American College of Radiology
ACR Appropriateness Criteria®
Imaging of Facial Trauma Following Primary Survey

<u>Variant 1:</u> **Tenderness to palpation or contusion or edema over frontal bone. Suspect frontal bone injury. Initial imaging following primary survey.**

Procedure	Appropriateness Category	Relative Radiation Level
CT maxillofacial without IV contrast	Usually Appropriate	☢☢
CT head without IV contrast	Usually Appropriate	☢☢☢
Radiography skull	Usually Not Appropriate	☢
Arteriography cervicocerebral	Usually Not Appropriate	☢☢☢
MRA head and neck with IV contrast	Usually Not Appropriate	O
MRA head and neck without and with IV contrast	Usually Not Appropriate	O
MRA head and neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine with IV contrast	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
MRI cervical spine without IV contrast	Usually Not Appropriate	O
MRI head with IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRI head without IV contrast	Usually Not Appropriate	O
MRI maxillofacial with IV contrast	Usually Not Appropriate	O
MRI maxillofacial without and with IV contrast	Usually Not Appropriate	O
MRI maxillofacial without IV contrast	Usually Not Appropriate	O
CT maxillofacial with IV contrast	Usually Not Appropriate	☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without IV contrast	Usually Not Appropriate	☢☢☢
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢
CT maxillofacial without and with IV contrast	Usually Not Appropriate	☢☢☢
CTA head and neck with IV contrast	Usually Not Appropriate	☢☢☢

Variant 2: **Pain with upper jaw manipulation or pain overlying zygoma or zygomatic deformity or facial elongation or malocclusion or infraorbital nerve paresthesia. Suspect midface injury. Initial imaging following primary survey.**

Procedure	Appropriateness Category	Relative Radiation Level
CT maxillofacial without IV contrast	Usually Appropriate	☢☢
Radiography chest	Usually Not Appropriate	☢
Radiography paranasal sinuses	Usually Not Appropriate	☢
Arteriography cervicocerebral	Usually Not Appropriate	☢☢☢
MRA head and neck with IV contrast	Usually Not Appropriate	O
MRA head and neck without and with IV contrast	Usually Not Appropriate	O
MRA head and neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine with IV contrast	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
MRI cervical spine without IV contrast	Usually Not Appropriate	O
MRI head with IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRI head without IV contrast	Usually Not Appropriate	O
MRI maxillofacial with IV contrast	Usually Not Appropriate	O
MRI maxillofacial without and with IV contrast	Usually Not Appropriate	O
MRI maxillofacial without IV contrast	Usually Not Appropriate	O
CT maxillofacial with IV contrast	Usually Not Appropriate	☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without IV contrast	Usually Not Appropriate	☢☢☢
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢
CT head without IV contrast	Usually Not Appropriate	☢☢☢
CT maxillofacial without and with IV contrast	Usually Not Appropriate	☢☢☢
CTA head and neck with IV contrast	Usually Not Appropriate	☢☢☢

Variant 3: **Visible nasal deformity or palpable nasal deformity or tenderness to palpation of the nose or epistaxis. Suspect nasal injury. Initial imaging following primary survey.**

Procedure	Appropriateness Category	Relative Radiation Level
CT maxillofacial without IV contrast	Usually Appropriate	☢☢
US maxillofacial	May Be Appropriate	O
Radiography paranasal sinuses	May Be Appropriate	☢
MRI maxillofacial with IV contrast	Usually Not Appropriate	O
MRI maxillofacial without and with IV contrast	Usually Not Appropriate	O
MRI maxillofacial without IV contrast	Usually Not Appropriate	O
CT maxillofacial with IV contrast	Usually Not Appropriate	☢☢
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢
CT head without IV contrast	Usually Not Appropriate	☢☢☢
CT maxillofacial without and with IV contrast	Usually Not Appropriate	☢☢☢

Variant 4: **Trismus or malocclusion or gingival hemorrhage or mucosal hemorrhage or loose teeth or fractured teeth or displaced teeth. Suspect mandibular injury. Initial imaging following primary survey.**

Procedure	Appropriateness Category	Relative Radiation Level
CT maxillofacial without IV contrast	Usually Appropriate	☢☢
Radiography mandible	May Be Appropriate	☢
Radiography chest	Usually Not Appropriate	☢
Arteriography cervicocerebral	Usually Not Appropriate	☢☢☢
MRA head and neck with IV contrast	Usually Not Appropriate	O
MRA head and neck without and with IV contrast	Usually Not Appropriate	O
MRA head and neck without IV contrast	Usually Not Appropriate	O
MRI cervical spine with IV contrast	Usually Not Appropriate	O
MRI cervical spine without and with IV contrast	Usually Not Appropriate	O
MRI cervical spine without IV contrast	Usually Not Appropriate	O
MRI head with IV contrast	Usually Not Appropriate	O
MRI head without and with IV contrast	Usually Not Appropriate	O
MRI head without IV contrast	Usually Not Appropriate	O
MRI maxillofacial with IV contrast	Usually Not Appropriate	O
MRI maxillofacial without and with IV contrast	Usually Not Appropriate	O
MRI maxillofacial without IV contrast	Usually Not Appropriate	O
CT maxillofacial with IV contrast	Usually Not Appropriate	☢☢
CT cervical spine with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without and with IV contrast	Usually Not Appropriate	☢☢☢
CT cervical spine without IV contrast	Usually Not Appropriate	☢☢☢
CT head with IV contrast	Usually Not Appropriate	☢☢☢
CT head without and with IV contrast	Usually Not Appropriate	☢☢☢
CT head without IV contrast	Usually Not Appropriate	☢☢☢
CT maxillofacial without and with IV contrast	Usually Not Appropriate	☢☢☢
CTA head and neck with IV contrast	Usually Not Appropriate	☢☢☢

IMAGING OF FACIAL TRAUMA FOLLOWING PRIMARY SURVEY

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Summary of Literature Review

Introduction/Background

Maxillofacial trauma patients are a substantial subset of patients presenting to emergency departments in the United States, accounting for approximately 500,000 emergency department visits and nearly one billion dollars in healthcare costs [1-5]. In descending order, assaults, motor vehicle collisions, falls, sporting activities, gunshot wounds, and occupational accidents account for the majority of facial fractures [6]. Of these, motor vehicle collisions and gunshot wounds result in a higher severity of facial injury. In motor vehicle collisions, the risk of facial fractures, especially panfacial fractures, is increased with the lack of seat belt or airbag usage [7]. The traumatic collapse of the face has a “cushion” effect that helps dissipate the impact force, shielding the head and cervical spine [8,9]. However, the facial buttresses may still distribute energy to the cervical spine and cranium. The injury patterns of facial trauma can vary with cause. For instance, motor vehicle collisions and recreational vehicle accidents are more likely to result in fractures of the mandible and nasal bones [10]. In contrast, penetrating trauma and assaults are more likely to produce midface and zygomatic fractures. In a combat environment, mandible and orbital fractures are most common [11]. Overall, the most common structures involved in facial fractures, in order of frequency, are nasal bones, orbital floor, zygomaticomaxillary complex, maxillary sinuses, and mandibular ramus [6].

