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Review of Multidetector Computed Tomography Angiography as a Screening Modality in the Assessment of Blunt Vascular Neck Injuries

Teresa Liang, BSc[a], Patrick D. McLaughlin, FFR(RCSI)[b], Luck Louis, BSc, MD, FRCPC[b], Savvas Nicolaou, MD, FRCPC[b,*]

[a]*Faculty of Medicine, University of British Columbia, Vancouver, British Columbia, Canada*
[b]*Division of Emergency and Trauma Imaging, Department of Radiology, Vancouver General Hospital, Vancouver, British Columbia, Canada*

Abstract

Blunt vascular neck injuries (BVNI), previously thought to be rare, have demonstrated increasing incidence rates in recent literature and are associated with significant mortality and morbidity. A radiologist needs to efficiently recognize these injuries on preliminary screening to enable initiation of early management. When initiation of accurate management is started promptly, decreased rates of postinjury complications, for example, stroke, have been demonstrated. This article reviews the incidence, pathophysiology, and rationale for screening for these BVNI injuries. The utility of computed tomography angiography (CTA) as the potential new criterion standard as the screening and follow-up imaging modality for BVNI will be discussed. The application of new multidetector CTA techniques available, such as dual-energy CT and iterative reconstruction, are also reviewed. In addition, the characteristic imaging findings on CTA and the associated Denver Grading scale for BVNI will be reviewed to allow readers to become familiar with the injury patterns and to understand the prognostic and clinical implications, respectively. Examples of the spectrum of injuries, potential injury mimics, and different artifacts on multidetector CTA are shown to help familiarize readers and allow them to successfully and confidently recognize a true BVNI.

Résumé

Les écrits récents font état d'une incidence croissante des traumatismes contondants des vaisseaux cervicaux, auparavant considérés comme rares, qui sont associés à une mortalité et une morbidité importantes. Le radiologiste doit reconnaître efficacement ces traumatismes en dépistage préliminaire afin de permettre une prise en charge précoce. On a démontré une diminution des taux de complications post-traumatiques, notamment les accidents vasculaires cérébraux, lorsqu'une prise en charge appropriée est effectuée rapidement. Le présent article passe en revue l'incidence, la physiopathologie et la justification du dépistage des traumatismes contondants des vaisseaux cervicaux. On y examine l'utilité de l'angiographie par tomodensitométrie (angio-TDM) comme nouvelle modalité de référence potentielle pour le dépistage et le suivi des traumatismes contondants des vaisseaux cervicaux. L'application des nouvelles techniques d'angio-TDM multi-barrettes, comme la TDM en double énergie et la reconstruction itérative, est également examinée. En outre, les aspects d'imagerie caractéristiques à l'angio-TDM et l'échelle d'évaluation de Denver pour les traumatismes contondants des vaisseaux cervicaux sont présentés afin que le lecteur puisse se familiariser avec la présentation des traumatismes et comprendre les conséquences pronostiques et cliniques. Des exemples du spectre des traumatismes possibles, une liste de phénomènes observés à l'angio-TDM pouvant imiter des traumatismes et des différents artefacts à l'angio-TDM multibarrettes sont fournis afin de permettre au lecteur de détecter avec précision et assurance les traumatismes contondants des vaisseaux cervicaux.

Key Words: Blunt vascular neck injury; Blunt cerebrovascular injury; Multidetector computed tomography

Blunt vascular neck injuries (BVNI), a term previously used to describe either carotid arterial injuries (CAI), vertebral arterial injuries (VAI), or both, usually occur as a consequence of direct trauma. These injuries are thought to be associated with high mortality rates from potential complications, for example, stroke. Although previously believed to be rare, recent literature has reported increased incidences, with estimates up to approximately 2.7% [1]. A brief review of the incidence and pathophysiology will be discussed. The evidence that supports the necessity and

* Address for correspondence: Savvas Nicolaou, MD, Radiology Department, Vancouver General Hospital, 899 W 12th Avenue, Vancouver, British Columbia V5Z 1M9, Canada.

E-mail address: savvas.nicolaou@vch.ca (S. Nicolaou).

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indications for screening for BVNI will also be examined. Although multiple imaging modalities, such as angiography, ultrasonography, and magnetic resonance imaging, are available for screening for BVNI, they have limited use in the acute setting of trauma, especially in patients with multiple injuries. Thus, we will limit our discussion to the utility of computed tomography angiography (CTA) for screening and follow-up for BVNI, and the potential new applications of multidetector CTA (MDCTA) to allow MDCTA to become the future criterion standard for diagnosis of BVNI. Examples of common characteristic findings of BVNI and potential mimics and artifacts will be reviewed to help familiarize the reader with these injuries.

Incidence and Pathophysiology

Originally estimated with an incidence rate of 0.08% in all blunt trauma cases [2], BVNIs were previously thought to be rare. However, with increasing literature, aggressive screening and improved imaging technology, significantly higher rates have been reported, which range from 0.30%−1.60% among all patients with blunt trauma [1,3−13]. The importance of recognizing BVNI early is because of the association with high morbidity and mortality due to the injury itself or potential devastating complications, such as stroke or cerebrovascular ischemia. The concern is that often these neurologic symptoms from complications appear late, estimated at 10−72 hours after trauma or even up to months after injury, after a clinically silent latent period [14−17], which leads to a significant delay in diagnosis and management until severe neurologic symptoms develop. It has been estimated that approximately 10% of patients show focal neurologic findings on initial presentation, whereas approximately 67% of patients develop symptoms within 24 hours [17]. Unfortunately, BVNI is associated with high mortality and morbidity rates, with recent estimates of stroke rates up to 60% [18]; therefore, it is imperative for prompt diagnosis to allow early management.

