Thoracic Aortic Trauma:

Who Gets Endovascular Intervention and How to Optimize Outcomes

The management of blunt thoracic aortic injury, from mechanism of injury and history of repair to indications for endovascular intervention, TEVAR techniques, and potential complications.

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Thoracic aortic trauma is a highly lethal event that can occur via a blunt or penetrating mechanism. For patients who survive to hospital admission, endovascular therapy is possible in many instances and offers a minimally invasive, less morbid treatment option relative to traditional open repair.

MECHANISM OF INJURY AND DIAGNOSIS

For blunt aortic injury (BAI), the portion of the thoracic aorta most susceptible to the stress produced on impact, particularly in cases of rapid deceleration, occurs distal to the left subclavian artery (LSA) and proximal to the third intercostal artery. This location is where the relatively mobile descending thoracic aorta joins the fixed aortic arch and is tethered 1 cm distally to the left pulmonary artery by the ligamentum arteriosum.[1-3] This location, referred to as the aortic isthmus, is the most common site of injury—noted in 54% to 66% of BAI patients in autopsy series and > 85% of patients who arrive to the hospital alive.[1,4-8] However, the exact mechanism by which these biomechanical forces translate to tissue disruption in blunt thoracic aortic injury (BTAI) is still debated, largely due to a lack of reproducible animal models and a wide spectrum of injury patterns.[1,3,9]

Chest radiography (CXR) is an adjunct to the Advanced Trauma Life Support secondary survey and is the initial imaging modality in both penetrating and blunt thoracic trauma. Some CXR clues to potential aortic injury include hemothorax, widened mediastinum, rib fractures, blunting of the aortic knob, or tracheal deviation. Unfortunately, the sensitivity of CXR for BAI is < 50%; thus, certain mechanisms of injury should trigger CTA, the gold standard diagnostic modality.[10-12] Patients who have experienced a rapid deceleration event (eg, a fall from > 3 times an individual's height, a vehicle moving > 40 mph, ejection from vehicle, significant vehicle intrusion, death in the same vehicle, vehicle moving > 20 mph vs pedestrian or cyclist) should undergo CTA, which is > 95% sensitive in detecting thoracic aortic injury.[13]

BAI of the proximal descending thoracic aorta is graded from 1 to 4 based on severity. Grade 1 injuries involve an intimal tear, grade 2 injuries have both intimal disruption and intramural hematoma, grade 3 BAI encompasses pseudoaneurysms without arterial phase contrast extravasation, and grade 4 injury is free rupture of the aorta.[14] Injury grade helps determine the need for repair and is predictive of mortality risk.[15]

EVOLUTION IN BLUNT THORACIC AORTIC INJURY MANAGEMENT

The first reports of BTAI date back as early as 1557.[16] Its incidence, both in the emergency department and in medical literature, has risen largely in parallel with the automotive industry because it is most frequently a result of a motor vehicle crash.[17,18] The first reported successful repair of an acute traumatic thoracic aortic injury was in 1958.[19] Throughout the next 4 decades, open repair via conventional high left posterolateral thoracotomy with or without cardiopulmonary bypass became the first-line treatment for BTAIs. Although the risk of impending rupture or ongoing hemorrhage necessitated intervention in patients whose other associated injuries were compatible with survival, the morbidity and mortality associated with open repair was considerably high. Of the 72% to 81% of patients who survived the procedure, up to 14.3% developed paraplegia secondary to spinal cord ischemia (SCI).[20-23]

Open repair remained the only treatment option for BTAI up until the turn of the 21st century. Four years after the first endovascular approach for aortic repair was performed by Drs. Juan C. Parodi and Julio Palmaz in 1990,[24] Dake et al described the first successful thoracic endovascular aortic repair (TEVAR) in a series of 13 patients.[25] The diagnosis and management of BAIs have since rapidly evolved over the last 2 decades. The risk of complications such as stroke, extremity ischemia, and SCI still exist with TEVAR, but evidence from numerous studies have reported a significant improvement in morbidity and mortality with TEVAR compared with open repair.[14,26,27]

During this time, the diagnosis of BAI also experienced significant change. A review of multicenter studies performed by the American Association for the Surgery of Trauma confirmed that CTA has replaced conventional aortography and transesophageal echocardiography (TEE) for definitive diagnosis of BTAI.[28] As advancements have translated to more prompt, accurate diagnoses and improved overall survival, the focus of surgeons today has shifted toward optimizing the endovascular approach, device selection, role of adjunct technologies such as intravascular ultrasound (IVUS), and long-term postoperative surveillance with CTA.

