Cervical spine injury associated with facial trauma

Maxillofacial fractures carry a high risk of associated cervical spine injury. Concomitant cervical spine injury in trauma patients may influence airway management, choice of diagnostic imaging, surgical approach, and timing of repair of associated facial fractures.

Patients with maxillofacial fractures are at risk of concomitant cervical spine or spinal cord injury (Baker and Mackenzie, 1976; Beirne et al, 1995). The presence or absence of a cervical spine injury has important implications in trauma patients, influencing airway management techniques, choice of diagnostic imaging studies, surgical approach, and timing for repair of concomitant facial fractures. Studies over the last decade have done much to elucidate the relationship between maxillofacial fractures and cervical spinal injury. Understanding the common patterns of facial fractures, their related patterns of cervical spine injuries, and how these relate to aetiology such as road traffic accidents, falls and assault, are important to enable prompt diagnosis, investigation and management of cervical spine injuries by emergency care practitioners and neurosurgeons, and facilitate timely treatment of the underlying facial trauma by maxillofacial surgeons.

This review describes the common types of facial fractures, the incidence and patterns of cervical spine injury associated with different types of maxillofacial fractures based on the most recent evidence, and the implications for diagnosis, investigation and management of cervical spine injury in patients with facial trauma.

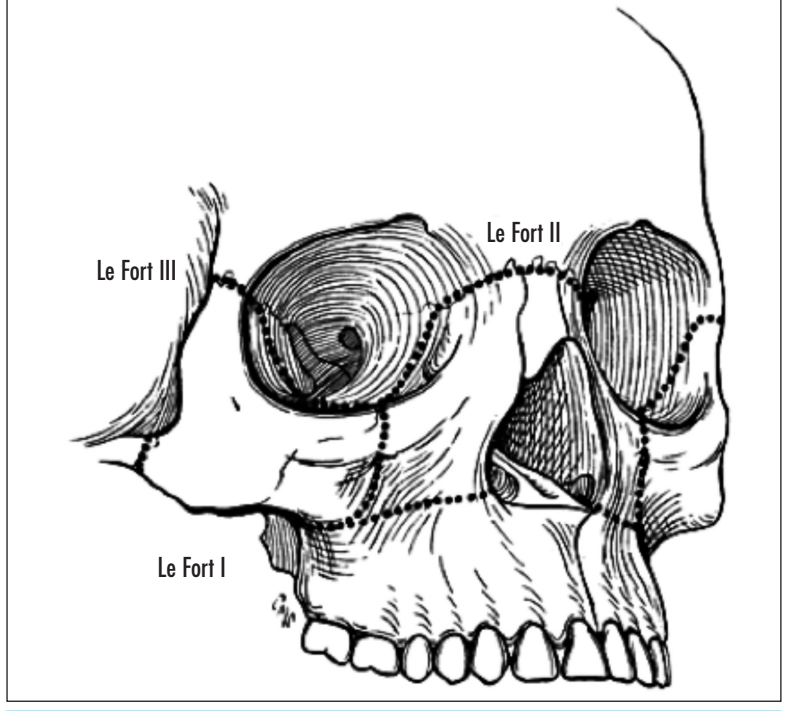
Types of facial fractures

Most injuries of the cervical spine associated with facial fractures are attributed to forces transmitted directly or indirectly from the facial skeleton to the cervical bony and connective tissue structures (Davidson and Birdsell, 1989; Ardekian et al, 1997).

Maxillary fractures often result from high-energy blunt force injury to the facial skeleton, typically from road traffic accidents, altercations and falls (Aksoy et al, 2002). With increased legislation requiring seat belt use, injuries from the driver hitting the steering wheel have shifted from chest trauma to facial trauma (Advanced Trauma Life Support, 2008).

