Incidence and pattern of direct blunt neurovascular injury associated with trauma to the skull base

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Object. Skull base fractures are often associated with potentially devastating injuries to major neural arteries in the head and neck, but the incidence and pattern of this association are unknown.

Methods. Between April and September 2002, 1738 Level 1 trauma patients were admitted to St. Joseph’s Hospital and Medical Center in Phoenix, Arizona. Among them, a skull base fracture was diagnosed in 78 patients following computed tomography (CT) scans. Seven patients had no neurovascular imaging performed and were excluded. Altogether, 71 patients who received a diagnosis of skull base fractures after CT and who also underwent a neurovascular imaging study were included (54 men and 17 women, mean age 29 years, range 1–83 years). Patients underwent CT angiography, magnetic resonance angiography, or digital subtraction angiography of the head and craniovertebral junction, or combinations thereof.

Results. Nine neurovascular injuries were identified in six (8.5%) of the 71 patients. Fractures of the clivus were very likely to be associated with neurovascular injury (p < 0.001). A high risk of neurovascular injury showed a strong tendency to be associated with fractures of the sella turcica–sphenoid sinus complex (p = 0.07).

Conclusions. The risk of associated blunt neurovascular injury appears to be significant in Level 1 trauma patients in whom a diagnosis of skull base fracture has been made using CT. The incidence of neurovascular trauma is particularly high in patients with clival fractures. The authors recommend neurovascular imaging for Level 1 trauma patients with a high-risk fracture pattern of the central skull base to rule out cerebrovascular injuries.

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KEY WORDS • blunt injury • carotid artery • fistula • pseudoaneurysm • skull base fracture • vertebral artery

The pathological substrate of direct arterial cerebrovascular trauma consists of vascular transection, dissection, thrombosis, incarceration (artery trapped within a fracture line), and formation of a pseudoaneurysm or AVF.3,8,10,15,17,20,22 These injuries can be fatal or cause significant neurological deficits.3,5,18,23,35 Often the manifestation of neurological deficits is delayed.18,24,35 Once neurological symptoms occur, the prognosis for the patient worsens.15 Consequently, the treating physician has a relatively narrow time window in which to detect these neurovascular injuries in trauma patients.

Treatment with medication, open surgical repair, or endovascular intervention improves the neurological outcome of patients with particular forms of cerebrovascular injury. Medical management of these injuries primarily consists of administration of anticoagulation therapy. In patients with traumatically induced neurovascular stenoocclusive disease or with a pseudoaneurysm not amenable to direct repair, anticoagulation therapy (typically using systemic heparinization) decreases the rate of associated neurological morbidity and improves clinical outcomes by minimizing the formation of local intravascular clots, diminishing the risk of clot propagation and embolization, and enhancing repair of the injured vascular wall.5,12,15 Open surgical repair is usually treated to use easily accessible lesions, primarily pseudoaneurysms in the neck.10

Recent progress in endovascular techniques allows reconstruction of injured vessel walls or occlusion of AVFs.1,11 The efficacy of any treatment for a cerebrovascular injury relies on appropriate and timely diagnosis of the condition. Optimally, the diagnosis should be made before neurological symptoms develop. Therefore, practical and effective screening methods and protocols are needed to identify the trauma population at risk for neurovascular injury.

The incidence rate of blunt trauma involving the carotid artery, VA, or both, ranges from 0.03 to 1.1%.3,5,14,15,17,21,23,26,30
Associated neurovascular injury and skull base trauma

If selection criteria are applied to identify a population at a higher risk, the incidence rate is even greater (29 to 88%).