Before evaluating facial trauma, an emergency or trauma physician must perform a primary survey being mindful of the “airway, breathing, and circulation” for patient stabilization [12-15]. Maxillofacial trauma can lead to airway compromise secondary to hemorrhage, soft-tissue edema, and loss of facial architecture from fractures. Depending upon the mechanism of injury and severity of the maxillofacial fractures, associated injuries to the brain, cervical spine, and cerebrovascular structures may be present [12,16-21]. Once life-threatening injuries have been managed successfully, a secondary survey of the face includes palpation, visual inspection, full visual acuity interrogation, cranial nerve evaluation, detection of a cerebrospinal leak, and dental occlusion assessment. Surgeons can conceptualize the facial skeleton as a series of horizontal and vertical buttresses or can partition the face into thirds [22,23]. Using the trigeminal nerve divisions to define each third’s borders, partition of the face into thirds may help plan surgical access. A good history and physical examination are often insufficient to accurately diagnose the full extent of facial trauma. Therefore, diagnostic imaging is vital in the evaluation of patients with maxillofacial trauma. The main objectives in managing these patients are to restore both function and cosmesis; an accurate diagnosis makes these goals possible. Thus, appropriate imaging improves clinical outcomes by providing correct identification of traumatic injuries and assisting with treatment decisions.

As the partition of the face into thirds has relevance for surgical intervention, this document follows this classification for delineating the variants (ie, frontal bone injury, midface injury, and mandibular injury). The imaging of suspected nasal injury by itself is considered separate from other midface injuries for reasons to be outlined later. It is essential to note the overlap of facial trauma and other conditions addressed by other ACR Appropriateness Criteria® documents. The ACR Appropriateness Criteria® topic on “Orbits, Vision and Visual

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Loss" [24] addresses the initial imaging of suspected orbital trauma. As such, orbital trauma, although falling under the umbrella of facial trauma, will not be discussed in this document. As stated above, maxillofacial trauma may coexist with injuries to the brain, cervical spine, and cerebrovascular structures [12,16-21]. However, this document should not replace or supersede the imaging recommendations in the ACR Appropriateness Criteria® topics on "Head Trauma" [25], "Penetrating Neck Injury" [26], "Cerebrovascular Disease" [27], "Cerebrovascular Diseases-Aneurysm, Vascular Malformation, and Subarachnoid Hemorrhage" [28], and "Suspected Spine Trauma" [29].

Initial Imaging Definition

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).

Discussion of Procedures by Variant

Variant 1: Tenderness to palpation or contusion or edema over frontal bone. Suspect frontal bone injury. Initial imaging following primary survey.

Representing 5% to 15% of all facial fractures, frontal bone fractures are often the result of high-energy blunt trauma, such as motor vehicle collisions, assaults, and significant falls [30]. Thick cortical bone comprises the anterior table of the frontal sinus, allowing it to withstand up to 1,000 kg of force before fracturing, rendering it the sturdiest bone in the face [31]. In contrast, the posterior table of the frontal sinus, separating the sinus from the anterior cranial fossa, is relatively easily fractured secondary to its thin, delicate nature. One-third of injuries are isolated to the anterior table, whereas two-thirds involve both anterior and posterior tables [31]. Injuries along the inferomedial aspect of the frontal sinus and anterior ethmoids may cause occlusion of the nasofrontal duct leading to potential mucocele formation and possibly osteomyelitis [9,15,22,31-33]. Likewise, fractures through the medial aspect of the frontal sinus floor typically involve the cribriform plate and fovea ethmoidalis and may result in cerebrospinal fluid (CSF) leak or chronic sinusitis. Fractures through the lateral part of the frontal sinus floor may involve the orbital roof.

CT Head

Coexisting intracranial injury is not uncommon in patients with frontal sinus injuries. According to one source, more than one-third of patients with frontal sinus fractures are likely to have a concomitant intracranial injury [21]. A study by Lee et al [34] recommended a contemporaneous head CT in patients with suspected frontal sinus fractures. As such, a head CT is complementary to a maxillofacial CT for providing information to fully characterize a patient's injury. Another source reported craniofacial injuries in 56% to 87% of patients with frontal sinus fractures [35]. A subdural or epidural hematoma requiring surgical intervention is existent in 8% to 10% of patients with frontal sinus fracture [15]. The forces needed to create frontal bone fractures are high energy. It is common for them to be associated with shock, brain injury, coma, and additional facial fractures in 75% of cases [36]. Displaced posterior table fractures imply disruption of the underlying dura and communication between the frontal sinus and the anterior cranial fossa. Head CT is proven to be beneficial in the evaluation of acute head trauma. The ACR Appropriateness Criteria® topic on "Head Trauma" [25] further addresses the role of imaging in the setting of head trauma. CT with intravenous (IV) contrast does not aid in detection of head injury.

MRI Head

There is no relevant literature to support the use of MRI of the brain in the initial imaging evaluation of suspected frontal bone injury. In patients with maxillofacial trauma, MRI is rarely necessary for an acute diagnostic workup [2]. A brain MRI is typically the most useful initial imaging for evaluating subacute or chronic head trauma. In the chronic setting, patients with isolated maxillofacial trauma may develop white matter microstructural damage as detected by diffusion tensor imaging, impairing cognitive performance [8]. The ACR Appropriateness Criteria® topic on "Head Trauma" [25] further addresses the role of imaging in the setting of head trauma.

CT Maxillofacial
Multidetector CT (MDCT) is useful in diagnosing maxillofacial injuries [2,30,31,37-43]. MDCT offers superb delineation of osseous and soft-tissue structures. CT provides high image resolution with thin-section acquisitions allowing for the detection of subtle nondisplaced fractures of the facial skeleton. Also, CT offers multiplanar and 3-D image reconstructions, allowing for better characterization of complex fractures. In particular, many surgeons find the 3-D reformations to be critical in their preoperative planning [13,15,21,39,41,44-46]. CT allows for a faster acquisition time than other modalities such as radiography and MRI. Also, it is less reliant on patient positioning than radiography. CT is typically the first-line of imaging to identify penetrating foreign bodies and the subsequent determination of their trajectory and extent of the injury [47,48]. A novel volume visualization tool, cinematic rendering, is a promising technique to illustrate maxillofacial fractures [41]. CT with IV contrast does not aid in detection of osseous facial injury.

MRI Maxillofacial
There is no relevant literature to support the use of MRI of the face in the initial imaging evaluation of suspected frontal bone injury. However, in patients with cranial nerve deficits not explained or incompletely characterized by CT, MRI can be a useful supplement [31]. Because of its superior soft-tissue contrast and multiplanar capabilities, MRI may help detect a CSF leak from a skull base fracture. The ACR Appropriateness Criteria® topic on "Head Trauma" [25] further addresses the role of imaging in the setting of head trauma with suspected CSF leak. MRI can aid in diagnosing the contents that have herniated through a defect in skull base injuries [49]. Also, MRI is superior to CT for detecting small pieces of asphalt, which could occur as facial foreign bodies [50]. MRI with IV contrast is not useful in detection of facial injury.

