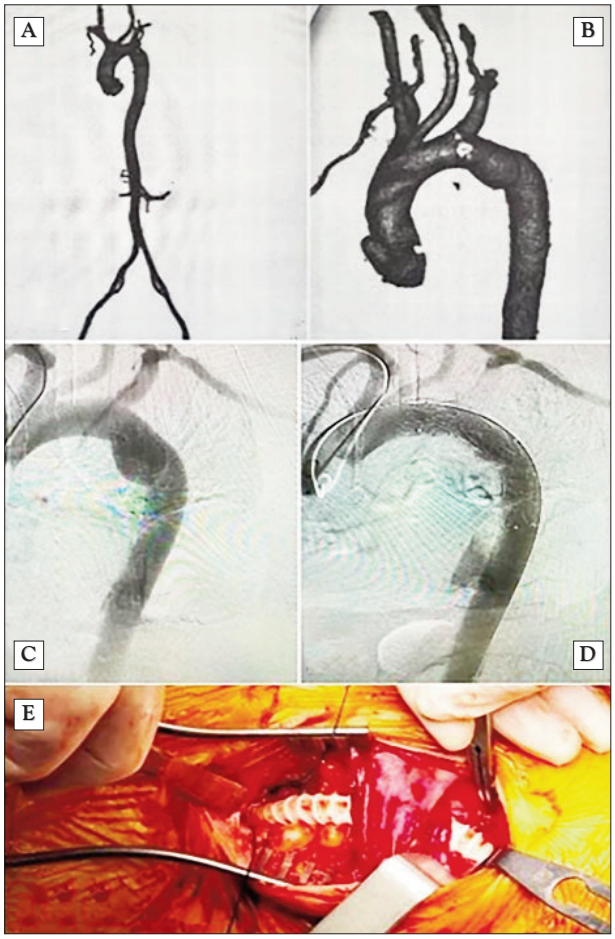

Figure 1. Case Report I imaging: (**A**,**B**) - 3D-CT preprocedural reconstruction of the aorta and close-up on the lesions of the Aortic Arch (left side projection); angiographic image before (**C**) and after (**D**) positioning of an E-VITA Thoracic 3G Straight Open of dimensions 26/26 x 130 mm downstream of the LCCA – zone 2 Ishimaru – and plugging of the LSA post the device implantation; (**E**) - Intraoperative aspect of the carotid-subclavian bypass.

Follow-up CT scan confirms permeability of the bypass with patency of cervical vascular structures. Similar result for the aortic graft. Evolution in the following days was favorable, with the patient hemodynamically stable, conscious, without post procedural complications. The patient is transferred to the general surgery ward and later discharged without significant events.

Case Report II

The second case is of a 27-year-old male patient, with a similar admission history of a 10-day-old polytrauma through car accident, diagnosed with:

post-traumatic aortic aneurysm; left basal hemothorax; bilateral pulmonary contusion; rib bone fractures at the 3rd-7th levels; operated displacement of medial 1/3 and diaphysis of the right femur; operated fracture of the right tibial malleolus; operated fracture of right talus.

CT scan reveals a saccular pseudoaneurysm originating on the medial fate of the descending aorta, ~48 mm from the LSA's origin (32 x 26 mm with a 28 mm colette) exerting a minimal compression on the left main bronchia and left side of the esophagus. An anatomical variant is present: patient has common origin of the brachiocephalic trunk and the LCCA as displayed in *Fig, 2*.

The same two-step approach is successfully performed as in the first described case. Post-procedural evolution is favorable with a fast uneventful recovery. No complications following intervention allow for a quick discharge. Patient is recommended to seek periodic orthopedic re-evaluation for the other injuries.

Case Report III

The following case is of a 65-year-old woman diagnosed with fissured aneurysm of the thoracic aorta with periaortic hematoma; light mitral and tricuspid failure with a left ventricle ejection fraction of 35-40%; class III NYHA hypertension; hyperlipidemia and hysterectomy for uterine fibroma. The patient is known with a history of heavy smoking and undergoing treatment for hypertension with carvedilol.

CT scan reveals a periaortic hematoma (D:81/40mm L:55mm) and bilateral pulmonary emphysema. The thoracic aorta is dilated with a maximum diameter of 35mm (at the level of the descending aorta), calcified atheroma is present and a lateral effraction is identified at this level. Also, a supradiaphragmatic hematic accumulation is viewed partially encircling the aorta (laterally and partially anterior and posterior sides) measured AP/T 81/40 mm, length of 55 mm.

