INTRODUCTION

Basilar skull fractures remain one of the more difficult head and neck fractures to evaluate and treat. They are defined as linear fractures in the skull base, and are usually a part of multitude of facial fractures that extend to the skull base. The sphenoid sinus, foramen magnum, temporal bone and sphenoid wings are the most common site of these fractures.

There are approximately 2 million head injuries that occur in the US. They remain one of the leading causes of death and disability of children. And motor vehicle accidents are the leading cause of trauma in industrialized countries. With motor vehicle accidents, head and neck injuries occur in up to 1/3 of accidents, with 28% of all fractures that do occur in the head and neck being from motor vehicle accidents.

With skull base fracture, they occur in 3.5-24% of all head injuries. This accounts for just 2% of all traumas. In a study from Behbahani et al in 2013, there was a retrospective study of 1606 patients with head trauma. They found that 965 of these patients had head fractures with 220 of these being from the skull base. This was further divided with temporal bone fracture accounting for 78, orbital roof 47, sphenoid 44, occipital bone 30, ethmoid 21, and clivus 2.

The incident of skull base fracture increased with orbital wall rim fractures and ZMC fractures. Nasal bone and mandible fractures did not necessary correlate with skull fractures, however. Also, the incidence of skull base fractures increased with number of skull fractures, with noted 10-12% increase of incidence with two or more fractures. Of the skull base fractures, temporal bone was associated 18-40% of the time and frontal fractures 15-20%

ANATOMY

With regards to anatomy, the skull base is complex in nature. It is made up of 5 bones. These bones are the frontal bone, the cribriform last of the ethmoid, the sphenoid bone, the occipital bone, and the squamous petrous portions of the temporal bone.
They are generally divided into 3 parts:

- anterior skull base
- middle skull base
- the posterior skull base

The anterior region is made of the paranasal sinus, the cribriform plate and the orbital roof. It is lined by the frontal bone anteriorly and posteriorly with the lessor wing of the sphenoid sinus. The middle vault or region is made of the sphenoid and temporal bone. Anteriorly, the lessor wing of the sphenoid and posteriorly the petrous bone make up this vault. Lastly, the posterior region is made up of the clivus, condylar and portions of the petrous bone, with the limits anteriorly by the posterior wall of the petrous bone and posteriorly by the grooves of the transverse sinuses.

The anterior skull base makes up 70% of skull base fractures. However the weakest portion of the skull base is the middle vault. Fractures only occur there in 20% of the time, with just 5% of fractures occurring in the posterior region.

Fractures can be classified as simple or multiple, and by multiple in one bone or crossing more than one bone, which is called contiguous.

**ANTERIOR SKULL BASE**

These fractures are divided up in the classification of Damianos to four types.

- **Type 1** is classified as cribriform fracture with a linear fracture. There is no involvement of the ethmoid or frontal sinus with this type of fracture.
- **Type 2** fractures are frontoethmoid fractures with ethmoid and medial frontal sinus walls. No cribriform involvement.
- **Type 3** is lateral frontal fractures, with lateral frontal sinus to the superomedial wall of the orbit.
- **Type 4** fractures are a mixture of any of the previous 3 fractures.

**MIDDLE SKULL BASE**

Ulrich’s classical classification of the temporal bone divided fractures to longitudinal and transverse with 80-90% being longitudinal and 10-20% transverse in nature. However, this has poor clinical correlation, and has been revised. The reasoning behind this was that most fractures are of a mixed type. Therefore, a new classification was note to be otic sparing and otic violating fractures. This allowed better radiologic findings with clinical findings. With otic capsule sparing being 91.5% of fracture and otic capsule violating being 8.5%. Also, 60.5% with hearing loss, that can be divided into 57.7% with CHL, 33.3% SNHL and 9% mixed.

With regard to the facial nerve, Little and Kesser in 2006 showed a 5 fold increase in facial nerve injury, a 25 x increased in SNHL, and 8 x increase in CSF leaks with otic capsule violating fractures. In the same study, there was 48% facial nerve function paresis/paralysis, with only 6% nerve damage in OCS.
POSTERIOR FOSSA

This is an uncommon area of fracture, but is divided into 2 main sections, the clivus fractures and the occipital bone fractures. Clivus fractures are uncommon, with only 9/25000 or 0.39% of recorded clivus fracture with head trauma over 5 years. However, in this study from Neurosurgery Review in 2004, all five patients had cranial nerve defects noted. Also, the type of fracture correlated with prognosis, with longitudinal fractures having 3 out of 5 patients die of vertebral injury.

