Cranial nerve pathology can range from the neoplasm, inflammation, infection, vascular, autoimmune, injury, and developmental abnormalities to anatomic variations. Involvement of cranial nerve can have a significant functional impact on the patient ranging from denervation, sensory, and motor deficits to autonomic abnormalities. Identification of common cranial nerve pathology is essential in adequately understanding basis of clinical presentation and guiding further management and follow-up. In this article, we present a summary of common pathologies affecting cranial nerves.

Cranial Nerve Neoplasms

Cranial nerves are susceptible to both primary and secondary neoplastic involvement. In addition, clinical cranial neuropathies can also result secondary to extrinsic mass effect from the adjacent neoplasm and rarely due to paraneoplastic neuropathies, such as anti-Hu paraneoplastic multiple cranial neuropathies.¹

Meningiomas

Meningioma is a common neoplasm that can involve cranial nerves by virtue of its predilection for dural reflections, sometime through which cranial nerves are coursing. These can occur involving any cranial nerve, but common locations are the olfactory groove (CN I), optic nerve (CN II), cavernous sinus (CN V1, V2, III, IV, and VI), cerebellopontine angle (CN VII and VIII), petroclival region (CN V and VI), and jugular foramen (CN IX, X, and XI). On imaging, they are typically hypointense on T1-weighted, iso- to hypointense on T2-weighted, low on apparent diffusion coefficient (ADC) due to cellularity, and intense enhancement on postcontrast T1-weighted. There is often a dural tail due to reactive changes in the adjacent dura. On CT, these masses can be hyperdense to cellularity and calcifications and often show hyperostosis of the adjacent bony surface. The clinical presentation and management depend on size, mass effect, location, and pathologic grade of the lesion.

Figure 1 shows an example of an olfactory groove meningioma, where there is a mass in the anterior cranial fossa involving the olfactory groove. These are common intracranial lesions that arise from the floor of the anterior cranial

Learning Objectives: After participating in this CME activity, the neurosurgeon should be better able to:
1. Describe common cranial nerve pathology, clinical presentation, and imaging appearance.
2. Propose management considerations for cranial nerve pathologies.
is intended for neurosurgeons, neurologists, neuroradiologists, and neuropathologists. The exact reason for propensity to this site for developing a meningioma is unclear. Initial presenting clinical sign can include such as anosmia and headache. Due to the slow rate of growth, and location, these tumors achieve a significantly large size at the time of diagnosis resulting in mass effect on frontal lobes, lateral ventricle, obstructive hydrocephalus, and herniation. It can also result in compression of the anterior cerebral artery in the interhemispheric fissure and venous invasion, latter commonly seen with higher-grade neoplasms.

Similarly, optic nerve meningiomas (Figure 2) are benign slow-growing tumors of the arachnoid “cap” cells of the optic nerve sheath with circumferential (most common) growth pattern. On CT and MRI, a tram-track pattern of calcifications and enhancement, and trapped cerebrospinal fluid (CSF) between the tumor and the globe may be seen. T2 signal can be variable based on the histologic subtype and degree of calcifications. Between 5% and 10% can be associated with neurofibromatosis type 2 (NF2).3,4

Skull base and cavernous sinus (CS) meningiomas can present with multiple cranial neuropathies, pose a resection challenge due to location, and may need stereotactic radiosurgery for treatment. CS meningiomas usually arise from the lateral dural wall and can cause compression of CN III, IV, VI, V2, and VI leading to polynuropathy. Mass effect and narrowing of the cavernous internal carotid artery (ICA) are common and there can be secondary extension to the Meckel cave.5 Similarly, skull base involvement such as with jugular foramen meningioma can cause multiple cranial neuropathies (CN IX, X, and XI). This can be primarily arising in the jugular fora and secondarily invading it from adjacent structures, the former characterized by extensive infiltration of the surrounding skull base.6

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**Figure 1. Olfactory groove meningioma.** Axial T2-weighted (A and C) and post-contrast coronal (B) and sagittal (D) images demonstrate midline T2, slightly hyperintense, homogenously enhancing extra-axial mass (dashed arrow) overlying planum sphenoidale with extension into the olfactory groove (solid arrows) consistent with meningioma.
Metastasis and Perineural Spread of Neoplasms

Metastasis can involve cranial nerve nuclei with brain stem parenchymal involvement, and can involve the nerve directly after it exits the brain parenchyma. Direct involvement of the cranial nerve can occur due to leptomeningeal (pial)/CSF dissemination, perineural spread of neoplasms, and rarely hematogenous metastatic seeding.

