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

Variant 1: **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

Expert Panel on Neurological Imaging: Matthew S. Parsons, MD[a]; Bruno Policeni, MD, MBA[b]; Amy F. Juliano, MD[c]; Mohit Agarwal, MD[d]; Elizabeth R. Benjamin, MD, PhD[e]; Judah Burns, MD[f]; Timothy Doerr, MD[g]; Prachi Dubey, MBBS, MPH[h]; Elliott R. Friedman, MD[i]; Maria K. Gule-Monroe, MD[j]; Karol A. Gutowski, MD[k]; Mari Hagiwara, MD[l]; Vikas Jain, MD[m]; Tanya J. Rath, MD[n]; Brian Shian, MD[o]; Devaki Shilpa Surasi, MD[p]; M. Reza Taheri, MD, PhD[q]; David Zander, MD[r]; Amanda S. Corey, MD.[s]

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

[a]Mallinckrodt Institute of Radiology, Saint Louis, Missouri. [b]Panel Chair, University of Iowa Hospitals and Clinics, Iowa City, Iowa. [c]Panel Vice-Chair, Massachusetts Eye and Ear Infirmary, Harvard Medical School, Boston, Massachusetts. [d]Froedtert Memorial Lutheran Hospital Medical College of Wisconsin, Milwaukee, Wisconsin. [e]Emory University, Atlanta, Georgia; American Association for the Surgery of Trauma. [f]Montefiore Medical Center, Bronx, New York. [g]University of Rochester Medical Center, Rochester, New York; American Academy of Otolaryngology-Head and Neck Surgery. [h]Houston Methodist Hospital, Houston, Texas. [i]University of Texas Health Science Center, Houston, Texas. [j]The University of Texas MD Anderson Cancer Center, Houston, Texas. [k]University of Illinois at Chicago, Chicago, Illinois; University of Chicago, Chicago, Illinois; American Society of Plastic Surgeons. [l]New York University Langone Health, New York, New York. [m]MetroHealth Medical Center, Cleveland, Ohio. [n]Mayo Clinic Arizona, Phoenix, Arizona. [o]University of Iowa Carver College of Medicine, Iowa City, Iowa, Primary care physician. [p]The University of Texas MD Anderson Cancer Center, Houston, Texas; Commission on Nuclear Medicine and Molecular Imaging. [q]George Washington University Hospital, Washington, District of Columbia. [r]University of Colorado Denver, Denver, Colorado. [s]Specialty Chair, Atlanta VA Health Care System and Emory University, Atlanta, Georgia.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through representation of such organizations on expert panels. Participation on the expert panel does not necessarily imply endorsement of the final document by individual contributors or their respective organization.

Reprint requests to: publications@acr.org

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."		

References

1. Rodman RE, Kellman RM. Controversies in the Management of the Trauma Patient. Facial Plast Surg Clin North Am 2016;24:299-308.
2. Meara DJ. Diagnostic Imaging of the Maxillofacial Trauma Patient. Atlas Oral Maxillofac Surg Clin North Am 2019;27:119-26.
3. Morrow BT, Samson TD, Schubert W, Mackay DR. Evidence-based medicine: Mandible fractures. Plast Reconstr Surg 2014;134:1381-90.
4. Harrington AW, Pei KY, Assi R, Davis KA. External Validation of University of Wisconsin's Clinical Criteria for Obtaining Maxillofacial Computed Tomography in Trauma. J Craniofac Surg 2018;29:e167-e70.
5. Allareddy V, Allareddy V, Nalliah RP. Epidemiology of facial fracture injuries. J Oral Maxillofac Surg 2011;69:2613-8.
6. Erdmann D, Follmar KE, Debruijn M, et al. A retrospective analysis of facial fracture etiologies. Ann Plast Surg 2008;60:398-403.
7. Follmar KE, Debruijn M, Baccarani A, et al. Concomitant injuries in patients with panfacial fractures. J Trauma 2007;63:831-5.
8. Sreedharan S, Veeramuthu V, Hariri F, Hamzah N, Ramli N, Narayanan V. Cerebral white matter microstructural changes in isolated maxillofacial trauma and associated neuropsychological outcomes. Int J Oral Maxillofac Surg 2020;49:1183-92.
9. Uzelac A, Gean AD. Orbital and facial fractures. Neuroimaging Clin N Am 2014;24:407-24, vii.
10. Smith H, Peek-Asa C, Nesheim D, Nish A, Normandin P, Sahr S. Etiology, diagnosis, and characteristics of facial fracture at a midwestern level I trauma center. J Trauma Nurs 2012;19:57-65.
11. Salinas NL, Faulkner JA. Facial trauma in Operation Iraqi Freedom casualties: an outcomes study of patients treated from April 2006 through October 2006. J Craniofac Surg 2010;21:967-70.
12. Tan JY, Khoo WX, Hing EC, et al. An Algorithm for the Management of Concomitant Maxillofacial, Laryngeal, and Cervical Spine Trauma. Ann Plast Surg 2016;77 Suppl 1:S36-8.