Identified criteria associated with a high risk for blunt neurovascular injury include: cervical spine fractures, particularly subluxations; fractures of the fora- men transversarium and C1–3; mechanism of injury (such as hyperextension or hyperflexion injuries of the neck); the presence of physical signs (such as anisocoria, Horner syndrome, expanding cervical hematoma, cervicothoracic seatbelt sign, hemorrhaging from the ear, nose, or mouth, and lateralizing neurological signs unexplained by CT scans of the head); diffuse axonal injury; LeFort II and III fractures; facial fractures; low GCS scores (< 6); elevated injury severity scores; associated chest, abdominal, or head trauma; fractures of the skull base near major neural arteries; and petrous bone fractures. Yet there has been little systematic analysis of neurovascular trauma associated with fractures of the skull base to identify fracture patterns and their associated risk of neurovascular injury. This study was undertaken to help address these issues.

Clinical Material and Methods

Patient Population

Between April and September 2002, all Level 1 trauma admissions at our institution with a CT diagnosis of fracture of the skull base (fracture involving the anterior, middle, or posterior fossa) related to blunt trauma were identified, and their medical records were retrospectively reviewed. For patients to be included in this study, their CT diagnosis had to be made before admission or during the same hospitalization. Patients transferred to our facility with a proven or suspected diagnosis of neurovascular trauma were excluded. The necessity of neurovascular imaging studies and the modality and timing of the study ordered were left to the discretion of the managing physician staff (neurosurgeons and trauma surgeons). According to our standard policy, most trauma patients with skull base fractures undergo a noninvasive screening neurovascular imaging study (CT angiography or MR angiography). Therefore, the study protocol did not change the standard medical management of these patients. A general radiologist interpreted the neurovascular imaging studies immediately. Within 10 hours, a neuroradiologist unaware of the study also interpreted the images.

Data Collection

Patients’ demographic, clinical, and neuroimaging data, including age, sex, mechanism of injury, admission GCS score, type of skull base fracture, type of neurovascular imaging study, presence of associated injuries, deposition, and discharge GCS score, were collected.

Of the 1738 Level 1 trauma patients admitted to our emergency room during the study period, a skull base fracture was diagnosed in 78 patients. Seven patients were excluded due to lack of neurovascular imaging. The final study population consisted of 71 patients (54 men and 17 women, mean age 29 years, range 1–83 years). On admission the mean GCS score of the patients was 11.

The mechanism of injury included MVAs in 37 patients, falls in 18, assaults in eight, and other accidents (including industrial accidents, diving accidents, injuries related to falling objects, and unknown mechanisms) in eight.

All patients underwent a neurovascular imaging study consisting of CT angiography, MR angiography, and/or DSA of the head and craniovertebral junction. Fifty-seven patients underwent CT angiography studies, 12 underwent MR angiography, and five had DSA. Long-term follow-up information was not required for the purpose of this study. The seven patients with severe trauma who were excluded from the study did not undergo neurovascular imaging because their clinical prognosis was deemed too poor to justify an evaluation of their vasculature.

Statistical Analysis

The Pearson chi-square test of proportions for nonparametric data was used to compare various anatomical fracture locations and associated neurovascular injury. A probability value of less than 0.05 was considered statistically significant.

Results

Of the 71 patients in whom a skull base fracture was diagnosed, six were found to have a neurovascular injury (Table 1), yielding an 8.5% rate of associated direct, blunt arterial neurovascular injury in Level 1 trauma patients with a CT diagnosis of skull base fracture. Of the six patients with neurovascular injuries, the use of CT angiography failed to assist in the diagnosis of all components of these injuries in three patients. Subsequently, these three patients had AVFs diagnosed using DSA. A false-positive result or questionable positive finding was diagnosed on CT angiography in two patients who underwent DSA; the suspected neurovascular injury was not confirmed but an unsuspected AVF was diagnosed.

Neurovascular injuries included one occlusive dissection involving an ICA in one patient, and one stenotic dissection involving a VA in another. One VA pseudoaneurysm and dural AVF involved the occipital sinus in a third patient. One patient had a dural AVF (indirect CCF), and another patient had three dural AVFs. One patient had a pseudoaneurysm involving the petrous ICA (Table 1).