INDICATIONS FOR INTERVENTION AND ANATOMIC CONCERNS FOR ENDOVASCULAR REPAIR

Penetrating aortic injury with arterial phase contrast extravasation, aortic pseudoaneurysm, or intra-aortic foreign body are firm indications for open surgical or endovascular intervention. Endovascular therapy has become first-line when anatomically feasible. The goal of any intervention is to prevent fatal hemorrhage and preserve flow to the brain and upper extremities. The primary anatomic constraint to endovascular therapy is preservation of flow into the great vessels of the aortic arch.

Regarding blunt trauma, the advent of TEVAR revolutionized treatment in the past 20 years.[29,30] Endovascular therapy has become the standard treatment for BAI of the descending thoracic aorta.[31] Although the 2011 Society for Vascular Surgery guidelines called for treating grade 2, 3, and 4 injuries with stent grafts,[14] observational studies in the past decade have proven conservative management with blood pressure (BP) control and serial imaging are safe in grade 2 injuries, with < 5% progressing to TEVAR and an aortic-related mortality rate < 2%.[32,33] Pseudoaneurysm and frank rupture (grade 3 and 4 injuries) remain firm indications for intervention. Intramural hematoma (grade 2) lies in the clinical judgment arena, with features such as extensive pleural effusion or hemomediastinum serving as relative indications for TEVAR. In addition, patients with grade 2 and 3 BAIs transferred to level 1 trauma centers with aortic care expertise have documented improved survival.[34] Strict systolic BP control to < 140 mm Hg is recommended for all patients being managed conservatively.

For patients who survive penetrating or blunt trauma to the ascending aorta or arch, open surgery remains the standard. Larger case series report the ascending aorta as the site of injury in 3.2% to 14% of blunt aortic trauma cases secondary to motor vehicle crash.[5,8] Such injuries are often highly lethal, with the majority of patients pronounced dead at the scene.[4] Despite recent techniques advancements for thoracic aortic trauma, the prognosis of ascending aortic injuries remains poor. Reviews of case reports published between 1996 to 2020 report successful repair via an open approach for ascending aortic arch injuries; however, none describe the use of endovascular techniques.[35-40] Although recent improvements have been made in perfusion via the axillary artery and use of intraoperative TEE, operative mortality after blunt traumatic injury of the ascending aorta/aortic arch remains high.[41] In a multicenter study of 17 patients presenting with traumatic ascending/aortic arch injuries from 2000 to 2011, open surgical repair was performed in 30% of patients, with an overall mortality rate of 53%.[37] There are sparse reports of endovascular therapy performed in conjunction with chimney parallel grafts of the innominate and left common carotid arteries for ascending aortic and arch injuries.[42]

TECHNIQUE: THORACIC AORTIC ENDOGRAFTING FOR TRAUMA

The guiding principle of TEVAR for trauma is to exclude the injured segment of aorta by landing an appropriately sized covered stent 2 cm proximal and distal to the injured segment, whereby blood flows through the stent graft and is excluded from potential extra-aortic flow. Minimal stent oversizing of 5% to 10% of the native aortic diameter is recommended to minimize the risk of retrograde aortic dissection. Trauma patients often present in a volume-depleted state, which can result in a modest reduction of aortic diameter estimation on the initial CTA. Therefore, usage of IVUS at the time of TEVAR is a helpful adjunct to measure aortic diameter during systole, intraoperatively after intravenous fluid administration.[42-47] The shortest possible stent graft that achieves seal should be selected to minimize the risk of SCI.

TEVAR can typically be accomplished via an entirely percutaneous approach using suture-mediated closure devices. If concomitant extremity injuries exist, a unilateral access approach can be achieved using a buddy wire for marker pigtail catheter insertion simultaneous to the large-bore TEVAR system. The extent of heparinization should be tailored to the presence and severity of coexisting injuries. Although the large-bore sheath necessary for TEVAR creates lower extremity thrombotic risk, anticoagulation use must be weighed against risk of intracranial or intracavitary hemorrhage.

