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American Association for the Surgery of Trauma—World Society of Emergency Surgery Guidelines on the diagnosis and management of cervical vascular injuries

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Cervical vascular injuries comprise 10% of all vascular trauma, equally affecting adult and pediatric patients. Approximately 65% occur after penetrating trauma and 35% after blunt trauma.[1,2] Untreated, blunt cerebrovascular injury (BCVI) results in stroke in up to 20% of patients, causing devastating neurologic consequences.[3,4] In one multicenter study, 37% of strokes were present on initial evaluation; the rest occurred at a median of 48 hours after admission.[5] This underscores the importance of adopting evidence-based screening protocols for blunt trauma patients for expeditious assessment of at-risk patients and early initiation of antithrombotic therapy (AT). Arterial injury occurs in up to 25% of penetrating neck trauma and

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has a mortality rate of up to 20% due to stroke and hemorrhage.[6,7] Rapid assessment, bleeding control, and restoration of cerebrovascular blood flow are critical to minimize morbidity and mortality. The purpose of this article is to provide the American Association for the Surgery of Trauma (AAST) and the World Society of Emergency Surgery (WSES) recommendations for the diagnosis and management of cervical vascular injuries (CVI).

METHODS

A computerized search of different databases (MEDLINE, EMBASE, COCHRANE) was performed. Citations were included for the period between January 2013 and September 2024 using the primary search strategy: trauma, traumatic, blunt, penetrating, blood vessel, vascular injury, supraclavicular, cervical, neck, carotid artery, vertebral artery, internal carotid artery, external carotid artery, internal jugular vein, external jugular vein, injury, surgery, diagnosis, operative, nonoperative, endovascular management, anticoagulant, antiplatelet, blunt cerebrovascular injury, BCVI, stent, combined with *and/or* as well as the MeSH terms: carotid artery Injuries, cerebrovascular trauma, vascular system injuries, vertebral artery dissection, endovascular procedures, neck injuries, cervical injuries. 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 were also included as landmark papers in the field. Three authors independently reviewed abstracts chosen for relevance, and any discrepancy between reviewers was settled after discussion.

The level of evidence was evaluated using a modified form of the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system (Table 1).[8] A group of experts in the field, coordinated by a central coordinator, was contacted to express their evidence-based opinion on several issues about cervical vascular trauma. 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 AAST and the WSES. An Executive Summary of the guidelines can be found in Supplemental Digital Content http://links.lww.com/TA/E997 as well as a list of abbreviations used in this manuscript http://links.lww.com/TA/E998.

RESULTS

Epidemiology

What is the incidence of vascular injury in blunt neck trauma?

What are the most common mechanisms of injury?

Statement: Blunt cerebrovascular injury is reported as infrequent (1–3%), but it is likely underdiagnosed unless broad

TABLE 1. Modified System for GoR[8]

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, t reatment 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.

TABLE 2. Signs of Cervical Vascular Injury

Hard Signs	Soft Signs
Active hemorrhage	Venous oozing
Expanding hematoma	Nonexpanding hematoma
Bruit or thrill in area of injury	Dysphonia
Shock unresponsive to fluids	Dysphagia
Massive hemoptysis or hematemesis	Minor hemoptysis
Air bubbling through the injury site	Subcutaneous emphysema
Evolving stroke	
Massive subcutaneous emphysema	

screening protocols are used. Stroke is the most devastating sequelae occurring in about 12% of carotid and 7% of vertebral artery injuries. The most common mechanisms causing blunt cerebrovascular injury are motor vehicle accidents and falls.

The incidence of BCVI is approximately 1% to 3% of trauma patients, but the rate of detection depends on institutional screening protocols.[9–12] The vertebral artery is more commonly injured than the carotid but has a lower risk of stroke, likely due to collateral flow through the Circle of Willis.[13,14] In one large multicenter study, 53% of BCVIs involved the vertebral artery (VA), and 47% involved the internal carotid artery (ICA). Stroke was more common in injuries to the ICA, occurring in 11.7% of injuries compared with 6.7% of injuries to the VA.[14] It is not uncommon for a patient to have more than one vessel injured.[15–17]

Motor vehicle accidents are the most common injury mechanism, accounting for half of BCVI cases.[14,18] Other common causes include falls (18%), motorcycle collisions (10%), and pedestrians struck by motor vehicles (10%).[14] Less common mechanisms of injury include assaults, bicycle accidents, skiing accidents, and hanging attempts.[19–22]

What is the incidence of vascular injury in penetrating neck trauma?

