Cranial Nerve Traumatic Avulsions and Iatrogenic Transections: A Neuroimaging and Clinical Review

Nicholas S. Bates, Yueyang Guo, Kassie L. McCullagh, Derek McAllister, Syed S. Hashmi, Tarik F. Massoud
Division of Neuroimaging and Neurointervention, Department of Radiology, Stanford University School of Medicine, Stanford, CA

BACKGROUND

Purpose
Cranial nerve (CN) injury is an overlooked aspect of neurotrauma. It may also occur after surgical procedures, whether planned or as inadvertent complications. Although CN injury in craniocerebral trauma is common, e.g. for CN1, CN7, and CN8, CN palsies secondary to a specific injury subtype, i.e. avulsions, are rare but clinically important. They may present with immediate onset, or diagnosed late in polytrauma scenarios. High resolution MRI is best to detect CN avulsions. Neuroradiologists should be familiar with the appearances of rare CN avulsions, since they can be challenging and their accurate diagnostic interpretation can greatly contribute to patient management.

Methods
We review mechanisms, clinical presentations, and neuroimaging examples of traumatic and iatrogenic CN avulsions.

Findings
CN2 avulsion is rare, occurring in 38% of patients with traumatic globe luxation (a rare injury) after severe facial trauma. This occurs at 3 locations: optic disc (in 12%), orbital apex (in 55%), and optic chiasm (33%). CN3 is particularly vulnerable to shearing injury over the posterior petroclinoid ligament, but CN3 avulsion is very rare, seen by its separated free margins in the interpeduncular cistern. Similarly, CN6 has a long cisternal course and unilateral palsy may follow minor head trauma, but its avulsion is also rare. CN6 may stretch and avulse between two fixed sites: the pontomedullary sulcus and Dorello's canal. CN7 avulsions can be perinatal at stylomastoid foramen, occurring after forceps delivery, or avulsion of both CN7 and CN8 nerves from the IAC fundus occurring in the presence or absence of temporal bone fractures or brain injury. We will also review the etiologies and clinical presentations of other known post-traumatic CN avulsions for CN1 and CN12. Notably, there are sparse accounts of traumatic avulsions for CN4, CN5, CN9, CN10, and CN11. We also review surgical therapeutic transections of CNs, e.g. CN1 is often resected when sinonasal tumors invade the cribriform plate region, or historical transections for sensory roots of CN5, CN7, and CN9; and iatrogenic inadvertent avulsions of CN1, CN7, and CN8 during neurosurgical procedures.

Summary
CN injuries are important causes of morbidity. Traumatic or iatrogenic CN avulsions should be diagnosed early to guide appropriate treatment. This presentation will aid in identifying and understanding the spectrum of these uncommon injuries for improved diagnostic interpretation and patient management.

CN 1 Olfactory

Olfactory nerve injury is the most common cranial nerve injury in the setting of trauma. The intimate nature of the olfactory filaments with adjacent osseous structures of the cribriform plate predispose them to laceration even in low grade trauma. Severe acceleration and deceleration forces result in olfactory filament avulsion and stretch injuries, more common in lateral and posterior impact trauma scenarios. Additionally, olfactory tracts can be torn in severe trauma particularly nasoorbitoethmoid complex fractures.

CN 1: Diagram of the olfactory bulb, roots, and filaments in intimate relationship with cribriform plate. Coronal T2WI of olfactory nerves in the olfactory fossae, common sites of traumatic injury. 3D reformatted image of nasoorbitoethmoid complex fracture with cribriform plate fracture.

CN 2 Optic

Optic nerve avulsion is rare but can be seen in severe facial trauma. There are three areas in which the nerve is susceptible to avulsion including the optic disc, orbital apex, and optic chiasm. Avulsion at the optic disc is thought to be secondary to a dramatic rise in intraocular pressure blowing the nerve off the sclera. These injuries are usually associated with rotational injuries with extreme abduction.

CN 2: Another example of left globe luxation and optic nerve avulsion on CT after a gouging injury.

CN 3 Oculomotor

The incidence of primary traumatic oculomotor palsy in craniocerebral trauma is very low (around 1%), and even rarer in the setting of mild head trauma. CN 3 avulsion is very rare. Typically CN3 injury is associated with severe neurologic impairment, with loss of consciousness and permanent neurologic dysfunction necessitating the need for urgent intracranial imaging especially if an expanding tectal hematoma is present. This commonly produces a CN 3 palsy. This nerve is vulnerable to injury at the posterior petroclinoid ligament. Additionally, it is susceptible to stretch injury and avulsion at the mesencephalon-pontine junction.