After initial arterial access, power injection aortography should be performed in left lateral oblique projection (30°-40°) via a diagnostic catheter 5 to 6 cm proximal to the injury. Care should be taken to ensure no air is in the injector or catheter tubing before power injection to minimize air embolic stroke potential. If IVUS is used, this adjunct can precede or follow the initial diagnostic angiogram.

Angiography is ideally performed with a stiff guidewire with a curved tip simultaneously in place that courses the aortic arch and is parked in the ascending aorta to mimic the degree of tortuosity present when the stent graft is deployed. It is also beneficial to pass the stent graft device over the stiff wire into the segment just distal to the injury at the time of the immediate predeployment angiography. The stent graft should then be deployed with ideally 2 cm of fixation proximal to the injury. In-stent balloon angioplasty is reserved for type I endoleaks or incompletely expanded stent grafts with a bird's beak phenomenon detected on secondary angiography.

Figure 1 is a case example of a proximal descending grade 3 BTAI with pseudoaneurysm. IVUS was used to facilitate true lumen sizing and ensure the guide-

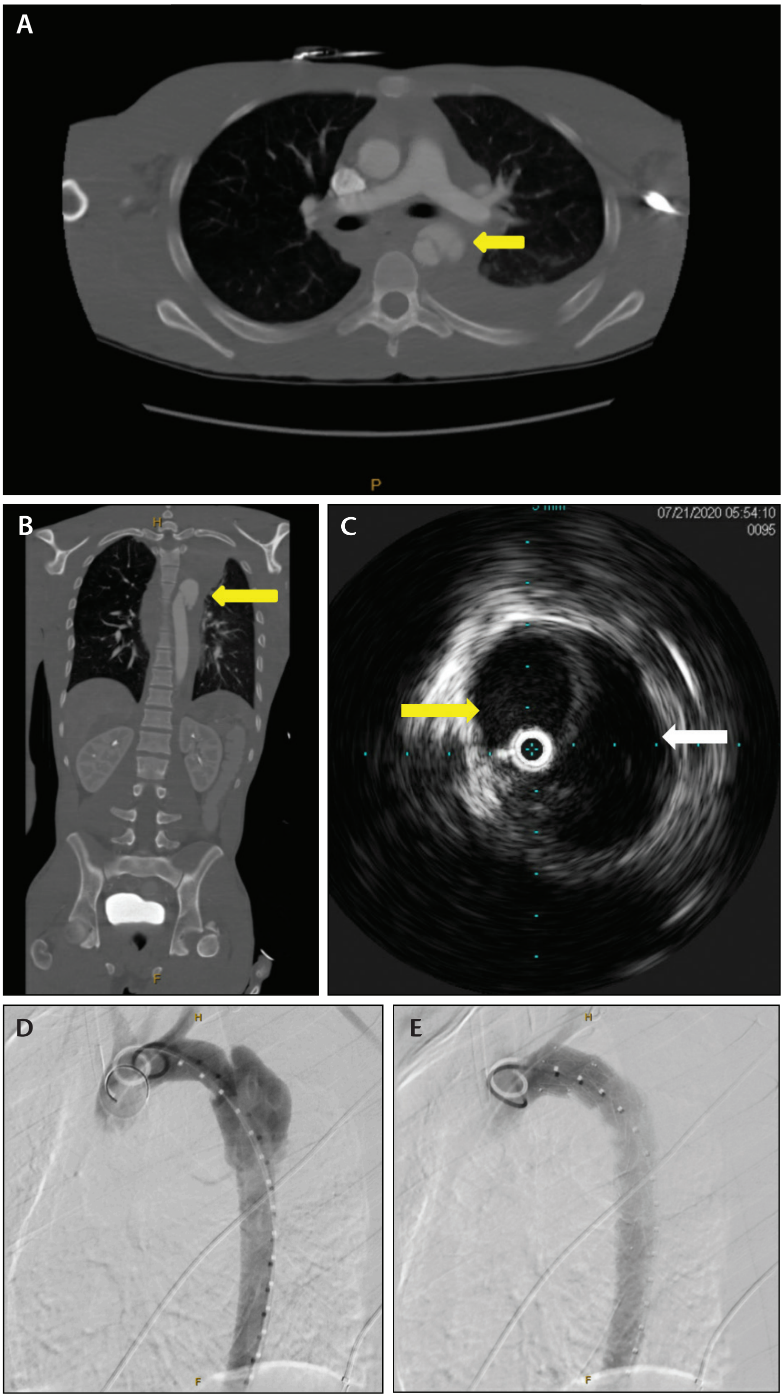

Figure 1. Grade 3 traumatic disruption of the proximal descending thoracic aorta secondary to motor vehicle accident in a 26-year-old man. Axial (A) and coronal CTA (B) revealed an intimal flap, pseudoaneurysm, and apical hematoma (yellow arrows). IVUS was used to optimize stent graft sizing with measurements during systole (C); the true aortic lumen (yellow arrow) and pseudoaneurysm (white arrow) are well distinguished on IVUS. Intraoperative angiogram before and after covered stent placement images (D, E). Exclusion was feasible in this case without subclavian artery coverage.

