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American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Cranial Neuropathy**

Variant 1: **Anosmia and abnormalities of the sense of smell.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	9	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the anterior skull base and paranasal sinuses to include multiple planes and thin slices. Additional sequences and extended anatomic ranges may be necessary to identify extracranial disease. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI head without contrast	7	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the anterior skull base and paranasal sinuses to include multiple planes and thin slices. Small olfactory groove lesions may be missed without use of intravenous contrast. Additional sequences and extended anatomic ranges may be necessary to identify extracranial disease.	O
CT head with contrast	6	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the anterior skull base and paranasal sinuses to include multiple planes and thin slices. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges may be necessary to identify extracranial disease.	☢☢☢
CT head without contrast	5	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the anterior skull base and paranasal sinuses to include multiple planes and thin slices. Small olfactory groove lesions may be missed without use of intravenous contrast. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges may be necessary to identify extracranial disease.	☢☢☢
Thallium SPECT head	1	May be useful as a problem-solving technique following initial imaging evaluation.	☢☢☢☢
FDG-PET head	1	May be useful as a problem-solving technique following initial imaging evaluation. PET-CT survey scan may be useful in patients with known primary malignancies.	☢☢☢☢
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Cranial Neuropathy**

Variant 2: **Weakness or paralysis of the muscles of mastication; sensory abnormalities of the head and neck.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	9	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the cerebellopontine angle, central skull base, orbit, and masticator space to include multiple planes and thin slices. Additional sequences and extended anatomic ranges may be necessary to identify extracranial disease. If facial pain is a clinical concern, high-resolution sequences such as CISS/FIESTA and MR angiography may be useful in identifying vascular compression. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI head without contrast	7	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the cerebellopontine angle, central skull base, orbit, and masticator space to include multiple planes and thin slices. Additional sequences and extended anatomic ranges may be necessary to identify extracranial disease. If facial pain is a clinical concern, high-resolution sequences such as CISS/FIESTA and MR angiography may be useful in identifying vascular compression. Inflammatory conditions and some tumors may be missed without use of intravenous contrast.	O
CT head with contrast	6	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the cerebellopontine angle, central skull base, orbit, and masticator space to include multiple planes and thin slices. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges may be necessary to identify extracranial disease.	☢☢☢

CT head without contrast	5	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the cerebellopontine angle, central skull base, orbit, and masticator space to include multiple planes and thin slices. Inflammatory conditions and some tumors may be missed without use of intravenous contrast. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges may be necessary to identify extracranial disease.	☢☢☢
Thallium SPECT head	1	May be useful as a problem-solving technique following initial imaging evaluation.	☢☢☢☢
FDG-PET head	1	May be useful as a problem-solving technique following initial imaging evaluation. PET-CT survey scan may be useful in patients with known primary malignancies.	☢☢☢☢
US neck	1	May be useful as a problem-solving technique in evaluating extracranial disease following initial imaging evaluation.	O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Clinical Condition: **Cranial Neuropathy**

Variant 3: **Weakness or paralysis of facial expression.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	9	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the central and posterior skull base, temporal bones, and parotid glands to include multiple planes and thin slices. Additional sequences and extended anatomic ranges may be necessary to identify extracranial disease. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI head without contrast	7	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the central and posterior skull base, temporal bones, and parotid glands to include multiple planes and thin slices. Small lesions and facial nerve pathology may be missed without use of intravenous contrast. Additional sequences and extended anatomic ranges may be necessary to identify extracranial disease.	O
CT head with contrast	6	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the central and posterior skull base, temporal bones, and parotid glands to include multiple planes and thin slices. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges may be necessary to identify extracranial disease.	☢☢☢
CT head without contrast	5	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the central and posterior skull base, temporal bones, and parotid glands to include multiple planes and thin slices. Small lesions and facial nerve pathology may be missed without use of intravenous contrast. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges may be necessary to identify extracranial disease.	☢☢☢
Thallium SPECT head	1	May be useful as a problem-solving technique following initial imaging evaluation.	☢☢☢☢

FDG-PET head	1	May be useful as a problem-solving technique following initial imaging evaluation. PET-CT survey scan may be useful in patients with known primary malignancies.	☢☢☢☢
US neck	1	May be useful as a problem-solving technique in evaluating extracranial disease following initial imaging evaluation.	O
<u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Clinical Condition: **Cranial Neuropathy**