Figures 3 and 4 show examples of perineural spread of neoplasms affecting the trigeminal nerve, CN V. Malignant involvement of the intracranial and extracranial parts of the trigeminal nerve and branches can be seen with tumors of the maxillofacial region. The tumor spread is usually retrograde through the V1, V2, or V3 branches toward the Meckel cave/trigeminal ganglion and may extend posteriorly along the cisternal segment of the nerve. On MRI, findings include enlargement and asymmetrical enhancement of the nerve. The auriculotemporal nerve is a possible route of perineural dissemination between the facial nerve and the V3 branch of the temporal nerve via its close proximity to the parotid gland, where the facial nerve is coursing. Figure 4 shows an example of perineural spread along the right auriculotemporal nerve.

Other Neoplasms

Glioma

Glioma can involve any of the cranial nerve nuclei, based on its location in the brain stem. It can also impact cranial nerves secondary to mass effect, and leptomeningeal spread of neoplasms. Glioma can primarily involve the optic pathway (Figure 5), causing fusiform nerve enlargement of the nerve, hyperintense signal on T2-weighted sequences, with variable enhancement based on tumor grade. They can be seen in association with NF1, which is also associated with risk of a brain stem glioma. On CT, assessment is limited but occasionally enlarged optic foramina can be seen. On MRI the lesion is usually isointense on T1, variable on T2 and enhances.7,8 Figure 5 is an example of the optic pathway glioma in an NF1 patient. Other features of NF1
may be present in the brain, such as myelin vacuolization and gliomas such as optic pathway and brain stem glioma.

**Esthesioneuroblastoma**

Esthesioneuroblastomas (Figure 6) also known as olfactory neuroblastomas are rare, slow-growing, malignant neuroectodermal tumors that arise from the basal layer of the olfactory epithelium. They have a bimodal age distribution with a peak in the second and fifth decades. Common clinical presentation is hyposmia or anosmia, nasal stuffiness, and epistaxis. It can secondarily extend into the orbit and sinuses resulting in visual symptoms and headache. On imaging, a “dumbbell-shaped” mass across the cribriform plate is the most characteristic appearance. Contrast-enhanced CT and MRI show an enhancing mass, with regions of necrosis. Treatment usually involves combined chemotherapy and/or radiotherapy with surgical excision.

**Paraganglioma**

Paragangliomas (Figure 7) are slowly growing tumors that arise from specialized parasympathetic chemoreceptor cells of neural crest origin. The most common locations of these tumors include the carotid space (carotid bifurcation/carotid body and upper carotid space/vagal), the jugular foramen (jugular), and within the middle ear (typanic). On CT, these lesions can exhibit “moth-eaten” osteolytic changes. On MRI, lesions are low signal on T1 images, high signal on T2 with characteristic salt and pepper appearance and markedly enhanced.

**Cranial Nerve Schwannoma**

Schwannoma is a benign nerve sheath tumor and can occur anywhere along the course of a cranial nerve. The majority (~90%) of CN schwannomas arise from the CN VIII, with the next most commonly involved nerves being the CN V and CN VII nerves, followed by the lower CNs, which include CN IX, CN X, CN XI, and CN XII nerves. Figure 8 is an example of a CN IX schwannoma.

In fact, the vestibular schwannoma is the most common primary cerebellopontine angle (CPA) neoplasm. In addition, CPA can have other lesions, such as meningioma, epidermoid, and arachnoid cysts. Characteristically, out of these lesions only epidermoid is a nonenhancing lesion with restricted diffusion.
Based on the location, the symptoms can vary; for example, vestibular schwannoma results in sensorineural hearing loss (SNHL) due to mass effect on the nerve. It arises from the nerve sheath and shows eccentric expansion. On MRI, a large lesion is ice-cream on cone-shaped with a large CPA and a small internal auditory canal (IAC) component and a small lesion would appear as a filling defect on high-resolution T2 steady-state free precession MRI (SSFP) with corresponding enhancement. Bilateral lesions are pathognomonic for patients with NF2.