The anatomic distribution of BVNI classically involves the carotid and vertebral arteries but can often involve multivessel injuries that involve more than 1 carotid or vertebral artery; recent literature has estimates of approximately 32% of patients with BVNI having bilateral arterial involvement [4,10,19]. CAIs often involve the cervical internal carotid artery (ICA) immediately proximal to the base of the skull, and the petrous and cavernous segments [10,18,20]. Whereas in VAIs, the transversarial portion between C3-C6 and the tonsillar segment are the most and second-most commonly involved, respectively [10,20,21].

The most widely accepted theory for pathogenesis of BVNI suggests that the layers of the vascular wall are overstretched and result in a traumatic injury [20]. With respect to each artery involvement, CAIs are believed to occur from hyperextension or rotation over the transverse processes of C1 and C2, whereas VAIs are thought to occur when spinal subluxation or dislocation stretches the vertebral artery over adjacent bony structures or dural margins [20]. Other potential mechanisms of injuries include direct trauma and displacement or dislocation of bony fragments from the skull and cervical spine, which cause direct injury [20].

Rationale and Indications for Screening

Previously, neurologic complications from BVNI were thought to be inevitable, however, more recent literature in the past decade has suggested the significance of timely diagnosis of BVNI [4]. The high morbidity rates are thought to be associated with the clinically occult and late onset of neurologic symptoms presentation of BVNI at admission. It has been estimated that 52% of CAIs are asymptomatic at presentation [22]. Early anticoagulation management has been demonstrated to have a significant impact on decreasing mortality and morbidity rates of BVNI [4,19,20,22−25]. For example, the stroke rate for CAI and VAI decreased from 64% to 6.8% and 54% to 2.6%, respectively, with the use of anticoagulation [17,24]. In addition, in a study of 15,767 patients, only 0.5% of the group that received antithrombotic treatment had a stroke compared with 21% of patients who did not receive treatment [25].

With the implementation of a CTA screening protocol, significantly increased detection rates up to 28.4% within a screened population from an overall BVNI incidence rate of 1.25% have been reported [7]. A recent study, in 2006, demonstrated the utility of CTA as a screening protocol for patients with high-risk trauma [5]; this study demonstrated a 10-fold increased detection, increased the incidence rate to 1.4%, and decreased the incidence of delayed stroke from 67% to 0% in a study of 1313 patients [5]. Thus, due to the increased detection rates for BVNI and the favorable outcomes from early anticoagulation management, screening for BVNI is justified, and screening protocols have been implemented in many institutions.

Two components of screening currently debated include: (1) the indications for screening and (2) the ideal screening modality. Previously, a collected set of symptoms, signs, and risk factors, commonly known as the Modified Denver Risk Criteria, has been used to aid in CTA screening for BVNI [26,27], as demonstrated in Table 1. Signs and symptoms, such as arterial hemorrhage, cervical bruits, expanding cervical hematomas, focal neurologic deficits, discrepancies between the neurologic examination and radiologic findings, and ischemic stroke on follow-up CT are indicative for an emergent CTA of the carotid and vertebral arteries to rule out a BVNI [25,28]. Other risk factors demonstrated to be associated with BVNI include a high-energy mechanism of injury and an associated cervical spine fracture, diffuse axonal brain injury with Glasgow Coma Scale score <6, LeFort II and III fractures, basilar skull fracture with carotid canal involvement, and near hanging with axonal brain injury [25,26,28], and, if present, also warrant an urgent CTA.

Table 1
Denver modified BVNI screening criteria[a]

Signs and symptoms of BVNI	
	Arterial hemorrhage
	Cervical bruit
	Expanding cervical hematoma
	Focal neurologic deficit
	Neurologic examination unexplained by neurologic imaging
	Ischemic stroke on secondary head CT
Risk factors for BVNI	
	Cervical spine fracture
	Diffuse axonal injury with GCS < 6
	LeFort II or III fracture
	Basilar skull fracture with carotid canal involvement
	Near hanging, with anoxic brain injury

BVNI = blunt vascular neck injury; CT = computed tomography; CTA = CT angiography; GCS = Glasgow Coma Scale.

[a] If any signs, symptoms, or risk factors are present, then an urgent CTA should be performed to rule out a potential BVNI.

