OPEN

American Association for the Surgery of Trauma–World Society of Emergency Surgery guidelines on the diagnosis and management of major thoracic vascular injuries

Leslie Kobayashi, MD, FACS, Louis Perkins, MD, Will Johnston, MD, Lisa Kurth, MD, Kendra Black, MD, Fikri Abu-Zidan, MD, FRCS, Goran Augustin, MD, PhD, Zsolt J. Balogh, MD, PhD, FRACS, FAOrthA, FACS, Walter L. Biffl, MD, FACS, L. D. Britt, MD, FACS, MPH, Fausto Catena, MD, PhD, FRCS, Ian Civil, MB, ChB, FRACS, Federico Coccolini, MD, Dimitris Damaskos, MBBS, FRCS, FACS, Nicola De'Angelis, MD, PhD, Belinda De Simone, MD, Joseph M. Galante, MD, MBA, FACS, Adenauer M. O. Góes, Jr., MD, Jose Gustavo Parreira, MD, PhD, Timothy Hardcastle, MBChB, PhD, FCS, Kenji Inaba, MD, FACS, FRCSC, Andrew Kirkpatrick, MD, FRCSC, FACS, Yoran Kluger, MD, Ari Leppäniemi, MD, PhD, Ron Maier, MD, FACS, Ernest E. Moore, MD, FACS, Andrew B. Peitzman, MD, FACS, Mauro Podda, MD, FACS, Massimo Sartelli, MD, Thomas M. Scalea, MD, FACS, Philip Stahel, MD, FACS, Edward Tan, MD, Matti Tolonen, MD, PhD, Dieter Weber, MBBS, FRACS, *and* **Raul Coimbra, MD, PhD, FACS**, *San Diego, California*

In the United States, 7% of patients arriving at adult level 1 trauma centers are diagnosed with a torso vascular injury, and about half of these cases will present with hemorrhage.[1] Hemorrhage is the leading cause of potentially preventable death following trauma.[2,3] Noncompressible torso hemorrhage (NCTH) from vessels in the thorax, abdomen, and pelvis is especially lethal, with death occurring in approximately 45% of cases. Blunt and penetrating mechanisms account for 65% and 35% of NCTH, respectively.[1] In one retrospective multicenter NCTH study, the chest was involved in 25% of cases. The most

Submitted: September 11, 2025, Accepted: September 30, 2025, Published online: December 17, 2025.

From the Division of Trauma, Surgical Critical Care, Burns and Acute Care Surgery, Department of Surgery (L. Kobayashi, L.P., W.J.), University of California San Diego School of Medicine; Sharp Healthcare (L. Kurth), San Diego, California; Division of Trauma/Surgical Critical Care, Department of Surgery (K.B.), University of Tennessee Health Science Center, Memphis, Tennessee; Department of Surgery (F.A.-Z.), College of Medicine and Health Sciences, United Arab Emirates University, Al-Ain, United Arab Emirates; Division of Oncologic Surgery, Department of Surgery (G.A.), University Hospital Centre Zagreb, Zagreb, Croatia; Department of Traumatology (Z.J.B.), John Hunter Hospital, University of Newcastle, Newcastle, New South Wales, Australia; Scripps Clinic/Scripps Clinic Medical Group, Division of Trauma Surgery (W.L.B.), La Jolla, California; Department of Surgery (L.D.B.), Eastern Virginia Medical School, Norfolk, Virginia; Department of Medical and Surgical Sciences (F. Catena), University of Bologna, Bologna; Department of General and Emergency Surgery (F. Catena), Bufalini Hospital, AUSL Romagna, Cesena, Italy; Trauma Services (I.C.), Auckland City Hospital, Auckland, New Zealand; General Emergency and Trauma Surgery (F. Coccolini), Pisa University Hospital, Pisa, Italy; Department of General Surgery (D.D.), Royal Infirmary of Edinburgh, Edinburgh, United Kingdom; Department of General Surgery (N.D.), Fondazione Poliambulanza, Brescia; Department of Translational Medicine (N.D.), University of Ferrara, Ferrara; Department of Emergency and General Minimally Invasive Surgery (B.D.S.), Trauma Hub Center, Bufalini Hospital, AUSL Romagna, Cesena, Italy; Hospital Clinical Care Services, Department of Surgery (J.M.G.), University of California Davis Health, Davis, California; Centro Universitário do Estado do Pará—CESUPA, Department of Surgery (A.M.O.G.); Universidade Federal do Pará, Department of Surgery, Belem (A.M.O.G.); Department of Surgery (J.G.P.), Santa Casa School of Medical Sciences, Sao Paulo, Brazil; Trauma, Burns, and Critical Care (T.H.), Inkosi Albert Luthuli Central Hospital; Department of Surgery, School of Medicine (T.H.), University of KwaZulu-Natal, Durban, South Africa; Division of Trauma and Surgical Critical Care (K.I.), Los Angeles General Medical Center, University of Southern California, Los Angeles, California; Department of Surgery (A.K.), and Department of Critical Care Medicine (A.K.), Foothills Medical Centre of the University of Calgary, Calgary, Alberta, Canada; Department of Surgery (Y.K.), Faculty of Medicine of the Technion-Israel Institute of Technology, Haifa, Israel; University of Helsinki, Department of Surgery (A.L.), Helsinki, Finland; Department of Surgery (R.M.), Harborview Medical Center, University of Washington, Seattle, Washington; Department of Surgery (E.E.M.), Denver General Hospital, University of Colorado School of Medicine, Denver, Colorado; Department of Surgery (A.B.P.), University of Pittsburgh School of Medicine, Pittsburgh; Department of Surgical Science (M.P.), University of Cagliari, Cagliari, Italy; Department of General and Emergency Surgery (M.S.), Macerata Hospital, Macerata, Italy; R Adams Cowley Shock Trauma Center (T.M.S.), University of Maryland, Department of Surgery; Banner Wyoming Medical Center, Department of Surgery (P.S.), Casper, Wyoming; Division of Trauma Surgery, Department of Surgery (E.T.), Radboud University Medical Center, Department of Surgery, Nijmegen, the Netherlands; Emergency Surgery (M.T.), Abdominal Center, HUS Helsinki University Hospital, University of Helsinki, Department of Surgery, Helsinki, Finland; Trauma Service, Department of General Surgery (D.W.), Royal Perth Hospital; School of Surgery, University of Western Australia (D.W.), Perth, Australia; Riverside University Health System Medical Center, Department of Surgery (R.C.); and Loma Linda University School of Medicine (R.C.), Moreno Valley, California.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).

Address for correspondence: Louis Perkins, MD, Division of Trauma, Surgical Critical Care, Burns and Acute Care Surgery, Department of Surgery, University of California San Diego School of Medicine, 200 West Arbor Dr, 8896, San Diego, CA; email: laperkins@health.ucsd.edu.

DOI: 10.1097/TA.0000000000004844

common bleeding vessels in the chest were the descending thoracic aorta (45%), intercostal/internal thoracic arteries (12%), ascending aorta (11%), right subclavian (7.3%), left subclavian (5%), pulmonary artery (4%), and subclavian vein (4%). The aortic arch, left and right carotid arteries, pulmonary vein, superior vena cava (SVC), and innominate vein were injured in less than 2% of cases. The most common cause of death after NCTH was exsanguination at a median time of 2 hours after presentation.[4] This underscores the importance of expeditious assessment, diagnosis, and management of these patients. Thoracic vessels that are injured but are not bleeding initially may result in thrombus formation, occlusion, or delayed hemorrhage and demand similar attention. The purpose of this document is to provide the American Association for the Surgery of Trauma and the World Society of Emergency Surgery recommendations for the diagnosis and management of thoracic vascular injuries (TVIs).

METHODS

A computerized search was done using different databases (Medline, Embase, Cochrane). Citations were included for the period between January 2013 and January 2025 using the primary search strategy: trauma, blunt, penetrating, blood vessel, vascular injury, chest, thoracic, aorta, subclavian artery, subclavian vein, heart, pulmonary artery, pulmonary vein, innominate artery, innominate vein, aortic arch, great vessels, superior vena cava, inferior vena cava, resuscitative thoracotomy, thoracotomy, sternotomy, pericardiotomy, injury, surgery, diagnosis, operative, nonoperative, shunting, shunt, endovascular, anticoagulant, antiplatelet, focused assessment with sonography for trauma, and focused assessment with sonography in trauma, combined with *and/or* as well as the MeSH terms: thoracic injuries, thoracic aorta dissection, endovascular procedures, thoracotomy, and sternotomy. No search restrictions were imposed. The dates were selected to allow comprehensive published abstracts of clinical trials, consensus conferences, comparative studies, congresses, guidelines, government publications, multicenter studies, systematic reviews, meta-analyses, large case series, original articles, and randomized controlled trials. Selected older articles considered landmark papers in the field were also included. Three authors independently reviewed abstracts chosen for relevance, and any discrepancies between reviewers were settled after a discussion.

The level of evidence was evaluated using a modified form of the Grading of Recommendations Assessment, Development, and Evaluation system (Table 1).[5] A group of experts in the field, coordinated by a central coordinator, was contacted to express their evidence-based opinions on several issues about TVI. Based on the evidence available, the central coordinator assembled the different answers derived from a round of discussion and created a set of recommendations. The recommendations were submitted for comments multiple times using an online modified Delphi process until complete consensus was achieved. The definitive version reported herein represents the position of the expert group from both the American Association for the Surgery of Trauma and the World Society of Emergency Surgery. An executive summary of the guidelines can be found in Supplemental Digital Content (Supplementary Data 1, http://links.lww.com/TA/E993) as well as a list of abbreviations used in this article (Supplementary Data 2, http://links.lww.com/TA/E994).

RESULTS

Epidemiology

What Is the Incidence of Major Vascular Injury in Blunt Chest Trauma?

Statement: Blunt mechanisms of injury are responsible for more than 60% of cases of TVI, but this varies by geography. The thoracic aorta is the most commonly injured vessel, followed by the innominate/subclavian arteries and the pulmonary artery in a minority of cases. Most blunt thoracic aortic injuries (BTAIs) are located distal to the takeoff of the left subclavian artery (LSA) at the level of the ligamentum arteriosum. Injuries to the ascending aorta, SVC, thoracic inferior vena cava, and azygous vein are infrequent after blunt trauma.

The incidence of TVI is less than 1% in pediatric and adult civilian trauma patients who reach the hospital and is more common in adults than in pediatric patients.[6–11] Blunt trauma is the cause of 62% of TVI in the United States and 77% in Australia.[6,12] The epidemiology of injury prevalence and mechanism varies by geographic region. Still, it is typically related to deceleration injury resulting in a spectrum of vessel wall disruption from intimal tears to complete rupture.[13] In patients sustaining TVI, the aorta is injured in approximately 80% of patients, followed by the innominate and subclavian vessels in 11% and the pulmonary vessels in 5%.[6,14] The absolute incidence of TVI in trauma is much higher, as many patients do not survive to reach the hospital alive. Blunt thoracic aortic injury is the second most common cause of death in blunt trauma after head injury. It has been identified in a third of blunt traumatic fatalities, and an estimated 80% die at the scene of injury. Most injuries occur at the aortic isthmus, which extends from the origin of the LSA to the insertion of the ligamentum arteriosum. The ascending aorta is injured in less than 5% of patients sustaining BTAI who survive transport but is identified more frequently in autopsy patients and is associated with cardiac injury.[15,16] Blunt injuries to the thoracic inferior vena cava (TIVC), the SVC, and the azygous vein are not commonly seen by health care providers, as they are associated with severe nonsurvivable injuries. Blunt injuries to the proximal carotid arteries are also uncommon.[16,17]

What Are the Most Common Injury Mechanisms in Blunt TVI?