Variant 4: **Palate weakness.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	9	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Additional sequences and extended anatomic ranges to include the neck may be necessary to identify extracranial disease. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI head without contrast	7	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Small lesions and glossopharyngeal nerve pathology may be missed without use of intravenous contrast. Additional sequences and extended anatomic ranges to include the neck may be necessary to identify extracranial disease.	O
CT head with contrast	6	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges to include the neck may be necessary to identify extracranial disease.	☢☢☢
CT head without contrast	5	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Small lesions and glossopharyngeal nerve pathology may be missed without use of intravenous contrast. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges to include the neck may be necessary to identify extracranial disease.	☢☢☢
Thallium SPECT head	1	May be useful as a problem-solving technique following initial imaging evaluation.	☢☢☢☢

FDG-PET head	1	May be useful as a problem-solving technique following initial imaging evaluation. PET-CT survey scan may be useful in patients with known primary malignancies.	☢☢☢☢
US neck	1	May be useful as a problem-solving technique in evaluating extracranial disease following initial imaging evaluation.	O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Clinical Condition: **Cranial Neuropathy**

Variant 5: **Vocal cord paralysis.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head and neck without and with contrast	8	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Additional sequences and extended anatomic ranges to include the neck from the skull base to the aortopulmonary window are necessary to identify extracranial disease. Alternatively, a chest CT with contrast may be substituted for the thoracic portion of the MRI. See statement regarding contrast in text under "Anticipated Exceptions."	O
CT head and neck with contrast	8	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges to include the neck from the skull base to the aortopulmonary window are necessary to identify extracranial disease. High-resolution images using a soft tissue algorithm may be useful in evaluating the larynx.	☢☢☢
MRI head and neck without contrast	7	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Small lesions and vagal nerve pathology may be missed without use of intravenous contrast. Additional sequences and extended anatomic ranges to include the neck from the skull base to the aortopulmonary window are necessary to identify extracranial disease. Alternatively, a chest CT with contrast may be substituted for the thoracic portion of the MRI.	O
CT chest with contrast	6	May be used as alternative to MRI of chest or supplement to MRI or CT of the head and neck to evaluate the intrathoracic course of the vagal nerve and to evaluate thoracic pathology.	☢☢☢

CT head and neck without contrast	5	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Small lesions and vagal nerve pathology may be missed without use of intravenous contrast. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges to include the neck from the skull base to the aortopulmonary window are necessary to identify extracranial disease. High-resolution images using a soft tissue algorithm may be useful in evaluating the larynx.	☢☢☢
FDG-PET head and neck	2	May be useful as a problem-solving technique following initial imaging evaluation. PET-CT survey scan may be useful in patients with known primary malignancies.	☢☢☢☢
X-ray chest	2	May be used as a screening tool if chest CT or chest MRI unavailable.	☢
Thallium SPECT head and neck	1	May be useful as a problem-solving technique following initial imaging evaluation.	☢☢☢☢
US neck	1	May be useful as a problem-solving technique in evaluating extracranial disease following initial imaging evaluation.	O
<u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Clinical Condition: **Cranial Neuropathy**

Variant 6: **Weakness or paralysis of the sternocleidomastoid and trapezius muscles.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head and neck without and with contrast	9	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Additional sequences and extended anatomic ranges to include the neck are necessary to identify extracranial disease. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI head and neck without contrast	7	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Small lesions and spinal accessory nerve pathology may be missed without use of intravenous contrast. Additional sequences and extended anatomic ranges to include the neck are necessary to identify extracranial disease.	O
CT head and neck with contrast	6	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges to include the neck are necessary to identify extracranial disease.	☢☢☢
CT head and neck without contrast	5	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Small lesions and spinal accessory nerve pathology may be missed without use of intravenous contrast. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges to include the neck are necessary to identify extracranial disease.	☢☢☢
FDG-PET head and neck	2	May be useful as a problem-solving technique following initial imaging evaluation. PET-CT survey scan may be useful in patients with known primary malignancies.	☢☢☢☢

Thallium SPECT head and neck	1	May be useful as a problem-solving technique following initial imaging evaluation.	☢☢☢☢
US neck	1	May be useful as a problem-solving technique in evaluating extracranial disease following initial imaging evaluation.	O
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