Of significant note was that the intra-operative finding of the right common femoral artery is revealed to be fragile (5-6 mm) and deemed improper for implant of the inductor system. Therefore, an abdominal incision is performed at a pararectal level for the retro-peritoneal approach of the common iliac artery, in hope that this artery is more suited for induction of the graft. *Fig. 3* presents the post procedural CT angiography. Evolution under double platelet anti-aggregation (with clopidogrel) anti-hypertensives, painkiller and anti-inflammatory treatment is marked by an episode of pain during palpation of the right flank and hypochondrium.

Post-procedural thoraco-abdomino-pelvian CT scan with contrast confirms patency of stent

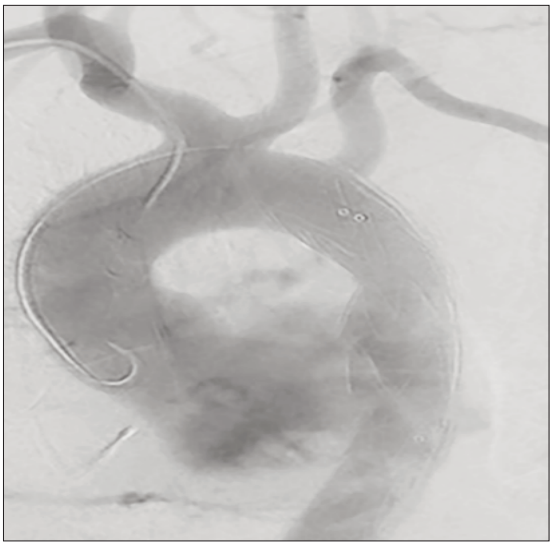

Figure 2. Angiographic image -Intraprocedural view of graft implantation, note LCCA's origin.

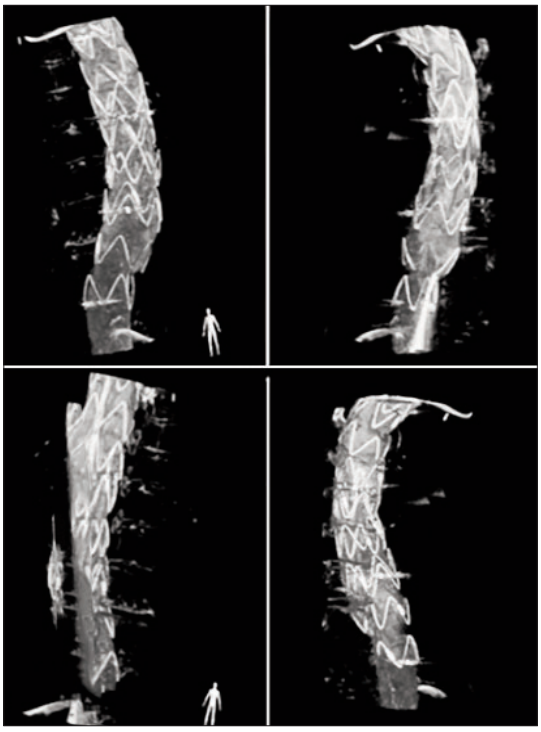

Figure 3. CT images showing multiple incidences of post-procedural stent-graft implat: (**A**) - anterior; (**B**) - left side; (**C**) - posterior; (**D**) - right side.

graft at level of the descending thoracic aorta, no leak is present; para-aortic accumulation of fluid on the left side of the descending aorta, sized 82/60/60 mm (A-P/TR/C-C); retroperitoneal accumulation of fluid (hematic component with gas bubbles) at the level of the right iliac fossa and right lumbar region, no active hemorrhage is detected. At the abdominal level slight enlargement of the liver and a possible hysterectomy stump are noted. After careful discussions with our general surgery colleague, the patient is diagnosed with choledolithiasis and since the patient had multiple cardiovascular comorbidities, she is scheduled for a coronary examination.

Following coronarography, it is determined that the interventricular artery (IVA) has atherosclerotic infiltrations, a 40-50% stenosis at the medial segment, the circumflex artery also presents infiltrations with a 30% stenosis of the marginal segment and the dominant right coronary artery (RCA), with severe infiltrations, 80-90% stenosis. With the patient approval and request, it is decided to implant two DES Xience ProA 3 X 38mm stents. The patient is discharged in good condition and is scheduled to seek surgical treatment for the newly diagnosed choledolithiasis.