Much of the understanding of patterns of traumatic facial fractures originates from the work of the French surgeon René Le Fort. In 1901, he reported his analysis on cadaver skulls that were subjected to blunt forces of various magnitudes and directions. He concluded that predictable patterns of fractures follow certain types of injuries. He described three predominant types of facial fractures of the midfacial region resulting from blunt trauma termed Le Fort I, II and II (*Figure 1*). Le Fort I fractures may result from the force of an injury directed low on the maxillary alveolar rim in a downward direction. Le Fort II fractures may result from a blow to the

Figure 1. Le Fort classification of facial fractures involving the mid-facial region. A Le Fort I fracture extends from the nasal septum, travels horizontally above the teeth apices, crosses below the zygomaticomaxillary junction, and traverses the pterygomaxillary junction to interrupt the pterygoid plates. A Le Fort II fracture has a pyramidal shape and courses upward through the infraorbital rim, through the medial orbit and the nasal bones. A Le Fort III fracture starts at the nasofrontal and frontomaxillary sutures, extends posteriorly along the medial wall of the orbit through the nasolacrimal groove and ethmoid bones, and continues along the floor of the orbit through the zygomaticofrontal junction and zygomatic arch. Intranasally, a branch of the fracture extends through the base of the ethmoid towards the base of the sphenoid.



Dr Soumya Mukherjee *is Specialist Registrar in Neurosurgery in the Department of Neurosurgery, Leeds General Infirmary, Leeds LS1 3EX and*
Mr Peter Revington *is Consultant Maxillofacial Surgeon in the Department of Maxillofacial Surgery, Frenchay Hospital, Bristol*

Correspondence to: Dr S Mukherjee (soumya1701@googlemail.com)

lower or mid maxilla and usually involve the inferior orbital rim. Le Fort III fractures are also known as craniofacial dissociation and involve the zygomatic arch. These may follow impact to the nasal bridge or upper maxilla. This type of fracture predisposes the patient to CSF rhinorrhoea more commonly than the other types.

Traumatic facial fractures may also be categorized according to the region of the face: skull and upper third, middle third and lower third (*Figure 2*). The facial bones and Le Fort patterns involved in each region of facial fracture are shown in *Table 1*.

Incidence of cervical spine injury with concomitant facial fractures

The majority of cohort studies have reported wide variations in the incidence of cervical spine injury in maxillofacial trauma patients, ranging between 0 and 8%, although in specific subgroups of patients such as road traffic accident fatalities, the incidence of cervical spine injury has been cited as high as 24% (Bucholz et al, 1979). The variation in incidence of cervical spine injury is not only the result of differences in the mechanism of injury (Davidson and Birdsell, 1989; Ardekian et al, 1997), but also the anatomical location of impact (Gwyn et al, 1971; Haug et al, 1991; Oller et al, 1992; Merritt and Williams, 1997; Elahi et al, 2008; Mulligan et al, 2010), location of trauma centre (Baker and Mackenzie, 1976; Bucholz et al, 1979; Beirne et al, 1995), and patient demographics including age and gender (Reiss et al, 1986; Sinclair et al, 1988; Williams et al, 1992; Roccia et al, 2007). Trauma protocols including the Advanced Trauma Life Support Manual (Advanced Trauma Life Support, 2008) stress the importance of the association between maxillofacial and cervical spine injuries and the catastrophic consequences that can ensue if the diagnosis is missed or its presence or absence ignored.

Cervical spine injury and aetiology of trauma

The vast majority of cervical spine injuries are seen in association with road traffic accidents and high falls (*vs* other traumatic scenarios such as workplace accidents or assault) – this most likely reflects the greater velocity and therefore force of impact to the face, since force is a product of mass and acceleration. This mechanical force is transmitted from the facial skeleton to the cervical bony and connective tissue structures causing spinal injury (Haisová and Krámová, 1970; Lewis et al, 1985; Davidson and Birdsell, 1989; Williams et al, 1992; Ardekian et al, 1997; Merritt and Williams, 1997).