Statement: Injuries to the carotid and vertebral artery occur in approximately 25% of patients sustaining a penetrating neck Injury. The presence of associated aerodigestive injuries is common and must be investigated. GOR 1C

The common and internal carotid arteries are injured in 6% to 20% of cases of penetrating neck trauma and carry a mortality rate of up to 20%. Concomitant vascular injuries to the internal jugular (25%), external carotid (6%), and vertebral artery (6%) are common.[23] In the United States, two-thirds of penetrating cervical vascular injuries occur after gunshot wounds (GSWs) and the other third after stab wounds, while in South Africa, stab wounds are more common.[7,23] In combat-related trauma, shrapnel from explosive devices is a significant source of injury.[24,25] Importantly, penetrating injuries to the vessels in the neck are commonly associated with injuries to the aerodigestive tracts.[7,23,26]

Clinical Presentation, Initial Assessment, and Diagnosis

What is the optimal approach for the initial evaluation of a patient with suspected cervical vascular injury?

Statement: Blunt trauma patients without a clear indication for an emergent operation should be broadly screened for vascular injury with computed tomography angiography (CTA) to decrease the incidence of stroke. In penetrating trauma without hard signs of vascular injury (see Table 2), CTA is indicated. Other diagnostic modalities, such as airway and digestive endoscopy and an esophagogram, may also be needed. GOR 1B

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 immediate resuscitation and transfusions if needed. Identification of immediate life-threatening associated injuries, such as tension pneumo/hemothorax or cardiac tamponade, is critical. In blunt injuries, there should be a high suspicion of concomitant traumatic brain injury (TBI), and a careful neurological examination is warranted. In penetrating injuries, careful examination should identify all external wounds to assess for potential concomitant injuries to the thorax, abdomen, or extremities. Adjunct imaging with a chest x-ray (CXR) with or without Extended Focused Assessment with Sonography in Trauma (eFAST) should be performed to assist with identifying associated injuries.[27] Patients with clear indications for operative intervention (Table 2) should be immediately taken to the operating room.

In penetrating neck trauma, patients with soft signs (Table 2) should undergo screening, whereas those without hard or soft signs of injury may forgo imaging and undergo only close observation.[28,29]

Various screening criteria have been proposed for BCVI, although most are based on the Denver or Memphis criteria with variation across institutions (Table 3). The Eastern Association for the Surgery of Trauma (EAST) recommends adopting a screening protocol to improve detection and reduce the risk of stroke.[9,10,30,31] Protocols are centered on the physical examination

TABLE 3. Screening Criteria for BCVI*

Denver Criteria	Memphis Criteria
Signs/symptoms of BCVI	Unexplained neurologic deficit
Arterial hemorrhage or expanding hematoma	Horner's syndrome
Cervical bruit in patient <50 years old	Lefort II or III fracture
Focal neurologic defect	Cervical spine injury
Stroke on CT or MRI	Skull base fracture involving foramen lacerum
Risk factors for BCVI	Neck soft tissue injury (e.g., seatbelt or hanging)
High energy mechanism	
Lefort II or III midface fracture	
Mandible fracture	
Complex skull fracture, basilar skull fracture, occipital condyle fracture	
Severe TBI with GCS <6	
Cervical spine injury	
Near hanging with anoxic brain injury	
Clothesline type injury or seatbelt abrasion	
TBI with thoracic injuries	
Scalp degloving	
Thoracic vascular injuries	
Blunt cardiac rupture	
Upper rib fractures	

*Adapted from Kim, et al.[9]

and the presence of specific concomitant injuries that increase the risk of BCVI. Direct signs or symptoms of BCVI are uncommon. The most common findings in patients with BCVI are cervical spine injuries and traumatic brain injury (TBI).[32] BCVI is present in 9% of patients with severe TBI.[33] Other important associated injuries include upper rib fractures, mandibular, midface, and skull base fractures, thoracic vascular injuries, and cervical soft tissue injuries, such as a seatbelt sign or ligature marks from hanging.[10,30,31]