Occipital condylar fractures tend to be high-energy blunt traumas. These are divided into 3 types.

- **Type 1** - axial compression with comminution of the occipital condyle. This type of injury tends to be stable.
- **Type 2** – direct blow that occurs with skull base and occipital condyle. The alar ligaments tend to be intact.
- **Type 3** – Avulsion, torn ligaments with fractures.

PHYSICAL EXAM FINDINGS

There are typical exam findings that are consistent with skull fractures. Typical findings include raccoon eyes, conjunctiva hemorrhage, anosmia, Battle signs, vision changes, CSF rhinorrhea or otorrhea, step off supraorbital edge, hearing loss, facial paralysis, facial numbness. FrONTAL fractures were the most common fracture to have clinical signs. However, each clinical finding had its own predictive value to having skull base fractures. Battles sign is 100% associated with skull fractures, with periorbital ecchymosis at 90% and bloody otorrhea with 70% association. In one study out of the Journal of Neurosurgical Science in 2000 from Brazil, they found a correlation of GCS and symptoms. They found that with patient with GCS of 13-15, there was a PPV for intracranial lesion (hematoma, pneumocephalus, contusion, and swelling) of 78% with periorbital ecchymosis, 66% with Battle sign, and 41% with bloody otorrhea.

CSF leak

With CSF leak, 80% occur following non-surgical trauma. They occur in 2% of all head trauma, but up to 12-30% of basilar skull fractures. In terms of presentation, 50% of CSF leaks occur in the first 2 days, then 70% in one week, and almost 100% seen in 3 months. The most common place for CSF leaks are the ethmoid in 19%, orbital bone in 14.89%, temporal bone in 14%, sphenoid in 11.36%, and occipital in 3.33%. They do tend to resolve spontaneously, however, up to 24% of leaks need to have intervention for treatment.

Cranial nerves

Each cranial nerve gets affected in different ways by skull base fractures. Olfactory nerve CN I, can get affected from cribiform trauma with shearing or tearing of the nerve fibers. Typically, however, the sense of smell may return over several months. Ophthalmic CN II, is not a true cranial nerve as it is more of a direct extension from the brain. Therefore, the axons do not regenerate. Transection from trauma causes blindness dilated pupil and absent pupillary reflex. Surgical decompression of a swollen nerve had the same results as just spontaneous recovery. Therefore, decompression is limited to only known bone fragments on the nerve.
In the middle cranial fossa, the oculomotor nerve CN III can also be impaired from skull base fracture, with signs of diplopia and impaired extraocular movements. The etiology of damage is typically from direct frontal blow. The treatment is conservative and can involve wearing an eye patch over the affected eye until recover occurs, which should happen within 4-6 weeks if the nerve is not transected. With the trochlear nerve, CN IV, injury is less common but can happen with nerve stretching from dorsal midbrain. Conservative treatment, therefore, is used with eye patch and usually spontaneous recovery.

With the trigeminal nerve, CN V, deficits are usually from the sensation to the face. The most common site is the V1 portion of the face with injury at the supraorbital notch. The abducens nerve is rarely damage from skull fractures with damage from the clivus or from avulsion from leaving the pons. However, with super orbital fissure fractures, damage can occur to the CN III, IV, VI and V1. This is known as superior orbital fissure syndrome, and if it also involves the optic foramen, it is the orbital apex syndrome.

With CN VII, the facial nerve, facial paralysis occurs from damage to the temporal bone, with 50% of facial nerve damage from transverse and 25% of longitudinal fractures. An ENoG should be done with 90% degeneration needed to undergo surgical decompression. The vestibulocochlear nerve, CN VIII, would have hearing loss and vestibular damage. Total degeneration with deafness and labyrinthine dysfunction can occur. An Audiogram, ABR, and ENG are needed to assess the nerve function after damage.