A multi-centre cohort study in over 250 000 patients assessed predictors of cervical spine injury and found that road traffic accidents and falls from a height >2 metres were each associated with a greater than 2.5-fold risk of cervical spine injury (Merritt and Williams, 1997). In a road traffic accident when a seatbelt is not worn, the driver is subject to further indirect cervical spine trauma as the head is easily hyperflexed or hyperextended by an

Table 1. Region of facial fracture

Area of face	Definition of facial fracture
Upper third or skull	Fractures involving the supraorbital rim, orbital roof, frontal bone, skull base, temporal bones or occipital bones
Middle third	Fractures including Le Fort I and II, maxillary, periorbital, nasal, nasoethmoid or zygomatic bones
Lower third	Fractures involving the mandible, alveolar bones or temporomandibular joint
Combined	Any combination of two or more facial fracture areas including the skull or upper third, middle third and lower third areas. Le Fort III included

Figure 2. Maxillofacial fractures stratified by region of fracture: (a) skull and upper third facial fractures, (b) middle third facial fractures and (c) lower third facial fractures.

impact with the windshield, steering wheel or other structures inside the vehicle (Advanced Trauma Life Support, 2008). A North American study showed that the incidence of cervical spine injury after blunt assault is very low (0.7%), and that the pattern and severity of injury is related not to the assault but to a fall occurring after the assault. This has implications for elucidating a clear history of injury including whether the patient has had a fall after an assault (Kulvatunyou et al, 2012). In summary, the typical patient with facial trauma and concomitant cervical spine injury is male, between 30 and 40 years old, and has usually been involved in a road traffic accident (Hackl et al, 2001).

Several studies have demonstrated that the incidence of cervical spine injury associated with facial trauma is higher in patients presenting with a lower initial Glasgow Coma Scale score than in those who present fully alert and orientated (Sinclair et al, 1988; Demetriades et al, 2000; Holly et al, 2002; Elahi et al, 2008; Mulligan et al, 2010; Mulligan and Mahabir, 2010). A Glasgow Coma Scale score less than 8 in the setting of a facial fracture should increase the index of suspicion for cervical spine injury.

Cervical spine injury and facial fracture pattern

It is known that high-velocity impacts are required to fracture the structures of the frontal and supraorbital ridges, whereas relatively weaker forces can fracture the skull (Luce et al, 1979). This discrepancy is responsible for a relatively higher frequency of cervical spine injuries seen with isolated upper third facial fractures *vs* isolated skull, middle third and lower third facial fractures (Elahi et al, 2008). Intuitively, one can expect that fractures of the most cephalic portion of the facial skeleton, because of the high resistance to impact, would be associated with more severe associated injuries.

The risk of cervical spine injury is higher in association with combined facial fractures involving more than one facial bone. A large study on over 1.3 million trauma patients from the United States and Puerto Rico found that in the setting of two or more facial fractures, the prevalence of cervical spine injury ranged from 7.0% to 10.8% while in the setting of an isolated mandible, nasal, orbital floor, malar or maxilla, or frontal or parietal bone fracture, cervical spine injury ranged from 4.9% to 8.0% (Mulligan and Mahabir, 2010). These findings most likely reflect the greater impact and force of injury involved when two or more facial regions have been fractured compared with one isolated facial region, which is then transmitted to the neck causing cervical spinal injury. In particular, Le Fort facial fractures (I, II, III) have been associated with increased risk of cervical spine injury (Hasler et al, 2012).

Various authors have reported a correlation between mandibular fractures and cervical spine injuries (Ardekian et al, 1997; Merritt and Williams, 1997). Tu et al (2010) found a 1.07% diagnosis rate of cervical subluxation in 653 patients with mandibular bone fractures following a road traffic accident, while Ardekian et al (1997) observed an incidence of cervical spine injury of 2.6% among 424 patients with mandibular fractures predominantly resulting from a road traffic accident. An example of a patient who sustained both a mandibular fracture and concomitant cervical spine injury is shown in *Figure 3*. Although not replicated by many authors, Lalani and Bonanthaya (1997) have described a typical cervical spine injury model in relation to the maxillofacial fracture site and believe that injuries to the upper segment of the cervical spine are associated with fractures of the lower third of the face, principally mandibular fractures, whereas injuries to the lower segments of the cervical spine are associated with fractures of the middle third of the face. An example of a patient who sustained middle third facial fractures with concomitant lower segment cervical spine injury as a result of a road traffic accident is shown in *Figure 4*.