Clinical Condition: **Cranial Neuropathy**

Variant 7: **Weakness or paralysis of the tongue.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	9	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Additional sequences and extended anatomic ranges to include the neck may be necessary to identify extracranial disease. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI head without contrast	7	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Small lesions and hypoglossal nerve pathology may be missed without use of intravenous contrast. Additional sequences and extended anatomic ranges to include the neck may be necessary to identify extracranial disease.	O
CT head with contrast	6	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges to include the neck may be necessary to identify extracranial disease.	☢☢☢
CT head without contrast	5	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Small lesions and hypoglossal nerve pathology may be missed without use of intravenous contrast. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges to include the neck may be necessary to identify extracranial disease.	☢☢☢

FDG-PET head	2	May be useful as a problem-solving technique following initial imaging evaluation. PET-CT survey scan may be useful in patients with known primary malignancies.	☢☢☢☢
Thallium SPECT head	1	May be useful as a problem-solving technique following initial imaging evaluation.	☢☢☢☢
US neck	1	May be useful as a problem-solving technique in evaluating extracranial disease following initial imaging evaluation.	O
<u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Clinical Condition: **Cranial Neuropathy**

Variant 8: **Perineural spread of tumor.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head and neck without and with contrast	9	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Additional sequences and extended anatomic ranges to include the neck may be necessary to identify extracranial disease. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI head and neck without contrast	6	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Small lesions and nerve pathology may be missed without use of intravenous contrast. Additional sequences and extended anatomic ranges to include the neck may be necessary to identify extracranial disease.	O
CT head and neck with contrast	5	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges to include the neck may be necessary to identify extracranial disease.	☢☢☢
CT head and neck without contrast	4	In addition to survey images to evaluate possible intracranial disease, the scan should focus on the skull base to include multiple planes and thin slices. Small lesions and nerve pathology may be missed without use of intravenous contrast. High-resolution images using a bone algorithm may be useful in evaluating patients sustaining trauma and in evaluating the bony foramina and possible bone erosion. Extended anatomic ranges to include the neck may be necessary to identify extracranial disease.	☢☢☢

FDG-PET head and neck	2	May be useful as a problem-solving technique following initial imaging evaluation. PET-CT survey scan may be useful in patients with known primary malignancies.	☢☢☢☢
Thallium SPECT head and neck	1	May be useful as a problem-solving technique following initial imaging evaluation.	☢☢☢☢
US neck	1	May be useful as a problem-solving technique in evaluating extracranial disease following initial imaging evaluation.	O
Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**			***Relative Radiation Level**

CRANIAL NEUROPATHY

Expert Panel on Neurologic Imaging: Franz J. Wippold II, MD[1]; Rebecca S. Cornelius, MD[2]; Daniel F. Broderick, MD[3]; Douglas C. Brown, MD[4]; James A. Brunberg, MD[5]; Patricia C. Davis, MD[6]; Robert L. De La Paz, MD[7]; Charles F. Garvin, MD[8]; Kathryn Holloway, MD[9]; Charles T. McConnell Jr, MD[10]; Suresh Kumar Mukherji, MD[11]; Brian Nussenbaum, MD[12]; Joshua M. Rosenow, MD[13]; David J. Seidenwurm, MD[14]; Konstantin Slavin, MD[15]; Michael A. Sloan, MD, MS[16]; James G. Smirniotopoulos, MD.[17]

Summary of Literature Review

Nerves are bundles of axons in the peripheral nervous system that carry sensory (afferent) electrochemical impulses from the body to the brain and motor (efferent) impulses from the brain to the body. The cranial nerves arise from nuclei within the brain and brainstem and supply sensory and motor innervation to the head and neck region, whereas the spinal nerves arise from the spinal cord and supply the rest of the body. As a group, the cranial nerves have both sensory and motor components similar to those of the spinal nerves. Individually the cranial nerves may be purely sensory or purely motor or a mixture of both sensory and motor. Functions of the cranial nerves may be divided into three sensory and three motor categories. The sensory group includes visceral sensory, which supplies sensory input from the internal organs; general sensory, which supplies tactile, pain, temperature and other sensations; and special sensory, which includes the special senses of smell, vision, taste, hearing, and balance. Of the three motor functions, somatic motor innervates muscles that develop from the body somites; branchial motor innervates muscles derived from the branchial arches; and visceral motor innervates the viscera, glands, and smooth muscle [1-3].