13. Nastri AL, Gurney B. Current concepts in midface fracture management. Curr Opin Otolaryngol Head Neck Surg 2016;24:368-75.
14. Ray JM, Cestero RF. Initial management of the trauma patient. Atlas Oral Maxillofac Surg Clin North Am 2013;21:1-7.
15. Gentile MA, Tellington AJ, Burke WJ, Jaskolka MS. Management of midface maxillofacial trauma. Atlas Oral Maxillofac Surg Clin North Am 2013;21:69-95.
16. Evans D, Vera L, Jeanmonod D, Pester J, Jeanmonod R. Application of National Emergency X-Ray Utilizations Study low-risk c-spine criteria in high-risk geriatric falls. Am J Emerg Med 2015;33:1184-7.
17. Mundinger GS, Dorafshar AH, Gilson MM, Mithani SK, Manson PN, Rodriguez ED. Blunt-mechanism facial fracture patterns associated with internal carotid artery injuries: recommendations for additional screening criteria based on analysis of 4,398 patients. J Oral Maxillofac Surg 2013;71:2092-100.
18. Sitzman TJ, Hanson SE, Alsheik NH, Gentry LR, Doyle JF, Gutowski KA. Clinical criteria for obtaining maxillofacial computed tomographic scans in trauma patients. Plast Reconstr Surg 2011;127:1270-78.
19. Reich W, Surov A, Eckert AW. Maxillofacial trauma - Underestimation of cervical spine injury. J Craniomaxillofac Surg 2016;44:1469-78.
20. Shumate R, Portnof J, Amundson M, Dierks E, Batdorf R, Hardigan P. Recommendations for Care of Geriatric Maxillofacial Trauma Patients Following a Retrospective 10-Year Multicenter Review. J Oral Maxillofac Surg 2018;76:1931-36.
21. Gelesko S, Markiewicz MR, Bell RB. Responsible and prudent imaging in the diagnosis and management of facial fractures. Oral Maxillofac Surg Clin North Am 2013;25:545-60.
22. Winegar BA, Murillo H, Tantiwongkosi B. Spectrum of critical imaging findings in complex facial skeletal trauma. Radiographics 2013;33:3-19.
23. Hopper RA, Salemy S, Sze RW. Diagnosis of midface fractures with CT: what the surgeon needs to know. Radiographics 2006;26:783-93.
24. Kennedy TA, Corey AS, Policeni B, et al. ACR Appropriateness Criteria® Orbits Vision and Visual Loss. J Am Coll Radiol 2018;15:S116-S31.