CT Cervical Spine
CT of the cervical spine is not useful as the initial imaging study in suspected frontal bone injury. CT excels at identifying cervical spine injuries and is useful for identifying cervical spine fractures [29,51]. Fractures of the frontal bone are the consequence of a direct anterior force applied to the forehead, which drives the cervical spine into extension. Thus, concomitant cervical spine injury is not uncommon in patients with maxillofacial injuries in the setting of high-velocity trauma [12,52]. Studies have demonstrated an association between maxillofacial (including frontal bone) and cervical spine injuries:

- A study of 1.3 million trauma patients investigated the relationship between facial fractures and cervical spine injuries, finding 7% of facial fracture patients had a concomitant cervical spine injury [53].
- In a retrospective review of a trauma registry for maxillofacial injuries in severely injured patients after road traffic accidents, there was a high incidence of cervical spine fractures (11.3% versus 7.8%) and traumatic brain injuries (62.6% versus 34.8%) among patients with maxillofacial injuries compared with those without maxillofacial injuries [54].
- In a 10-year retrospective multicenter review of geriatric maxillofacial trauma patients, spinal injuries accounted for 9.23% of all associated injuries, with most spinal injuries being cervical spine injuries [20].
- A study performed over 10 years at a single trauma center revealed 1.3% of patients with facial fractures had associated cervical spine injuries [19].

Additional studies have shown cervical spine injuries are present in 6% to 19% of cases with significant maxillofacial trauma [55,56]. With increased severity of the maxillofacial injury, the likelihood of blunt cervical spine injury increases [57]. The ACR Appropriateness Criteria® topic on "Suspected Spine Trauma" [29] further addresses the role of imaging in the setting of cervical spine trauma. CT with IV contrast is not useful in detection of spinal injury.

MRI Cervical Spine
There is no relevant literature to support the use of MRI of the cervical spine in the initial imaging evaluation of suspected frontal bone injury. MRI is better at detecting soft-tissue injuries of the cervical spine compared with CT. However, CT can detect fractures with higher sensitivity than MRI. Soft-tissue injuries are identified on MRI in 5% to 24% of trauma patients with a negative cervical spine CT [29]. In patients with a negative CT scan, unconscious patients may require a MRI to rule out ligamentous injury [7,58]. As outlined above, concomitant cervical spine injury is not uncommon in patients with frontal bone injuries in the setting of high-velocity trauma. The ACR Appropriateness Criteria® topic on "Suspected Spine Trauma" [29] further addresses the role of imaging in the setting of cervical spine trauma.

Radiography Skull

CT has replaced radiographs for the initial imaging evaluation of suspected frontal bone injury because radiographs cannot characterize the full extent of fractures, detect nasofrontal duct involvement, and ascertain intracranial pathology [30,59]. Approximately 3% of radiographs that did not detect skull fracture had fractures visible on CT in one study. In the group in which radiographs failed to detect a skull fracture, half of the group eventually developed an epidural hematoma [60]. Radiographs may be useful in identifying and determining the location of foreign bodies in the maxillofacial region [50].

CTA Head and Neck

CTA of the head and neck may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality to identify frontal bone injury. Guidance on the imaging of vascular injuries in various clinical scenarios is provided by other ACR Appropriateness Criteria topics. Suspected intracranial arterial injury due to clinical risk factors or positive findings on prior imaging is found in the ACR Appropriateness Criteria® topic on "Head Trauma" [25]. Penetrating neck injury imaging guidance is found in the ACR Appropriateness Criteria® topic on "Penetrating Neck Injury" [26]. Additional imaging recommendations and scenarios addressing vascular injury are found in the ACR Appropriateness Criteria® topics on "Cerebrovascular Disease" [27] and "Cerebrovascular Diseases-Aneurysm, Vascular Malformation, and Subarachnoid Hemorrhage" [28].

High-velocity maxillofacial trauma and penetrating neck trauma are the most common causes of traumatic vascular injuries. Identification and treatment of these injuries should be swift because irreversible neurologic damage or death may occur. Although blunt cerebrovascular injuries (BCVI) are uncommon in maxillofacial trauma, exclusion of these injuries is necessary when clinical suspicion is present [21]. The excellent negative predictive value and high sensitivity of the revised Denver criteria make them an excellent screening tool for BCVI [61]. Using these criteria, blunt trauma patients with particular signs and symptoms of BCVI or risk factors for BCVI should undergo cerebrovascular imaging. Complex skull fractures or scalp degloving are both risk factors for BCVI, which may occur in frontal injuries. Occult neurovascular injury, carotid-cavernous fistula, or carotid transection can occur with severe facial fractures [62,63]. A penetration trajectory, vessel wall hematoma, infiltration of perivascular fat, or foreign bodies <5 mm from a vessel wall should raise suspicion of vascular injury requiring vascular imaging [64,65]. CT angiography (CTA) has been recommended over digital subtraction angiography for initial vascular evaluation because of its short acquisition time and low complication rate [21,29]. CTA detects almost all clinically relevant blunt cervical arterial injuries [29,66].

MRA Head and Neck

MRA of the head and neck may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality to identify frontal bone injury. Guidance on the imaging of vascular injuries in various clinical scenarios is provided by other ACR Appropriateness Criteria topics. Suspected intracranial arterial injury due to clinical risk factors or positive findings on prior imaging is found in the ACR Appropriateness Criteria® topic on "Head Trauma" [25]. Penetrating neck injury imaging guidance is found in the ACR Appropriateness Criteria® topic on "Penetrating Neck Injury" [26]. Additional imaging recommendations and scenarios addressing vascular injury are found in the ACR Appropriateness Criteria® topics on "Cerebrovascular Disease" [27] and "Cerebrovascular Diseases-Aneurysm, Vascular Malformation, and Subarachnoid Hemorrhage" [28].

As stated above, BCVI, although uncommon in maxillofacial trauma, carries significant morbidity and mortality if not identified and treated early. Therefore, the exclusion of these injuries is necessary in the correct clinical context. Although MR angiography (MRA) is inferior to conventional arteriography, it is considered equivalent to CTA in BCVI. Similar to CTA, MRA does distinguish almost all clinically significant cervical arterial injuries [29,66]. However, MRA without IV contrast in the neck may be limited because of artifacts and limited resolution. Subtle vascular injuries such as wall irregularity and thickening and mild luminal irregularity can be difficult to detect [67]. Also, MRA with or without IV contrast is time-consuming, making it challenging to use in an acute trauma setting. Some debate exists as to whether CTA is superior to MRA in BCVI. One study found CTA to be superior [68], whereas another found them to be equivalent [29,69]. Virtual arteriograms can be created without IV contrast using time-of-flight or phase-contrast sequences. Nevertheless, pseudoaneurysms or subtle stenoses are more easily detected by administering contrast intravenously using 3-D time-of-flight imaging.

Arteriography Cervicocerebral

Angiography of the head and neck may logically follow identification of specific bony or soft tissue injuries but is not useful as the initial imaging modality to identify frontal bone injury. Angiography is used as a problem-solving tool in selected cases when artifacts from adjacent shrapnel fragments limit evaluation and CTA of the head and neck is nondiagnostic or inconclusive. It is usually used as a precursor to therapeutic interventions to control active extravasation, transection of vessels, expanding hematoma, or treatment of pseudoaneurysms and arteriovenous fistula. Guidance on the imaging of vascular injuries in various clinical scenarios is provided by other ACR Appropriateness Criteria topics. Suspected intracranial arterial injury due to clinical risk factors or positive findings on prior imaging is found in the ACR Appropriateness Criteria® topic on "Head Trauma" [25]. Penetrating neck injury imaging guidance is found in the ACR Appropriateness Criteria® topic on "Penetrating Neck Injury" [26]. Additional imaging recommendations and scenarios addressing vascular injury are found in the ACR Appropriateness Criteria® topics on "Cerebrovascular Disease" [27] and "Cerebrovascular Diseases-Aneurysm, Vascular Malformation, and Subarachnoid Hemorrhage" [28].