CTA is the study of choice for patients with suspected cervical blunt and penetrating trauma and has high sensitivity and specificity for vascular injury.[9,34–38] Computed tomography angiography also provides information on soft tissue and skeletal injuries, which are often associated with BCVI, and can provide information on the trajectory of penetrating injuries caused by gunshot or stab wounds. The injury trajectory seen on CTA can guide decision-making on whether more invasive diagnostic tests such as endoscopy, bronchoscopy, laryngoscopy, or contrast swallow evaluations are needed to further screen for aerodigestive injuries.[6,28] In patients with equivocal findings on a CTA, or if there is a high index of suspicion for vascular injury with a negative CTA, digital subtraction angiography (DSA) should be performed.[35,39] Importantly, artifacts from dental hardware or retained metallic fragments can interfere with CTA quality.[40,41] In resource-limited settings, duplex ultrasound imaging may be considered if CTA or DSA is not readily available. Ultrasound is specific but has poor sensitivity and cannot adequately evaluate osseous segments of the carotid and vertebral arteries.[42] Figure 1 and Figure 2 demonstrate CTA images of vertebral and carotid BCVI.

Management

What are the indications for emergent operative intervention?

Statement: Patients with active hemorrhage should undergo immediate operative intervention. In patients with penetrating trauma, those with hard signs of injury should also undergo immediate surgical intervention. In selected patients with hard signs of injury but who are hemodynamically stable, CTA may be considered to determine if an open or endovascular approach is optimal. GOR 1B

Regardless of the mechanism, injuries with hemodynamic instability and hard signs of vascular injury should undergo

Figure 1. Blunt vertebral artery injury. Right vertebral artery occlusion with distal reconstitution from contralateral artery after BCVI following fall from height.