Unfortunately, the previously reported screening criteria have been criticized for not being sensitive enough, because approximately 20% of patients diagnosed with BVNI do not present with components of the screening criteria, thus, more liberal screening criteria are necessary to improve detection rates [26]. For example, a Glasgow Coma Scale score of <13 has demonstrated a significant association with BVNI, as estimated to occur in 31%–39% of patients with BVNI [5,29] and, if present, should warrant an urgent CTA to rule out a BVNI. In a recent meta-analysis of 122,176 admissions, cervical spine and thoracic spine injuries were suggested as additional indications for screening because they were demonstrated to have the greatest association with BVNI [30]. In addition, in a study of 222 patients who underwent CTA after experiencing gunshot wounds to the face and/or neck, 5 patients were demonstrated to have BVNI remote from the penetrating trauma [31]. Thus, collectively, when components of the Modified Denver Risk Criteria are present, or if the patient presents with a history of cervical or thoracic spine injuries, a remote craniofacial gunshot wound, or on examination has a Glasgow Coma Scale score <13, then screening for BVNI should be conducted.

Traditionally thought to be the criterion standard, digital subtraction angiography (DSA) has been criticized for the invasiveness of the procedure itself and its potential for complications, such as arterial dissection, thrombosis, and renal failure from contrast [32–35]. Thus, there have been numerous studies that researched potential other modalities, including ultrasound [1,36], magnetic resonance imaging, and magnetic resonance angiography [3,37–39] as potential screening modalities for BVNI; however, each has several limitations, which deter each as the ideal screening modality for a patient with a potential BVNI in the setting of acute trauma. We will not discuss the abilities and limitations of ultrasonography, magnetic resonance imaging, and magnetic resonance angiography for screening of BVNI here because they have been extensively discussed in previous literature [3,5,17,40–43]. Instead, we will focus on the utility of CTA as a screening modality for BVNI.

CTA for BVNI

Although earlier work with 1-, 2-, and 4-slice CTA demonstrated poor sensitivities and specificities, between 47%-68% and 67%, respectively [32,39], with the advent of MDCTA technology, the detection for BVNI has significantly improved. Five published studies have evaluated the detection ability of 16-slice CTA for BVNI. Initially, in 2004, Berne et al [4] screened 435 patients with CTA for BVNI and demonstrated 100% sensitivity and 94% specificity, and, aside from 1 study, which was misread by the radiologist, no negative CTA was found to have a subsequently missed BVNI [4]. In 2006, Eastman et al [7] evaluated 162 patients with CTA and reported 97.7% sensitivity and 100% specificity, with only 1 false-negative CTA, for a grade 1 injury. That same year, another study, by Utter et al [6], screened 372 patients with CTA for BVNI and demonstrated a negative predictive value of 92% when compared with subsequent DSA studies in 82 patients. It was noted that CTA missed 7 BVNIs; however, upon closer retrospective analysis, 5 injuries were visualized on CTA but not reported, 1 injury was not of traumatic origin, and 1 injury was obscured by dental artifact [6]. These early studies supported the ability of 16-slice CTA to act as a highly sensitive and specific imaging modality for detection of BVNI.

However, 2 later studies, in 2007 and 2009, offered caution for using 16-slice CTA as the sole screening modality for BVNI and reported significantly lower sensitivities of 74% and 29%, respectively [9,12]. Interestingly, in both studies by Utter et al [6] in 2006 and Malhotra, et al [9] in 2007, the investigators reported that their results needed to be interpreted with caution because all missed injuries occurred in the first half of their studies. For example, in the study by Malhotra et al [9], the sensitivity in the first half of the study was 67%, whereas it was 100% in the second half. In addition, both studies recognized that injuries in the region of the skull base seemed to be the most difficult to identify and emphasized the importance of carefully examining this high-risk region [6,9]. Newer studies that researched the utility of 32- and 64-slice CTA for detection of BVNI also reported poor sensitivities, at 51% and 54%, respectively [12,34]. Thus, it seems that 16-slice CTA is the most reliable for detection of clinically significant BVNI and, in 2009, was recommended as the initial screening modality by the Western Trauma Association [44].

CTA has been suggested as the forerunner as a screening imaging modality for detecting BVNI and associated injuries due to its accessibility, noninvasiveness, cost-effective and rapid nature, and ability to detect other potential associated injuries with one imaging series. With the advent of MDCTA, higher-resolution images with decreased motion artifact can be produced with a faster acquisition time. In addition, multiplanar reformatting allows easy visualization in 3 different planes for analysis of lumen and the walls of carotid and vertebral arteries [45]. Although, some limitations, such as streak artifacts from dental amalgams, difficulty visualizing vessels due to the skull bone, the necessary radiation exposure, and contrast-mediated renal toxicity remain, newer technologies with MDCTA have helped minimize some of these disadvantages. Dual-energy CT has allowed improved removal of bony interference with the implementation of a bone subtraction algorithm and with the addition of a tin filter, which results in better visualization of carotid arteries [46]. Iterative reconstruction allows the use of lower radiation dose protocols by lowering the kVp while still satisfactorily maintaining diagnostic quality [47].

The Denver Injury Grading Scale

BVNI can present as a variety of luminal irregularities on CTA. Biffl et al [26] initially developed a grading scale based on DSA findings for blunt injuries in carotid vessels to help provide an accurate description of the injury and define stroke risk by injury grade. This grading scale has been widely adapted and has significant prognostication abilities [32]. Biffl et al [26] initially investigated 76 patients with 109 CAIs and reviewed the overall prognosis and response to treatment at different grades of injury. An overall stroke rate has been estimated to range from 21%–64% for untreated BVNIs [22,24,48]. A difference of the corresponding risk of stroke after injury was demonstrated between CAIs and VAIs [26]; although CAIs have a stroke rate that increased linearly with the corresponding increasing grade, VAIs tend to have a more consistent stroke rate, steady at approximately 30% for grades 2–4 injuries [25]. This may be attributed to the protective abilities of collateral vessels present, which allows the reconstitution of flow [49].