Cranial nerves emerge in an orderly fashion from the rostral portion of the embryologically developing neural tube, which will subsequently mature to form the brain and brain stem. Anatomically, the 12 pairs of cranial nerves are designated by numbers and are organized most rostral to most caudal in descending order. The cranial nerves (CN) include the olfactory (CN I), optic (CN II), oculomotor (CN III), trochlear (CN IV), trigeminal (CN V), abducens (CN VI), facial (CN VII), vestibulocochlear (CN VIII), glossopharyngeal (CN IX), vagus (CN X), spinal accessory (CN XI), and hypoglossal (CN XII) nerves. The olfactory (CN I) and optic (CN II) nerves are actually tracts formed from the telencephalon and diencephalon, respectively, and are not considered true nerves [1]. The optic (CN II), oculomotor (CN III), trochlear (CN IV), and abducens (CN VI) nerves are considered functionally to be part of the visual and extraocular motor system and have been discussed in the ACR Appropriateness Criteria® on "Orbits, Vision and Visual Loss." Also, the vestibulocochlear nerve (CN VIII) has been reviewed in the ACR Appropriateness Criteria® on "Vertigo and Hearing Loss." Therefore, this discussion will focus on cranial nerves CN I, CN V, CN VII, CN IX, CN X, CN XI, and CN XII.

In approaching cranial neuropathy, several concepts should be emphasized:

1. Because of the complex anatomic structures within the brain and brainstem and because the cranial nerves may take long, circuitous routes to their destinations, a detailed knowledge of cranial nerve anatomy is essential for proper clinical localization of potential lesions and for appropriate application of specific imaging protocols.
2. Because some individual nerve fibers, such as the autonomic nerves, may travel with several different cranial nerves from their nuclei of origin to their ultimate destinations, loss of a specific function may indicate involvement of potentially more than one cranial nerve.
3. Because of the close proximity of many cranial nerve nuclei and of many exiting sites of the nerves themselves, some mass lesions may involve multiple cranial nerves.

Imaging Modalities

Magnetic resonance imaging (MRI) has emerged as the modality of choice when evaluating the cranial nerves; computed tomography (CT) remains useful for visualizing the skull base neural foramina, calcific matrices within lesions, and osseous erosions [4-5]. In general, high-field-strength magnets (1.5T-3.0T) are preferred to low-field-strength units because of achievable signal-to-noise ratios, gradient strength, and spatial resolution [5]. A phased-array head coil suffices for most examinations; specialized surface coils may supplement examinations of peripherally located nerves. The primary plane of study is

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usually the axial plane. Additional orthogonal planes may be useful, depending upon the course of the various nerves. Fundamental techniques include T1-weighted, T2-weighted, and enhanced T1-weighted imaging sequences. The unenhanced T1-weighted sequence remains an excellent baseline technique for anatomical evaluation because of the natural contrast provided by soft tissue, cerebrospinal fluid, and skull base fat. Specialized versions of sequences may be available on scanners depending on manufacturer options. For example, various three-dimensional (3D) and heavily T2-weighted sequences — such as constructive interference in steady-state (CISS), 3D-balanced fast-field-echo (b-FFE), 3D-driven equilibrium radio frequency reset pulse (DRIVE), 3D fast-spin-echo (3D-FSE), fast imaging employing steady-state acquisition (FIESTA), and 3D fast-spin-echo extended echo-train acquisition (3D FSE XETA) — may provide excellent spatial resolution of the cisternal segments of some of the cranial nerves, but they must be used judiciously because of potentially misleading artifacts [4-13]. Enhanced fat suppression T1-weighted techniques may emphasize abnormal enhancing lesions and nerves, but may potentially mask subtle pathology if the suppression is nonuniform. Additional sequences, such as diffusion-weighted imaging (DWI), may be added to evaluate specific pathologies, such as infarctions, or specific lesions, such as epidermoids, which may affect cranial nerve function. Slice thickness should be calculated for optimal spatial resolution without introducing partial-volume effect. Because cranial nerve examinations tend to be lengthy, strategies such as parallel imaging may improve patient compliance and image quality [5].