25. Shih RY, Burns J, Ajam AA, et al. ACR Appropriateness Criteria® Head Trauma: 2021 Update. J Am Coll Radiol 2021;18:S13-S36.
26. Schroeder JW, Ptak T, Corey AS, et al. ACR Appropriateness Criteria® Penetrating Neck Injury. J Am Coll Radiol 2017;14:S500-S05.
27. American College of Radiology. ACR Appropriateness Criteria®: Cerebrovascular Disease. Available at: https://acsearch.acr.org/docs/69478/Narrative/. Accessed September 30, 2021.
28. American College of Radiology. ACR Appropriateness Criteria®: Cerebrovascular Diseases-Aneurysm, Vascular Malformation, and Subarachnoid Hemorrhage. Available at: https://acsearch.acr.org/docs/3149013/Narrative/. Accessed September 30, 2021.
29. Beckmann NM, West OC, Nunez D, Jr., et al. ACR Appropriateness Criteria® Suspected Spine Trauma. J Am Coll Radiol 2019;16:S264-S85.
30. Chukwulebe S, Hogrefe C. The Diagnosis and Management of Facial Bone Fractures. Emerg Med Clin North Am 2019;37:137-51.
31. Bernstein MP. The Imaging of Maxillofacial Trauma 2017. Neuroimaging Clin N Am 2018;28:509-24.
32. Patel R, Reid RR, Poon CS. Multidetector computed tomography of maxillofacial fractures: the key to high-impact radiological reporting. Semin Ultrasound CT MR 2012;33:410-7.
33. Louis PJ, Morlandt AB. Advancements in Maxillofacial Trauma: A Historical Perspective. J Oral Maxillofac Surg 2018;76:2256-70.
34. Lee HJ, Kim YJ, Seo DW, et al. Incidence of intracranial injury in orbital wall fracture patients not classified as traumatic brain injury. Injury 2018;49:963-68.
35. Fraioli RE, Branstetter BFt, Deleyiannis FW. Facial fractures: beyond Le Fort. Otolaryngol Clin North Am 2008;41:51-76, vi.
36. Rohrich RJ, Hollier LH. Management of frontal sinus fractures. Changing concepts. Clin Plast Surg 1992;19:219-32.
37. Lynham A, Tuckett J, Warnke P. Maxillofacial trauma. Aust Fam Physician 2012;41:172-80.
38. Adeyemo WL, Akadiri OA. A systematic review of the diagnostic role of ultrasonography in maxillofacial fractures. Int J Oral Maxillofac Surg 2011;40:655-61.
39. Strong EB, Gary C. Management of Zygomaticomaxillary Complex Fractures. Facial Plast Surg Clin North Am 2017;25:547-62.