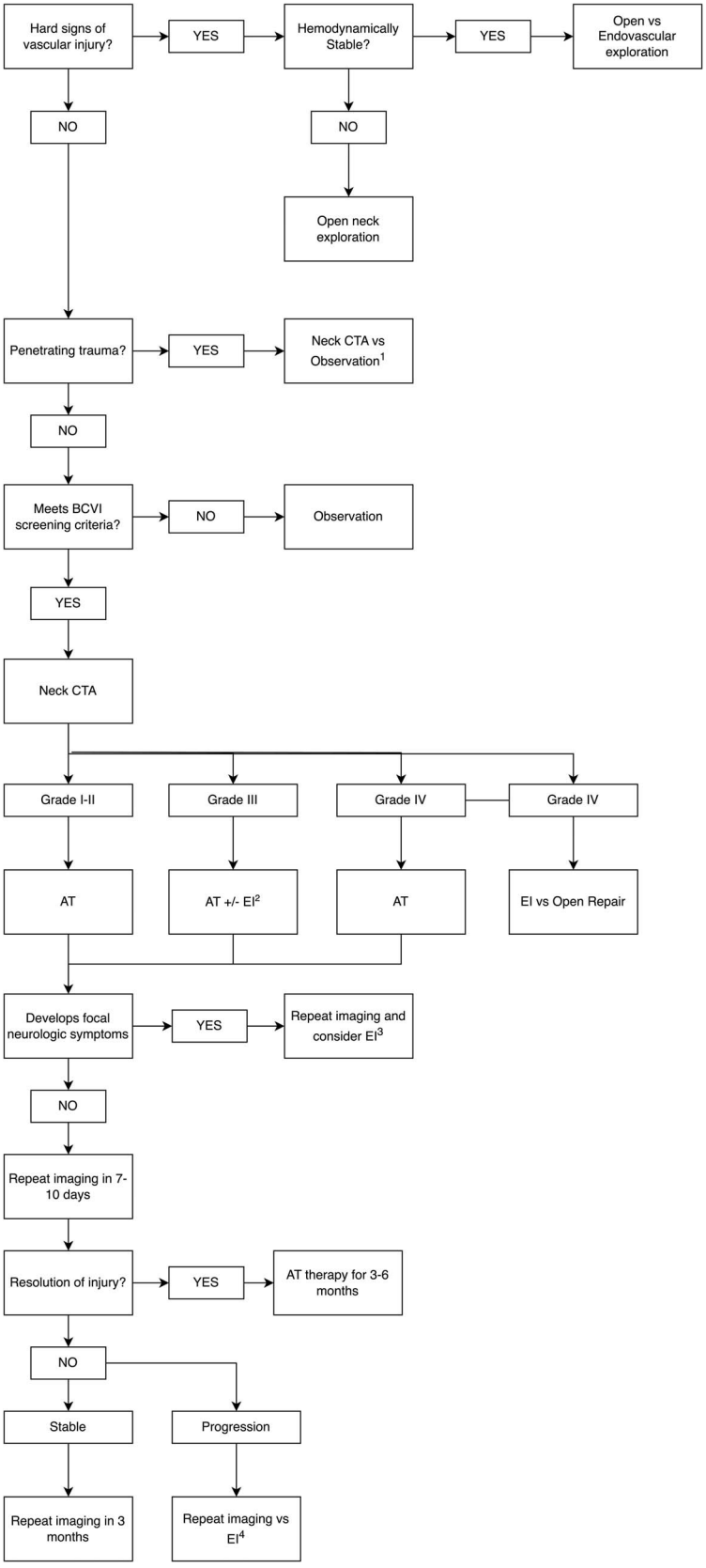

Figure 2. Blunt carotid artery injury. (*A*) Right internal carotid artery dissection after motorcycle vs. auto collision. (*B*) Left internal carotid artery dissection in the same patient.

immediate operative exploration (Table 2). Hard signs include external hemorrhage, massive hemoptysis, hematemesis, expanding or pulsatile hematoma, vascular bruit or thrill, air bubbling at the injury site, and acute neurologic symptoms in the absence of other causes.[23,34,43] In selected penetrating trauma patients with hard signs of injury but who are hemodynamically stable, CTA may be obtained before surgical exploration to plan for the optimal surgical approach.[44–46] In patients with blunt trauma, hemodynamic instability without clinical evidence of active bleeding from a neck source may be due to bleeding in other areas; shock may also be due to associated high spinal cord injury. In these patients, resuscitation and further clinical and radiographic investigation may be required to determine the optimal treatment strategy.

Classically, in penetrating cervical trauma, an anatomic approach was used to pursue immediate cervical exploration by outlining management protocols for each of the three anatomic zones of the neck. However, with the high sensitivity and specificity of modern non-invasive imaging, this zone approach has resulted in many unnecessary operations in up to 56% of patients and is no longer recommended.[28,47–51]

In resource-limited or military settings without access to prompt imaging, patients with soft signs of injury, including venous oozing, non-expanding hematoma, dysphonia, dysphagia, minor hemoptysis, or subcutaneous emphysema, or with certain high-risk injury mechanisms such as fragmentation from explosives, should also be considered for surgical exploration.[24]

Nonoperative Management

Which patients with cervical vascular injury are best treated by non-operative management?

Statement: Grades I to IV blunt carotid injuries should initially undergo AT. Management with medical therapy alone versus endovascular intervention (EI) for certain Grade III and IV carotid injuries is controversial. Blunt vertebral artery injuries are mostly amenable to AT. GOR 2C

BCVI severity is commonly graded using the Denver grading scale, which guides management strategies[9,19] (Table 4). Grade I to III carotid injuries can be managed with only AT, which reduces the risk of stroke and mortality.[9,52] Certain Grade III injuries with large pseudoaneurysms may benefit from prophylactic EI, but this is still being debated. Asymptomatic Grade IV injuries (occlusion) can be managed with AT alone, although there is some controversy as to the utility of revascularization in those with neurological symptoms. Grade V injuries (transection) mandate either open or endovascular surgery.[53,54] Vertebral artery BCVIs have a lower rate of stroke and are more clearly amenable to medical therapy alone, including Grade IV injuries.[55]

TABLE 4. BCVI Grading System*

Grade	Description
I	Luminal irregularity or dissection with <25% luminal narrowing
II	Dissection or intramural hematoma with >25% luminal narrowing, intraluminal thrombus, or raised intimal flap
III	Pseudoaneurysm
IV	Occlusion
V	Transection with free extravasation

*Adapted from Kim et al.[9]

Penetrating arterial injuries will almost always require surgery for hemorrhage control. However, selected low-grade injuries may be similarly managed medically with AT when imaging modalities (CTA or angiography) show arterial wall injury without contrast extravasation.[56,57] Penetrating venous injuries, including internal jugular vein injuries, can be safely managed nonoperatively if there is no active hemorrhage.[34,58,59]

What is the optimal medical therapy for blunt cervical vascular injuries? What is the optimal timing for initiation?