As stated above, BCVI, although uncommon in maxillofacial trauma, carries significant morbidity and mortality if not identified and treated early. Therefore, the exclusion of these injuries is necessary in the correct clinical context. Despite improvements in CTA and MRA, the reference standard for identifying cervical arterial injury remains arteriography because of its ability to detect low-grade injuries missed on other modalities [29,70-72]. However, CTA or MRA is generally utilized over arteriography currently, secondary to the 1% to 2% risk of meaningful complications such as stroke and dissection [29].

Variant 2: Pain with upper jaw manipulation or pain overlying zygoma or zygomatic deformity or facial elongation or malocclusion or infraorbital nerve paresthesia. Suspect midface injury. Initial imaging following primary survey.

Injuries to the midface encompass fractures of the zygoma, naso-orbital-ethmoid region, and maxilla, which are often the result of blunt or penetrating facial trauma from motor vehicle accidents, assaults, falls, or gunshot wounds. Injuries within this region often involve many facial bones and form fracture patterns. Similar to the nasal bones, the zygoma is prominent on the face, making it susceptible to injury. Zygoma fractures are the second most common isolated facial fracture [73]. These fractures may impinge on the mandible's coronoid process or lead to cosmetic deformity requiring surgical repair [31]. A direct blow to the zygoma may transmit the force to adjacent weaker areas of the orbit and maxilla, resulting in zygomaticomaxillary complex fracture. This complex fracture consists of fractures of the zygomatic arch, inferior orbital rim, anterior and posterior maxillary sinus walls, and lateral orbital rim. Another significant injury that involves the midface is the naso-orbital-ethmoid fracture, which results from trauma to the upper nasal bridge. In this injury, the nasal bones, medial orbital walls, nasal septum, and nasofrontal junction are all fractured, resulting in the telescoping of the nose. Without suitable treatment, these patients can develop enophthalmos, telecanthus, lacrimal obstruction, and ptosis [74]. Patients with injuries to the maxilla often present with severe edema, periorbital ecchymosis, enophthalmos, facial asymmetry, and malocclusion. Injuries to the maxilla often occur in 3 main patterns: Le Fort I, Le Fort II, and Le Fort III. All 3 Le Fort fracture patterns involve the pterygoid plates. Le Fort I injuries are transversely oriented, involving all maxillary sinus walls and resulting in a mobile hard palate relative to the remainder of the midface [46]. Le Fort II injuries are pyramidal in configuration involving the posterior alveolar ridge, nasal bones (diathesis at the nasofrontal suture), inferior orbital rims, and lateral walls of the maxillary sinus resulting in a mobile hard palate and nose in relation to the balance of the face. Le Fort III injuries are transversely oriented involving the zygoma, medial and lateral orbital walls, and nasal bridge. Le Fort III injuries result in complete craniofacial separation along with potential involvement of the orbital apex and carotid canal. Le Fort II and III injures are often associated with naso-orbital-ethmoid fractures [31,75], whereas isolated bilateral zygomatic arch fractures are associated with skull base fractures [76]. A midfacial smash is the most complex fracture involving the maxillary region, resulting in severe comminution of the anterior midface and multiple other facial regions and facial buttresses [77].

CT Head

CT of the head may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality to identify midface injury. Coexisting intracranial injury is not uncommon in patients with maxillofacial injuries. A study of 1.3 million trauma patients investigated the relationship between facial fractures and head injuries, finding 68% had associated head injury [53]. In a 10-year retrospective multicenter review of geriatric maxillofacial trauma patients, a head CT alone detects 95% of facial fractures [20]. However, the authors recommended a dedicated maxillofacial CT, because a head CT often only partially images fractures of the midface. Another study suggested a contemporaneous head CT in patients with suspected orbital wall fractures as the incidence of concomitant intracranial injury was found to be 9% [34]. Head CT is proven to be beneficial in the evaluation of acute head trauma. The ACR Appropriateness Criteria® topic on "Head Trauma" [25] further addresses the role of imaging in the setting of head trauma. CT with IV contrast does not aid in detection of head injury.

MRI Head
There is no relevant literature to support the use of MRI of the brain in the initial imaging evaluation of suspected midface injury. In patients with maxillofacial trauma, MRI is rarely necessary for an acute diagnostic workup [2]. A brain MRI is typically the most useful initial imaging for evaluating subacute or chronic head trauma. In the chronic setting, patients with isolated maxillofacial trauma may develop white matter microstructural damage as detected by diffusion tensor imaging, impairing cognitive performance [8]. The ACR Appropriateness Criteria® topic on "Head Trauma" [25] further addresses the role of imaging in the setting of head trauma.

CT Maxillofacial
MDCT is useful in diagnosing maxillofacial injuries [2,30,31,37-43]. MDCT offers superb delineation of osseous and soft-tissue structures. CT provides high image resolution with thin-section acquisitions, allowing for the detection of subtle nondisplaced fractures of the facial skeleton. CT is useful in evaluating naso-orbital-ethmoid fractures because the most common classification system of these fractures uses the medial canthal tendon's status and the degree of comminution of the lacrimal crest bone to which it remains attached [40,78,79]. Although the tendon is not visible, CT detects the degree of comminution of the medial orbital wall at the level of the lacrimal fossa [22]. In zygomaticomaxillary complex fractures, CT is essential in determining the zygomaticosphenoid suture status, which is an indicator of asymmetry and orbital volume changes [40]. Also, CT offers multiplanar and 3-D image reconstructions, allowing for better characterization of complex fractures. In particular, many surgeons find the 3-D reformations afforded by CT to be critical in their preoperative planning [13,15,21,39,41,44-46]. CT allows for a faster acquisition time than other modalities such as radiography and MRI. As well, it is less reliant on patient positioning than radiography. CT is generally considered as the first-line of imaging to identify penetrating foreign bodies and the subsequent determination of their trajectory and extent of the injury [47,48]. A novel volume visualization tool, cinematic rendering, is a promising technique to illustrate maxillofacial fractures [41]. CT with IV contrast is not useful in detection of facial injury.

MRI Maxillofacial
There is no relevant literature to support the use of MRI of the face in the initial imaging evaluation of suspected midface injury. However, in patients with cranial nerve deficits not explained or incompletely characterized by CT, MRI can be a useful supplement [31]. In particular, some Le Fort II injuries can disrupt the infraorbital nerve (V2), leading to anesthesia of the upper teeth, gingiva, upper lip, and lateral aspects of the nose [15,32,80]. Zygomatic maxillary complex fractures are often associated with infraorbital nerve (V2) deficits as well [4,79]. In naso-orbital-ethmoid fractures, olfactory nerve injury often occurs. Because of its superior soft-tissue contrast and multiplanar capabilities, MRI may be helpful in the detection of CSF leak from a skull base fracture. High resolution heavily T2-weighted images are useful in the evaluation of the olfactory nerve and for potential CSF leaks. MRI aids in diagnosing the contents that have herniated through a defect in skull base injuries [49]. These skull base injuries can occur in naso-orbital-ethmoid fractures [31]. Also, MRI is superior to CT for detecting small pieces of asphalt, which could occur as facial foreign bodies [50]. MRI with IV contrast is not useful in detection of facial injury.