Case Report IV

Next, a 67-year-old male who presented with recent history of massive hemoptysis with acute respiratory failure that required orotracheal intubation, mechanical ventilation, and vasopressor drug support was transferred to our hospital from an infectious disease hospital, where he was diagnosed with pseudoaneurysm of descending thoracic aorta caused by ruptured atherosclerotic plaque after a series of paraclinical investigations (video bronchoscopy showed extrinsic compression of inferior lobe of left lung without any evidence of neoplastic disease while the thoracic CT with intravenous contrast showed saccular pseudoaneurysm of descending thoracic aorta with periaortic collection of ~3 cm causing compression of segmental bronchi of inferior lobe of left lung).

CT-scan in our department diagnosed a ruptured pseudoaneurysm of descending thoracic aorta. CT angiography reveals an aortic ulceration (maximal width of about 20 mm, measuring 26/38/54 mm TR/AP/CC) at the T8 level of the DTA which lead to the pseudoaneurysmal formation, presenting a peripheral thrombosis process, leaving an active portion measuring 26/9/17 mm (TR/AP/CC). In lateral position to the pseudoaneurysm a liquid collection is discovered, maximal width of 8 mm. The thoracic aorta at the level of the arch, descending portion and the abdominal aorta present slightly irregular contours, with multiple mixed circumferential plates (up to 6mm thickness), with multiple ulcerations (the largest located immediately above the emergence of the celiac trunk, with a package of approximately 8 mm and axial dimensions of 9/5 mm).

The patient also presents an anatomical variation: origin of the right subclavian artery (RSA) at the level of the aortic arch (artera lusoria) with a retroesophageal trajectory as shown in *Fig. 4 A*.

The patient was transferred to catheterization lab where endovascular repair of the descending thoracic aorta pseudoaneurysm using Jotec 36/36/23 stent graft implantation was performed through right approach of common femoral artery.

Follow-up CT examination 48 hours after the procedure showed a fully expanded thoracic aorta prosthesis from the origin of right sub-clavicular artery until the level of diaphragmatic level of descending thoracic aorta. The pseudoaneurysm was excluded from circulation. No periprosthetic endoleak was observed. Some intraprosthetic thrombosis was observed as presented in *Fig. 4 B*.

Postprocedural evolution is favorable under anticoagulant treatment. Apixaban was used as this anticoagulant was used previously by the patient. The patient was discharged with the recommendations of periodic CT scan evaluation of endoprosthesis and continuation of oral anticoagulant medication.

Case Report V

We present a case of a 38-year-old male patient, known with hypertension, dyslipidemia and a mild ectatic ascending aorta on bicuspid valve, with moderate aortic insufficiency.

On admission to the hospital, the patient presented with a subacute type B aortic dissection (on the 4th week of evolution); and biological signs of visceral hypoperfusion - a creatinine increase to 6 mg/dL with progressive renal failure signs.

After CT angiography is performed, we find ourselves in front of Type B subacute aortic dissection starting close to the left subclavian artery and extending the full length of the