Statement: AT starting as soon as feasible is the medical management of choice in patients with BCVI to prevent or decrease the stroke risk. The choice of anticoagulant versus antiplatelet therapy remains controversial. Full anticoagulation with unfractionated heparin should be considered for higher-grade injuries. Those with low-grade injuries or with contraindications to anticoagulation should receive antiplatelet therapy with Aspirin or Clopidogrel. Early initiation of AT in patients with concomitant TBI is safe in certain patients, but this should be discussed with a multidisciplinary team. Continuation of treatment for 3-6 months is advisable in stable injuries documented by CTA. See Figure 3. GOR 2B

Antithrombotic therapy is the mainstay of medical therapy for BCVI to reduce the risk of stroke and mortality and should be initiated as soon as possible while weighing the risks of hemorrhage, particularly in patients with concomitant TBI and solid organ injury.[9] As previously stated above, the median time to stroke after admission is 48 hours following injury, so this is the optimal time to initiate medical therapy for stroke prevention.[4] While there have been no randomized controlled trials in trauma examining the choice of therapy, several meta-analyses and studies in cervical artery dissection have shown that antiplatelet therapy (i.e., aspirin) is non-inferior to full anticoagulation.[3,60–62] In one large retrospective study of BCVI patients, antiplatelet therapy was also associated with a reduced risk of hemorrhage compared with anticoagulation.[63] Importantly, when looking at retrospective data, patients given anticoagulation therapy tended to have higher-grade injuries and overall higher risks of stroke.[64] Indeed, several studies in trauma have shown a persistent risk of stroke in some patients despite antiplatelet therapy.[5,65] Given the lack of prospective data, many experts recommend anticoagulation with unfractionated heparin over antiplatelet therapy for high-risk patients, such as those with luminal stenosis >50% or higher-grade injuries.[54,66] The duration of therapy depends on the clinical stability and improvement or progression of arterial injury on repeat imaging. The American Heart Association guidelines for carotid artery dissection recommend continuation of AT for at least 3 to 6 months after diagnosis.[54,67] Although not as widely studied, low-grade penetrating arterial injuries may be successfully managed with antiplatelet therapy, similar to low-grade BCVI.[56,57]

How should we monitor patients receiving medical therapy, and how long should they be monitored?

Statement: Patients with low-grade (I-II) blunt injury may benefit from early interval repeat imaging, as many will resolve with medical therapy, and further treatment and surveillance can be discontinued. Higher-grade injuries should also undergo surveillance as progression may occur, and management may change. It is unclear if repeat imaging in TBI patients is beneficial after initiation of medical therapy for BCVI in the absence of neurological deterioration. GOR 2B