Statement: Blunt TVIs occur after high-energy transfer mechanisms of injury such as MVCs, falls from height, and pedestrians struck by an auto. Blunt thoracic aortic injuries are frequently observed in head-on collisions and T-bone crashes. They are usually accompanied by other severe injuries such as traumatic brain injury (TBI), intra-abdominal solid organ injury, and pelvic fractures.

The most common blunt injury mechanisms in TVI are motor vehicle collisions (MVCs) in 83% of patients and falls from height in 6% of patients.[6,12] In a large multicenter prospective study, BTAI occurred following MVC in 81%, autopedestrian accidents in 7%, and falls from height in 3%. Of the BTAIs diagnosed after MVC, 72% occurred after a head-on collision, 24% after a side impact, and 4% after a rear impact.[18] Because of the nature of these high-energy mechanisms, 80% of BTAIs are accompanied by other concomitant life-threatening injuries.[8,19]

TABLE 1. Modified System for GoR[5]

GoR	Clarity of Risks/Benefit	Quality of Supporting Evidence	Implications
1A			
Strong recommendation, high-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs without important limitations or overwhelming evidence from observational studies	Strong recommendation, applies to most patients in most circumstances without reservation
1B			
Strong recommendation, moderate-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs with important limitations (inconsistent results, methodological flaws, indirect analyses or imprecise conclusions) or exceptionally strong evidence from observational studies	Strong recommendation, applies to most patients in most circumstances without reservation
1C			
Strong recommendation, low-quality or very low-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	Observational studies or case series	Strong recommendation but subject to change when higher quality evidence becomes available
2A			
Weak recommendation, high-quality evidence	Benefits closely balanced with risks and burden	RCTs without important limitations or overwhelming evidence from observational studies	Weak recommendation, best action may differ depending on the patient, treatment circumstances, or social values
2B			
Weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burden	RCTs with important limitations (inconsistent results, methodological flaws, indirect or imprecise) or exceptionally strong evidence from observational studies	Weak recommendation, best action may differ depending on the patient, treatment circumstances, or social values
2C			
Weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	Observational studies or case series	Very weak recommendation; alternative treatments may be equally reasonable and merit consideration

GoR, grading of recommendations; RCT, Randomized controlled trial.

These include TBI (20–31%), abdominal injury (28–29%), and pelvic injury (15–35%).[7,20] Nonaortic great vessel mechanisms of injury are similar: blunt innominate artery and left carotid injuries tend to be more proximal, while left subclavian injuries tend to be more distal.[13]

What Is the Incidence of TVI in Penetrating Chest Trauma?

Statement: Penetrating injury mechanisms are responsible for 40% of all TVIs and carry a high mortality rate because of massive bleeding. Other associated intrathoracic injuries are common.

In US adults, 38% of TVI occurs after penetrating trauma, mostly from gunshot (53%) and stab wounds (30%). The aorta is injured in 27%, the innominate and subclavian vessels in 24%, the pulmonary vessels in 17%, the internal mammary in 12%, and the SVC in 8%.[6] Penetrating TVI is more common in Latin America than in the United States and Europe.[21,22] Penetrating injuries typically result in vessel laceration or transection, resulting in hemorrhage and high mortality.[1,10,17,23] Notably, the subclavian veins are anterior and medial to the arteries and are concurrently injured in approximately 20% of cases.[17] Penetrating thoracic aorta injuries (PTAIs) are commonly associated with injuries to the heart, esophagus, diaphragm, and vena cava.[10]

Clinical Presentation and Diagnosis

What Is the Optimal Initial Evaluation of a Patient With Suspected TVI?

Statement: The optimal initial evaluation of a patient with suspected TVI includes concomitant (hemostatic) resuscitation and assessment of life-threatening injuries, including tension pneumothorax, massive hemothorax, exsanguinating hemorrhage, and cardiac tamponade. A chest x-ray (CXR) may help identify intrathoracic pathology and radiographic signs suggestive of BTAI and localize potential projectiles. Decreased or absent pulses in the upper extremities and periclavicular hematomas suggest the presence of a subclavian artery injury. GOR 1C

The initial evaluation is the same as with any trauma patient and begins with the assessment of airway, breathing, and circulation. Vascular access should be established quickly to allow for the administration of blood products if hemorrhage is suspected (hemostatic resuscitation), as well as other medications and fluids as needed. Identification of immediate life-threatening associated injuries, such as tension pneumothorax or massive hemothorax, cardiac tamponade, or external hemorrhage, is critical.[24] In blunt injuries, there should be a high suspicion of concomitant TBI, and particular attention to the neurologic status is warranted.[25] In penetrating injuries, careful examination should identify all external wounds to assess for potential concomitant injuries in the abdomen, neck, or extremities. Adjunct imaging with a CXR should be performed, but it is neither sensitive nor specific for TVI. A CXR can evaluate chest wall injuries, mediastinal trauma, pneumothorax, hemothorax, pulmonary contusion, and pleural effusions, as well as guide further management without the need to transport a potentially unstable patient.[26] Evidence of BTAI on CXR includes mediastinal widening, widened left paraspinal stripe, rightward deviation of the trachea, left mainstem bronchus depression, loss of the aortic knob, or apical capping.[27–29] These signs help when present, but their absence does not rule out BTAI. Subclavian artery injury may result in a periclavicular hematoma or diminished radial pulses, but these "hard signs" are only present in 20% to 30% of patients. First rib, clavicular, or scapular fractures, as well as extremity neurologic deficit from brachial plexus injury, should also raise suspicion for subclavian vessel injury.[30]

What Is the Role of Imaging in Chest Trauma?

Statement: The extended focused assessment with sonography in trauma (eFAST) may help diagnose pneumothorax and hemothorax, pericardial fluid, and intra-abdominal fluid without delaying interventions such as chest tube placement or surgical intervention. A chest computed tomography angiography (CTA) is the criterion standard for assessing potential TVI and should be obtained in stable patients. Unstable patients should undergo immediate surgical intervention. GOR 1C

The eFAST quickly inspects the abdomen for free fluid and the chest for pericardial fluid, pneumothorax, and hemothorax.[31] However, it should not delay necessary lifesaving interventions that are warranted based on physical examination, such as needle or tube thoracostomy for tension physiology or transportation to the operating room for a surgical abdomen.[32] Extended focused assessment with sonography in trauma should be used in all blunt thoracic patients because of the likelihood of concomitant abdominal trauma and to ascertain in the unstable patient the body cavity(ies) needing exploration. Positive findings (pericardial or peritoneal fluid, pneumo- or hemothorax) should prompt additional imaging with computed tomography (CT) in the stable patient or surgical intervention in the unstable patient.[33] The role of eFAST in penetrating thoracic trauma is limited to stable patients to assess for cardiac injury and tamponade. Unstable patients require emergent operative exploration, which should not be delayed with additional imaging such as CT scans.[32] Importantly, while the eFAST subxiphoid view has high sensitivity and specificity for cardiac injury (>96% and >97%, respectively), there is a possibility of a false-negative pericardial eFAST because of possible decompression of the pericardium into the pleural cavity. Thus, there should be a high index of suspicion for cardiac injury in patients with wounds to the precordium and an associated hemothorax despite a negative eFAST, particularly if hypotension and ongoing hemorrhage from chest tubes are present.[32,34]

Stable patients with penetrating injuries to the chest should undergo CTA to rule out major vascular trauma.[35–37] There are no universal guidelines for the optimal screening of blunt chest trauma patients. The NEXUS Chest algorithm recommends that all blunt trauma patients with an abnormal CXR undergo CT chest imaging, as 13% of these patients would have a significant thoracic injury (including vascular injury) identified on CT. For patients with a normal CXR, a CT scan of the chest can be considered for patients with distracting injuries, thoracic wall tenderness (including chest wall, sternum, thoracic spine, and scapula), or a rapid deceleration mechanism of injury. Patients with a normal CXR and one positive criterion had a 1.1% chance of significant injury; those with two had a 3.2% chance. These rates increased to 19% and 25% if the CXR was abnormal.[38] Similarly, another large study demonstrated that only 2.7% of blunt trauma patients with a normal CXR had a clinically significant injury on CT.[39] The Eastern

Association for the Surgery of Trauma and the Western Trauma Association recommend screening all blunt trauma patients with significant high-energy deceleration or acceleration mechanisms with CTA, yet this relies on clinical judgment, and there remains a lack of definitive criteria for optimal screening.[40,41]

Computed tomography angiography is the screening examination of choice for diagnosing blunt and penetrating TVI. It has a 95% to 100% sensitivity and a 99% to 100% negative predictive value in detecting BTAI.[13,35,37,40,41] Types of TVI include dissection, intramural hematoma, thrombosis, pseudoaneurysm (PSA), laceration, transection, and arteriovenous fistula.[42] Importantly, if there is suspicion of a subclavian artery injury, intravenous contrast should be administered via the unaffected arm to avoid artifacts.[35] Conventional angiography and transesophageal echocardiogram can also be used, but these are more invasive and resource-intensive modalities. Conventional angiography may still be used in stable patients with a high suspicion of vascular injury to use endovascular repair at diagnosis or in the presence of metallic implants or foreign bodies that would cause obscuring artifacts on CTA.[17,35,43]

When Should a Chest Tube Be Placed in Chest Trauma?

Statement: Urgent tube thoracostomy is indicated in patients with suspected or clinically diagnosed large or tension pneumothorax and large hemothorax. In emergent situations, tube thoracostomy should be performed based on clinical diagnosis, and a CXR or eFAST examination should not delay tube placement. GOR 1B

Upon arrival, a chest tube should be placed for the symptomatic patient with suspected pneumo- or hemothorax. Tension physiology is a clinical diagnosis based on physical examination findings, and the treating trauma provider should not rely on imaging to confirm the diagnosis before intervening with decompression. However, if clinically stable, CXR and eFAST can help diagnose, and a chest CT can confirm the diagnosis of hemopneumothorax. An asymptomatic hemothorax of less than 300 to 500 mL may be observed without drainage, but this is still debatable.[44,45] Indications for tube thoracostomy for the asymptomatic pneumothorax are discussed elsewhere.[46]

How Does Chest Tube Output Alter Management? What Are the Indications for Emergent Operative Management?