There were seven clival fractures, 15 fractures of the sella turcica–sphenoid sinus complex, 25 fractures of the petrous bone, seven fractures of the occipital condyle, 15 fractures of the occiput, 16 fractures of the orbital roof, 10 fractures of the cribriform plate, nine fractures of the middle fossa floor, and three fractures of the orbital apex (Table 2). Only the relationship between clival fractures and neurovascular injury was statistically significant. The risk of neurovascular injury with clival fractures was 43% (p < 0.001). The risk tended to be higher for sella turcica–sphenoid sinus fractures, but did not reach statistical significance (p = 0.07).

Associated injuries included 18 extremity fractures, 16 facial injuries and fractures, 13 chest injuries, 11 spine fractures, three pelvic injuries, and three abdominal injuries. A total of 27 patients had no associated injuries that were not involving the head.

Ten patients died during hospitalization. The remainder had a mean GCS score of 12 at discharge. Discharge dispo-
sition was home for 39 patients, rehabilitation for 15, and a skilled nursing facility for seven patients.

Illustrative Cases

Case 1

This 13-year-old girl was involved in an MVA. Her admission GCS score was 6. She suffered from brain contusions and a skull base fracture through the clivus, sellar floor, and sphenoid sinus (Fig. 1A and B). Her DSA showed an indirect CCF with drainage into the inferior petrosal sinus (Fig. 1C). The patient developed right hemiparesis from a watershed stroke involving the left anterior middle cerebral artery. The stroke was not associated with a structural neurovascular abnormality. During follow-up angiography 2 days later, spontaneous occlusion of the fistula was detected. The patient was discharged to neurorehabilitation with a GCS score of 7. Her DSA test performed 1 year later was normal.

Case 3

This 44-year-old woman was admitted with a GCS score of 6 after being involved in an MVA. Her initial head CT showed multiple brain contusions and fractures of the left temporal bone and clivus (Fig. 2A and B). Computed tomography angiography showed that the left ICA was occluded within the petrous bone (Fig. 2C). The patient died the next day from high intracranial pressure refractory to maximal therapy.

Discussion

Fractures of the skull base can be associated with neurovascular injury, but only a few reports have analyzed this association in detail. In a series of five patients with fractures of the sella, Young and colleagues found...
one case of associated neurovascular injury. Unger and co-workers found two instances of pseudoaneurysm formation and one case of laceration of the ICA in a retrospective chart review of 66 cases of sphenoid bone fractures. West et al. found two CCFs among 40 patients with sphenoid bone fractures.

Biffl and colleagues, however, statistically analyzed the risk of neurovascular injury associated with fractures of the sphenoid and petrous bones, and found that petrous bone fractures were associated with a significant risk of blunt injury to the carotid artery (19% incidence rate). Neither sphenoid fractures nor any skull base fractures were significantly associated with blunt cerebrovascular trauma. The overall incidence of blunt carotid or VA injury in patients with any type of skull base fracture was 27 and 10%, respectively. Altogether, 59 patients with skull base fractures after nonpenetrating trauma were studied prospectively for associated cerebrovascular injury using DSA as the screening method. These authors did not examine other types of skull base fractures separately.

In our Level 1 trauma population, the risk for neurovascular injury associated with fractures of the skull base was 8.5%. The highest risk was associated with clival fractures (43%), followed by orbital apex fractures (33%), sphenoid sinus fractures (20%), occipital condyle fractures (14%), occiput fractures (13%), and petrous bone fractures (12%), but only the risk for clival fractures was significant (p < 0.001). Fractures of the sphenoid sinus complex tended to be associated with neurovascular injury, but this finding did not reach statistical significance (p = 0.07). Therefore, based on our data, a fracture involving the central skull base (clivus, sella turcica, and sphenoid sinus) was considered a high-risk pattern of trauma for associated neurovascular injury.