40. Dreizin D, Nam AJ, Diaconu SC, Bernstein MP, Bodanapally UK, Munera F. Multidetector CT of Midfacial Fractures: Classification Systems, Principles of Reduction, and Common Complications. Radiographics 2018;38:248-74.
41. Dreizin D, Nam AJ, Hirsch J, Bernstein MP. New and emerging patient-centered CT imaging and image-guided treatment paradigms for maxillofacial trauma. Emerg Radiol 2018;25:533-45.
42. Dreizin D, Nam AJ, Tirada N, et al. Multidetector CT of Mandibular Fractures, Reductions, and Complications: A Clinically Relevant Primer for the Radiologist. Radiographics 2016;36:1539-64.
43. Gohel A, Oda M, Katkar AS, Sakai O. Multidetector Row Computed Tomography in Maxillofacial Imaging. Dent Clin North Am 2018;62:453-65.
44. Rizzi CJ, Ortlip T, Greywoode JD, Vakharia KT, Vakharia KT. A novel computer algorithm for modeling and treating mandibular fractures: A pilot study. Laryngoscope 2017;127:331-36.
45. Jarrahy R, Vo V, Goenjian HA, et al. Diagnostic accuracy of maxillofacial trauma two-dimensional and three-dimensional computed tomographic scans: comparison of oral surgeons, head and neck surgeons, plastic surgeons, and neuroradiologists. Plast Reconstr Surg 2011;127:2432-40.
46. Avery LL, Susarla SM, Novelline RA. Multidetector and three-dimensional CT evaluation of the patient with maxillofacial injury. Radiol Clin North Am 2011;49:183-203.
47. Ko AC, Satterfield KR, Korn BS, Kikkawa DO. Eyelid and Periorbital Soft Tissue Trauma. Facial Plast Surg Clin North Am 2017;25:605-16.
48. Reginelli A, Santagata M, Urraro F, et al. Foreign bodies in the maxillofacial region: assessment with multidetector computed tomography. Semin Ultrasound CT MR 2015;36:2-7.
49. Kim E, Russell PT. Prevention and management of skull base injury. Otolaryngol Clin North Am 2010;43:809-16.
50. de Santana Santos T, Avelar RL, Melo AR, de Moraes HH, Dourado E. Current approach in the management of patients with foreign bodies in the maxillofacial region. J Oral Maxillofac Surg 2011;69:2376-82.
51. Bailitz J, Starr F, Beecroft M, et al. CT should replace three-view radiographs as the initial screening test in patients at high, moderate, and low risk for blunt cervical spine injury: a prospective comparison. J Trauma 2009;66:1605-9.
52. Tuckett JW, Lynham A, Lee GA, Perry M, Harrington U. Maxillofacial trauma in the emergency department: a review. Surgeon 2014;12:106-14.
53. Mulligan RP, Friedman JA, Mahabir RC. A nationwide review of the associations among cervical spine injuries, head injuries, and facial fractures. J Trauma 2010;68:587-92.
54. Pietzka S, Kammerer PW, Pietzka S, et al. Maxillofacial injuries in severely injured patients after road traffic accidents-a retrospective evaluation of the TraumaRegister DGU(R) 1993-2014. Clin Oral Investig 2020;24:503-13.
55. Jamal BT, Diecidue R, Qutob A, Cohen M. The pattern of combined maxillofacial and cervical spine fractures. J Oral Maxillofac Surg 2009;67:559-62.
56. Lewis VL, Jr., Manson PN, Morgan RF, Cerullo LJ, Meyer PR, Jr. Facial injuries associated with cervical fractures: recognition, patterns, and management. J Trauma 1985;25:90-3.
57. Mulligan RP, Mahabir RC. The prevalence of cervical spine injury, head injury, or both with isolated and multiple craniomaxillofacial fractures. Plast Reconstr Surg 2010;126:1647-51.
58. Wang L, Lee TS, Wang W, Yi DI, Sokoya M, Ducic Y. Surgical Management of Panfacial Fractures. Facial Plast Surg 2019;35:565-77.
59. Rodriguez ED, Stanwix MG, Nam AJ, et al. Twenty-six-year experience treating frontal sinus fractures: a novel algorithm based on anatomical fracture pattern and failure of conventional techniques. Plast Reconstr Surg 2008;122:1850-66.
60. Nakahara K, Shimizu S, Utsuki S, et al. Linear fractures occult on skull radiographs: a pitfall at radiological screening for mild head injury. J Trauma 2011;70:180-2.
61. Burlew CC, Biffl WL, Moore EE. Blunt cerebrovascular injuries in children: broadened screening guidelines are warranted. J Trauma Acute Care Surg 2012;72:1120-1.
62. Kerwin AJ, Bynoe RP, Murray J, et al. Liberalized screening for blunt carotid and vertebral artery injuries is justified. J Trauma 2001;51:308-14.
63. Yang WG, Chen CT, de Villa GH, Lai JP, Chen YR. Blunt internal carotid artery injury associated with facial fractures. Plast Reconstr Surg 2003;111:789-96.