Statement: Greater than 1,500 mL of chest tube output immediately, >250 mL/h for >2 hours, or persistent hypotension regardless of chest tube output constitutes indication for emergent thoracotomy. GOR 1B

Initial chest tube output can be used to identify patients needing surgical intervention. Traditionally, an initial chest tube output of 1,500 mL or 200 to 300 mL/h for the first 2 to 4 consecutive hours merits operative exploration with emergent thoracotomy.[13,24,47] Mortality has been shown to increase linearly with the amount and rate of blood loss through the chest tube.[47] Regardless of actual output, clinical stability is the best indicator of the need for intervention.[32]

Patients with recent cardiac arrest and those arriving in extremis require resuscitative thoracotomy.[48–51] Patients who are hemodynamically unstable, transient responders, and those with ongoing hemorrhage from their chest tube should also undergo emergent surgery. A large retained hemothorax after appropriate thoracostomy tube placement may indicate clotted blood and should mandate thoracotomy in an unstable patient. Stable patients who have contrast extravasation or vessel occlusion on CTA should undergo emergent endovascular or operative intervention.

Medical Nonoperative Management

Which Patients With TVI Are Best Treated With Medical Therapy?

Statement: The Society of Vascular Surgery (SVS) BTAI grades I and II are usually treated nonoperatively. Smaller aortic PSAs may, in selected circumstances, be treated conservatively but require close imaging follow-up. Patients with associated TBI may need BTAI intervention because of hypotension caused by drugs used to decrease the tension in the aortic wall. Subclavian and innominate artery injuries follow similar management strategies for low-grade BTAI. Penetrating thoracic aorta injury is generally associated with hemorrhagic shock and is almost always managed operatively. GOR 1C

The SVS described a BTAI grading system: grade I (intimal tear), grade II (intramural hematoma), grade III (PSA), and grade IV (rupture)[52–54] (Table 2). Low-grade injuries (grades I and II) can be managed with medical therapy alone.[20,55–61] However, in those with concomitant severe TBI, operative intervention may be preferred given the need to maintain cerebral perfusion pressure and prevent secondary brain injury. There is evidence that nonoperative management (NOM) may also be considered for select patients with grade III injuries without TBI, who have small PSAs, and who are likely to be compliant with follow-up for repeat imaging.[56,62–65] In one meta-analysis, only 4% of 93 selected patients with small PSAs managed nonoperatively required late repair (predominantly endovascular) for injury progression, and aortic-related mortality was only 2% of 168 patients.[64] These studies suggest defining small PSA as less than 50% of the aortic circumference or by the PSA size-to-neck ratio. However, the optimal cutoff and metric for PSA size for NOM have not been well established. Patients with SVS grade III injuries not amenable to NOM should undergo urgent or delayed operative repair, which is dictated by the severity of concomitant injuries and the need for ongoing resuscitation. Grade IV injuries should be repaired emergently.[40] In resource-limited settings, the decision for operative versus NOM of BTAI must be made according to institutional endovascular expertise and local capabilities for follow-up imaging.

TABLE 2. Injury Grading Scales for BTAI

SVS	
Grade I	Intimal tear
Grade II	Intramural hematoma
Grade III	PSA
Grade IV	Free rupture
Harborview classification	
Minimal	No external contour abnormality; intimal tear/thrombus <10 mm
Moderate	External contour abnormality or intimal tear >10 mm
Severe	Active extravasation; LSA hematoma >15 mm

Although the SVS grading system is the most widely used, other grading systems have been developed to guide the management of BTAI.[66] The Harborview grading system suggests a simplified scale of minimal, moderate, and severe aortic injury based on external aortic contour abnormality and the size of an intimal tear or intramural thrombus. Mild injuries can be managed with NOM, moderate with delayed repair, and severe with emergent repair.[67,68] In one study, the Harborview scale demonstrated high agreement with the SVS grading system. However, one in six SVS grade I or II injuries were upgraded or downgraded, demonstrating the need for individualized clinical judgment, particularly in larger intimal tears or PSAs.[69]

The management of patients with BTAI and TBI remains challenging. Treatment goals for BTAI emphasize reducing aortic wall tension with drugs (β-blockers) to achieve strict blood pressure and heart rate control. In contrast, optimal TBI management demands maintaining adequate cerebral perfusion pressure. While early reports suggested increased mortality of patients undergoing early repair, more recent research suggests that timing is less critical and stresses the importance of a multidisciplinary and individualized approach to these patients, who have an overall mortality of 19%.[25,70,71]

Similar grading of injury severity may also be applied to blunt injuries of the innominate and subclavian arteries, ranging from minimal injury involving the intima alone to various degrees of vessel laceration depending on the circumference involved, PSA, transection, and occlusion.[43] Low-grade injuries, including minimal intimal tears and small PSA, account for 25% to 40% of injuries and may undergo NOM, as well as select cases of subclavian artery occlusion in the absence of limb ischemia due to collateral blood flow. Large PSA, occlusions causing limb ischemia, or vessel ruptures merit emergent operative repair.[43,72,73] Carotid injuries have classically been described using a grading system developed by Biffl et al.[74] The management of blunt cerebrovascular injuries is discussed elsewhere.[75] Blunt injury to the pulmonary artery is rare, but similarly, those of lower grade may be treated nonoperatively, given the lower arterial pressure of the pulmonary artery.[76] There are rare cases of stable and low-grade PTAI treated nonoperatively with impulse control.[77]

What Is the Optimal Medical Therapy for TVI? What Is the Optimal Timing for Initiation?

Statement: Intravenous β-blockade (esmolol) is the therapy of choice in the NOM of BTAI, and it should be initiated as soon as feasible and as allowed by concomitant injuries. Patients should be monitored in an intensive care unit. An antiplatelet agent (e.g., aspirin) is indicated as part of the NOM of subclavian and innominate artery injuries, followed by interval follow-up imaging. GOR 1C

In BTAI patients, medical therapy is directed at impulse control, which seeks to reduce aortic wall stress by regulating heart rate and blood pressure. This is typically achieved with β-blocker infusion, such as esmolol, to maintain a heart rate between 60 and 100 beats per minute and systolic blood pressure of <100 mm Hg. If first-line therapy does not achieve target goals, other drugs such as calcium channel blockers (nicardipine or diltiazem) or vasodilators (nitroprusside) can be added. Vasodilatory drugs should be avoided as first-line agents because of the risk of reflex tachycardia, which can increase aortic wall stress. Anti-impulse therapy should begin as soon as feasible in the setting of clinical stability and barring other life-threatening injuries.[40,78] Importantly, in patients with concomitant TBI, anti-impulse therapy must be balanced with the risk of secondary TBI because of hypotension. Patients should be monitored in an intensive care setting for the first 48 to 72 hours after BTAI and initiation of anti-impulse therapy. If the injury is stable on repeat imaging, patients can be transitioned to an oral antihypertensive regimen.[46] Although not well studied, some institutions also advocate using aspirin in NOM of BTAI for several weeks postinjury.[67,79]

In subclavian or other supra-aortic branch vessel injury, NOM consists of initiating an antiplatelet agent, typically 81 mg of aspirin, and interval follow-up imaging. However, this has not been well studied.[17,43] For subclavian artery injury managed nonoperatively, peripheral pulse checks in the affected extremity should be assessed frequently.

What Is Considered a Failure of NOM?

Statement: New onset tachycardia or hypotension and aortic injury progression (from minor to major in the SVS classification) based on repeat imaging constitute a failure of NOM. GOR 1C

Progression of low-grade BTAI occurs in 5% to 10% of cases but rarely requires intervention. However, if a low-grade injury progresses to a high-grade injury on repeat imaging, the patient should undergo emergent repair.[58–60,79,80] An abrupt change in patient hemodynamics, including tachycardia and hypotension, should trigger concern for possible rupture and expeditious reimaging or operative exploration depending on the location and severity of the initial injury. In subclavian artery injuries treated nonoperatively, new claudication, diminished pulses, or other evidence of limb ischemia should prompt immediate reimaging or intervention.

When Should Reimaging Occur During NOM of TVI?

Statement: Blunt thoracic aortic injuries treated nonoperatively should be reimaged within 72 hours to exclude injury progression and at 1 and 3 months to document healing progression. Serial imaging after hospital discharge with CTA or magnetic resonance angiography (MRA) should be performed to ensure injury resolution. Subclavian and innominate artery injuries should be reimaged at the time of discharge from the hospital. GOR 2C

For BTAI, repeat CTA should be obtained within 48 to 72 hours of admission and, if stable, should also be obtained on outpatient follow-up to confirm healing. Most injuries resolve within 8 weeks, after which antihypertensive medication can be stopped.[40] The European Society for Vascular Surgery (ESVS) guidelines recommend yearly MRA until BTAI is healed.[81] There is evidence that grade 1 injuries may not require surveillance imaging.[79] Although not well documented, it is reasonable to consider reimaging other great vessel injuries treated with NOM before discharge to ensure stability.

Surgical Management

What Are the Surgical Treatment Options for TVI?

Statement: Thoracic endovascular aortic repair (TEVAR) is the treatment of choice for BTAI when surgical management is indicated. It is associated with decreased

mortality, lower risk of paraplegia, shorter hospital stays, and similar stroke rates compared with open repair. Grade IV BTAI (rupture) requires emergent intervention. An initial trial of NOM with β-blockade is acceptable in patients with associated injuries, delaying TEVAR for 48 to 72 hours. Hemodynamically unstable patients sustaining PTAI should undergo emergent open surgery. Thoracic endovascular aortic repair may be indicated in stable PTAI patients. Endovascular repair can be considered in hemodynamically stable patients with other TVIs, most commonly the subclavian artery. Most penetrating TVIs are associated with active hemorrhage and shock and require open repair. See Figure 1**. GOR 1B, 1C**

Traditionally, all TVIs were treated with open surgery. However, as endovascular technology and techniques have improved, the use of endovascular approaches to manage vascular trauma has increased rapidly.[73,82] The first Food and Drug Administration approval of TEVAR devices was in 2005. By 2007, 37% of BTAI had undergone TEVAR; by 2015, this had grown to 94%.[83,84] Similar adoption of TEVAR for BTAI has also been seen in other countries.[85–87] Between 2007 and 2016, 25% of innominate or subclavian artery injuries underwent endovascular repair versus 29% undergoing open repair.[72] The utilization rate of endovascular subclavian repair is increasing by 5% yearly.[73] The choice of repair depends on patient stability, injury location, the grade of injury, and the resources and expertise of the treating trauma center.

Thoracic endovascular aortic repair is now the standard of care for BTAI.[40,41,84] Although there are no prospective randomized clinical trials directly comparing open repair and TEVAR for BTAI, several studies have shown decreased mortality, significantly lower risk of paraplegia, and reduced length of stay with similar stroke rates compared with open repair.[41,84,88–91] The most recent study of the American College of Surgeons Trauma Quality Improvement Program registry data on patients undergoing TEVAR for BTAI demonstrated 4.1% all-cause mortality, 2.8% risk of stroke, 1.6% unplanned return to the operating room, 0.7% conversion to open aortic repair, and 0.2% risk of paraplegia.[92]

Timing of repair depends on clinical stability, grade of injury, and presence of severe concomitant injuries. Patients with grade IV injuries (aortic rupture) should undergo emergent repair. Patients with lower-grade BTAI who do not have significant concomitant injuries also may proceed with immediate repair. For those with serious associated injuries or who have ongoing resuscitation needs, delayed TEVAR within 48 to 72 hours is safe and has been associated with reduced mortality.[41,93–95] Importantly, TEVAR may be limited by anatomy, including the location of injury in the ascending aorta or aortic arch, the diameter and length of landing zones, aortic calcification and tortuosity, intraluminal thrombus, and quality of access vessels.[96] During TEVAR, the LSA is occluded in up to 54% of cases, which may lead to claudication and ischemia of the left upper extremity.[97] Rescue operations, including carotid to subclavian bypass, can have high morbidity. Selective LSA occlusion and endovascular revascularization techniques at the time of repair are important targets of ongoing research.[97–100] In retrospective studies, intraprocedural heparin use during TEVAR was safe, even among TBI patients.[95,101–103] Postoperatively, patients should be admitted to an intensive care unit for monitoring of bleeding, neurologic changes, and vascular complications (e.g., vessel occlusion and ischemia). Anti-impulse therapy can be discontinued with normalization of heart rate and blood pressure goals.