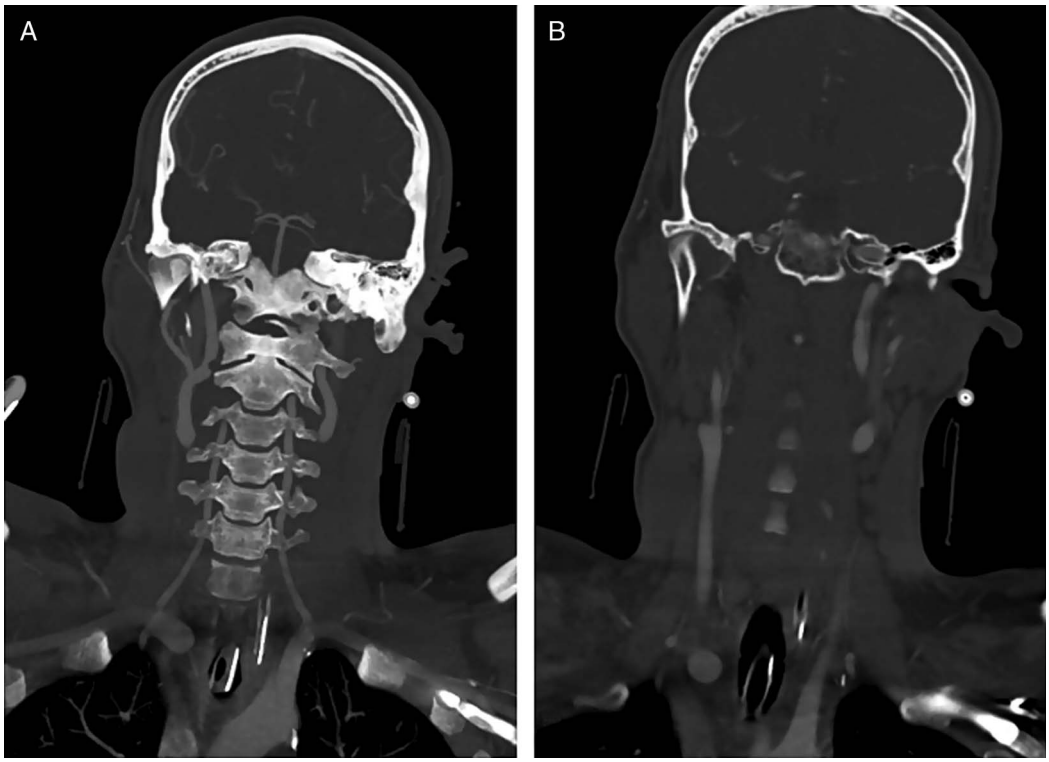

Figure 3. Cervical vascular injury management algorithm. [1]Penetrating injuries with soft signs of vascular injury should prompt imaging while those without can be observed. [2]Small PSAs can be managed with antithrombotic therapy alone. [3]The benefit of endovascular or open surgical intervention after stroke in the setting of acute dissection remains unknown. [4]The optimum frequency of reimaging or indications for intervention after BCVI progression has not been established.

Since BCVIs are typically the result of a high-energy mechanism and are accompanied by other severe injuries such as TBI, patients are typically initially monitored in an intensive care setting. Hourly neurologic checks should be performed to identify signs of developing stroke in the first 24-hour period. There is no consensus on the role of routine brain reimaging after starting AT for BCVI in TBI patients. Studies investigating early initiation of therapy in these patients suggest that the risk of rebleeding is low.[33,68,69] Repeat head imaging should be performed if there is an acute change in neurologic status.

There are no established guidelines for imaging surveillance after nonoperative management of BCVI. Many centers perform reimaging within the first 7-10 days to evaluate for injury resolution or progression.[18,52,55] Repeated imaging may be performed at 3 months or sooner if neurologic symptoms develop in those without injury resolution.[70–72] Isolated low-grade vertebral BCVIs likely do not require reimaging.[73,74]

The role of repeat imaging after nonoperative management of penetrating vascular neck trauma has not been studied.

What is considered a failure of nonoperative management?

Statement: In BCVI, progression of the initial injury is common in Grades I to III within the first two weeks after injury. Repeat CTA in that time frame is advisable and may change management from antiplatelet therapy to an endovascular approach when indicated. GOR 2C

Despite AT, some BCVIs will progress to higher grades. In one large retrospective study, 56% of Grade I BCVIs had resolved at a mean of 11 days after injury compared with 18% of Grade II injuries, 8% of Grade III injuries, and 2% of Grade IV injuries. In the same study, the progression of BCVI to a higher grade occurred in 10% of Grade 1 injuries, 27% of Grade II injuries, and 2% of Grade III injuries.[75] The development of new neurologic deficits should prompt an expedited workup for possible BCVI-related stroke. However, if a stroke occurs in the setting of acute dissection, there remains no definitive evidence that endovascular or open surgical intervention will improve patient outcomes.[76,77] In one systematic review of patients with spontaneous or traumatic carotid dissections who developed pseudoaneurysm, 97% remained unchanged or regressed/resolved at a mean follow-up of 39 months. New neurologic symptoms occurred in only 2% of patients.[78]

Operative Management

What are the surgical treatment modalities and their indications in cervical vascular injury?