64. Munera F, Cohn S, Rivas LA. Penetrating injuries of the neck: use of helical computed tomographic angiography. J Trauma 2005;58:413-8.
65. Stallmeyer MJ, Morales RE, Flanders AE. Imaging of traumatic neurovascular injury. Radiol Clin North Am 2006;44:13-39, vii.
66. Maung AA, Johnson DC, Barre K, et al. Cervical spine MRI in patients with negative CT: A prospective, multicenter study of the Research Consortium of New England Centers for Trauma (ReCONECT). J Trauma Acute Care Surg 2017;82:263-69.
67. Nagpal P, Policeni BA, Bathla G, Khandelwal A, Derdeyn C, Skeete D. Blunt Cerebrovascular Injuries: Advances in Screening, Imaging, and Management Trends. AJNR Am J Neuroradiol 2017.
68. Vertinsky AT, Schwartz NE, Fischbein NJ, Rosenberg J, Albers GW, Zaharchuk G. Comparison of multidetector CT angiography and MR imaging of cervical artery dissection. AJNR Am J Neuroradiol 2008;29:1753-60.
69. Biffl WL, Ray CE, Jr., Moore EE, Mestek M, Johnson JL, Burch JM. Noninvasive diagnosis of blunt cerebrovascular injuries: a preliminary report. J Trauma 2002;53:850-6.
70. Paulus EM, Fabian TC, Savage SA, et al. Blunt cerebrovascular injury screening with 64-channel multidetector computed tomography: more slices finally cut it. J Trauma Acute Care Surg 2014;76:279-83; discussion 84-5.
71. Payabvash S, McKinney AM, McKinney ZJ, Palmer CS, Truwit CL. Screening and detection of blunt vertebral artery injury in patients with upper cervical fractures: the role of cervical CT and CT angiography. Eur J Radiol 2014;83:571-7.
72. Wang AC, Charters MA, Thawani JP, Than KD, Sullivan SE, Graziano GP. Evaluating the use and utility of noninvasive angiography in diagnosing traumatic blunt cerebrovascular injury. J Trauma Acute Care Surg 2012;72:1601-10.
73. Noyek AM, Kassel EE, Wortzman G, Jazrawy H, Greyson ND, Zizmor J. Contemporary radiologic evaluation in maxillofacial trauma. Otolaryngol Clin North Am 1983;16:473-508.
74. Leipziger LS, Manson PN. Nasoethmoid orbital fractures. Current concepts and management principles. Clin Plast Surg 1992;19:167-93.
75. Garg RK, Hartman MJ, Lucarelli MJ, Leverson G, Afifi AM, Gentry LR. Nasolacrimal System Fractures: A Description of Radiologic Findings and Associated Outcomes. Ann Plast Surg 2015;75:407-13.
76. Kelamis JA, Mundinger GS, Feiner JM, Dorafshar AH, Manson PN, Rodriguez ED. Isolated bilateral zygomatic arch fractures of the facial skeleton are associated with skull base fractures. Plast Reconstr Surg 2011;128:962-70.
77. Pathria MN, Blaser SI. Diagnostic imaging of craniofacial fractures. Radiol Clin North Am 1989;27:839-53.
78. Markowitz BL, Manson PN, Sargent L, et al. Management of the medial canthal tendon in nasoethmoid orbital fractures: the importance of the central fragment in classification and treatment. Plast Reconstr Surg 1991;87:843-53.
79. Kochhar A, Byrne PJ. Surgical management of complex midfacial fractures. Otolaryngol Clin North Am 2013;46:759-78.
80. Mast G, Ehrenfeld M, Cornelius CP, Litschel R, Tasman AJ. Maxillofacial Fractures: Midface and Internal Orbit-Part I: Classification and Assessment. Facial Plast Surg 2015;31:351-6.
81. Chawla H, Malhotra R, Yadav RK, Griwan MS, Paliwal PK, Aggarwal AD. Diagnostic Utility of Conventional Radiography in Head Injury. J Clin Diagn Res 2015;9:TC13-5.
82. Bromberg WJ, Collier BC, Diebel LN, et al. Blunt cerebrovascular injury practice management guidelines: the Eastern Association for the Surgery of Trauma. J Trauma 2010;68:471-7.
83. Epstein JB, Klasser GD, Kolbinson DA, Mehta SA, Johnson BR. Orofacial injuries due to trauma following motor vehicle collisions: part 1. Traumatic dental injuries. J Can Dent Assoc 2010;76:a171.
84. Ellis E, 3rd, Scott K. Assessment of patients with facial fractures. Emerg Med Clin North Am 2000;18:411-48, vi.
85. Lee MH, Cha JG, Hong HS, et al. Comparison of high-resolution ultrasonography and computed tomography in the diagnosis of nasal fractures. J Ultrasound Med 2009;28:717-23.
86. Hong HS, Cha JG, Paik SH, et al. High-resolution sonography for nasal fracture in children. AJR Am J Roentgenol 2007;188:W86-92.
87. Hirai T, Manders EK, Nagamoto K, Saggers GC. Ultrasonic observation of facial bone fractures: report of cases. J Oral Maxillofac Surg 1996;54:776-9; discussion 79-80.