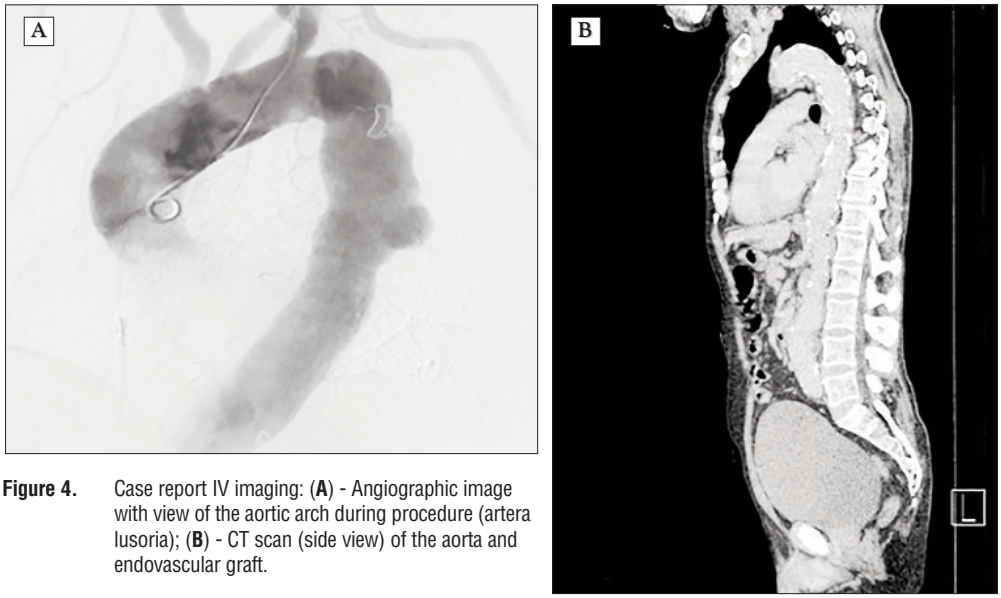

Figure 4. Case report IV imaging: (**A**) - Angiographic image with view of the aortic arch during procedure (artera lusoria); (**B**) - CT scan (side view) of the aorta and endovascular graft.

thoracic and abdominal aorta, with both iliac arteries involved, as seen in the multiple slides of *Fig. 5*.

Furthermore, we have to mention that the true lumen is excessively compressed at the distal thoracic and abdominal aorta. The true lumen being compressed by the false lumen, locally the celiac trunk is very hard to separate. Moreover, several intercostal arteries were perfused from the false lumen.

After seeing the CT angiography result, we decided to have a 2-step hybrid approach. First, we performed a carotid-subclavian artery bypass with left subclavian artery ligature. The following day, TEVAR with valiant captivia thoracic endoprosthesis. As operative mentions, the patient underwent general anesthesia, right radial approach with 5f sheath, and right femoral approach by surgical cut-down and 7f sheath.

The patient had a good procedural result with a

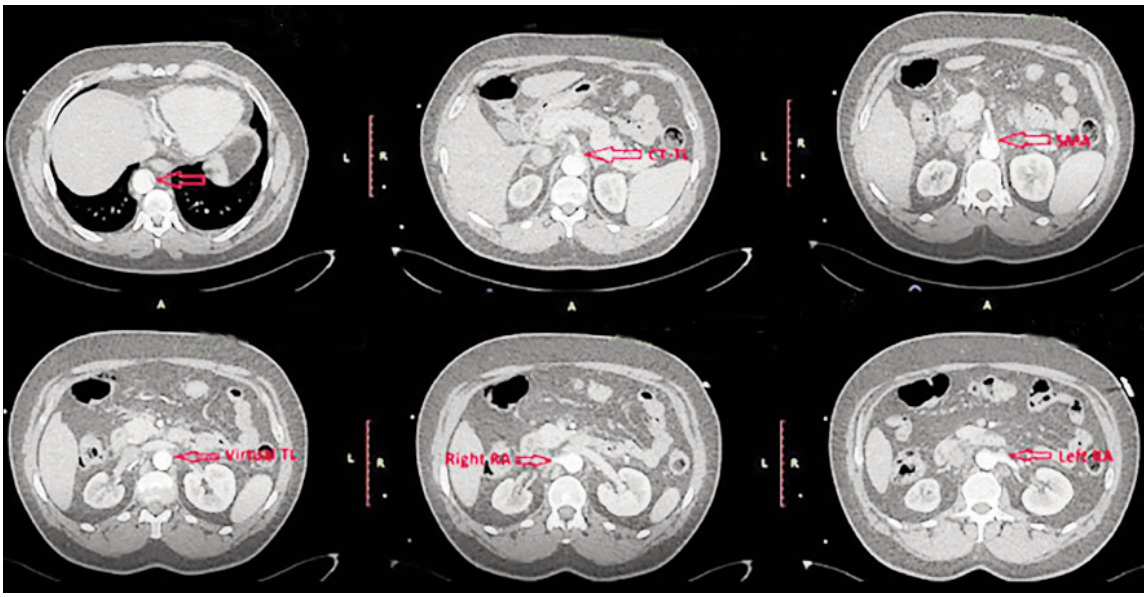

Figure 5. CT angiography images of Type B aortic dissection.

regression in renal failure. He was discharged 5 days after the procedure with a creatinine of 1.38mg/dL.

Case Report VI

Lastly, we present the case of a 70-year-old patient who presented in the ER for hemoptysis. On CT angiography evaluation the patient is diagnosed with a penetrating aortic ulcer (PAU) at the level of the descending aorta that associated bronchi erosion, as seen in *Fig. 6 A.*

After careful preoperative planning as observed in *Fig. 6 B* we decided that the best option was performing TEVAR with two Medtronic stent-grafts. As operative mentions, we used a therapeutic approach with surgical exposure of the right common femoral artery for the 24 sheath Fr. and a diagnostic pigtail via the right radial artery. There was an optimal angiographic result, as seen in *Fig. 6 C,D.* The patient had a good postprocedural evolution, and he was discharged on his 5th postprocedural day.