Imaging protocol design should balance specificity and sensitivity. Patients referred with detailed history and physical examination information benefit from tightly focused imaging evaluations, whereas patients with little clinical evaluation prior to imaging and who are referred for so-called "screening" studies are best served with scans that cover all of the potentially affected regions of the head and neck. Protocols should focus on optimally demonstrating the anatomic territories associated with the cranial nerve or nerves in question. In general, the course of the entire nerve should be imaged.

Positron emission tomography (PET) and ultrasound (US) of the neck may be useful modalities for assessing lesions such as tumors or lymphadenopathy that have caused cranial neuropathy.

Anosmia and Abnormalities of the Sense of Smell

Abnormalities of the special sense of smell are mediated by the olfactory nerve (CN I) and can be grouped into clinical categories. Quantitative disturbances imply diminished or enhanced sense of smell (anosmia, hyposmia, or hyperosmia). Qualitative disturbances involve distortions of the sense of smell (dysosmia). Discrimination disturbances involve an inability to differentiate among various smells. Hallucinations or delusions in the sense of smell may also occur. The latter may be caused by temporal lobe dysfunction (see the ACR Appropriateness Criteria® on "Epilepsy"), or by degenerative or psychiatric disease. Taste, mediated by the facial (CN VII) and glossopharyngeal (CN IX) nerves, may also be affected by pathology involving the olfactory nerve (CN I).

Most patients with olfactory complaints do not require imaging [14]. Chronic tobacco use and upper respiratory infections most commonly affect the sense of smell [15]. More serious conditions affecting the olfactory nerve include trauma (the olfactory nerve is the nerve most commonly disrupted by trauma); cribriform plate tumors such as invasive squamous cell carcinomas of the paranasal sinuses, meningiomas, and esthesioneuroblastomas; inflammatory lesions such as sarcoidosis and Wegener's granulomatosis; and congenital conditions such as cephaloceles and Kallman's syndrome [4,14,16-18]. Recent investigations have focused on olfactory bulb volume as an indicator of olfactory dysfunction and even a harbinger of Parkinson's disease [16,19-21].

MRI is the mainstay for examining the olfactory apparatus, although CT remains useful when evaluating fractures, paranasal sinus inflammatory disease, and bony anatomy [14,16,22-23]. Imaging protocols should cover the major anatomic divisions of the olfactory nerve and pathway, including the olfactory epithelium, which is located in the upper nasal cavity; the olfactory neurons and bulbs, located in the cribriform plate and inferior frontal lobes; and the olfactory pathways, which travel in portions of the temporal and frontal lobes [5]. Efforts using functional MRI, single photon emission tomography (SPECT), and PET in studying olfactory dysfunction remain largely investigative and are not generally used in routine evaluations [24-29].

Weakness or Paralysis of the Muscles of Mastication; Sensory Abnormalities of the Head and Neck

The trigeminal nerve (CN V) provides general sensation to large portions of the head and neck and branchial motor innervation to the muscles of mastication [3]. It is the largest cranial nerve and is divided into three main divisions known as the ophthalmic (V1) , maxillary (V2), and mandibular (V3) branches [4]. Symptoms largely depend on the involved segment and division [30]. Abnormalities of the nerve may manifest as sensory disturbances, such as trigeminal neuralgia (*tic douloureux*) or facial numbness, or motor abnormalities such as weakness when chewing food.

The trigeminal nerve (CN V) is the nerve of the first branchial arch and may be involved in congenital conditions such as Goldenhar-Gorlin syndrome [30]. Intra-axial and extra-axial processes may affect the brainstem trigeminal nuclei and nerve root entry and exit zones. Conditions localized to the brainstem portion of the trigeminal nerve (CN V) include vascular lesions (such as compressing vascular loops, aneurysms, and infarctions), inflammatory and infectious conditions (such as meningitis, encephalitis, sarcoidosis, and multiple sclerosis), and tumors (such as gliomas, lymphomas, metastases, and meningiomas) [31-34]. The cisternal portion of the nerve may be especially vulnerable to compression from adjacent vascular loops, causing trigeminal neuralgia [31,35]. Tumors, vascular lesions, and inflammatory processes may also affect the branches of the nerve as they traverse Meckel's cave, the pterygopalatine fossa, the orbit, the skull base, and the masticator space [30,36].