88. Friedrich RE, Heiland M, Bartel-Friedrich S. Potentials of ultrasound in the diagnosis of midfacial fractures*. Clin Oral Investig 2003;7:226-9.
89. Lou YT, Lin HL, Lee SS, et al. Conductor-assisted nasal sonography: an innovative technique for rapid and accurate detection of nasal bone fracture. J Trauma Acute Care Surg 2012;72:306-11.
90. Nemati S, Jandaghi AB, Banan R, Aghajanpour M, Kazemnezhad E. Ultrasonography findings in nasal bone fracture; 6-month follow-up: can we estimate time of trauma? Eur Arch Otorhinolaryngol 2015;272:873-76.
91. Becker OJ. Nasal fractures; an analysis of 100 cases. Arch Otolaryngol 1948;48:344-61.
92. Clayton MI, Lesser TH. The role of radiography in the management of nasal fractures. J Laryngol Otol 1986;100:797-801.
93. Hwang K, You SH, Kim SG, Lee SI. Analysis of nasal bone fractures; a six-year study of 503 patients. J Craniofac Surg 2006;17:261-4.
94. Logan M, O'Driscoll K, Masterson J. The utility of nasal bone radiographs in nasal trauma. Clin Radiol 1994;49:192-4.
95. Rhee SC, Kim YK, Cha JH, Kang SR, Park HS. Septal fracture in simple nasal bone fracture. Plast Reconstr Surg 2004;113:45-52.
96. Lee K. Global trends in maxillofacial fractures. Craniomaxillofac Trauma Reconstr 2012;5:213-22.
97. Fridrich KL, Pena-Velasco G, Olson RA. Changing trends with mandibular fractures: a review of 1,067 cases. J Oral Maxillofac Surg 1992;50:586-9.
98. Hammond D, Welbury R, Sammons G, Toman E, Harland M, Rice S. How do oral and maxillofacial surgeons manage concussion? Br J Oral Maxillofac Surg 2018;56:134-38.
99. Roth FS, Kokoska MS, Awwad EE, et al. The identification of mandible fractures by helical computed tomography and panorex tomography. J Craniofac Surg 2005;16:394-9.
100. Wilson IF, Lokeh A, Benjamin CI, et al. Prospective comparison of panoramic tomography (zonography) and helical computed tomography in the diagnosis and operative management of mandibular fractures. Plast Reconstr Surg 2001;107:1369-75.
101. Viozzi CF. Maxillofacial and Mandibular Fractures in Sports. Clin Sports Med 2017;36:355-68.
102. Scarfe WC. Imaging of maxillofacial trauma: evolutions and emerging revolutions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100:S75-96.
103. Wilson IF, Lokeh A, Benjamin CI, et al. Contribution of conventional axial computed tomography (nonhelical), in conjunction with panoramic tomography (zonography), in evaluating mandibular fractures. Ann Plast Surg 2000;45:415-21.
104. Gerhard S, Ennemoser T, Rudisch A, Emshoff R. Condylar injury: magnetic resonance imaging findings of temporomandibular joint soft-tissue changes. Int J Oral Maxillofac Surg 2007;36:214-8.
105. Emshoff R, Rudisch A, Ennemoser T, Gerhard S. Magnetic resonance imaging findings of temporomandibular joint soft tissue changes in type V and VI condylar injuries. J Oral Maxillofac Surg 2007;65:1550-4.
106. Chayra GA, Meador LR, Laskin DM. Comparison of panoramic and standard radiographs for the diagnosis of mandibular fractures. J Oral Maxillofac Surg 1986;44:677-9.
107. Yamaoka M, Furusawa K, Iguchi K, Tanaka M, Okuda D. The assessment of fracture of the mandibular condyle by use of computerized tomography. Incidence of sagittal split fracture. Br J Oral Maxillofac Surg 1994;32:77-9.
108. Raustia AM, Pyhtinen J, Oikarinen KS, Altonen M. Conventional radiographic and computed tomographic findings in cases of fracture of the mandibular condylar process. J Oral Maxillofac Surg 1990;48:1258-62; discussion 63-4.
109. Escott EJ, Branstetter BF. Incidence and characterization of unifocal mandible fractures on CT. AJNR Am J Neuroradiol 2008;29:890-4.
110. Braasch DC, Abubaker AO. Management of mandibular angle fracture. Oral Maxillofac Surg Clin North Am 2013;25:591-600.
111. Shankar DP, Manodh P, Devadoss P, Thomas TK. Mandibular fracture scoring system: for prediction of complications. Oral Maxillofac Surg 2012;16:355-60.
112. Schneidereit NP, Simons R, Nicolaou S, et al. Utility of screening for blunt vascular neck injuries with computed tomographic angiography. J Trauma 2006;60:209-15; discussion 15-6.

113. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf. Accessed September 30, 2021.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.