CN IX schwannomas commonly arise intracranially in the cerebellomedullary cistern. CN X schwannomas usually arise from the inferior vagal ganglion within the jugular foramen. CN XII schwannoma can result in widening of the hypoglossal canal.

On MRI, the lesion can be of variable size and shape, sometimes characteristic “dumbbell” shaped based on location, such as secondary to constriction at the porus trigeminus or a skull base foramen. They are T1 iso- to hypointense, T2 hyperintense, and demonstrate variable enhancement. Management relies on location and size, ranging from conservative follow-up to surgical resection and stereotactic radiosurgery.

**Infection and Inflammation**

Demyelination [multiple sclerosis (MS), neuromyelitis optica spectrum disorder (NMOSD), and anti-myelin oligodendrocyte glycoprotein (anti-MOG) syndrome] (Figure 9) can involve optic nerve, resulting in acute optic neuritis. On MRI the inflammation can be focal or segmental, central, or diffuse with nerve enlargement during the acute phase that is T2 hyperintense and enhancing. The nerve is atrophic and gliotic in the chronic stage. Brain and spinal cord lesions are usually present. In anti-aquaporin-4 NMOSD and anti-MOG-associated disease, the optic neuritis is more commonly bilateral, with former more commonly associated with intracranial/chiasmatic involvement and latter with retrobulbar/intraorbital involvement.

In anti-MOG syndrome, the immune dysfunction targets the MOG on the outermost myelin membranes surrounding the optic nerves, spinal cord, and brain. It is thus more commonly associated with optic perineuritis. MS on the other hand typically has short segment involvement of the optic nerve, commonly unilateral with short-segment spinal cord lesions, compared with longitudinally extensive myelitis seen with NMOSD and anti-MOG syndrome (>3 vertebral segments).

Idiopathic orbital inflammatory syndrome (orbital pseudotumor) (Figure 10) is an inflammatory process of the orbit with no known local or systemic cause. A subset of these are due to immunoglobulin G4 (IgG4)-related disease, which can have multisystemic involvement including orbits. On MRI the lesions are enhancing, poorly defined and infiltrative in appearance and can involve any orbital structure (the extraocular muscles, lacrimal gland, globe, retrobulbar orbit, or orbital apex). On T2 the lesions are hypointense due to cellular infiltrate and fibrosis particularly in IgG4 disease.

Infections of the skull base especially, in diabetics and immunocompromised patients, are important causes of lower cranial nerve palsies (Figure 11). Skull base osteomyelitis...
Affected cranial nerves show enhancement and thickening with or without associated leptomeningeal involvement. Bell’s palsy (Figure 13) is a facial neuritis, with acute-onset unilateral lower motor neuron facial nerve paralysis. Exact etiology is unclear but has been hypothesized as due to reactivation of latent herpes simplex infection of the geniculate ganglion, other viral infections, or autoimmune. It is a common cause of lower motor neuron facial paralysis. MRI is required only in atypical cases including prolonged palsy, subacute onset, recurrent involvement, or multiple cranial nerve involvement. The classic MRI findings including tuft-like enhancement in the IAC intracanalicular, premeatal, and labyrinthine segment of CN VII are distinctive MR findings. Compared to Bell’s Palsy, Ramsay Hunt syndrome is a facial neuritis caused by herpes zoster virus, accompanied by an erythematous vesicular rash on the ear or in the mouth. Additionally, Ramsay Hunt syndrome is commonly more painful than Bell’s palsy and less likely to have complete recovery.