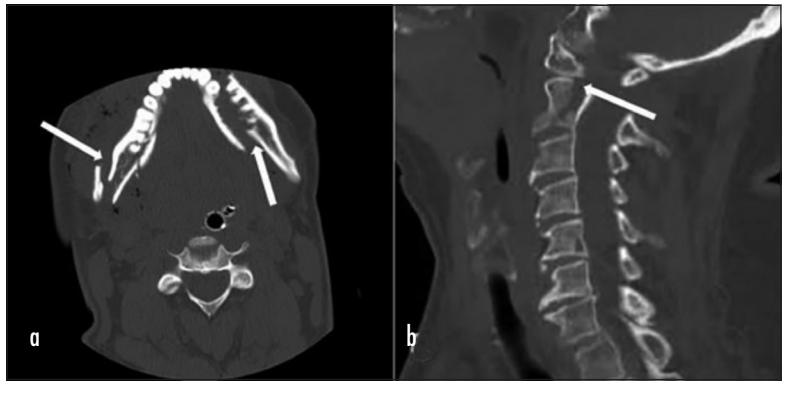
Cervical spine injuries according to level of injury

Cervical spine injuries occur at two main levels: the C1–C2 and C6–C7 intervals. A Canadian study by Elahi et al (2008) described a 67% share of 124 cervical spine injuries associated with maxillofacial trauma occurring at the C1–C2 and C6–C7 levels. They also found an increasing frequency of disc herniation and cord contusion as one travels in a cephalic to caudal direction along the cervical spine, which may be the result of accentuation of direct and indirect forces transmitted from the facial skeleton farther down the spinal cord (Ardekian et al, 1997).

Management of cervical spine injury in patients with facial fractures

Until proven otherwise, any patient with a maxillofacial injury should be suspected of having a cervical spine injury, and as such, mandatory cervical spinal immobilization together with radiographical assessment of the

Figure 3. Computed tomography of a 68-year-old man involved in a road traffic accident with severe jaw and neck pain and no neurological deficit, showing a comminuted mandibular fracture (a, white arrows) and concomitant C2 fracture (b, white arrow).



cervical spine is required. However, clearance of spinal injury in patients with multiple trauma and associated maxillofacial injuries can be difficult. In the cervical spine, the radiographs may remain normal in patients with pure ligamentous injuries. A clear systematic approach can help to minimize the consequences of missing a spinal injury. Determining which radiological study to order for a potential cervical spine injury is critical. Patients who do not have altered mental status, a neurological deficit, intoxication, neck pain or midline tenderness, or an associated distracting injury do not require radiographical assessment. The presence of a craniofacial fracture requires mandatory radiological assessment of the cervical spine.