When a CTA or angiogram is reviewed, recognition of normal vasculature and different manifestations of BVNI is essential for early and accurate diagnosis. A grade 1 injury is described as an intimal irregularity or dissection with less than 25% luminal narrowing [20]. These injuries manifest on MDCTA as areas of nonstenotic luminal irregularity of less than 25%, as demonstrated in Figures 1 and 2. Grade 2 injuries are dissections or intramural hematomas with greater than or equal to 25% luminal narrowing, intraluminal clot, or a visible intimal flap [20]. A narrowed lumen diameter (from minimal to nearly occlusive) and a widened arterial diameter is demonstrated with these injuries, as shown in Figure 3. Pseudoaneurysms, which look like an eccentric outpouching or ballooning of the contrast material while still contained in the arterial lumen, are defined as grade 3 injuries and an example is demonstrated in Figure 4 [20]. Grade 4 injuries are recognized as complete occlusions and, on MDCTA, are manifested as areas with the lack of any intraluminal enhancement while other arteries are simultaneously visualized to fill with contrast, as demonstrated in Figures 5 and 6 [20]. It has been suggested that CAI can manifest as a tapered or abrupt lost of contrast, whereas VAIs tend to manifest as abrupt transitions. Grade 5 injuries are either arterial transections with active extravasation or traumatic arteriovenous fistulas or specifically traumatic carotid cavernous fistulas [20]. An arterial transection with active extravasation manifests as an irregular collection of extravascular contrast material surrounding the parent vessel, as demonstrated in Figures 7 and 8. A summary of the injury characteristics of different grades of injuries and their respective prognosis are exhibited in Table 2.

Follow-up Imaging BVNI

All patients with previously discussed indications for screening and no contraindications to antithrombotic therapy should urgently undergo imaging. However, for those who are not imaged with CTA initially, if there are no severe

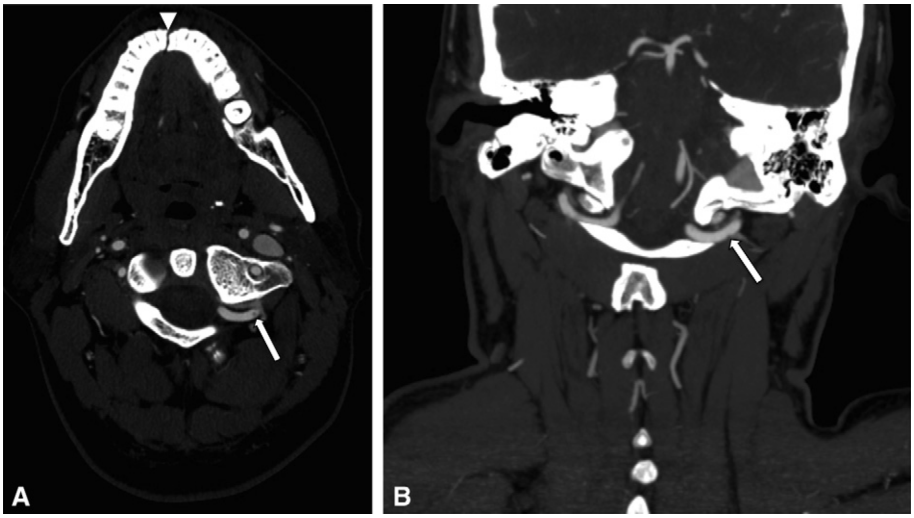

Figure 1. A 47-year-old woman involved in a motor vehicle collision. (A) Axial and (B) coronal contrast-enhanced images, revealing slight wall irregularity of the left vertebral artery. There also is a focal region of low attenuation best seen on the axial image, indicative of focal intimal thrombus attributed to a dissection with less than 25% narrowing of the left vertebral artery at the C1 region (arrows), consistent with a grade 1 injury. (A) Lucency involving the anterior midline of the mandible is in keeping with a fracture on the axial image (arrowhead).