Vascular Pathology

Vascular etiology for cranial neuropathy encompasses a wide range of pathophysiology ranging from extrinsic compression, such as due to an aneurysm or coursing artery or due to ischemia from thrombosis. Posterior communicating artery aneurysm is a common cause of oculomotor nerve palsy, which can develop directly via mass effect of the growing aneurysm or indirectly after rupture of the aneurysm and adjacent clot formation. In addition, multiple cranial neuropathies can result from carotid cavernous fistula (CCF) and cavernous sinus thrombosis (CST), which can lead to CN III, IV, V1, V2, and VI polyneuropathy. Both CST and CCF may be associated with enlargement of the superior ophthalmic vein and/or the extraocular muscles. CST commonly occurs secondary to infection of the sinonasal cavities, or orbits. On CT and MRI, the CS can be enlarged and can demonstrate filling defects on postcontrast sequences.

Neurovascular compression commonly associated with trigeminal neuralgia due to compression from an adjacent coursing artery (Figure 14) is one of the examples of

Neurosarcoidosis (Figure 12) is a multisystem inflammatory disease characterized by noncaseating epithelioid cell granulomas. Cranial nerves are affected in up to 50% of patients’ albeit with poor correlation between imaging findings and clinical symptoms. Although facial nerve deficits are most commonly found clinically, the optic nerve is the most common cranial nerve to appear abnormal on MRI.

Figure 11. Skull base osteomyelitis. Coronal CT scan (A) demonstrates permissive osteolytic destruction involving the left occipital condyle, left C1 lateral mass (white arrow). The destructive changes extend to the left hypoglossal nerve canal (arrowhead). B, Axial 3D T1 C+ FSPGR image demonstrates enhancement in the left hypoglossal nerve canal (dotted white arrow).

Figure 12. Central nervous system sarcoidosis. A 63-year-old man with known sarcoidosis presented with bilateral SNHL and tinnitus. Multiple axial T1 C+ MR images demonstrate enhancement along multiple cranial nerves. A, nodular enhancement along the left eighth cranial nerve (solid arrow). B, nodular enhancement along left CN VII nerve (dotted arrow). C, Punctate nodular enhancement along the cisternal segment of the right CN VI (open arrow). D, Subtle enhancement along the cisternal segment of the right CN V (double dotted arrow). E, Enhancement of the cisternal segment of the right CN III (curved arrow). F, 1-year follow-up demonstrates persistent right CN III enhancement (curved arrow) and additional extensive nodular leptomeningeal enhancement along the cerebellar folia (arrowheads).
extrinsic compression causing neuropathy. On MRI, there is compression on the root entry zone by vascular loops of the superior cerebellar artery or anterior inferior cerebellar artery. In some cases, the loop results in separation of the motor and sensory fibers. Treatment options include medical management, surgical decompression, which can produce improvement in nerve conduction and symptom relief, or stereotactic radiosurgery.

Venous malformation, commonly seen with facial nerve, previously referred to as facial nerve hemangiomia, is a benign vascular malformation composed of dilated vascular channels commonly involving the geniculate fossa of the facial nerve. On CT, a honeycomb matrix can be seen with a characteristic stippled appearance. On MRI, it can appear as a T2 hyperintense, enhancing mass in the geniculate ganglion.

References


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1. Schwannoma arises from the olfactory neuroectoderm. True or False?

2. Tram-track calcifications can reliably differentiate optic nerve meningioma from other lesions of the optic nerve. True or False?

3. The vessel most commonly implicated in compression of the root entry zone of the trigeminal nerve, causing trigeminal neuralgia, is the superior cerebellar artery. True or False?

4. The auriculotemporal nerve is the most likely route of perineural dissemination between the facial and trigeminal nerves. True or False?

5. Bell’s palsy is a common cause of peripheral facial nerve paralysis. True or False?

6. The most common primary cerebellopontine angle mass is meningioma. True or False?

7. The masticator space is a common location for paragangliomas. True or False?

8. The characteristic imaging finding of intracranial epidermoid lesions is restricted diffusion. True or False?

9. Miller Fisher syndrome is a regional variant of Guillain-Barré syndrome and characterized by cranial nerve involvement (most commonly ophthalmoplegia), ataxia, and areflexia. True or False?

10. Posterior communicating artery aneurysm is a common cause of oculomotor nerve palsy. True or False?