Thoracic endovascular aortic repair is also being increasingly used for PTAI, although most of these patients will present in extremis or with unstable vital signs requiring immediate open operative exploration. Those stable enough for CT diagnosis of their injury may be candidates for TEVAR.[10,11]

There are likewise no prospective randomized clinical trials comparing endovascular and open repair for subclavian artery injuries. However, several retrospective studies have demonstrated the effectiveness and safety of endovascular repair for blunt and penetrating injuries.[43,72,104–110] A recent large retrospective study of 1,200 cases of subclavian artery injuries showed that endovascular management has been associated with reduced mortality and decreased need for fasciotomy compared with open surgery.[110] Endovascular repair in subclavian artery injuries has traditionally been reserved for stable patients who presented to centers with the capability and expertise. However, with increasing prevalence of hybrid operating room suites and staff expertise, unstable patients with complex injuries and in hemorrhagic shock have also benefited from an endovascular approach.[110] Endovascular repair using a stent graft can be used for subclavian PSA, arteriovenous fistula, occlusion, transection, perforation, or dissection and has low reintervention rates.[107,111] Endovascular repairs are especially useful in obtaining proximal control of the LSA, possibly avoiding transthoracic open exposure or as a damage-control procedure before open repair ("hybrid" repair). Some lesions, such as those with greater than 50% circumference lacerations, vessel transections, and complete occlusions, may not be amenable to endovascular repair.[43,105] Examples of subclavian artery endovascular repairs are shown in Figures 2 and 3, and an example of endovascular repair of BTAI is shown in Figure 4.

Endovascular repair may also be considered for blunt and, rarely, penetrating innominate or proximal carotid artery injuries, although the literature is scarce.[105,106,112,113] Blunt ascending aorta and arch injuries typically require open repair under complete cardiopulmonary bypass. However, the use of endovascular techniques for nontraumatic pathologies of the ascending aorta and aortic arch is a subject of research and may have future applications in trauma.[114,115]

Which TVIs Require Open Surgical Management, and What Is the Optimal Open Repair?

Statement: Open surgery is indicated in hemodynamically unstable patients and when endovascular capabilities and expertise are unavailable. Patients in shock with intrathoracic bleeding usually undergo an anterolateral left-side thoracotomy, which may be extended through the sternum to the right chest (clamshell). In hemodynamically stable patients, injury location dictates the surgical approach. GOR 1B

Open surgery is necessary if the patient is unstable and cannot wait for endovascular expertise to arrive, the injury or patient anatomy is not amenable to endovascular approaches, or endovascular resources and expertise are unavailable. The choice of open technique will depend on the patient's hemodynamic status and whether the injury location is known. Most patients, particularly after penetrating injury, will be unstable and

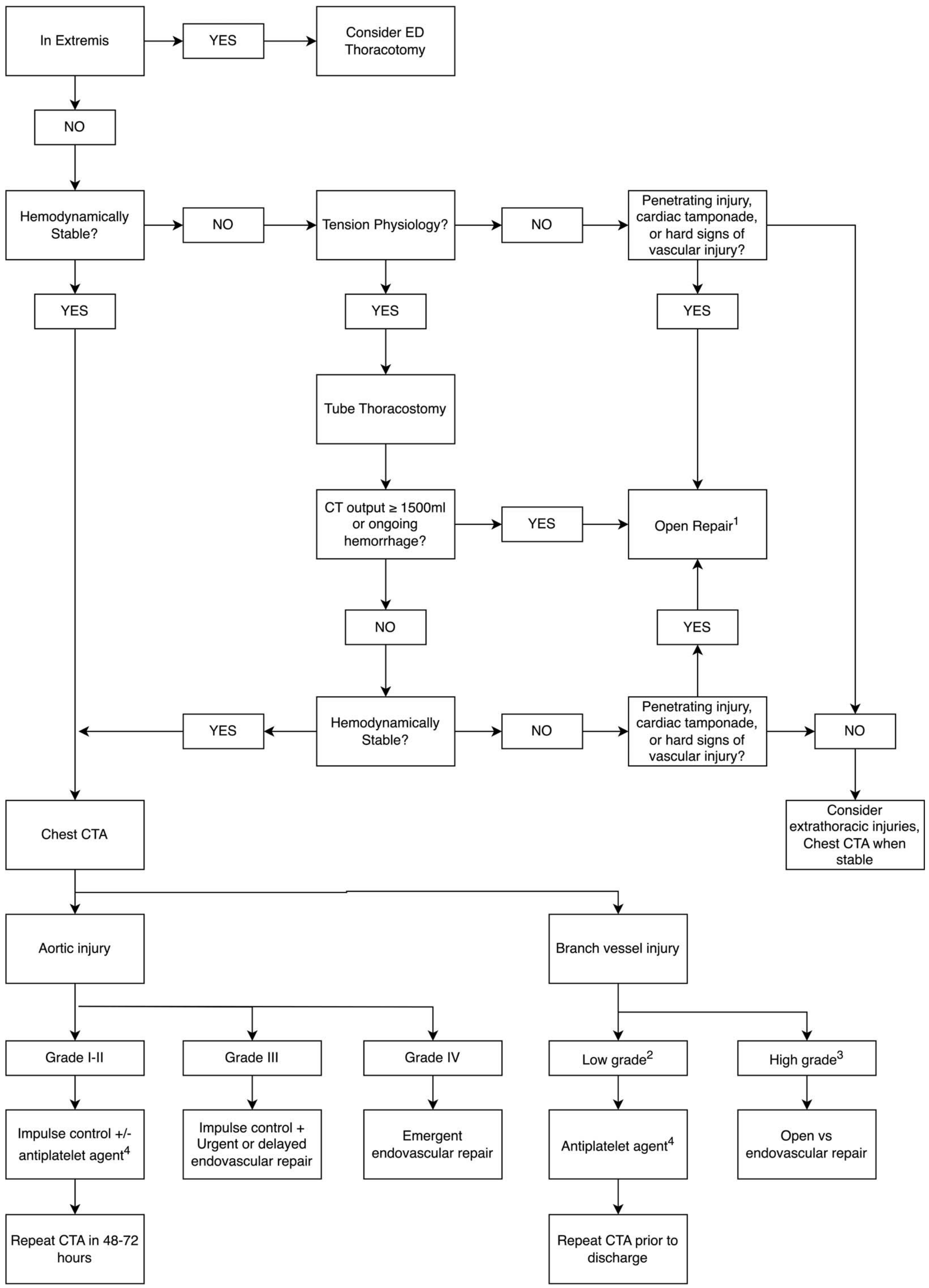

Figure 1. Thoracic vascular injury management algorithm. [1]In experienced centers with prompt access to hybrid operating room suites, endovascular repair can be considered for unstable patients with suspected subclavian artery injuries. [2]Low-grade injuries, including minimal intimal tears and small PSAs may undergo NOM. [3]High-grade injuries including large PSA, occlusion causing limb ischemia, or vessel rupture merit emergent operative repair. [4]Aspirin (81 mg) is used most commonly. ED, emergency department; CT, chest tube.

will require anterolateral thoracotomy as the initial exposure with evaluation for associated cardiac or pulmonary injury. This can be extended to a clamshell thoracotomy if there is suspected bleeding in the contralateral chest or for better visualization and access to the origin of the great vessels. In stable patients, the operation will depend on the location of the injury. The ascending

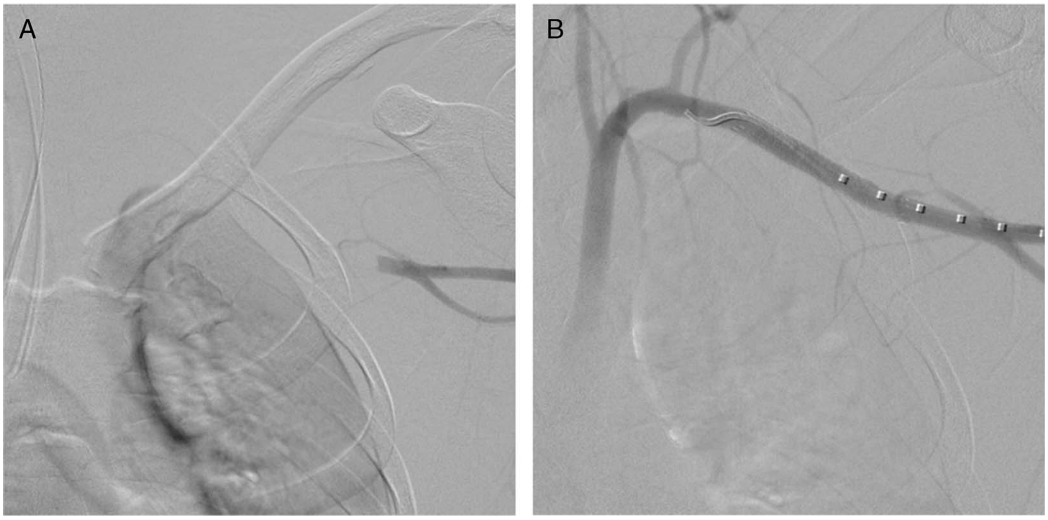

Figure 2. Subclavian artery occlusion after chest trauma. (*A*) Angiogram demonstrating occluded subclavian artery. (*B*) Endovascular placement of stent graft with restored flow.