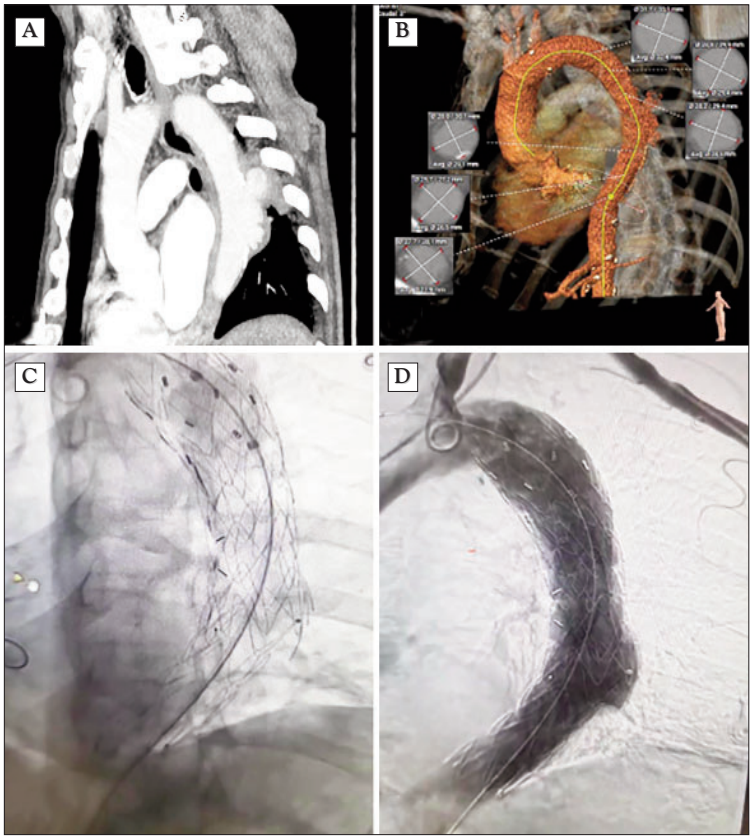

Figure 6. Case Report VI imaging: (**A**) - 3D-CT reconstruction of penetrating aortic ulcer (PAU) of descending aorta; (**B**) - 3D-CT TEVAR planning; (**C, D**) – Angiographic image of optimal TEVAR result.

Discussion

TEVAR is a procedure which sees a continuous increase in application nowadays, current advancements making us hope for it to become a complete replacement of open repair of conditions affecting the thoracic aorta, both those caused through blunt trauma or from chronic diseases (5,14). Further study is required to determine mortality and long-term survival rates in patients post-TEVAR procedures (15). Thoracic endovascular aortic repair is a new step in the development of personalized, minimally invasive interventions (16). Polytrauma patients would receive the most benefit of reparatory surgery, even when deemed high-risk for classic procedures, if we take into consideration the benefits of minimal invasive treatment such as avoiding postoperative complications associated with the classic treatment (renal insufficiency, spinal cord ischemia and infection of the graft) (10, 17-23). The prospect of a multi-purpose endovascular technique is promising yet more research needs to be put into improving cost-effectiveness and study long time patency of the grafts (11,24-33).

Many studies highlight the superior outcomes associated with TEVAR, particularly in terms of survival rates, lower complication rates, and reduced mortality when compared to traditional open repair (OR). These findings demonstrate that TEVAR is a safer, less invasive, and equally cost-effective alternative to open surgery (34-36).

A study conducted in 2019 by Agostinelli et al. evaluated the long-term outcomes of TEVAR for blunt thoracic aortic injuries (BTAI) over a 20-year period at a single center. Among 35 patients treated since 1998, TEVAR showed excellent success rates, with survival rates of 92% and 87% at 5 and 10 years, respectively, and freedom from aortic redo of 96% and 91%. The findings highlight the durability and effectiveness of the procedure, with no aorta-related deaths and minimal complications, emphasizing the importance of ongoing surveillance with cross-sectional imaging (34).

Azizzadeh et al. conducted a study comparing TEVAR to OR for treating traumatic aortic injury (TAI), a leading cause of death after blunt trauma.