wire is traversing the true lumen of the aorta. Exclusion was feasible in this case without subclavian artery coverage. The most common location of blunt aortic disruption is at the aortic isthmus, 2 to 4 cm distal to the LSA origin. Coverage of the LSA is therefore needed in 35% of BAI. Stroke risk is < 3% with LSA coverage in the acute trauma setting.[48] Given the frequency of multiple coexisting complex injuries, left carotid-subclavian bypass is not typically performed in the traumatic aortic injury setting. If signs of hand ischemia or vertebral steal syndrome develop after LSA coverage, then subsequent left carotid-subclavian bypass or subclavian-carotid transposition can be performed.

Indications to perform prophylactic LSA revascularization include the presence of a left internal thoracic (mammary) artery coronary bypass or an occluded/atretic right vertebral artery with left vertebral patency and dominance. Using proximal landing zones as short as 15 mm has been reported with acceptable outcomes to avoid LSA coverage.[49] Off-the-shelf single fenestrated endografts to achieve LSA preservation in the trauma setting have recently been described as well.[50,51] Figure 2 depicts a grade 3 BAI directly adjacent to the LSA, which necessitated coverage to achieve a proximal seal. This patient tolerated LSA coverage well, with no postoperative neurologic or upper extremity ischemic symptoms.

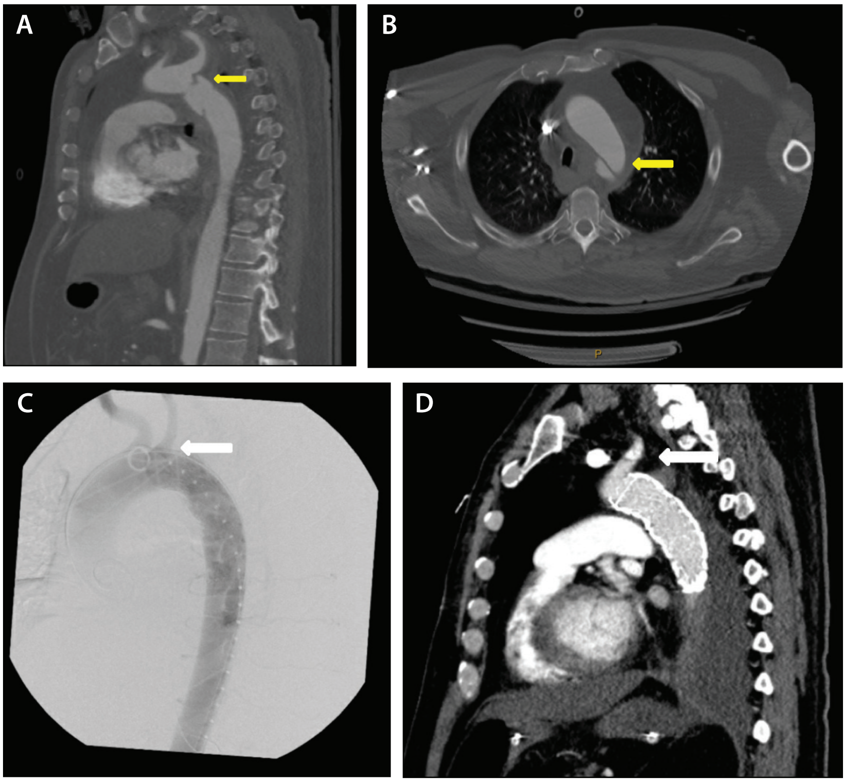

Figure 2. Blunt traumatic disruption of the descending thoracic aorta in a 63-year-old man directly adjacent to the LSA. CTA showed extensive mediastinal hematoma and complete intimal separation (yellow arrows) (A, B). Subclavian artery coverage with stent graft landing just beyond the left common carotid artery was necessary. Carotid preservation was seen on intraoperative completion angiogram and follow-up CTA (white arrows; C, D).