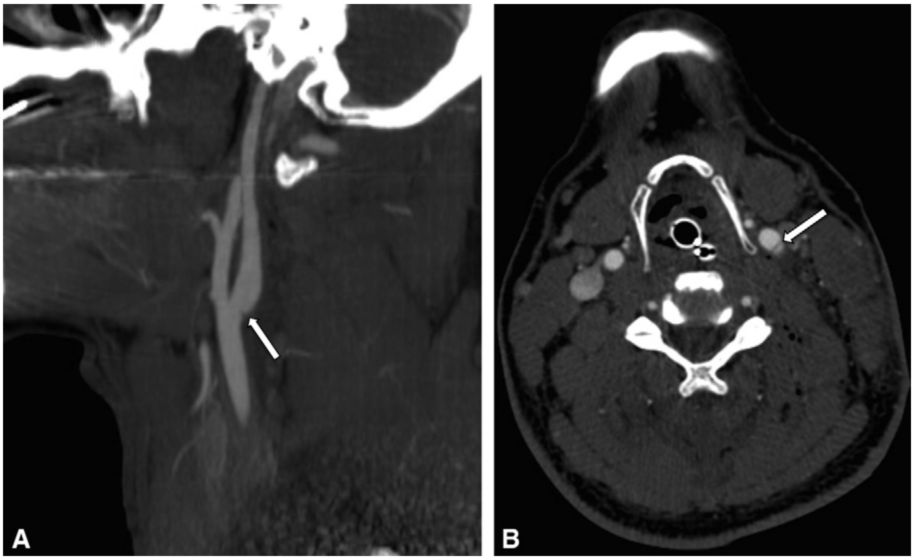

Figure 2. A 39-year-old man with high-grade neck trauma. (A) Oblique sagittal and (B) axial contrast-enhanced images, demonstrating a minimal smooth intimal flap present along the posterior aspect of the left internal carotid bulb region (arrows). This injury is consistent with a grade 1 injury.

contraindications to CTA, then follow-up imaging should be conducted. Due to the dynamic evolution of BVNI, follow-up imaging after a diagnosis of BVNI should be conducted because grades, and thus management, often change. Biffl et al [32] reviewed 179 carotid and vertebral arteries collectively by using DSA a week after injury and concluded that more than half of grade 1 injuries healed, which allowed cessation of antithrombic therapy. Conversely, few grades 2–4 injuries healed; 43% of grade 2 injuries progressed to form pseudoaneurysms that required interventional treatment, and 93% and 82% of grades 3 and 4 injuries, respectively, remained stable [32]. Recently, based on these results, the Western Trauma Association has recommended that a follow-up CTA be conducted after diagnosis of BVNI at 7–10 days after injury [44].

Treatment of BVNI

The usefulness of anticoagulation and intervention management has been previously studied, and, although no criterion standard treatment protocol for BVNI has been established, as previously discussed, the involvement of antithrombotics has allowed a significant reduction in post-injury neurologic complications, for example, stroke. The application of anticoagulation is to prevent the thrombosis of the injured vessel after the exposure of subendothelial

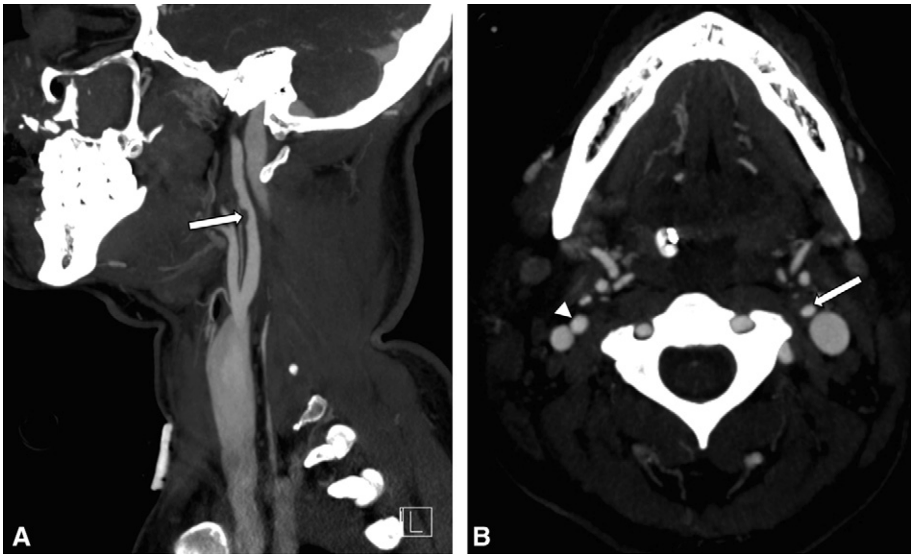

Figure 3. A 26-year-old man involved in a head-on motor vehicle collision. (A) Oblique sagittal contrast-enhanced images, revealing an approximately 50% narrowing of the left cervical internal carotid artery at the angle of the mandible, with mild thrombus, consistent with a grade 2 dissection injury (arrow). (B) On the corresponding axial image, a moderately narrowed lumen diameter of the left internal carotid artery (ICA) (arrow) compared with the right ICA (arrowhead), which is normal size in diameter.