In the posterior fossa, the CN IX, X, XI all exits out of the jugular foramen and CN XII out of hypoglossal foramen. Glossopharyngeal nerve injury causes dysphagia and loss of gag reflex, with vagus nerve leading to ipsilateral cord or palate weakness and hoarseness. Spinal accessory nerve damage has weakness with shoulder movement and hypoglossal nerve damage causes ipsilateral tongue weakness. All treatment is usually support for these nerve defects.

Imaging

Imaging for cranial nerve defects is difficult to assess for even the most advanced radiologist. Also, the type of imaging to order can be confusing. In 2005, a criteria was made to determine if imaging is needed. The New Orleans criteria states that a CT scan is needed for minor head trauma, which is defined as loss of consciousness with normal neurological findings, if the following occurred: headache, vomit, >60 yo, drug/alcohol use, witness seizure, anterograde amnesia, and soft tissue injury. Xrays in the past were used as initial screening before CT scan, but have fell to the wayside. This is because they provided little clinical value and only delayed the CT. The high resolution CT scan is the gold standard for evaluation of the skull base. It has the best modality for evaluation of fractures. The typically size of the fracture should be 1-1.5 mm thick. Use of a helixal ct is best for occipital condyle fracture, with angiography is best for evaluation of cerebral vasculature.

One key issue with the skull base is to identify the difference between sutures and fractures. This is an issue as there are many suture lines and fractures can be hairline in size and cause significant damage.

With sutures, they tend to be less than 2 mm width, same thickness throughout, lighter to see on scans, have specific anatomical locations. However, fractures are more likely 3 mm in width or greater, have different width throughout, appear darker, and usually more in straight lines with angular turns.
Vascular damage can occur in up to 50% of patients as delayed ischemic brain damage. Carotid injury can be occlusion, dissection, compression with fracture, or fistula formation. One study by Biffl et al in 1999 from the American Journal of Surgery showed that out of 249 patients with skull fractures with concern over vascular injury, about 34% had noted injuries. Independent predictor of carotid damage was GCS of <6, petrous bone fracture, diffuse axonal brain injury, and Le Fort II/III fracture. Any one of these injuries was associated with 41% risk of injury to the vascular region.

MRI also can play a role with evaluation of skull base. It has better soft tissue detail than CT scan. A fast spin echo T1 or T2 with post contrast enhancement are preferred methods to evaluate the skull base. The T2 fat suppression with image reversal is used to highlight CSF leaks. The T2 weighted thin sliced images of Fast imaging using steady state acquisition (FIESTA) protocol can be used to provide greater detail of the cranial nerves.

CSF

Evaluation of any CSF leak can be tricky as well. CSF evaluation with a typical halo ring has been stated in the past, however, this can provide false positives as blood and water, saline and other mucous can do the same thing.

Beta-2-transferrin is the gold standard for evaluation. The test can require having 0.5 cc of fluid, and is highly specific CSF. Beta trace protein can also be used, but is not as accurate as beta transferrin. CT cisternograms is useful for detection of CSF leaks. It involves intrathecal administration of radiopaque contrast with followed of CT scan. This can have up to 80% sensitivity. However, the results may depend on intermittent leaks with contrast may obscure the visualization of the leak site. Treatment begins with conservative management of strict bedrest, HOB > 30 degrees, no cough, sneezing, and straining. Currently, the recommendation for antibiotics prophylaxis for leaks is not recommended, as no data supports that this has any benefit. Conservative management over 7 days has 85% chance of resolution. Continued leakage is then treated with lumbar puncture to drainage of 10 ml/hr. This will increase resolution to 90%. Therefore, surgical intervention is reserved for patients who do not resolve with the above procedures.

CONCLUSION

In conclusion, skull base injuries offer complex fractures that require thorough evaluation. Division of the cranial vaults provides a reasonable way to evaluate. Radiographic evaluation is important, along with history and physical examination. Treatment measures are typically conservative, with surgical intervention for persistent disease.
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* The analysis concluded that the evidence does not support the use of prophylactic antibiotics to reduce the risk of meningitis in patients with basilar skull fractures or basilar skull fractures with active CSF leak