CT Cervical Spine
CT of the cervical spine may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality to identify midface injury. CT excels at identifying cervical spine injuries and is useful for identifying cervical spine fractures [29,51]. Concomitant cervical spine injury is not uncommon in patients with maxillofacial injuries in the setting of high-velocity trauma [12,52]. Several studies have demonstrated an association between maxillofacial and cervical spine injuries:

- A study of 1.3 million trauma patients investigated the relationship between facial fractures and cervical spine injuries, finding 7% of facial fracture patients had a concomitant cervical spine injury [53].
- In a retrospective review of a trauma registry for maxillofacial injuries in severely injured patients after road traffic accidents, there was a high incidence of cervical spine fractures (11.3% versus 7.8%) and traumatic brain injuries (62.6% versus 34.8%) among patients with maxillofacial injuries compared with those without maxillofacial injuries [54].
- In a 10-year retrospective multicenter review of geriatric maxillofacial trauma patients, spinal injuries accounted for 9.23% of all associated injuries, with most spinal injuries being cervical spine injuries [20].

- A study performed over 10 years at a single trauma center revealed 1.3% of patients with facial fractures had associated cervical spine injuries [19].

Additional studies have shown cervical spine injuries are present in 6% to 19% of cases with significant maxillofacial trauma [55,56]. With increased severity of the maxillofacial injury, the likelihood of blunt cervical spine injury increases [57]. The ACR Appropriateness Criteria® topic on "Suspected Spine Trauma" [29] further addresses the role of imaging in the setting of cervical spine trauma. CT with IV contrast does not aid in detection of spinal injury.

MRI Cervical Spine
There is no relevant literature to support the use of MRI of the cervical spine in the initial imaging evaluation of suspected midface injury. MRI is better at detecting soft-tissue injuries of the cervical spine compared with CT. However, CT can detect fractures to a greater degree than MRI. Soft-tissue injuries are identified on MRI in 5% to 24% of trauma patients with a negative cervical spine CT [29]. In patients with a negative CT scan, unconscious patients may require an MRI to rule out ligamentous injury [7,58]. As outlined above, concomitant cervical spine injury is not uncommon in patients with maxillofacial injuries in the setting of high-velocity trauma. The ACR Appropriateness Criteria® topic on "Suspected Spine Trauma" [29] further addresses the role of imaging in the setting of cervical spine trauma.

Radiography Paranasal Sinuses
For injuries of the midface, CT has largely replaced radiographs [15,30]. The limitations with radiographs are primarily related to inaccuracies, especially with small or fine structures, associated with the superimposition of adjacent anatomic structures and the lack of technical skill resulting from disuse and a lack of training [2]. In one study, radiologists missed 12% of maxillofacial fractures on radiographs compared with CT [81]. When combined with an appropriate physical examination, the Waters, Caldwell, and submentovertex views can provide sufficient information to verify the clinical diagnosis of a zygomaticomaxillary complex fracture. Still, both patient positioning and technological experience are essential [15]. Radiographs may be useful in identifying and determining the location of foreign bodies in the maxillofacial region [50].

CTA Head and Neck
CTA of the head and neck may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality to identify midface injury. Guidance on the imaging of vascular injuries in various clinical scenarios is provided by other ACR Appropriateness Criteria topics. Suspected intracranial arterial injury due to clinical risk factors or positive findings on prior imaging is found in the ACR Appropriateness Criteria® topic on "Head Trauma" [25]. Penetrating neck injury imaging guidance is found in the ACR Appropriateness Criteria® topic on "Penetrating Neck Injury" [26]. Additional imaging recommendations and scenarios addressing vascular injury are found in the ACR Appropriateness Criteria® topics on "Cerebrovascular Disease" [27] and "Cerebrovascular Diseases-Aneurysm, Vascular Malformation, and Subarachnoid Hemorrhage" [28].

High-velocity maxillofacial trauma and penetrating neck trauma are the most common causes of traumatic vascular injuries. Identification and treatment of these injuries should be swift because irreversible neurologic damage or death may occur. Occult neurovascular injury, carotid-cavernous fistula, or carotid transection can occur with severe facial fractures [62,63]. Although BCVI are uncommon in maxillofacial trauma, exclusion of these injuries is necessary when clinical suspicion is present [21]. The excellent negative predictive value and high sensitivity of the revised Denver criteria make them an excellent screening tool for BCVI [61]. Using these criteria, blunt trauma patients with particular signs and symptoms of BCVI or risk factors for BCVI should undergo cerebrovascular imaging. Le Fort II and Le Fort III fractures are both risk factors for BCVI. Also, the Eastern Association for the Surgery of Trauma currently recommends screening all patients with Le Fort II or III facial fractures for the presence of BCVI [82]. One study based on an analysis of 4,398 patients recommended screening for BCVI in Le Fort I facial fractures [17]. A penetration trajectory, vessel wall hematoma, infiltration of perivascular fat, or foreign bodies <5 mm from a vessel wall should raise suspicion of vascular injury requiring vascular imaging [64,65]. CTA has been recommended over digital subtraction angiography for initial vascular evaluation because of its short acquisition time and low complication rate [21,29]. CTA detects almost all clinically relevant blunt cervical arterial injuries [29,66].

MRA Head and Neck
MRA of the head and neck may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality to identify midface injury. Guidance on the imaging of vascular injuries in

various clinical scenarios is provided by other ACR Appropriateness Criteria topics. Suspected intracranial arterial injury due to clinical risk factors or positive findings on prior imaging is found in the ACR Appropriateness Criteria® topic on "Head Trauma" [25]. Penetrating neck injury imaging guidance is found in the ACR Appropriateness Criteria® topic on "Penetrating Neck Injury" [26]. Additional imaging recommendations and scenarios addressing vascular injury are found in the ACR Appropriateness Criteria® topics on "Cerebrovascular Disease" [27] and "Cerebrovascular Diseases-Aneurysm, Vascular Malformation, and Subarachnoid Hemorrhage" [28].

As stated above, BCVI, although uncommon in maxillofacial trauma, carries significant morbidity and mortality if not identified and treated early. Therefore, the exclusion of these injuries is necessary in the correct clinical context. Although MRA is inferior to conventional arteriography, it is considered equivalent to CTA in BCVI. Similar to CTA, MRA does distinguish almost all clinically significant cervical arterial injuries [29,66]. However, MRA without IV contrast in the neck may be limited because of artifacts and limited resolution. Subtle vascular injuries such as wall irregularity and thickening and mild luminal irregularity can be difficult to detect [67]. Also, MRA with or without IV contrast is time-consuming, making it challenging to use in an acute trauma setting. Some debate exists as to whether CTA is superior to MRA in BCVI. One study found CTA to be superior [68], whereas another found them to be equivalent [29,69]. Virtual arteriograms can be created without IV contrast using time-of-flight or phase-contrast sequences. Nevertheless, pseudoaneurysms or subtle stenoses are more easily detected by administering contrast intravenously using 3-D time-of-flight imaging.