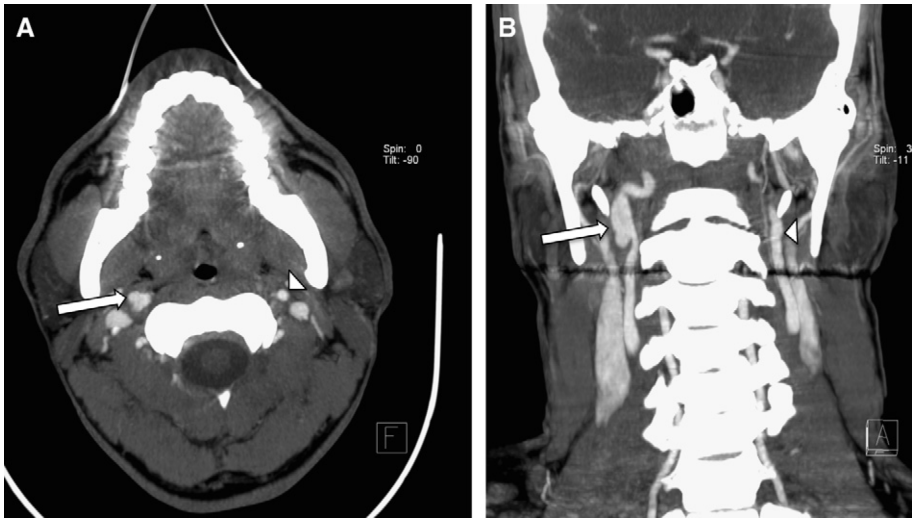

Figure 4. A 38-year-old man involved in an all-terrain-vehicle injury. An eccentric outpouching of contrast material (arrows) is demonstrated on (A) axial and (B) coronal images enhanced images that arise from the cervical internal carotid artery on the right, in keeping with a dissection and formation of a pseudoaneurysm. This traumatic pseudoaneurysm of the right internal carotid artery is consistent with a grade 3 injury. Note a normal internal carotid artery is demonstrated on the left (arrowheads).

collagen, which instigates platelet aggregation and thrombosis [50]. The majority of the literature supports the administration of an antithrombotic agent in patients with BVNI, without known contraindications [28]. In a study of 114 patients with confirmed CAI on angiography, 0% of patients who were treated with anticoagulation experienced a stroke, whereas 46.3% of patients who did not receive any anticoagulation developed neurologic sequelae [19]. The exact agent to be used in the setting of a BVNI (ie, heparin, aspirin, or clopidogrel) has yet to be determined; and, even though studies have failed to demonstrate significant difference in outcome among different pharmacologic interventions [19,32], the Eastern Trauma Group has recommended heparin as the first-line agent for BVNI in patients without contraindications [28]. Alternatively, results of recent studies have suggested the use of endovascular stenting as an substitute to pharmacologic treatment [51]. This intervention has demonstrated potential in grades 2 and 3 injuries, whereas anticoagulation therapy remains the preferred management for grades 1 and 4 injuries [51].

Mimics and Artifacts

When using CTA for a diagnosis of BVNI, it is important that the reader recognizes the potential diagnostic artifacts that may arise. For example, if a patient is in pain or is unable to breath-hold, then he or she may move during the scan, which results in motion artifacts. In addition, streak artifacts from dental amalgams or other internal metal fragments may potentially obscure the injury in the examined vessel, as demonstrated in Figure 9 [20,41]. Fortunately, newer techniques in MDCTA, for example, iterative reconstruction, have the potential to reduce streak artifacts. Alternative techniques, such as open-mouth positioning can be used to help transfer the streak artifact from dental amalgam away from the region of interest, which allows better visualization, and faster scanning

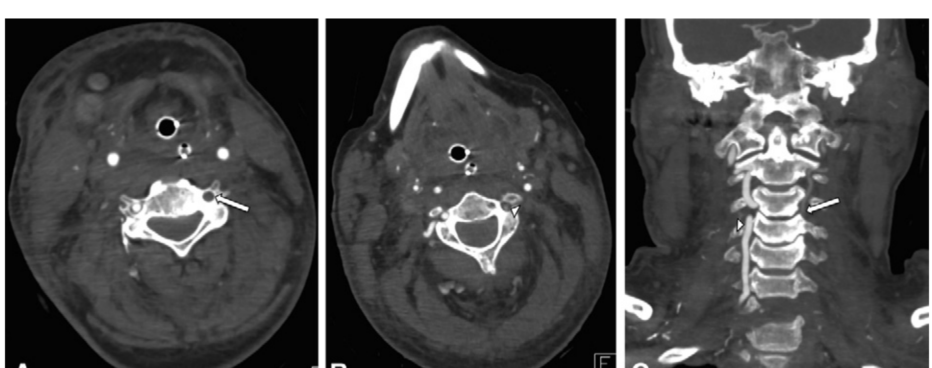

Figure 5. A 49-year-old man involved in a motor vehicle collision. (A) On the axial slice, there is a lack of intraluminal enhancement of the left vertebral artery (arrow), consistent with an occlusion. (B) On a different axial slice, the left vertebral artery is reconstituted at C2−C3 (arrowhead), faintly superior to the occlusion retrogradely, most likely from cervical collaterals that are not demonstrated on the images provided. (C) The coronal image demonstrates the presence of contrast enhancement in the normal right vertebral artery (arrowhead), whereas the left vertebral artery demonstrates an occlusion at its cervical and transversarial portions and eventually weakly reconstitutes at C2−C3 superiorly (arrow). This occlusion is consistent with a grade 4 injury.