Statement: Open and endovascular approaches may be used to manage CVI. Endovascular interventions are used more often in BCVI cases, but can also be used in stable penetrating trauma at experienced centers. The open approach is used primarily for penetrating cervical injuries below the angle of the mandible in hemodynamically unstable patients with external bleeding or presenting with a rapidly expanding cervical hematoma. If a stroke occurs from acute dissection, there is no definitive evidence that surgical intervention improves outcomes. GOR 1C

When indicated, BCVI can be managed by EIs, including stenting, coiling, thrombectomy, and embolization.[74] Endovascular intervention may also be used in penetrating injuries, particularly in difficult-to-reach vessels such as the distal vertebral artery and the internal carotid artery above the angle of the mandible.[79,80] Open surgery is typically performed in the setting of penetrating vascular injury and is rarely indicated for BCVI in the absence of hard signs of injury. There is no clear consensus on the role of EI in managing internal carotid BCVI. The EAST guidelines recommend against routine endovascular stenting for Grades II and III injuries.[9] The use of EI for carotid BCVI has decreased over the last decade due to increasing success with nonoperative management. In a 2018-2020 multi-institutional prospective study of 16 US trauma centers, 0% of injuries in Grade I, 8% in Grade II, 24% in Grade III, and 5% in Grade IV underwent EI. The best predictor of the use of EI was a pseudoaneurysm greater than 9 mm.[81] The degree of luminal stenosis has also been proposed as an indication of EI, but this is still debatable.[66] The stroke rate is higher or no different in patients undergoing EI compared with AT alone, which may be due to selection bias.

Furthermore, stenting does not obviate the need for AT.[82–85] However, in one large retrospective study, among patients presenting with neurologic deficits after BCVI, EI was not associated with a decrease in mortality but was associated with greater odds of discharge home, suggesting a possible benefit.[77] Endovascular intervention may be considered in patients with a large pseudoaneurysm, persistent progression of BCVI, and/or in those who developed new neurologic symptoms following medical management.[43,72,86] Higher-grade injuries should warrant a multidisciplinary discussion with vascular surgery and/or neurosurgical teams.[87]

Similarly, no prospective comparative studies of EI and medical therapy have been conducted in vertebral BCVIs.[88] The majority of vertebral BCVIs, including Grades III and IV injuries, can be managed with AT alone.[16,89,90] EI is reserved for Grade V injuries, symptomatic patients, or those with enlarging pseudoaneurysms.[73,74,84]

Most open surgeries are to address penetrating cervical injuries. Open surgical treatment is indicated in unstable patients with hard signs of vascular injury, including hemorrhage and acute neurologic changes. For hemorrhage, the immediate use of a Foley catheter balloon tamponade to occlude flow may be beneficial in identifying the anatomy and preparing for the repair.[91–93] The optimal approach depends on the injury site but usually involves an initial incision along the anterior border of the sternocleidomastoid muscle with extensions proximally and distally as needed. For better exposure, this can be extended anteriorly with a collar incision to the opposite side of the neck. If there is a concern for a proximal injury or injury to the great vessels, an extension can include a median sternotomy or a supraclavicular incision. For distal or skull base injuries, the incision can be extended posteriorly along the angle of the mandible and mastoid process behind the ear. Exposure of the proximal vertebral artery is obtained through a supraclavicular incision. Distal vertebral artery injuries are challenging to access in open surgery and should be considered for an endovascular approach. In cases of significant bleeding from the vertebral canal, proximal control of the vertebral artery at its origin in the subclavian artery associated with the insufflation of a Fogarty catheter balloon at the level of the hemorrhage in the vertebral canal usually provides temporary control of the bleeding, which can be definitively managed by an EI approach and deflation of the balloon. During open neck exploration for cervical vascular injury, the adjacent trachea and esophagus should be inspected for associated injuries. Care should be taken to avoid important nerve structures, including the vagus, hypoglossal, phrenic nerves, and the carotid body. Specific surgical steps, illustrations, and videos are discussed elsewhere.[94]

For carotid artery injuries, primary repair may be used in minor injuries, while patch angioplasty or interposition grafts are required for more extensive injuries. A carotid shunt should be considered if clamping of the ICA or common carotid artery (CCA) is required during repair to prevent stroke. Shunting should also be considered for more extensive injuries where complex reconstruction may lead to prolonged ischemia. For proximal vertebral artery injuries proximal to its entrance in the vertebral canal, ligation is common due to difficulties repairing destructive lesions and the presence of good collateral blood flow. However, 15% of patients may have a diminutive contralateral vessel; thus, primary repair should be attempted if possible.[79,94]

Damage-control techniques should also be considered for unstable patients with multiple life-threatening injuries, and this includes temporary shunting of the ICA or CCA and/or ligation of severely damaged vessels. The internal jugular vein can be ligated unilaterally if primary repair is not feasible or would require a time-intensive repair. The external carotid artery may also be ligated.[94,95] In extreme circumstances, even the ICA or CCA can be ligated, although this should be avoided if possible due to the high risk of stroke.[96]