Arteriography Cervicocerebral

Angiography of the head and neck may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality to identify midface injury. Angiography is used as a problem-solving tool in selected cases when artifacts from adjacent shrapnel fragments limit evaluation and CTA of the head and neck is nondiagnostic or inconclusive. It is usually used as a precursor to therapeutic interventions to control active extravasation, transection of vessels, expanding hematoma, or treatment of pseudoaneurysms and arteriovenous fistula. Guidance on the imaging of vascular injuries in various clinical scenarios is provided by other ACR Appropriateness Criteria topics. Suspected intracranial arterial injury due to clinical risk factors or positive findings on prior imaging is found in the ACR Appropriateness Criteria® topic on "Head Trauma" [25]. Penetrating neck injury imaging guidance is found in the ACR Appropriateness Criteria® topic on "Penetrating Neck Injury" [26]. Additional imaging recommendations and scenarios addressing vascular injury are found in the ACR Appropriateness Criteria® topics on "Cerebrovascular Disease" [27] and "Cerebrovascular Diseases-Aneurysm, Vascular Malformation, and Subarachnoid Hemorrhage" [28].

As stated above, BCVI, although uncommon in maxillofacial trauma, carries significant morbidity and mortality if not identified and treated early. Therefore, the exclusion of these injuries is necessary in the correct clinical context. Despite improvements in CTA and MRA, the reference standard for identifying cervical arterial injury remains arteriography because of its ability to detect low-grade injuries missed on other modalities [29,70-72]. However, CTA or MRA is generally utilized over arteriography currently, secondary to the 1% to 2% risk of meaningful complications such as stroke and dissection [29].

Radiography Chest

There is no relevant literature to support the use of chest radiography in the initial imaging evaluation of suspected midface injury. However, a chest radiograph may be warranted to exclude tooth aspiration if there is a tooth that is absent [46,83]. A physician or surgeon should remove an avulsed tooth in the airway because of the risk of developing obstructive pneumonia [9].

Variant 3: Visible nasal deformity or palpable nasal deformity or tenderness to palpation of the nose or epistaxis. Suspect nasal injury. Initial imaging following primary survey.

Because of its prominent location and the bones' relative thinness, the nasal bones are the most common facial skeletal injury, accounting for approximately 50% to 59% of all facial fractures [5,9,31]. These fractures are often the result of an anterior or lateral directed force resulting in nasal deformity, epistaxis, instability, or crepitus on physical examination. More complex fractures are secondary to a high-velocity force directed anteriorly toward the bridge of the nose. In contrast, simple fractures are often the result of a lateral low-velocity force against the nasal prominence. Because the overwhelming majority of isolated fractures are diagnosed clinically and require only closed reduction techniques for proper repair, radiographic analysis is often unnecessary [30-32,37,84]. These fractures must be appropriately managed because unsuitably healed nasal bone fractures may lead to a permanent cosmetic deformity and nasal obstruction [32]. In particular, a fracture involving the nasal cartilage may cause a septal hematoma leading to cartilage necrosis or resorption, and if untreated, a subsequent saddle nose deformity.

US Maxillofacial

Ultrasound (US) is typically not the first-line imaging test for evaluation of nasal injuries. However, researchers have investigated whether US might be useful in this scenario. Research using US has revealed a very high accuracy with sensitivity ranging from 90% to 100%, a specificity of 98% to 100%, and high predictive values [38,85,86]. This is particularly true of isolated nasal bone fractures [87,88]. According to two reports, US better detects nondepressed fractures of the nasal bridge and anterior septal cartilage deviation than CT [85,86]. A conductor-assisted nasal US technique detected nasal fractures, with 100% sensitivity and 89% specificity, 96% positive predictive value, and 100% negative predictive value [89]. Another study revealed that US is a reliable diagnostic tool for estimating the time of nasal bone fracture [90].

Radiography Paranasal Sinuses

Nasal radiographs have limited diagnostic value in the evaluation of nasal trauma. According to several studies, the diagnostic accuracy for radiographs to detect nasal bone fractures ranges from 53% to 82% [91-93]. Radiographs do not considerably alter the diagnosis or management of nasal fractures [94].

CT Head

There is no relevant literature to support the use of CT of the head in the initial imaging evaluation of suspected nasal bone injury.

CT Maxillofacial

MDCT is useful in diagnosing maxillofacial injuries [2,30,31,37-43]. MDCT offers superb delineation of osseous and soft-tissue structures. CT provides high image resolution with thin-section acquisitions allowing for the detection of subtle nondisplaced fractures of the facial skeleton. Also, CT offers multiplanar and 3-D image reconstructions, allowing for better characterization of complex fractures. In particular, many surgeons find the 3-D reformations afforded by CT to be critical in their preoperative planning [13,15,21,39,41,44-46]. In complex nasal injuries and other associated facial fractures, CT can fully characterize the extent of injuries and detect any additional facial injuries [30]. When compared with radiographs, CT is more sensitive in confirming the clinical suspicion of nasal bone fracture [93]. Several classification systems exist for nasal bone fractures, and one classification system created by Rhee et al [95] relies solely on CT to determine the degree of septal deviation. CT allows for a quicker acquisition time compared with other modalities such as radiography and MRI. Also, it is less reliant on patient positioning than radiography. CT is useful as the first-line of imaging to identify penetrating foreign bodies and the subsequent determination of their trajectory and extent of the injury [47,48]. A novel volume visualization tool, cinematic rendering, is a promising technique to illustrate maxillofacial fractures [41]. CT with IV contrast does not aid in detection of facial injury.

MRI Maxillofacial

There is no relevant literature to support the use of MRI of the face in the initial imaging evaluation of suspected nasal bone injury.

Variant 4: Trismus or malocclusion or gingival hemorrhage or mucosal hemorrhage or loose teeth or fractured teeth or displaced teeth. Suspect mandibular injury. Initial imaging following primary survey.

Fractures of the mandible comprise a large proportion of facial fractures because it is vulnerable to low-energy forces. In the setting of assaults and ballistic trauma, the mandible is the most common maxillofacial fracture site [6,96]. Mandibular fractures are classified according to the degree of comminution, location, and the presence of displaced fragments [22]. The mandible is a U-shaped bone forming an incomplete ring that articulates with the calvaria via the temporomandibular joints. Secondary to this ring-like configuration, two separate fractures occur in the mandible in approximately 67% of cases [22,31]. Thus, a second fracture must be sought and excluded after the first fracture is detected. A frequent pattern with two distinct fractures is a mandibular angle or subcondylar fracture with a contralateral parasymphyseal fracture. Another critical pattern, a flail mandible, consists of bilateral subcondylar fractures with a symphyseal fracture. In addition to these osseous injuries, fractures of the mandible may damage the inferior alveolar nerve because they extend through the mandibular canal. Beyond the mandible, approximately 20% to 40% of patients with mandibular fractures have further injuries [97].

CT Head

CT of the head may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality to identify mandibular injury. Coexisting intracranial injury is not uncommon in patients with mandibular injuries. In patients with mandibular fractures, coexisting intracranial injuries are found in approximately 39% of patients [57,97]. Another study of 1.3 million trauma patients investigated the relationship between facial fractures and head injuries, finding 68% had associated head injury [53]. An appreciable association between mandibular fractures and concussion has been reported [98]. Head CT is proven to be beneficial in the evaluation of acute head trauma. The ACR Appropriateness Criteria® topic on "Head Trauma" [25] further addresses the role of imaging in the setting of head trauma. CT with IV contrast does not aid in detection of head injury.