Analyzing data from 106 patients, they found that TEVAR was associated with significantly fewer complications, including in-hospital mortality, compared to OR (48% vs. 69.6%). Although TEVAR patients were older and had longer preoperative hospital stays due to delayed selective management, the total hospital costs were similar between the two groups. The study highlights TEVAR as a safer and equally cost-effective alternative to OR, supporting its preferential use for TAI patients. This aligns with clinical guidelines recommending endovascular repair for improved patient outcomes (35).

Al-Thani et al. conducted a retrospective study to evaluate the management and outcomes of BTAI center between 2000 and 2020. Among 87 patients (82% male, mean age 37.3), 40% were treated conservatively whereas aortic interventions were performed in 60% of cases: 63.5% TEVAR and 36.5% open surgery. TEVAR had the lowest in-hospital mortality rate (6.1%) compared to OR (31.6%) and conservative management (40.0%), demonstrating a clear survival advantage and was recommended as the preferred approach for severe BTAIs unless contraindicated (36).

TEVAR complications include endoleaks, upper extremity limb ischemia, cerebrovascular ischemia, spinal cord ischemia, and post implantation syndrome (37). While TEVAR eliminates the embolism risk associated with aortic cross-clamping and cardiopulmonary bypass, it can still lead to embolization from manipulating a diseased aortic arch and great vessels, and remains associated with a frequent complication of acute kidney injury (AKI) (incidence up to 34%) (38-40).

The risk of stroke increases with greater aortic coverage, occlusion or coverage of the left subclavian artery (LSA), perioperative hypotension, and prolonged surgery (41). The incidence of endoleak after TEVAR ranges between 4% to 15%, and its development can be influenced by several factors such as large aneurysm size, coverage of the left subclavian artery, tortuous aortic anatomy, and a shorter landing zone. Careful consideration of these factors during the procedure can help minimize the risk of endoleak. Graft migration after TEVAR occurs in 1-3% of cases, often during deployment or when the delivery system is removed. Delayed migration is typically associated with aneurysm neck dilation, tortuous aortic anatomy, and excessive graft oversizing (42).

Open surgical repair has several significant disadvantages compared to endografting (5), these include: the necessity for a posterolateral thoracotomy or thoracoabdominal incision depending on the extent of the required repair, single lung ventilation is required, full or partial cardiopulmonary bypass, possible circulatory arrest and hypothermia (3).

Studies show that TEVAR is more cost-effective than open surgery when considering the overall costs from admission to discharge. Although the initial procedure cost for TEVAR (£26,536) is higher than open surgery (£17,239) due to the expense of stent graft devices, these higher upfront costs are offset by significant savings in the post-procedure period. The total cost from admission to discharge is lower for TEVAR (£34,020) compared to open surgery (£45,875), indicating that TEVAR leads to overall cost savings despite its higher procedural costs. While surgical costs for TEVAR are higher due to device expenses, open surgery has higher in-hospital costs due to longer hospital and critical care stays. Follow-up costs over 12 months are slightly higher for TEVAR, mainly due to hospital readmissions (43). TEVAR proves to be a more cost-effective option compared to traditional surgical methods, not only during the initial hospital stay but also in the long-term, as demonstrated by studies evaluating both in-hospital and post-intervention costs (44,45).

The fast pace of change in the field of minimal invasive procedures reveals the importance of continuous study of literature and peer-review of case studies. Follow-up care and periodic checkups on our patients will help to better establish efficiency of technique, drawbacks in current technique, possible limits, and future improvements to be implemented. Multi-year studies on post-TEVAR patients will help to better understand patient life expectancy with given personal medical history and comorbidities (19,20).

Understanding of anatomical variation and pathophysiology will also receive benefits from development of better imaging (17). The road towards real-time digitally reconstructed anatomical structures is still in its nascency, yet it continues to prove an essential tool for a growing number of applications like minimal invasive treatment of high-risk patients deemed unsuited for classic open procedures (30,32).

Conclusions

Today, TEVAR procedures represent a superior alternative to classic open surgery, especially in these 4 aortic diseases presented. Both immediate and mid-term results are superior when compared to open surgery approach. We will continue to

follow up the patients for a long-term result analysis.

From our clinical experience, debranching technique is beneficial before the implantation of the stent graft as it creates an adequate landing zone that aids in the prevention of medullar and superior limb ischemia.

Last but not least, the rising endovascular methods give us the opportunity to solve in a fast, safe, and efficient manner both chronic and acute clinical cases.

Conflict of Interest

The authors declare no conflict of interest.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

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