Nine neurovascular injuries (five AVFs, one occlusive dissection, one stenotic dissection, and two pseudoaneurysms) were diagnosed in six patients. Three patients were treated for these injuries. Two patients underwent endovascular occlusion of the fistula. Two fistulas occluded spontaneously, and the pseudoaneurysms were not treated because of the patients' poor conditions. The VA dissection was treated with coil embolization of the proximal vessel to diminish the risk of thromboembolism; anticoagulation was believed risky due to the presence of a cerebral contusion.

Fractures of the petrous bone or fractures along the path of the ICA at the skull base have been suggested as indications for neurovascular screening in Level 1 trauma patients suffering from blunt trauma. The gold standard of screening remains DSA despite its own associated risk of morbidity. Using DSA as the primary imaging modality, 29 to 34% of prospectively selected Level 1 trauma patients suffering from blunt injury have been diagnosed with neurovascular injuries. A significant number of patients are asymptomatic from their neurovascular injuries; potentially, however, they could be treated to prevent the later onset of neurological symptoms.

Symptomatic patients can be treated to prevent symptoms from progressing and to alleviate symptoms. Most authors of studies that have evaluated screening for associated neurovascular injury in bluntly injured Level 1 trauma patients have favored aggressive screening protocols.
Some investigative groups, however, see no clear clinical advantage in screening this population. No prospective randomized study results have demonstrated that neurological outcomes improve in a screened population, but sufficient clinical data suggest that screening patients may be associated with a potential benefit. The DSA test is invasive and a time- and cost-intensive modality. Therefore, several investigative groups have tried other screening modalities, including MR angiography and CT angiography. The best comparative data have not shown that CT angiography and MR angiography are as sensitive or as effective as DSA in detecting neurovascular injury. Therefore, the main centers involved in clinical research in this field recommend DSA as the primary diagnostic modality.

We agree that DSA is still the gold standard for imaging the cerebrovasculature. We believe, however, that there is a strong potential benefit to using noninvasive cerebrovascular imaging (CT angiography or MR angiography) to screen trauma populations. Technologies continue to improve, providing better imaging quality. The current study was not designed to answer questions about which imaging modality to use. Nonetheless, we believe that most clinically significant and morbid neurovascular trauma (such as stenoocclusive dissection, pseudoaneurysm formation, and direct CCFs) associated with skull base fractures can be diagnosed using CT angiography. Low-flow AVFs are difficult to detect on CT angiography or MR angiography, but these injuries may not be acutely detrimental to trauma patients and can even occlude on their own as demonstrated in two of our patients. Spontaneous occlusion of low-flow AVFs has been reported to occur in as many as 60% of patients in a review of the literature. Once diagnosed, stenoocclusive dissections are treated with anticoagulation therapy if no overt contraindications exist. Some authors recommend systemic heparinization, whereas others recommend antiplatelet therapy in patients with a high risk of bleeding complications and reserve systemic heparinization for patients with fairly isolated neurovascular injuries or with crescendo neurological symptoms. We treat asymptomatic lesions without imaging evidence of stroke with 81 mg of aspirin/day. Symptomatic patients are treated using systemic heparinization unless there is a significant potential for hemorrhagic conversion of a stroke. If coexisting injuries (including brain contusion, pending surgical intervention, laceration and contusion of organs, and major skeletal fractures) are present, we wait several days to start the patient on anticoagulation therapy.

Conclusions

A significant number of Level 1 trauma patients with a CT diagnosis of skull base fracture have an associated neurovascular injury. This association is statistically significant for fractures of the clivus and shows a strong trend for sella turcica–sphenoid sinus fractures. The best imaging modality for screening is DSA, although noninvasive modalities such as CT angiography and MR angiography are reasonable options. The clinical outcome of screened patients might be improved by earlier detection of neurovascular lesions, particularly asymptomatic lesions. We recommend screening all patients with central skull base fractures for neurovascular injuries.

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References


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