MRI Head

There is no relevant literature to support the use of MRI of the brain in the initial imaging evaluation of suspected mandibular injury. In patients with maxillofacial trauma, MRI is rarely necessary for an acute diagnostic workup [2]. A brain MRI is typically the most useful initial imaging for evaluating subacute or chronic head trauma. In the chronic setting, patients with isolated maxillofacial trauma may develop white matter microstructural damage as detected by diffusion tensor imaging, impairing cognitive performance [8]. The ACR Appropriateness Criteria® topic on "Head Trauma" [25] further addresses the role of imaging in the setting of head trauma.

CT Maxillofacial

MDCT is useful in diagnosing maxillofacial injuries [2,30,31,37-43]. MDCT offers superb delineation of osseous and soft-tissue structures. CT provides high image resolution with thin-section acquisitions allowing for the detection of subtle nondisplaced fractures of the facial skeleton. CT is superior to radiography for the evaluation of mandibular fractures [96]. Nearly 100% sensitive with an improved interobserver agreement, CT with multiplanar reformations is proficient in detecting fractures of the mandible [31,99]. This is especially true of posterior mandibular fractures [3,100]. According to one study, more fractures are identified on CT when there is no fracture visible on orthopantomogram (OPG) [99]. CT is beneficial when evaluating ramus or condyle fractures, because the degree of displacement in these areas can be subtle [101]. CT is especially useful in identifying comminution and displacement of mandibular fractures. These are critical findings because they result in a change in surgical management [100,102,103]. Also, CT offers both multiplanar and 3-D image reconstructions, which allow for better characterization of complex fractures. In particular, many surgeons find the 3-D reformations afforded by CT to be critical in their preoperative planning [13,15,21,39,41,44-46]. CT allows for a faster acquisition time than other modalities such as radiography and MRI. Also, it is less reliant on patient positioning than radiography. CT is typically the first-line of imaging to identify penetrating foreign bodies and the subsequent determination of their trajectory and extent of the injury [47,48]. A novel volume visualization tool, cinematic rendering, is a promising technique to illustrate mandibular fractures [41]. CT with IV contrast does not aid in detection of facial injury.

MRI Maxillofacial

In rare instances, some reports have advocated for MRI in the acute setting to diagnose temporomandibular joint disc morphology and position in certain condylar fractures [2,104,105]. Also, in patients with cranial nerve deficits not explained or incompletely characterized by CT, MRI can be a useful supplement [31]. In particular, fractures through the mandibular canal may damage the inferior alveolar nerve as it travels through the mandibular canal. Damage to the inferior alveolar nerve may result in anesthesia of the ipsilateral lower lip, chin, anterior tongue, and mandibular teeth. Also, MRI is superior to CT for detecting small pieces of asphalt, which could occur as facial foreign bodies [50]. MRI with IV contrast is not useful in detection of facial injury.

Radiography Mandible

In patients with a low clinical suspicion of injury, an OPG (panoramic radiograph) or mandibular series consisting of Towne, bilateral lateral oblique, and lateral views may be obtained to evaluate for mandibular fractures. With a sensitivity of 86% to 92%, OPG has better sensitivity for detecting simple mandibular fractures than a standard 4-view mandibular imaging series [31,101,102,106]. Specifically, an OPG demonstrated a sensitivity of 92% in detecting a mandibular fracture in contrast with 66% with a mandibular series [106]. A mandibular series possess several disadvantages compared with an OPG such as superimposition of osseous structures, difficulty in placing the film perpendicular to the fracture, and presence of confusing spatial relationships. A mandibular series does not require the patient to be upright, remain motionless for an extend period, or cervical spine clearance like an OPG [31]. Although isolated mandibular fractures have often been accurately diagnosed using radiography techniques, notable limitations include fractures of the mandible condyle and subcondylar fractures having anterior displacement, both of which are more easily demonstrated on CT [107,108]. In addition, an OPG can miss both nondisplaced and minimally displaced anterior fractures when there is overlap with the cervical spine [99,109]. A complex fracture may be mistaken for an isolated fracture if OPG is used initially [42]. An OPG can better visualize dental root fractures compared with CT, particularly when the fracture is located at an angle [31]. The use of OPG and mandibular series radiographs has become less favorable in emergency and trauma care settings [110]. Despite this fact, some authors have used radiographs for creating scoring systems for mandibular fractures for an objective and standardized assessment for the degree of severity of mandibular fractures [111].

CT Cervical Spine

CT of the cervical spine may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality used to identify mandibular injury. CT excels at identifying cervical spine injuries and is considered the preferable standard for identifying cervical spine fractures [29,51]. In the setting of high-speed injuries, a co-association between mandible fractures and cervical spine injury exists [6, 98]. In patients with mandibular fractures, coexisting cervical spine injuries are found in approximately 11% of patients [97]. Concomitant cervical spine injury is not uncommon in patients with maxillofacial injuries in the setting of high-velocity trauma [12,52]. Several studies have demonstrated an association between maxillofacial and cervical spine injuries:

- A study of 1.3 million trauma patients investigated the relationship between facial fractures and cervical spine injuries, finding 7% of facial fracture patients had a concomitant cervical spine injury [53].
- In a retrospective review of a trauma registry for maxillofacial injuries in severely injured patients after road traffic accidents, there was a high incidence of cervical spine fractures (11.3% versus 7.8%) and traumatic brain injuries (62.6% versus 34.8%) among patients with maxillofacial injuries compared with those without maxillofacial injuries [54].
- In a 10-year retrospective multicenter review of geriatric maxillofacial trauma patients, spinal injuries accounted for 9.23% of all associated injuries, with most spinal injuries being cervical spine injuries [20].
- A study performed over 10 years at a single trauma center revealed 1.3% of patients with facial fractures had associated cervical spine injuries [19].

Additional studies have shown cervical spine injuries are present in 6% to 19% of cases with significant maxillofacial trauma [55,56]. With increased severity of the maxillofacial injury, the likelihood of blunt cervical spine injury increases [57]. The ACR Appropriateness Criteria® topic on "Suspected Spine Trauma" [29] further addresses the role of imaging in the setting of cervical spine trauma. CT with IV contrast does not aid in detection of spinal injury.

MRI Cervical Spine

There is no relevant literature to support the use of MRI of the cervical spine in the initial imaging evaluation of suspected mandibular injury. MRI is better at detecting soft-tissue injuries of the cervical spine compared with CT. However, CT can detect fractures to a greater degree than MRI. Soft-tissue injuries are identified on MRI in 5% to 24% of trauma patients with a negative cervical spine CT [29]. In patients with a negative CT scan, unconscious patients may require an MRI to rule out ligamentous injury [7,58]. As outlined above, concomitant cervical spine injury is not uncommon in patients with mandibular injuries in the setting of high-velocity trauma. The ACR Appropriateness Criteria® topic on "Suspected Spine Trauma" [29] further addresses the role of imaging in the setting of cervical spine trauma.