CN 3: A, Axial FIESTA image of the mesencephalon showing a normal cisternal course of the right oculomotor nerve (white arrow), however the left oculomotor nerve is not seen. There is a focal irregularity of the brainstem surface at the expected origin of the left oculomotor nerve with underlying signal abnormality (white arrowhead). B, Axial-oblique FIESTA image of the suprasellar cistern showing the posterior cisternal segment of the left oculomotor nerve courses medially and terminates anterior to the basilar artery (black arrow), and does not extend posteriorly to the interpeduncular fossa. C, Coronal STIR image of the interpeduncular fossa showing hyperintense signal at the site of the avulsed nerve (white arrow). D, Axial diffusion-weighted image at the level of the mesencephalon showing a focal area of diffusion restriction at the expected location of the origin of the cisternal segment of the left oculomotor nerve (white arrowhead), representing focal injury related to the avulsion.

CN 4 Trochlear

The trochlear nerve is the only cranial nerve that decussates before emerging from the posterior aspect of the brainstem. Lesions involving the trochlear nucleus or fascicles mostly give rise to contralateral superior oblique palsy. For example, a blow to the left forehead could result in damage by the tentorial ridge near the right posterolateral aspect of the midbrain (contrecoup injury). Also if a patient hits the right front of the head, a lesion at the right anterior side of the pons (coup injury) may ensue. Lesions caused by compression of the nerve against the rigid tentorial edge may result in unilateral fourth nerve palsies. However, documented proven avulsion of CN4 must be extremely rare, as there are no reports in the literature to describe this entity

CN 5 Trigeminal

Trigeminal nerve branches are frequently injured during craniocerebral trauma, however, injury to the cisternal segment of the trigeminal nerve is rare. The large trigeminal ganglion can be injured with penetrating injuries as this ganglion lies immediately proximal to foramen ovale within Meckel's cave. A more frequent imaging presentation of CN 5 injury is secondary to iatrogenic sectioning or ablation of the nerve in refractory cases of trigeminal neuralgia. CN 5 section procedures aim at interrupting the sensory fibers of the trigeminal ganglion while preserving the motor component innervating the muscles of mastication. These procedures have been associated with significant morbidity and have largely been replaced with microvascular decompression procedures. Additionally, alcohol ablation has largely been replaced with radiofrequency ablation of the Gasserian ganglion.

CN 5: Diagram of trigeminal nerve section of the afferent fibers in trigeminal neuralgia surgery. **CN 5:** Intra-procedural images of Gasserian ganglion radiofrequency ablation. Note the radiofrequency probe tip is at the level of foramen ovale

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CN 6 Abducens

While CN 6 palsy is frequently seen in clinical practice, injury secondary to traumatic avulsion is rare and seen in less than 3% of head trauma cases. While traumatic injury to cranial nerve 6 can occur in the presence of comminuted skull base fractures, cases have been reported after minor head trauma. Avulsion may happen due to stretching injury between the two sites: the pontomedullary sulcus and Dorello's canal.

CN 6: Oblique FIESTA [A] shows the avulsed ends of both CN6s in the preponitine cistern (white arrows). The proximal end of the avulsed nerve is seen on the left (arrowhead). In [B], sagittal FIESTA shows the avulsed, superiorly retracted right CN6 in the cistern (arrow), as well as the proximal segment (arrowhead). The brainstem origin of the right CN6 is not clearly seen. In [C], sagittal FIESTA shows the avulsed, superiorly retracted left CN6 in the cistern (white arrow) adjacent to the basilar artery.

CN 7 and 8 Facial and Vestibulocochlear

Traumatic injury to the facial and vestibulocochlear nerves most commonly occurs within the temporal bone as a result of skull base fractures. Usually this occurs at the level of the geniculate ganglion. Avulsion of the intra-canalicular or cisternal segments of the facial and vestibulocochlear nerves is exceedingly rare.

CN 9 and 10 Glossopharyngeal and Vagus

Glossopharyngeal neuralgia is a rare but distinctive syndrome, named by Wilfred Harris. It has many causes. Investigation must exclude MS, and local compression, especially by tumors that require treatment in their own right. Dandy deserves credit for first indicating vascular compression of cranial nerve roots as a cause of cranial neuralgias, and Jannetta for establishing neurovascular decompression. Vascular compression is a common and treatable cause but does not account for all previously designated idiopathic cases. The mechanism involves hyperexcitability of the nerve and ephaptic conduction, but is not yet fully understood.

Medical treatment of glossopharyngeal neuralgia with carbamazepine or gabapentin can be effective in suppressing painful paroxysms. Although spontaneous remissions are common, the relapses may become refractory to drug therapy. Surgical methods include CN9 transection, tractotomy or microvascular decompression. Intracranial root section has been the most often employed and is generally effective but additional transection of the upper CN10 rootlets is considered necessary in some cases.

CN 11 Accessory

Rarely, the spinal accessory nerve (SAN) is inadvertently transected during exploration of the posterior cervical triangle. Due to the close relationship between the lymph nodes and the CN11, approximately 3% to 10% of all lymph node biopsy procedures result in SAN injuries.

CN 12 Hypoglossal

The hypoglossal nerve supplies motor function to the tongue. Bilateral traumatic hypoglossal nerve transection is an extremely rare condition, which in one case was reported to occur after a blast injury.