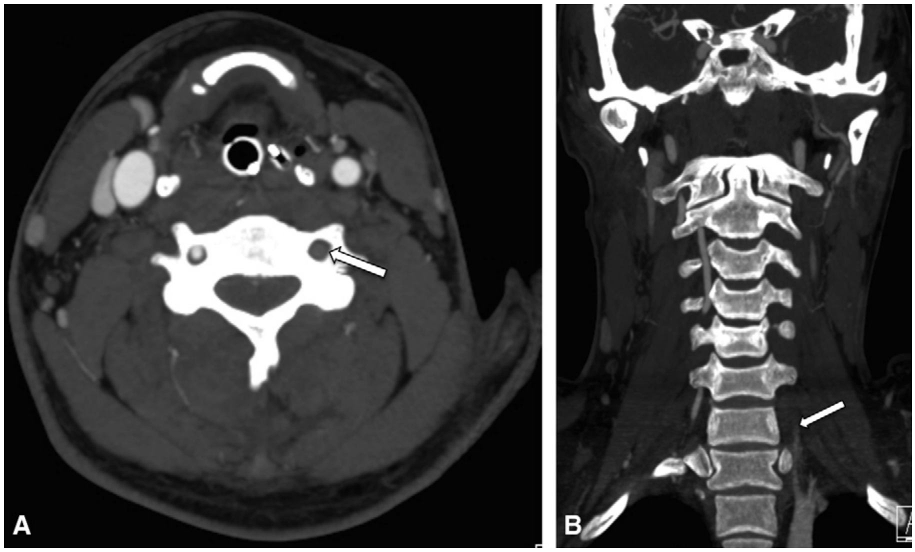

Figure 6. A 43-year-old man sustained blunt trauma to the neck with a hyperflexion injury to the cervical spine. (A) There is an absence of intraluminal enhancement within the left vertebral artery in keeping with a dissection with complete occlusion (arrow), and (B) the coronal image, demonstrates a complete occlusion that originated 2 cm superiorly from an attenuated origin of the left vertebral artery (arrow). This injury is consistent with a grade 4 injury.

methods, for example, high-pitch imaging, may help eliminate breathing-motion artifacts [52].

Radiologists reading CTA for a diagnosis of BVNI should also be aware of normal anatomic variants, such as coiled or looped cervical ICA segments, fibromuscular dysplasia, and dysgenesis of the carotid arteries, that can mimic arterial injuries. Anatomic coiled or looped variants of cervical ICA can occur up to 15% in the generally population, and it is important to be aware that these variants commonly exist and to remember to refer to previous studies, if available, to rule this out [20,53]. Fibromuscular dysplasia has an estimated 1% incidence and can commonly be found in young to middle-aged women in the craniocervical arteries bilaterally, manifested by the "strings of beads" sign, which is described as multiple areas of stenosis and adjacent dilatations [45,54,55]. An example of a patient with fibromuscular dysplasia is visualized in Figure 10. Finally, a rare vascular phenomenon, known as dysgenesis of the carotid arteries, with an estimated incidence rate of 0.13%, can mimic a CAI [53]. When depending on the severity of the agenesis, 3 degrees of severity have been reported, agenesis, hypoplasia, and aplasia of the ICA [53]. Thus, the spectrum of dysgenesis of the carotid arteries imaging manifestations can range from a small to an absent carotid canal on CTA and generally presents unilaterally [20,53,56].

Conclusion

BVNIs, previously thought to be rare, are now more commonly recognized and are clinically significant because

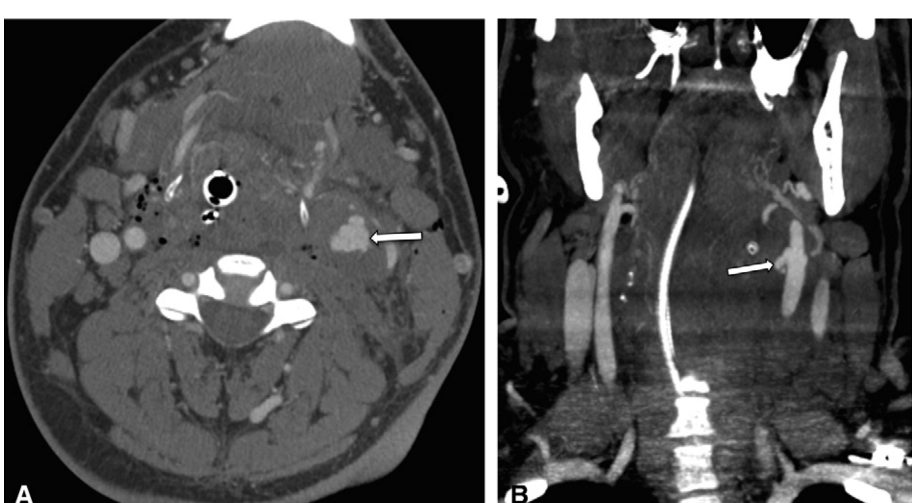

Figure 7. A 27-year-old man with a significant trauma to the neck. Both the (A) axial and (B) coronal images demonstrate a collection of extravascular contrast material surrounding an irregular left internal carotid artery (arrows), consistent with an active extravasation of contrast material consistent with complete disruption of the cervical portion of the left internal carotid artery. This is consistent with a grade 5 injury.