CTA Head and Neck

CTA of the head and neck may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality to identify mandibular injury. Guidance on the imaging of vascular injuries in various clinical scenarios is provided by other ACR Appropriateness Criteria topics. Suspected intracranial arterial injury due to clinical risk factors or positive findings on prior imaging is found in the ACR Appropriateness Criteria® topic on "Head Trauma" [25]. Penetrating neck injury imaging guidance is found in the ACR Appropriateness Criteria® topic on "Penetrating Neck Injury" [26]. Additional imaging recommendations and scenarios addressing vascular injury are found in the ACR Appropriateness Criteria® topics on "Cerebrovascular Disease" [27] and "Cerebrovascular Diseases-Aneurysm, Vascular Malformation, and Subarachnoid Hemorrhage" [28].

High-velocity maxillofacial trauma and penetrating neck trauma are the most common causes of traumatic vascular injuries. Identification and treatment of these injuries should be swift because irreversible neurologic damage or death may occur. Occult neurovascular injury, carotid-cavernous fistula, or carotid transection can occur with severe facial fractures [62,63]. Although BCVI are uncommon in maxillofacial trauma, exclusion of these injuries is necessary when clinical suspicion is present [21]. The excellent negative predictive value and high sensitivity of the revised Denver criteria make them an excellent screening tool for BCVI [61]. As a risk factor for BCVI, condylar and extracapsular subcondylar fractures should heighten suspicion for concomitant BCVI [9,112]. The data support a force transmission mechanism of injury in addition to direct damage from bony fragments [72,105]. A penetration trajectory, vessel wall hematoma, infiltration of perivascular fat, or foreign bodies <5 mm from a vessel wall should raise suspicion of vascular injury requiring vascular imaging [64,65]. CTA has been recommended over digital subtraction angiography for initial vascular evaluation because of its short acquisition time and low complication rate [21,29]. CTA detects almost all clinically relevant blunt cervical arterial injuries [29,66].

MRA Head and Neck

MRA of the head and neck may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality to identify mandibular injury. Guidance on the imaging of vascular injuries in various clinical scenarios is provided by other ACR Appropriateness Criteria topics. Suspected intracranial arterial injury due to clinical risk factors or positive findings on prior imaging is found in the ACR Appropriateness Criteria® topic on "Head Trauma" [25]. Penetrating neck injury imaging guidance is found in the ACR Appropriateness Criteria® topic on "Penetrating Neck Injury" [26]. Additional imaging recommendations and scenarios addressing vascular injury are found in the ACR Appropriateness Criteria® topics on "Cerebrovascular Disease" [27] and "Cerebrovascular Diseases-Aneurysm, Vascular Malformation, and Subarachnoid Hemorrhage" [28].

As stated above, BCVI, although uncommon in maxillofacial trauma, carries significant morbidity and mortality if not identified and treated early. Therefore, the exclusion of these injuries is necessary in the correct clinical context. Regarding mandibular injuries, condylar and extracapsular subcondylar fractures should heighten suspicion for concomitant BCVI [9,112]. The data support a force transmission mechanism of injury in addition to direct damage from bony fragments [72,105]. Although MRA is inferior to conventional arteriography, it is considered equivalent to CTA in the setting of BCVI. Similar to CTA, MRA does distinguish almost all clinically significant cervical arterial injuries [29,66]. However, MRA without IV contrast in the neck may be limited because of artifacts and limited resolution. Subtle vascular injuries such as wall irregularity and thickening and mild luminal irregularity can be difficult to detect [67]. Also, MRA with or without IV contrast is time-consuming, making it challenging to use in an acute trauma setting. Some debate exists as to whether CTA is superior to MRA in BCVI. One study found CTA to be superior[68], whereas another found them to be equivalent [29,69]. Virtual arteriograms can be created without IV contrast using time-of-flight or phase-contrast sequences. Nevertheless, pseudoaneurysms or subtle stenoses are more easily detected by administering contrast IV using 3D time-of-flight imaging.

Arteriography Cervicocerebral

Angiography of the head and neck may logically follow identification of specific bony or soft-tissue injuries but is not useful as the initial imaging modality to identify mandibular injury. Angiography is used as a problem-solving tool in selected cases when artifacts from adjacent shrapnel fragments limit evaluation and CTA of the head and neck is nondiagnostic or inconclusive. It is usually used as a precursor to therapeutic interventions to control active extravasation, transection of vessels, expanding hematoma, or treatment of pseudoaneurysms and arteriovenous fistula. Guidance on the imaging of vascular injuries in various clinical scenarios is provided by other ACR Appropriateness Criteria topics. Suspected intracranial arterial injury due to clinical risk factors or positive findings on prior imaging is found in the ACR Appropriateness Criteria® topic on "Head Trauma" [25]. Penetrating neck injury imaging guidance is found in the ACR Appropriateness Criteria® topic on "Penetrating Neck Injury" [26]. Additional imaging recommendations and scenarios addressing vascular injury are found in the ACR Appropriateness Criteria® topics on "Cerebrovascular Disease" [27] and "Cerebrovascular Diseases-Aneurysm, Vascular Malformation, and Subarachnoid Hemorrhage" [28].

As stated above, BCVI, although uncommon in maxillofacial trauma, carries significant morbidity and mortality if not identified and treated early. Therefore, the exclusion of these injuries is necessary in the correct clinical context. Regarding mandibular injuries, condylar and extracapsular subcondylar fractures should heighten suspicion for concomitant BCVI [9,112]. The data support a force transmission mechanism of injury in addition to direct damage from bony fragments [72,105]. Despite improvements in CTA and MRA, the reference standard for identifying cervical arterial injury remains arteriography because of its ability to detect low-grade injuries missed on other modalities [29,70-72]. However, CTA or MRA is generally utilized over arteriography currently secondary to the 1% to 2% risk of meaningful complications such as stroke and dissection [29].

Radiography Chest

There is no relevant literature to support the use of chest radiography in the initial imaging evaluation of suspected mandibular injury. However, a chest radiograph may be warranted to exclude tooth aspiration if there is a tooth that is absent [46,83]. A physician or surgeon should remove an avulsed tooth in the airway because of the risk of developing obstructive pneumonia [9].

Summary of Recommendations

- **Variant 1**: CT maxillofacial without IV contrast and CT head without IV contrast is usually appropriate for the initial imaging of patients following primary survey with tenderness to palpation or contusion or edema over frontal bone of suspected frontal bone injury. These procedures are complementary (ie, more than one should be performed to provide the clinical information to effectively manage the patient's care).
- **Variant 2**: CT maxillofacial without IV contrast is usually appropriate for the initial imaging of patients following primary survey with pain with upper jaw manipulation or pain overlying zygoma or zygomatic deformity or facial elongation or malocclusion or infraorbital nerve paresthesia of suspected midface injury.
- **Variant 3**: CT maxillofacial without IV contrast is usually appropriate for the initial imaging of patients following primary survey with visible nasal deformity or palpable nasal deformity or tenderness to palpation of the nose or epistaxis of suspected nasal injury.
- **Variant 4**: CT maxillofacial without IV contrast is usually appropriate for the initial imaging of patients following primary survey with trismus or malocclusion or gingival hemorrhage or mucosal hemorrhage or loose teeth or fractured teeth or displaced teeth of suspected mandibular injury.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document [113].

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

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