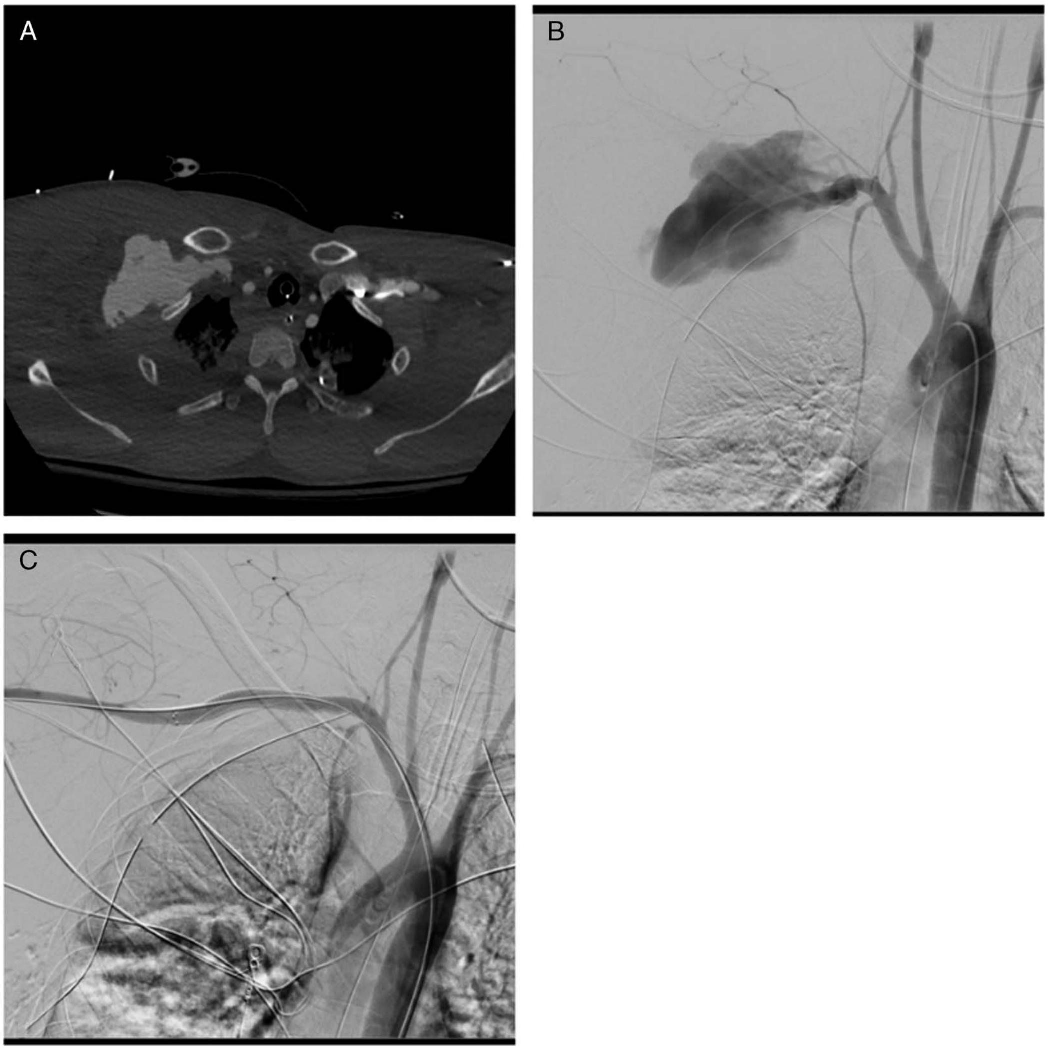

Figure 3. Subclavian artery PSA/transection after chest trauma. (*A*) Chest CTA showing large subclavian artery PSA. (*B*) Angiogram of subclavian artery again with large PSA. (*C*) Successful endovascular repair with stent graft across the injury site.

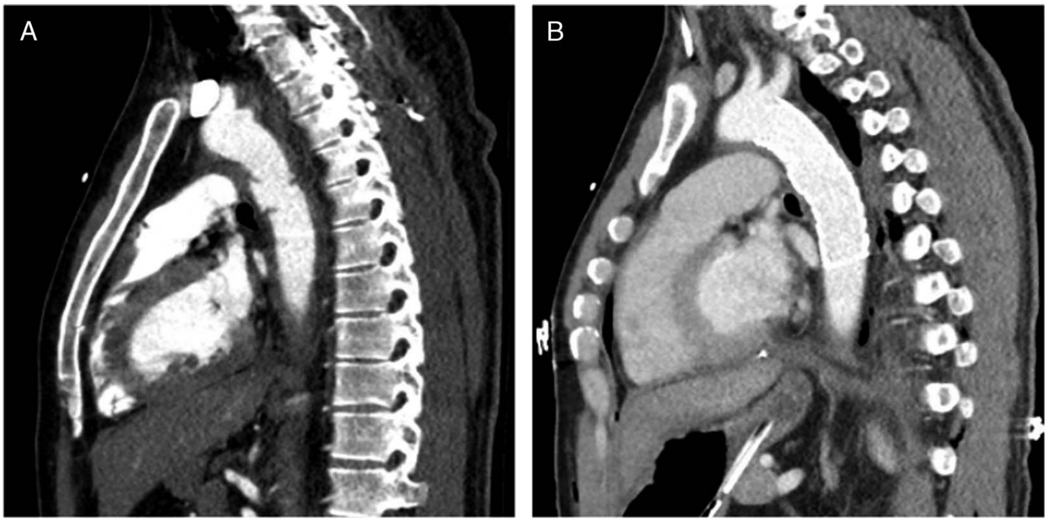

Figure 4. Blunt trauma aortic injury after chest trauma. (*A*) Chest CTA imaging showing grade III BTAI. (*B*) Chest CTA imaging showing post-TEVAR repair of BTAI.

aorta, aortic arch, innominate artery, proximal common carotid artery, right subclavian artery (with cervical extension), and pulmonary vessels are approached via a median sternotomy.

In contrast, the descending aorta is accessed via a posterolateral thoracotomy at the fourth intercostal space. Left subclavian artery injuries can be approached by an anterolateral thoracotomy at the third intercostal space or supra-, infra-, or transclavicular incisions. If the injury to the artery is minor, primary arteriorrhaphy is preferred. More significant injuries may require resection with end-to-end anastomosis, interposition graft, or ligation with a bypass graft if near the vessel origin. Significant injuries to the ascending aorta, aortic arch, and pulmonary vessels require cardiopulmonary bypass. Injuries to the innominate artery typically require bypass exclusion with a graft from the ascending aorta to the distal innominate artery.[116–118] Injuries to the descending aorta are challenging and associated with a 2% to 3% incidence of postoperative paraplegia when open repair is used.[41,91] Unless the operative time is estimated at less than 30 minutes, a partial left heart bypass is preferred over the traditional clamp and sew technique. Simple lacerations or injuries less than 50% of the vessel diameter are best treated with simple arteriorrhaphy if accomplished without significant vessel narrowing. More extensive or destructive injuries may be repaired with a vein or synthetic patch or resection and primary anastomosis with or without interposition graft, depending on the size of the defect. Specific surgical steps and exposure techniques are discussed elsewhere.[13,116–118] Damage-control techniques, including temporary intravascular shunts, may be used[119,120] when appropriate.

Venous injuries are approached similarly to their respective arteries. Primary repair of the vein is the first choice. If there is extensive injury, most veins can be ligated without significant morbidity. A singular injured innominate vein may be ligated, but ligation of both veins is likely to cause SVC syndrome. Likewise, subclavian vein injuries are challenging, and ligation is often preferable. Pulmonary vein injuries are rare and typically require cardiopulmonary bypass during operative repair. Injuries to the SVC and TIVC are best approached with primary repair, although extensive injuries may require patch angioplasty with autologous or bovine pericardium. Most posterior injuries to the TIVC require venovenous bypass.[117]

Outcomes

What Is the Long-term Prognosis for Patients Treated by Endovascular Techniques?

Statement: Complications after TEVAR for BTAI are uncommon but include endoleaks and claudication of the left arm because of the occlusion of the LSA by the stent graft. Long-term follow-up data for subclavian and innominate artery injuries are lacking. GOR 2C

Thoracic endovascular aortic repair–related complications after BTAI repair have decreased dramatically over time as technology has progressed. As discussed previously, the most common complications relate to LSA occlusion and endoleaks, which occur in 4% to 9% of patients, of which up to a third require reintervention. Other long-term complications, including stent migration, collapse, or fracture, are exceedingly rare.[102,121–134] Importantly, long-term data are still relatively lacking, and follow-up in this patient population is poor.[102,135] In a comparative study from Taiwan with 100% follow-up over 5 years, TEVAR exhibited the same long-term survival and reintervention after hospital discharge as open surgery, with a late reintervention rate of 2%.[86]

Similarly, complications following endovascular repair of the subclavian artery are rare, including access site PSA, stent thrombosis, endoleak, and stent migration. However, data on long-term follow-up are also lacking.[43,107,108,110,111]

What Is the Optimal Plan for Postoperative Follow-up?

Statement: After TEVAR for BTAI, CTA or MRA at 1 month, 12 months, and yearly thereafter is recommended. There is controversy about the need for frequent imaging surveillance after TEVAR for BTAI because of the risk of excessive

radiation and the differences between injury and aneurysmal disease. There are no clear guidelines for follow-up after open or endovascular repair of the subclavian artery. GOR 2B

The SVS recommends CTA at 1 month, 12 months, and then annually after TEVAR for BTAI, with shorter interval follow-up if there is any progression of injury.[136] The ESVS recommends CTA or MRA after TEVAR for BTAI at 1 month and then MRA every year for 5 years.[81] However, there is controversy regarding the frequency of surveillance for BTAI patients given their younger age, the nonprogressive nature of injury (in contrast to aneurysmal disease), and substantial radiation exposure risks.[40,137] Magnetic resonance angiography, if available, may be preferred for post-TEVAR surveillance, particularly in younger patients or those with repeated radiation exposure concerns. There is evidence of long-term aortic changes associated with TEVAR, but the clinical significance of these changes is unknown.[138] The screening decision should involve a patient-centered discussion between the patient and the surgeon.[139,140] The SVS and ESVS also recommend CTA or MRA every 5 years after open surgical repair of the thoracic aorta, and it would seem reasonable to apply this recommendation to surveillance after repair of the innominate artery as well. There are no clear guidelines for follow-up after open or endovascular repair of the subclavian artery. Given SVS guidelines for lower extremity arterial procedures, a reasonable regimen would be a physical examination with brachial-brachial index and Doppler ultrasound or repeat CTA at 6 months, 12 months, and annually.[136]

DISCUSSION

Thoracic vascular injury is a rare but highly lethal condition, and rapid diagnosis is critical. Advances in endovascular treatment have led to vast improvements in outcomes, particularly for BTAIs. The role of NOM is also expanding, although universal criteria are still needed regarding which lesions are the ideal candidates. More research is required to determine the long-term outcomes and optimum surveillance regimen after endovascular repair. Penetrating injuries demand rapid assessment and management to control hemorrhage. The trauma surgeon should be well versed in performing the appropriate open exposure techniques to obtain vascular control and facilitate expeditious repair.

AUTHORSHIP

L. Kobayashi, L.P., and R.C. contributed in the conception and study design. L. Kobayashi, L.P., W.J., L. Kurth, K.B., and R.C. contributed in the literature review. L. Kobayashi, L.P., W.J., L. Kurth, K.B., and R.C. contributed in the data acquisition. L. Kobayashi, L.P., W.J., L. Kurth, K.B., F.A.-Z., G.A., Z.J.B., W.L.B., L.D.B., F. Catena, I.C., F. Coccolini, D.D, N.D., B.D.S., J.M.G., A.M.O.G., J.G.P., T.H., K.I., A.K., Y.K., A.L., R.M., E.E.M., A.B.P., M.P., M.S., T.M.S., P.S., E.T., M.T., D.W., and R.C. contributed in the data analysis and interpretation. L. Kobayashi, L.P., W.J., L. Kurth, K.B., and R.C. contributed in the drafting of the manuscript. L. Kobayashi, L.P., W.J., L. Kurth, K.B., F.A.-Z., G.A., Z.J.B., W.L.B., L.D.B., F. Catena, I.C., F. Coccolini, D.D., N.D., B.D.S., J.M.G., A.M.O.G., J.G.P., T.H., K.I., A.K., Y.K., A.L., R.M., E.E.M., A.B.P., M.P., M.S., T.M.S., P.S., E.D., M.T., D.W., and R.C. contributed in the critical revision.

DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/E995).

REFERENCES

1. Kisat M, Morrison JJ, Hashmi ZG, Efron DT, Rasmussen TE, Haider AH. Epidemiology and outcomes of non-compressible torso hemorrhage. *J Surg Res*. 2013;184(1):414–421.
2. Tien HC, Spencer F, Tremblay LN, Rizoli SB, Brenneman FD. Preventable deaths from hemorrhage at a level I Canadian trauma center. *J Trauma*. 2007;62(1):142–146.
3. Sauaia A, Moore FA, Moore EE, Moser KS, Brennan R, Read RA, et al. Epidemiology of trauma deaths: a reassessment. *J Trauma*. 1995;38(2): 185–193.
4. Chang R, Fox EE, Greene TJ, Eastridge BJ, Gilani R, Chung KK, et al. Multicenter retrospective study of noncompressible torso hemorrhage: anatomic locations of bleeding and comparison of endovascular versus open approach. *J Trauma Acute Care Surg*. 2017;83(1):11–18.
5. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008;336(7650):924–926.
6. Barmparas G, Inaba K, Talving P, David JS, Lam L, Plurad D, et al. Pediatric vs adult vascular trauma: a National Trauma Databank review. *J Pediatr Surg*. 2010;45(7):1404–1412.
7. Arthurs ZM, Starnes BW, Sohn VY, Singh N, Martin MJ, Andersen CA. Functional and survival outcomes in traumatic blunt thoracic aortic injuries: an analysis of the National Trauma Databank. *J Vasc Surg*. 2009;49(4): 988–994.
8. de Mestral C, Dueck A, Sharma SS, Haas B, Gomez D, Hsiao M, et al. Evolution of the incidence, management, and mortality of blunt thoracic aortic injury: a population-based analysis. *J Am Coll Surg*. 2013;216(6):1110–1115.
9. Shibahashi K, Matsunaga H, Ishida T, Sugiyama K, Hamabe Y. A new screening model for quantitative risk assessment of blunt thoracic aortic injury. *Eur J Trauma Emerg Surg*. 2022;48(6):4607–4614.
10. Slocum C, Chiba H, Emigh B, Tam B, Schellenberg M, Inaba K, et al. Nationwide analysis of penetrating thoracic aortic injury: injury patterns, management, and outcomes. *J Surg Res*. 2023;284:290–295.
11. Branco BC, Musonza T, Long MA, Chung J, Todd SR, Wall MJ, et al. Survival trends after inferior vena cava and aortic injuries in the United States. *J Vasc Surg*. 2018;68(6):1880–1888.
12. Friend J, Rao S, Sieunarine K, Woodroof P. Vascular trauma in Western Australia: a comparison of two study periods over 15 years. *ANZ J Surg*. 2016;86(3):173–178.
13. Pereira BM, Chiara O, Ramponi F, Weber DG, Cimbanassi S, De Simone B, et al. WSES position paper on vascular emergency surgery. *World J Emerg Surg*. 2015;10:49.
14. Chen MYM, Miller PR, McLaughlin CA, Kortesis BG, Kavanagh PV, Dyer RB. The trend of using computed tomography in the detection of acute thoracic aortic and branch vessel injury after blunt thoracic trauma: single-center experience over 13 years. *J Trauma*. 2004;56(4):783–785.
15. Teixeira PG, Inaba K, Barmparas G, Georgiou C, Toms C, Noguchi TT, et al. Blunt thoracic aortic injuries: an autopsy study. *J Trauma*. 2011; 70(1):197–202.
16. Ketai L, Primack SL. Thoracic trauma. In: Hodler J, Kubik-Huch RA, von Schulthess GK, eds. Diseases of the Chest, Breast, Heart and Vessels 2019–2022: Diagnostic and Interventional Imaging [Internet]. Cham, Switzerland: Springer; 2019.
17. Naidoo S, Hardcastle TC. Traumatic injury to the great vessels of the chest. *Mediastinum*. 2021;5:26.
18. Fabian TC, Richardson JD, Croce MA, Smith JS, Rodman G, Kearney PA, et al. Prospective study of blunt aortic injury: multicenter trial of the American Association for the Surgery of Trauma. *J Trauma*. 1997;42(3): 374–383.
19. Mouawad NJ, Paulisin J, Hofmeister S, Thomas MB. Blunt thoracic aortic injury — concepts and management. *J Cardiothorac Surg*. 2020;15(1):62.
20. DuBose JJ, Charlton-Ouw K, Starnes B, Saqib N, Quiroga E, Morrison J, et al. Do patients with minimal blunt thoracic aortic injury require thoracic endovascular repair? *J Trauma Acute Care Surg*. 2021;90(2):384–387.
21. Góes AMO, Parreira JG, Kleinsorge GHD, Dalio MB, Alves PHF, Gomes FJSDV, et al. Brazilian guidelines on diagnosis and management of traumatic vascular injuries. *J Vasc Bras*. 2023;22:e20230042.
22. Kobayashi L, Coimbra R, Goes AMO Jr., Reva V, Santorelli J, Moore EE, et al. American Association for the Surgery of Trauma–World Society of Emergency Surgery guidelines on diagnosis and management of abdominal vascular injuries. *J Trauma Acute Care Surg*. 2020;89(6):1197–1211.

23. Okoye OT, Talving P, Teixeira PG, Chervonski M, Smith JA, Inaba K, et al. Transmediastinal gunshot wounds in a mature trauma Centre: changing perspectives. *Injury*. 2013;44(9):1198–1203.
24. *American College of Surgeons Committee on Trauma. 10th Edition of the Advanced Trauma Life Support (ATLS) Student Course Manual*. Chicago, IL: American College of Surgeons; 2018.
25. Zambetti BR, Huang DD, Lewis RH Jr., Fischer PE, Croce MA, Magnotti LJ. Use of thoracic endovascular aortic repair in patients with concomitant blunt aortic and traumatic brain injury. *J Am Coll Surg*. 2021;232(4):416–422.
26. Governatori NJ, Saul T, Siadecki SD, Lewiss RE. Ultrasound in the evaluation of penetrating thoraco-abdominal trauma: a review of the literature. *Med Ultrason*. 2015;17(4):528–534.
27. Crapps JL, Efird J, DuBose JJ, Teixeira PG, Shrestha B, Brown CV. Is chest x-ray a reliable screening tool for blunt thoracic aortic injury? Results from the American Association for the Surgery of Trauma/Aortic Trauma Foundation prospective blunt thoracic aortic injury registry. *J Am Coll Surg*. 2023;236(5):1031–1036.
28. Gutierrez A, Inaba K, Siboni S, Effron Z, Haltmeier T, Jaffray P, et al. The utility of chest X-ray as a screening tool for blunt thoracic aortic injury. *Injury*. 2016;47(1):32–36.
29. Polireddy K, Hoff C, Kinger NP, Tran A, Maddu K. Blunt thoracic trauma: role of chest radiography and comparison with CT — findings and literature review. *Emerg Radiol*. 2022;29(4):743–755.
30. Kou HW, Liao CH, Huang JF, Hsu CP, Wang SY, Ou Yang CH, et al. Eighteen years' experience of traumatic subclavian vascular injury in a tertiary referral trauma center. *Eur J Trauma Emerg Surg*. 2019;45(6):973–978.
31. Kirkpatrick AW, Sirois M, Laupland KB, Liu D, Rowan K, Ball CG, et al. Hand-held thoracic sonography for detecting post-traumatic pneumothoraces: the extended focused assessment with sonography for trauma (EFAST). *J Trauma*. 2004;57(2):288–295.
32. Schellenberg M, Inaba K. Critical decisions in the management of thoracic trauma. *Emerg Med Clin North Am*. 2018;36(1):135–147.
33. Stengel D, Leisterer J, Ferrada P, Ekkernkamp A, Mutze S, Hoenning A. Point-of-care ultrasonography for diagnosing thoracoabdominal injuries in patients with blunt trauma. *Cochrane Database Syst Rev*. 2018;12(12): CD012669.
34. Platz JJ, Fabricant L, Norotsky M. Thoracic trauma: injuries, evaluation, and treatment. *Surg Clin North Am*. 2017;97(4):783–799.
35. Balakrishnan S. CT angiography of non-aortic thoracic arterial trauma. *Emerg Radiol*. 2023;30(5):667–681.
36. Dreizin D, Munera F. Multidetector CT for penetrating torso trauma: state of the art. *Radiology*. 2015;277(2):338–355.
37. Strumwasser A, Chong V, Chu E, Victorino GP. Thoracic computed tomography is an effective screening modality in patients with penetrating injuries to the chest. *Injury*. 2016;47(9):2000–2005.
38. Rodriguez RM, Hendey GW, Mower WR. Selective chest imaging for blunt trauma patients: the national emergency X-ray utilization studies (NEXUS-chest algorithm). *Am J Emerg Med*. 2017;35(1):164–170.
39. Kea B, Gamarallage R, Vairamuthu H, Fortman J, Lunney K, Hendey GW, et al. What is the clinical significance of chest CT when the chest x-ray result is normal in patients with blunt trauma? *Am J Emerg Med*. 2013;31(8): 1268–1273.
40. Brown CVR, de Moya M, Brasel KJ, Hartwell JL, Inaba K, Ley EJ, et al. Blunt thoracic aortic injury: a Western Trauma Association critical decisions algorithm. *J Trauma Acute Care Surg*. 2023;94(1):113–116.
41. 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. *J Trauma Acute Care Surg*. 2015;78(1):136–146.
42. Almazedi B, Lyall H, Bhatnagar P, Kessel D, McPherson S, Patel JV, et al. Endovascular management of extra-cranial supra-aortic vascular injuries. *Cardiovasc Intervent Radiol*. 2014;37(1):55–68.
43. Waller CJ, Cogbill TH, Kallies KJ, Ramirez LD, Cardenas JM, Todd SR, et al. Contemporary management of subclavian and axillary artery injuries—a Western Trauma Association multicenter review. *J Trauma Acute Care Surg*. 2017;83(6):1023–1031.
44. DuBose J, Inaba K, Demetriades D, Scalea TM, O'Connor J, Menaker J, et al. Management of post-traumatic retained hemothorax: a prospective, observational, multicenter AAST study. *J Trauma Acute Care Surg*. 2012; 72(1):11–316.
45. Patel NJ, Dultz L, Ladhani HA, Cullinane DC, Klein E, McNickle AG, et al. Management of simple and retained hemothorax: a practice management guideline from the Eastern Association for the Surgery of Trauma. *Am J Surg*. 2021;221(5):873–884.
46. de Moya M, Brasel KJ, Brown CVR, Hartwell JL, Inaba K, Ley EJ, et al. Evaluation and management of traumatic pneumothorax: a Western Trauma Association critical decisions algorithm. *J Trauma Acute Care Surg*. 2022;92(1):103–107.
47. Bouzat P, Raux M, David JS, Tazarourte K, Galinski M, Desmettre T, et al. Chest trauma: first 48 hours management. *Anaesth Crit Care Pain Med*. 2017;36(2):135–145.
48. Burlew CC, Moore EE, Moore FA, Coimbra R, McIntyre RC, Davis JW, et al. Western Trauma Association critical decisions in trauma: resuscitative thoracotomy. *J Trauma Acute Care Surg*. 2012;73(6):1359–1363.
49. Seamon MJ, Haut ER, Van Arendonk K, Barbosa RR, Chiu WC, Dente CJ, et al. An evidence-based approach to patient selection for emergency department thoracotomy: a practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg*. 2015; 79(1):159–173.
50. Cothren CC, Moore EE. Emergency department thoracotomy for the critically injured patient: objectives, indications, and outcomes. *World J Emerg Surg*. 2006;1:4.
51. Nevins EJ, Bird NTE, Malik HZ, Mercer SJ, Shahzad K, Lunevicius R, et al. A systematic review of 3251 emergency department thoracotomies: is it time for a national database? *Eur J Trauma Emerg Surg*. 2019;45(2): 231–243.
52. Azizzadeh A, Keyhani K, Miller CC 3rd, Coogan SM, Safi HJ, Estrera AL. Blunt traumatic aortic injury: initial experience with endovascular repair. *J Vasc Surg*. 2009;49(6):1403–1408.
53. 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. *J Vasc Surg*. 2011;53(1):187–192.
54. Fortuna GR Jr., Perlick A, DuBose JJ, Leake SS, Charlton-Ouw KM, Miller CC, et al. Injury grade is a predictor of aortic-related death among patients with blunt thoracic aortic injury. *J Vasc Surg*. 2016;63(5):1225–1231.
55. Sandhu HK, Leonard SD, Perlick A, Saqib NU, Miller CC, Charlton-Ouw KM, et al. Determinants and outcomes of nonoperative management for blunt traumatic aortic injuries. *J Vasc Surg*. 2018;67(2):389–398.
56. Rabin J, DuBose J, Sliker CW, O'Connor JV, Scalea TM, Griffith BP. Parameters for successful nonoperative management of traumatic aortic injury. *J Thorac Cardiovasc Surg*. 2014;147(1):143–149.
57. Gaffey AC, Zhang J, Saka E, Quatromoni JG, Glaser J, Kim P, et al. Natural history of nonoperative management of Grade II blunt thoracic aortic injury. *Ann Vasc Surg*. 2020;65:124–129.
58. Osgood MJ, Heck JM, Rellinger EJ, Doran SL, Garrard CL, Guzman RJ, et al. Natural history of grade I–II blunt traumatic aortic injury. *J Vasc Surg*. 2014;59(2):334–341.
59. Spencer SM, Safcsak K, Smith CP, Cheatham ML, Bhullar IS. Nonoperative management rather than endovascular repair may be safe for grade II blunt traumatic aortic injuries: an 11-year retrospective analysis. *J Trauma Acute Care Surg*. 2018;84(1):133–138.
60. Jacob-Brassard J, Salata K, Kayssi A, Hussain MA, Forbes TL, Al-Omran M, et al. A systematic review of nonoperative management in blunt thoracic aortic injury. *J Vasc Surg*. 2019;70(5):1675–1681.e6.
61. Soong TK, Wee IJY, Tseng FS, Syn N, Choong AMTL. A systematic review and meta-regression analysis of nonoperative management of blunt traumatic thoracic aortic injury in 2897 patients. *J Vasc Surg*. 2019;70(3): 941–953.e13.
62. Park J, Kwon Y, Hwang K, Lim SH, Hong YS, Moon J. Mid-term outcomes of nonoperative management for patients with grade III blunt thoracic aortic injury. *World J Surg*. 2022;46(12):2864–2871.
63. Tanizaki S, Maeda S, Matano H, Sera M, Nagai H, Nakanishi T, et al. Blunt thoracic aortic injury with small pseudoaneurysm may be managed by nonoperative treatment. *J Vasc Surg*. 2016;63(2):341–344.
64. Harris DG, Rabin J, Bhardwaj A, June AS, Oates CP, Garrido D, et al. Nonoperative management of traumatic aortic pseudoaneurysms. *Ann Vasc Surg*. 2016;35:75–81.
65. Gandhi SS, Blas JV, Lee S, Eidt JF, Carsten CG. Nonoperative management of grade III blunt thoracic aortic injuries. *J Vasc Surg*. 2016;64(6): 1580–1586.
66. Harris DG, Rabin J, Starnes BW, Khoynezhad A, Conway RG, Taylor BS, et al. Evolution of lesion-specific management of blunt thoracic aortic injury. *J Vasc Surg*. 2016;64(2):500–505.