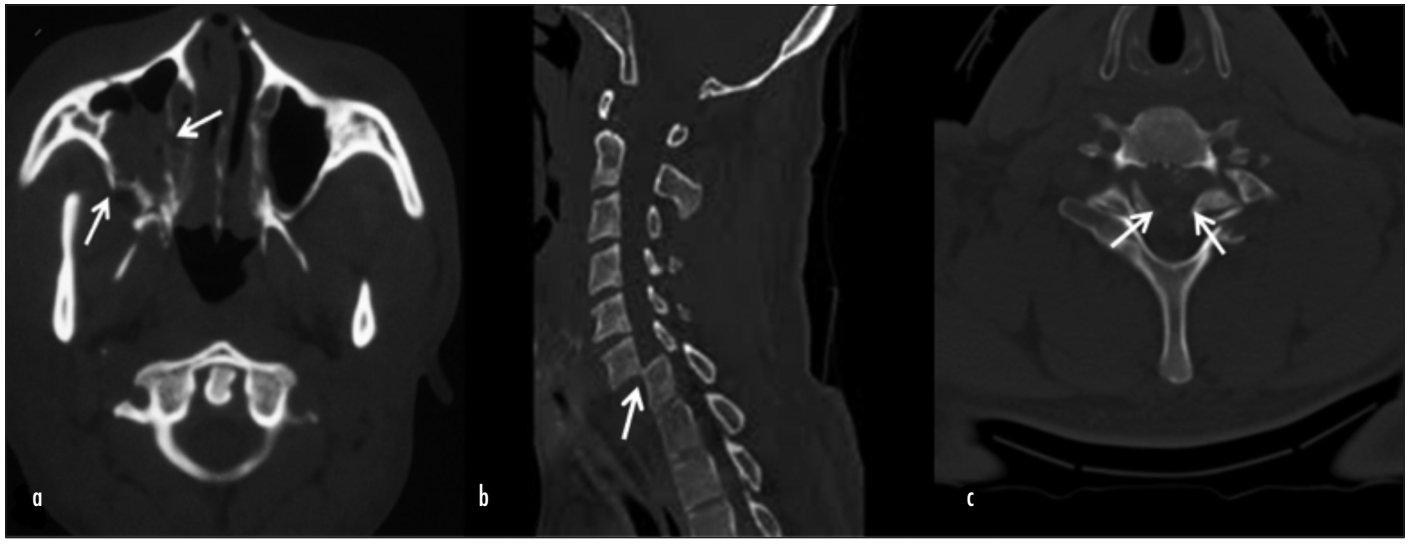
Generally, plain radiographs are routinely performed but these will not detect all cervical spine injuries. Indeed, lateral cervical radiographs have limited sensitivity with a significant false negative rate, with cited sensitivity values no higher than 85% (Ross et al, 1987). Sensitivity is increased to approximately 90% with the addition of anteroposterior and odontoid views (Besman et al, 2003). Computed tomography may further improve sensitivity to over 99% (Morris and McCoy, 2004). Indeed various authors recommend computed tomography of the cervical spine as the radiological examination of first choice in all unconscious patients and in patients who are conscious and alert with neck pain and associated muscle spasm after high-speed trauma (Beirne et al, 1995; Ardekian et al, 1997; Roccia et al, 2007).

For unconscious patients with normal cervical spine films and computed tomographic scans, the cervical spine may be cleared with passive dynamic flexion/extension films under fluoroscopy or a normal magnetic resonance imaging scan within 48 hours of injury (Bachulis et al, 1987; Grossman et al, 1999; Brooks and Willett, 2001). For blunt trauma patients in whom there is a clinical suspicion of cervical spine injury but whose initial plain radiographs or cervical computed tomography scans are negative, magnetic resonance imaging is considered by some to be the gold standard for clearing the cervical spine (Muchow et al, 2008). Until these studies have been completed, the patient should be managed as having a potentially unstable spinal injury with full nursing care and complete spinal immobilization with head supports.

All facial fractures should be referred to the maxillofacial or plastic surgery department for management. Diagnosis of the facial fractures is facilitated by fine-cut axial and reconstructed coronal, sagittal and three-dimensional maxillofacial reconstructions. Primary consultation within 24 hours of admission and early surgical intervention in facial fracture patients, once stabilized from a haemodynamic and neurological point of view, may offer the best possible outcome in fracture and facial soft tissue management by minimizing bony complications of non-union, mal-union, osteomyelitis, and malocclusion and simultaneously minimizing soft tissue contractures, infection and delayed wound healing (Roccia et al, 2007; Elahi et al, 2008; Mulligan et al, 2010).