There are no consensus guidelines regarding optimal follow-up after open or endovascular surgery for carotid or vertebral BCVI. The Society of Vascular Surgery recommends surveillance after carotid endarterectomy or stenting, which includes Doppler ultrasound studies at 3 months post-procedure, followed by every 6 months to 1 year and then annually.[97] Although most studies lack long-term follow-up, the complication and reintervention rates following EI for BCVI are low.[98–100]

Outcomes

What is the long-term prognosis of patients with cervical vascular injuries?

Statement: The presence of a neurologic deficit or an established stroke upon presentation is highly associated with high mortality rates and poor long-term outcomes in BCVI and penetrating injury cases.

Prognosis after BCVI is primarily affected by the presence of neurologic deficits on presentation. In a study of BCVI cases in the United States using the Trauma Quality Improvement Program database from 2010 to 2017, the overall in-hospital mortality was 16%, and the in-hospital stroke rate was 6%. Few patients (7%) presented with neurologic deficits due to BCVI at admission, but those that did had higher mortality (32% vs. 15%), higher risk of subsequent stroke (32% vs. 4%), and were less likely to be discharged home (14% vs. 42%) than initially asymptomatic BCVI patients.[77] Long-term follow-up regarding BCVI resolution or late complications is lacking in the trauma literature and should be a focus of future trauma research. In the prospective CADISS

study of cervical artery dissection, in which only 21% had a traumatic injury before diagnosis, the 1-year risk of recurrent stroke was 3%, despite patients receiving either antiplatelet or anticoagulation therapy. There was no difference between patients with or without pseudoaneurysm.[61,101] This should be interpreted with caution, as BCVI patients may differ from those enrolled in the study, where 90% of patients presented with neurologic symptoms.

Deaths after penetrating CVI are mostly from cerebral infarction and hemorrhage, followed by airway obstruction. Morbidity and mortality of these injuries are highly dependent on which structures are injured. Overall mortality from penetrating cervical injuries is estimated to be as high as 11%; however, mortality may increase to 50% with major vascular injury.[102,103]

DISCUSSION

Blunt cerebrovascular injury is uncommon but has potentially devastating consequences if a stroke results. Most strokes occur before presentation or within the initial 48 hours post-injury, and this determines the overall prognosis. Patients who progress to stroke after presentation are those who likely would benefit most from medical therapy. The mainstay of management for most BCVI is AT and interval reimaging. It is still unclear which injuries would benefit from EI, but likely those with persistent pseudoaneurysms or progressive injuries on repeat imaging. Penetrating injuries usually present with bleeding rather than ischemia and demand rapid assessment and management to control hemorrhage and restore cerebrovascular blood flow. The trauma surgeon should be well versed in performing the appropriate open exposure approach to quickly obtain proximal and distal vascular control and facilitate expeditious repair. The vertebral and external carotid arteries, as well as most venous injuries, can be ligated, while common and internal carotid artery injuries should be repaired or reconstructed.

AUTHORSHIP

L.Ko., L.P., R.C. participated in the conception and study design. L.Ko., L.P., W.J., L.Ku., K.B., R.C. participated in the literature review. L.Ko., L.P., W.J., L.Ku., K.B., R.C. participated in the data acquisition. L.Ko., L.P., W.J., L.Ku., K.B., F.A., G.A., Z.B., W.B., L.B., F.Ca., I.C., F.Co., D.D., N.D., B.D., J.G., A.G., J.P., T.H., K.I., A.K., Y.K., A.L., R.M., E.M., A.P., M.P., M.S., T.S., P.S., E.D., M.T., D.W., R.C. participated in the data analysis and interpretation. L.Ko., L.P., W.J., L.Ku., K.B., R.C. participated in the drafting of the article. L.Ko., L.P., W.J., L.Ku., K.B., F.A., G.A., Z.B., W.B., L.B., F.Ca., I.C., F.Co., D.D., N.D., B.D., J.G., A.G., J.P., T.H., K.I., A.K., Y.K., A.L., R.M., E.M., A.P., M.P., M.S., T.S., P.S., E.D., M.T., D.W., R.C. participated 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/E996).

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