TIMING OF INTERVENTION

For grade 3 BAIs, it can be challenging to determine whether to go forward with emergent repair versus wait 24 to 48 hours to optimize management of other injuries before aortic intervention. Delaying intervention for 24 hours is associated with a 50% reduction in mortality for patients with BAI across equal injury severity scores.[52] Nevertheless, potential for bias exists in this retrospective assessment because patients selected for immediate intervention would likely have more concerning clinical presentations not detectable in large database retrospective reviews. A recent retrospective review of grade 3 injuries identified admission lactate > 4 mm, posterior mediastinal hematoma > 10 mm, and lesion/normal aortic diameter ratio > 1.4 on the admission CT to be independently associated with aortic rupture.[53] Timing of stent graft deployment remains an individualized process, prioritizing immediate ongoing hemorrhage followed by hemodynamic stabilization and correction of any metabolic derangement before proceeding with TEVAR if feasible. Real-world decision-making is confounded by variables such as availability of operating rooms, adequate range of implantables, appropriate equipment, and optimal staff to manage equipment. In addition, coexisting brain or spinal cord injuries may contraindicate a systolic BP goal of < 130 mm Hg and mandate TEVAR sooner.

COMPLICATIONS, OUTCOMES, AND FOLLOW-UP

TEVAR-specific complications include stroke, SCI/paralysis, access site–related lower extremity thrombosis or hemorrhage, contrast nephropathy, retrograde aortic dissection, endoleak, and long-term risk of stent graft collapse that induces either acute ischemia or a coarctation phenomenon.

Avoidance of SCI is facilitated with cerebrospinal fluid drains in TEVAR for aneurysm disease, but it is not recommended in the trauma setting because most cases can be treated with just 10 to 20 cm of aortic coverage. Further, there is an increased risk of epidermal hematoma in unstable trauma patients, as well as logistical issues with obtaining timely off hours during spinal drain placement.[14] In patients with symptoms of SCI in the postoperative period, spinal drain placement and a maintained mean arterial pressure > 90 mm Hg is recommended.

Hemorrhagic risk can be reduced by reversing heparin with protamine at the completion of TEVAR. Minimizing stent graft oversizing and in-stent ballooning help minimize the risk of retrograde aortic dissection.

Newer-generation nitinol-based stent graft systems with increased conformability, smaller diameters, and lower-profile TEVAR systems have reduced the incidence of stent graft collapse and nonconformity of devices to aortic arch tortuosity. FDA-approved devices for traumatic aortic injury include the Conformable Gore TAG thoracic endoprosthesis (Gore & Associates), Valiant Navion device (Medtronic), and RelayPlus stent graft (Terumo Aortic).

Robust retrospective reviews in recent years have seen an 18% rate of overall in-hospital mortality for patients with thoracic aortic trauma, with 7% aortic-related mortality for BAI. This is reduced relative to historical cohorts because treatment has shifted from open repair to TEVAR.[54]

Long-term aortic surveillance with serial CTA is recommended to detect any partial stent graft collapse, endoleaks feeding a persistent pseudoaneurysm, development of aortic coarctation, or device migration. Most patients experience fairly rapid aortic healing, after which imaging frequency can be reduced to minimize long-term radiation exposure.[55] Long-term BP surveillance is recommended to capture any clinically significant coarctation. Finally, patients with subclavian artery coverage should be advised of an expected reduction in left arm systolic BP measurements and potential symptoms of hand ischemia or vertebral steal syndrome.

CONCLUSION

Endovascular therapy has emerged as the standard of care in treating grade 3 and 4 BTAI, as well as select grade 2 injuries. TEVAR offers an effective approach that is minimally invasive with lower morbidity and mortality relative to traditional open repair. ■

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