The presence of cervical spine injuries may delay the surgical repair of maxillofacial fractures. However, this possibility may be minimized by prompt consultation with the neurosurgical service to optimize stabilization of the cervical spine injury together with performing careful induction of anaesthesia, as appropriate, using endoscopically-guided endotracheal intubation. Indeed, a survey by Crosby (2006) indicated that the majority of American anaesthetists would prefer to use a fibreoptic broncho-

Figure 4. Computed tomography of a 54-year-old male unrestrained driver involved in a road traffic accident, with severe facial injuries, Glasgow Coma Score of 10 and quadriplegia with spinal shock. a. He suffered comminuted fractures of the medial and lateral walls of the right maxillary sinus with haematoma (arrows). The nasal septum and medial wall of the left maxillary sinus were also fractured. b. He had concomitant bifacetal fracture-dislocations at C6/C7 with anterior displacement of C6 on C7; and (c) impingement of the spinal cord at C6/7. The patient underwent closed reduction and application of Halo vest for his cervical spine injury, and reduction and fixation of his maxillary fractures. He subsequently underwent anterior spinal fusion and discectomy.



scope to intubate the trachea of patients with facial trauma and concomitant cervical spine injury and to do so with the patient awake, as the head and neck may be left in a neutral position, there is minimal spinal movement required to achieve laryngeal visualization and tracheal intubation, and the patient's protective reflexes are largely left intact. During facial fracture surgery, open reduction, a variety of fixation devices, and hard or soft collars can be applied without causing neurological deficit by avoidance of hyperextension or rotation of the head. Furthermore, operative exposure is usually not compromised as a result of spinal fixation.

Conclusions

The reported incidence of cervical spine injuries associated with maxillofacial fractures ranges between 0 and 8%. The presence of facial trauma has implications for mandatory exclusion and prompt management of cervical spine injuries, particularly in the setting of road traffic accident and combined facial fracture patterns. The highest incidence of cervical spine injury is seen in patients with combined facial fracture patterns reflecting the relationship between the severity of the impact and likelihood of a cervical spine injury. There may be an increasing risk of cervical cord contusion and disc herniation with injury occurring at increasingly lower levels along the cervical spine, and this may reflect accentuation of forces transmitted from the facial skeleton. It is important for non-specialist clinicians and medical staff, in particular emergency physicians and paramedics who may encounter such trauma patients, to facilitate prompt referral to neurosurgeons to optimize stabilization and treatment of cervical spine injuries, and thereby allow definitive maxillofacial fixation to proceed in a timely manner to optimize patient outcome. **BJHM**

Authors' contribution: Dr S Mukherjee was significantly involved in performing literature review, analysis and writing of the manuscript, and revised it for intellectual content; Mr P Revington contributed to the writing of the manuscript, and critically revised the manuscript for intellectual content. Both authors read and approved the final manuscript.

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KEY POINTS

- The reported incidence of cervical spine injury associated with maxillofacial fractures ranges between 0 and 8%. The typical patient with concomitant neck and facial trauma is male, 40 years old, and usually involved in a road traffic accident.
- The highest incidence of cervical spine injuries is seen in patients involved in road traffic accidents and with combined facial fracture patterns, reflecting the relationship between the severity of the impact and likelihood of a cervical spine injury.
- There may be an increasing risk of cervical cord contusion and disc herniation with injury occurring at increasingly lower levels of the cervical spine, and this may reflect accentuation of forces transmitted from the facial skeleton.
- Any patient with a maxillofacial injury should be suspected of having a cervical spinal injury, and as such, mandatory cervical spinal immobilization together with radiographical assessment of the cervical spine is required.
- Computed tomography to assess injury of the cervical spine is the imaging modality of choice in all unconscious patients and in patients who are alert with neck pain after high-speed trauma.
- Non-specialist medical staff, in particular emergency physicians and paramedics who may be the first to encounter facial trauma patients, must facilitate prompt referral to neurosurgeons to optimize stabilization and treatment of associated cervical spine injuries, to allow timely treatment of concomitant facial fractures.

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