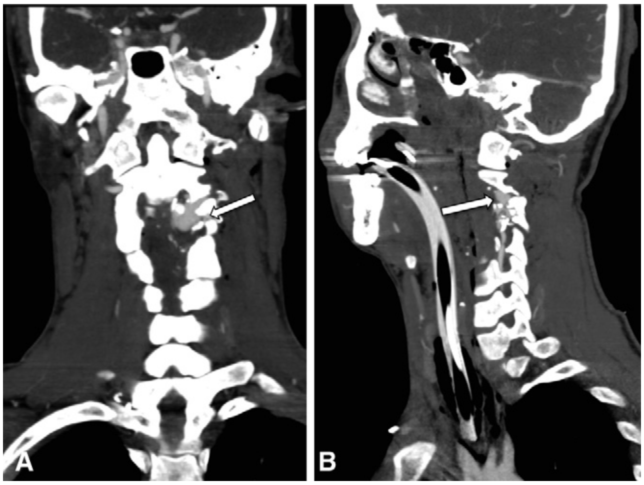

Figure 8. A 42-year-old man involved in a motor vehicle collision. The (A) coronal and (B) sagittal images demonstrate a collection of extravascular contrast material surrounding an irregular left vertebral artery (arrows), consistent with an active extravasation of contrast material. This is consistent with a grade 5 injury. Fragmentation of the cervical spine adjacent to the vertebral artery injury is also present in keeping a fracture of the lateral mass of C3.

of their high mortality and morbidity rates. An early accurate diagnosis allows for prompt management, which can decrease the neurovascular complication rate. Although previously the criterion standard for screening for BVNI, DSA has been criticized for being invasive, time consuming, and a high risk of inducing neurologic complications. CTA,

Table 2
Biffl injury grading scale for BVNI [20,26]

Injury	Grade of BVNI	CTA or DSA imaging characteristic	Stroke rate, %
Carotid arterial			
	1	Minimal intimal injury and/or intimal irregularity, <25% narrowing	3
	2	Dissection or intramural hematoma with ≥25% luminal narrowing, intraluminal clot, or a visible intimal flap	14
	3	Pseudoaneurysm	26
	4	Complete occlusion	50
	5	Transection with free extravasation and/or arteriovenous fistulas that are hemodynamically significant	100
Vertebral arterial			
	1	Minimal intimal injury and/or intimal irregularity, <25% narrowing	6
	2	Dissection or intramural hematoma, ≥25% luminal narrowing, intraluminal clot, or a visible intimal flap	38
	3	Pseudoaneurysm	27
	4	Complete occlusion	28
	5	Transection with free extravasation and/or arteriovenous fistulas that are hemodynamically significant	100

BVNI = blunt vascular neck injury; CTA = computed tomography angiography; DSA = digital subtraction angiography.

Figure 9. A 52-year-old male cyclist hit by a motor vehicle. Intimal irregularity in the left internal carotid artery at the C1 level is visualized anteriorly (arrow). However, the streak artifact from the dental amalgam (arrowhead) could be accounting for the wall irregularity and thus, makes it difficult to exclude or include the presence of a dissection. In the differential, one would have to include spasm or fibromuscular dysplasia. To decrease the dental amalgam artifact, a tube could be placed between teeth to open the gap between the teeth, which would reduce the artifact, or the images can also be reconstructed by using monoenergetic spectral imaging with iterative reconstruction that has been shown to reduce beam-hardening artifact from dense objects, because only a single-energy beam is used, which does not experience beam hardening that a polychromatic beam does.

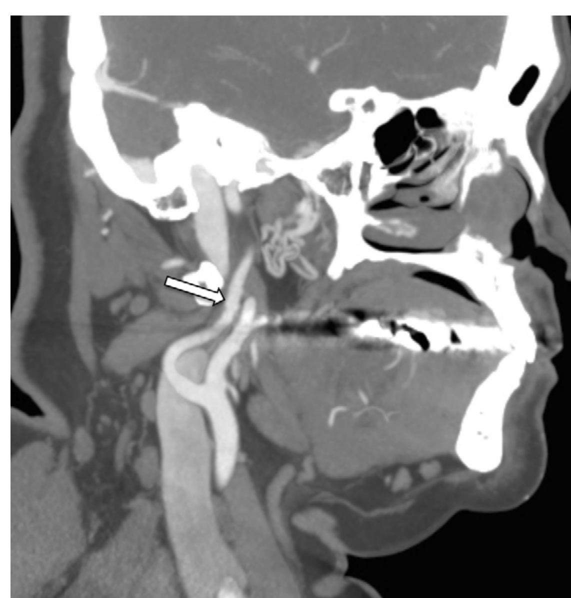

Figure 10. A 56-year-old woman with fibromuscular dysplasia (FMD) involved in a high-speed motor vehicle collision. On the oblique sagittal image, there is beading of the cervical internal carotid artery, in keeping with FMD (arrow).

especially 16 slice, has demonstrated high sensitivity and specificity rates for detecting BVNI in recent literature. Also, because of its efficiency, the availability for prompt and follow-up imaging, and the ability to simultaneously diagnose other potential injuries, the Western Trauma Association has suggested 16-slice MDCTA as the new imaging modality for screening for BVNI. As radiologists increase their experience with these injuries, recognize the grading scale and its clinical significance, learn to identify mimics, and implement techniques to minimize artifacts, the detection rates should continue to improve. Finally, as new techniques, such as dual-energy CT and iterative reconstruction, which allow improved visualization and minimization of artifacts, are continuously implemented, the capabilities of MDCTA in the detection of BVNI will continue to expand. Collectively, these strengths will allow MDCTA to likely become the new criterion standard for screening of BVNI.

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