67. Heneghan RE, Aarabi S, Quiroga E, Gunn ML, Singh N, Starnes BW. Call for a new classification system and treatment strategy in blunt aortic injury. *J Vasc Surg*. 2016;64(1):171–176.
68. Quiroga E, Starnes BW, Tran NT, Singh N. Implementation and results of a practical grading system for blunt thoracic aortic injury. *J Vasc Surg*. 2019; 70(4):1082–1088.
69. Lozano R, DiLosa K, Schneck M, Maximus S, Callcut R, Shatz D, et al. Comparison of treatment and outcomes in blunt thoracic aortic injury based on different vascular surgery guidelines. *J Vasc Surg*. 2023; 78(1):48–52.
70. Rabin J, Harris DG, Crews GA, Ho M, Taylor BS, Sarkar R, et al. Early aortic repair worsens concurrent traumatic brain injury. *Ann Thorac Surg*. 2014;98(1):46–52.
71. Arbabi CN, DuBose J, Starnes BW, Saqib N, Quiroga E, Miller C, et al. Outcomes of thoracic endovascular aortic repair in patients with concomitant blunt thoracic aortic injury and traumatic brain injury from the Aortic Trauma Foundation global registry. *J Vasc Surg*. 2022;75(3):930–938.
72. Chipman AM, Ottochian M, Ricaurte D, Gunter G, DuBose JJ, Stonko DP, et al. Contemporary management and time to revascularization in upper extremity arterial injury. *Vascular*. 2023;31(2):284–291.
73. Magee GA, Dubose JJ, Inaba K, Lucero L, Dirks RC, O'Banion LA. Outcomes of vascular trauma associated with an evolution in the use of endovascular management. *J Vasc Surg*. 2023;78(2):405–410.e1.
74. Biffl WL, Moore EE, Offner PJ, Brega KE, Franciose RJ, Burch JM. Blunt carotid arterial injuries: implications of a new grading scale. *J Trauma*. 1999;47(5):845–853.
75. Kim DY, Biffl W, Bokhari F, Brakenridge S, Chao E, Claridge JA, et al. Evaluation and management of blunt cerebrovascular injury: a practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg*. 2020;88(6):875–887.
76. Altoos R, Carr R, Chung J, Stern E, Nevrekar D. Selective common and uncommon imaging manifestations of blunt nonaortic chest trauma: when time is of the essence. *Curr Probl Diagn Radiol*. 2015;44(2):155–166.
77. Mohammed RK, Cheung S, Parikh SP, Asgaria K. Conservative management of aortic arch injury following penetrating trauma. *Ann R Coll Surg Engl*. 2015;97(3):184–187.
78. Akhmerov A, DuBose J, Azizzadeh A. Blunt thoracic aortic injury: current therapies, outcomes, and challenges. *Ann Vasc Dis*. 2019;12(1):1–5.
79. Jinadasa SP, Mueller AL, Apffel A, Cave B, DuBose JJ, Scalea TM, et al. Close surveillance imaging is unnecessary for patients with grade I blunt thoracic aortic injury. *Am J Surg*. 2022;224(5):1324–1328.
80. 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(7):1834–1847.
81. Wahlgren CM, Aylwin C, Davenport RA, Davidovic LB, DuBose JJ, Gaarder C, et al. Editor's choice — European Society for Vascular Surgery (ESVS) 2025 Clinical Practice Guidelines on the Management of Vascular Trauma. *Eur J Vasc Endovasc Surg*. 2025;69(2):179–237.
82. Faulconer ER, Branco BC, Loja MN, Grayson K, Sampson J, Fabian TC, et al. Use of open and endovascular surgical techniques to manage vascular injuries in the trauma setting: a review of the American Association for the Surgery of Trauma PROspective observational vascular injury trial registry. *J Trauma Acute Care Surg*. 2018;84(3):411–417.
83. Grigorian A, Spencer D, Donayre C, Nahmias J, Schubl S, Gabriel V, et al. National trends of thoracic endovascular aortic repair versus open repair in blunt thoracic aortic injury. *Ann Vasc Surg*. 2018;52:72–78.
84. Scalea TM, Feliciano DV, DuBose JJ, Ottochian M, O'Connor JV, Morrison JJ. Blunt thoracic aortic injury: endovascular repair is now the standard. *J Am Coll Surg*. 2019;228(4):605–610.
85. Boutin L, Caballero MJ, Guarrigue D, Hammad E, Rennuit I, Delhaye N, et al. Blunt traumatic aortic injury management, a French TraumaBase analytic cohort. *Eur J Vasc Endovasc Surg*. 2022;63(3):401–409.
86. Cheng YT, Cheng CT, Wang SY, Wu VCC, Chu PH, Chou AH, et al. Long-term outcomes of endovascular and open repair for traumatic thoracic aortic injury. *JAMA Netw Open*. 2019;2(2):e187861.
87. Ho XN, Wee IJ, Syn N, Harrison M, Wilson L, Choong AM. The endovascular repair of blunt traumatic thoracic aortic injury in Asia: a systematic review and meta-analysis. *Vascular*. 2019;27(2):213–223.
88. Shackford SR, Dunne CE, Karmy-Jones R, Long W, Teso D, Schreiber MA, et al. The evolution of care improves outcome in blunt thoracic aortic injury: a Western Trauma Association multicenter study. *J Trauma Acute Care Surg*. 2017;83(6):1006–1013.
89. DuBose JJ, Leake SS, Brenner M, Pasley J, O'Callaghan T, Luo-Owen X, et al. Contemporary management and outcomes of blunt thoracic aortic injury: a multicenter retrospective study. *J Trauma Acute Care Surg*. 2015; 78(2):360–369.
90. Pang D, Hildebrand D, Bachoo P. Thoracic endovascular repair (TEVAR) versus open surgery for blunt traumatic thoracic aortic injury. *Cochrane Database Syst Rev*. 2019;2(2):CD006642.
91. 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. *J Vasc Surg*. 2020; 71(1):270–282.
92. Abdou H, Elansary NN, Darko L, DuBose JJ, Scalea TM, Morrison JJ, et al. Postoperative complications of endovascular blunt thoracic aortic injury repair. *Trauma Surg Acute Care Open*. 2021;6(1):e000678.
93. 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. *J Vasc Surg*. 2018;68(1): 64–73.
94. Rudra P, Cardoso R, Echevarria S, Kaya B, Abdullah R, Baskara Salian R, et al. Early versus delayed thoracic endovascular aortic repair for blunt traumatic aortic injury: a systematic review and meta-analysis. *Cureus*. 2023; 15(6):e41078.
95. Zambetti BR, Zickler WP, Lewis RH Jr., Pettigrew BD, Valaulikar GS, Afzal MO, et al. Delayed endovascular repair with procedural anticoagulation: a safe strategy for blunt aortic injury. *Ann Vasc Surg*. 2022;84: 195–200.
96. Cline M, Cooper KJ, Khaja MS, Gandhi R, Bryce YC, Williams DM. Endovascular management of acute traumatic aortic injury. *Tech Vasc Interv Radiol*. 2018;21(3):131–136.
97. Grigorian A, Lewis M, Wlodarczyk JR, Chien CY, Park T, Demetriades D. Left subclavian artery coverage during endovascular repair of thoracic aorta injury in trauma and non-trauma patients. *Eur J Trauma Emerg Surg*. 2022; 48(6):4425–4429.
98. Delafontaine JL, Hu B, Tan TW, Tang GL, Starnes BW, Virk C, et al. Outcome comparison of TEVAR with and without left subclavian artery revascularization from analysis of Nationwide inpatient sample database. *Ann Vasc Surg*. 2019;58:174–179.
99. Romagnoli AN, Paterson J, Dua A, Kauvar D, Saqib N, Miller C, et al. Cover with caution: management of the left subclavian artery in TEVAR for trauma. *J Trauma Acute Care Surg*. 2023;94(3):392–397.
100. Kruger JL, Balceniuk MD, Zhao P, Ayers BC, Ellis JL, Doyle AJ, et al. Left subclavian artery coverage is not associated with neurological deficits in trauma patients undergoing thoracic endovascular repair. *Ann Vasc Surg*. 2022;86:408–416.
101. 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. *J Vasc Surg*. 2021;74(1):71–78.
102. Brenner M, Teeter W, Hadud M, Hoehn M, O'Connor J, Stein D, et al. Long-term outcomes of thoracic endovascular aortic repair: a single institution's 11-year experience. *J Trauma Acute Care Surg*. 2017;82(4):687–693.
103. Quiroga E, Levitt MR, Czerwonko ME, Starnes BW, Tran NT, Singh N. Management of moderate blunt thoracic aortic injuries in patients with intracranial hemorrhage. *Ann Vasc Surg*. 2021;73:15–21.
104. Carrick MM, Morrison CA, Pham HQ, Norman MA, Marvin B, Lee J, et al. Modern management of traumatic subclavian artery injuries: a single institution's experience in the evolution of endovascular repair. *Am J Surg*. 2010;199(1):28–34.
105. Sinha S, Patterson BO, Ma J, Holt PJ, Thompson MM, Carrell T, et al. Systematic review and meta-analysis of open surgical and endovascular management of thoracic outlet vascular injuries. *J Vasc Surg*. 2013;57(2): 547–567.e8.
106. Siada SS, Dirks RC, Davis JW, O'Banion LA. Endovascular treatment of axillosubclavian arterial injuries is a safe alternative to open repair. *Am J Surg*. 2022;224(6):1385–1387.
107. Branco BC, Boutrous ML, DuBose JJ, Leake SS, Charlton-Ouw K, Rhee P, et al. Outcome comparison between open and endovascular management of axillosubclavian arterial injuries. *J Vasc Surg*. 2016;63(3):702–709.
108. Boggs HK, Tomihama RT, Abou-Zamzam AM Jr., Mukherjee K, Turay D, Teruya TH, et al. Analysis of traumatic axillo-subclavian vessel injuries: endovascular management is a viable option to open surgical reconstruction. *Ann Vasc Surg*. 2022;79:25–30.

109. Zambetti BR, Stuber JD, Patel DD, Lewis RH, Huang DD, Zickler WP, et al. Impact of endovascular stenting on outcomes in patients with traumatic subclavian artery injury. *J Am Coll Surg*. 2022;234(4):444–449.
110. Kim M, Firek M, Coimbra BC, Allison-Aipa T, Zakhary B, Kwon J, et al. Outcomes comparison of endovascular and open surgical approaches for subclavian arterial injury: a nationwide analysis. *Ann Vasc Surg*. 2025;112:239–245.
111. DuBose JJ, Rajani R, Gilani R, Arthurs ZA, Morrison JJ, Clouse WD, et al. Endovascular management of axillo-subclavian arterial injury: a review of published experience. *Injury*. 2012;43(11):1785–1792.
112. Pereira-Neves A, Gouveia R, Dias-Neto M, Duarte-Gamas L, Rocha-Neves J, Teixeira J. Covered endovascular repair of innominate artery bifurcation after thoracic blunt trauma. *Vasc Endovascular Surg*. 2021;55(4):405–409.
113. Stafforini NA, Singh N. Management of vascular injuries in penetrating trauma. *Surg Clin North Am*. 2023;103(4):801–825.
114. Sun X, Hong J, Lowery R, Goldstein S, Wang Z, Lindsay J, et al. Ascending aortic injuries following blunt trauma. *J Card Surg*. 2013;28(6):749–755.
115. Baikoussis NG, Antonopoulos CN, Papakonstantinou NA, Argiriou M, Geroulakos G. Endovascular stent grafting for ascending aorta diseases. *J Vasc Surg*. 2017;66(5):1587–1601.
116. Sladojevic M, Markovic M, Ilic N, Pejkic S, Banzic I, Djoric P, et al. Open treatment of blunt injuries of supra-aortic branches: case series. *Ann Vasc Surg*. 2016;31:205.e5–205.e10.
117. Yilmaz TH, Evers T, Sussman M, Vassiliu P, Degiannis E, Doll D. Operating on penetrating trauma to the mediastinal vessels. *Scand J Surg*. 2014;103(3): 167–174.
118. Demetriades D, Inaba K, Velmahos G. *Atlas of Surgical Techniques in Trauma*. New York, NY: Cambridge University Press; 2020.
119. Roberts DJ, Bobrovitz N, Zygun DA, Ball CG, Kirkpatrick AW, Faris PD, et al. Indications for use of thoracic, abdominal, pelvic, and vascular damage control interventions in trauma patients: a content analysis and expert appropriateness rating study. *J Trauma Acute Care Surg*. 2015;79(4):568–579.
120. Douglas A, Puzio T, Murphy P, Menard L, Meagher AD. Damage control thoracotomy: a systematic review of techniques and outcomes. *Injury*. 2021;52(5):1123–1127.
121. Demetriades D, Velmahos GC, Scalea TM, Jurkovich GJ, Karmy-Jones R, Teixeira PG, et al. Operative repair or endovascular stent graft in blunt traumatic thoracic aortic injuries: results of an American Association for the Surgery of Trauma multicenter study. *J Trauma*. 2008;64(3):561–571.
122. Piffaretti G, Benedetto F, Menegolo M, Antonello M, Tarallo A, Grego F, et al. Outcomes of endovascular repair for blunt thoracic aortic injury. *J Vasc Surg*. 2013;58(6):1483–1489.
123. Spiliotopoulos K, Kokotsakis J, Argiriou M, Dedeilias P, Farsaris D, Diamantis T, et al. Endovascular repair for blunt thoracic aortic injury: 11-year outcomes and postoperative surveillance experience. *J Thorac Cardiovasc Surg*. 2014;148(6):2956–2961.
124. Canaud L, Marty-Ané C, Ziza V, Branchereau P, Alric P. Minimum 10-year follow-up of endovascular repair for acute traumatic transection of the thoracic aorta. *J Thorac Cardiovasc Surg*. 2015;149(3):825–829.
125. Serra R, de Franciscis S, Grande R, Butrico L, Perri P, Indolfi C, et al. Endovascular repair for acute traumatic transection of the descending thoracic aorta: experience of a single centre with a 12-years follow up. *J Cardiothorac Surg*. 2015;10:171.
126. Watson J, Slaiby J, Garcia Toca M, Marcaccio EJ, Chong TT. A 14-year experience with blunt thoracic aortic injury. *J Vasc Surg*. 2013;58(2): 380–385.
127. Estrera AL, Miller CC 3rd, Guajardo-Salinas G, Coogan S, Charlton-Ouw K, Safi HJ, et al. Update on blunt thoracic aortic injury: fifteen-year single-institution experience. *J Thorac Cardiovasc Surg*. 2013;145(3 Suppl): S154–S158.
128. Khoynezhad A, Azizzadeh A, Donayre CE, Matsumoto A, Velazquez O, White R, et al. Results of a multicenter, prospective trial of thoracic endovascular aortic repair for blunt thoracic aortic injury (RESCUE trial). *J Vasc Surg*. 2013;57(4):899–905.e1.
129. Khoynezhad A, Donayre CE, Azizzadeh A, White R, RESCUE investigators. One-year results of thoracic endovascular aortic repair for blunt thoracic aortic injury (RESCUE trial). *J Thorac Cardiovasc Surg*. 2015; 149(1):155–61.e4.
130. Azizzadeh A, Ray HM, Dubose JJ, Charlton-Ouw KM, Miller CC, Coogan SM, et al. Outcomes of endovascular repair for patients with blunt traumatic aortic injury. *J Trauma Acute Care Surg*. 2014;76(2):510–516.
131. Erben Y, Trejo G, Brownstein AJ, Jean RA, Ziganshin BA, Carino D, et al. Endovascular thoracic aortic transection repair has equivalent survival to open repair after blunt thoracic aortic injury. *Int Angiol*. 2018;37(2): 155–159.
132. 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. *Eur J Vasc Endovasc Surg*. 2015;50(4):460–465.
133. Martinelli O, Malaj A, Gossetti B, Bertoletti G, Bresadola L, Irace L. Outcomes in the emergency endovascular repair of blunt thoracic aortic injuries. *J Vasc Surg*. 2013;58(3):832–835.
134. Gennai S, Leone N, Mezzetto L, Veraldi GF, Santi D, Spaggiari G, et al. Systematic review and meta-analysis of long-term reintervention following thoracic endovascular repair for blunt traumatic aortic injury. *J Vasc Surg*. 2023;78(2):540–547.e4.
135. Kidane B, Plourde M, Chadi SA, Iansavitchene A, Meade MO, Parry NG, et al. The effect of loss to follow-up on treatment of blunt traumatic thoracic aortic injury. *J Vasc Surg*. 2015;61(6):1624–1634.
136. Zierler RE, Jordan WD, Lal BK, Mussa F, Leers S, Fulton J, et al. The Society for Vascular Surgery practice guidelines on follow-up after vascular surgery arterial procedures. *J Vasc Surg*. 2018;68(1):256–284.
137. Makaloski V, Spanos K, Schmidli J, Kölbel T. Surveillance after endovascular treatment for blunt thoracic aortic injury. *Eur J Vasc Endovasc Surg*. 2018;55(3):303–304.
138. Mandigers TJ, Bissacco D, Domanin M, D'Alessio I, Tolva VS, Piffaretti G, et al. Cardiac and aortic modifications after endovascular repair for blunt thoracic aortic injury: a systematic review. *Eur J Vasc Endovasc Surg*. 2022; 64(2–3):176–187.
139. Wong S, Mastracci TM. Part one: for the motion. All TEVAR patients must be followed lifelong by annual CTA/MRA. [pro]. *Eur J Vasc Endovasc Surg*. 2012;44(6):534–537.
140. Katsargyris A, Verhoeven EL. Part two: against the motion. All TEVAR patients do not require lifelong follow-up by annual CTA/MRA.[con]. *Eur J Vasc Endovasc Surg*. 2012;44(6):538–541.