MRI is the preferred modality for investigating the trigeminal nerve (CN V) [5,30,37]. CT is very useful for evaluating the skull base and neural foramina. Three-dimensional and heavily T2-weighted MR sequences and MR and CT angiography are helpful noninvasive methods for reviewing the anatomy of potentially compressing vascular loops [38-50]. With the growing popularity of radiosurgery, such as gamma knife procedures, and radiofrequency thermocoagulation in the treatment of trigeminal neuralgia, both CT and MRI have become indispensable planning and follow-up tools, although imaging may not reliably predict outcome [31-32,51-63]. Because of the complex branching patterns of the nerve, multiple imaging planes are essential [30]. Advanced imaging applications, such as fractional anisotropy derived from diffusion tensor imaging and virtual endoscopy, are promising future directions in investigating trigeminal neuralgia [64-65].

Weakness or Paralysis of Facial Expression

The facial nerve (CN VII) is one of the most complex cranial nerves and contains branchial motor (innervation to the muscles of facial expression), visceral motor (parasympathetic innervation to most of the glands of the head), general sensory (surface innervations to a small portion of the external ear and tympanic membrane), and special sensory (taste to the anterior two-thirds of the tongue) functions [3]. It is the one of the most commonly paralyzed nerves in the body, and most of the clinical attention it receives focuses on its role in facial expression [4]. Tinnitus, conductive and sensorineural hearing loss, and hemifacial spasm may also signal a lesion involving the facial nerve [13].

The intracranial course of the facial nerve includes pontine, cisternal, and intra-temporal segments [5]. Within the pons, the facial nuclei can be affected by intra-axial conditions such as infarction, vascular malformations, tumors, and multiple sclerosis [9]. As the nerve exits the brainstem and courses through the temporal bone, it may be affected by facial and vestibular schwannomas, meningiomas, vascular lesions, inflammation, cholesteatomas, paragangliomas, trauma, and intrinsic bone tumors [13,66]. The extracranial segment of the facial nerve courses through the parotid gland and may be affected by parotid tumors and inflammation and conditions of the neighboring anatomic spaces and skull base such as carcinomas, sarcomas, trauma, and inflammatory disease.

MRI is the mainstay of evaluating both intracranial and extracranial portions of the facial nerve [13,67-70]. CT provides useful information regarding temporal bone fractures and trauma, presurgical bony anatomy, nerve involvement with inflammatory middle ear disease, foraminal expansion, patterns of bone erosion, and intrinsic bone tumor matrices [71-73]. Facial paralysis in the form of Bell's palsy is one of the most common syndromes confronting the otolaryngologist. In general, Bell's palsy patients need not be imaged unless the symptoms are atypical or persist for more than 2 months [13]. When imaging is considered, MRI is the method of choice [13,70-71]. Enhancement may be seen in the labyrinthine, geniculate, tympanic, and mastoid portions of the nerve in neuritis, although tympanic and mastoid portions may enhance normally [13,74-77]. MRI may also be useful in establishing prognosis [77-82].

Palate Weakness

The glossopharyngeal nerve (CN IX) arises in the medulla and is responsible for branchial motor innervation to the stylopharyngeus muscle, which elevates the palate, and visceral motor parasympathetic innervation to the parotid gland [3]. Visceral sensory innervation to the carotid sinus plays a role in regulating circulation and general and special sensory functions that supply sensation and taste to the posterior tongue. The nerve exits the jugular foramen in close proximity to the vagus (CN X) and the spinal accessory (CN XI) nerves [3,5,9,14,83]. Therefore, isolated syndromes involving the glossopharyngeal nerve are rare [14]. Intra-axial lesions include gliomas, lymphomas, metastases, vascular malformations, infarctions, and inflammatory abnormalities. Multiple sclerosis may also affect the medulla adjacent to the cranial nerve nuclei. Leptomeningeal metastases, granulomatous disease, and even tortuous or aneurysmal dilatation of vessels may affect the nerve as it enters the cistern. Lesions in the region of the posterior skull base and jugular foramen, such as metastases, schwannomas, paragangliomas, and meningiomas, usually also involve the other lower cranial nerves [83]. Tonsillar pain syndromes, palate weakness, and loss of gag reflex accompanied by loss of taste and sensation in the posterior pharynx may signal a glossopharyngeal nerve lesion [83].

As with the other cranial nerves, MRI of CN IX is the preferred modality for investigating possible lesions such as masses or vascular compression, with CT providing information on the bony integrity of the foramina [5,14,84-85]. Imaging protocols should focus on the posterior skull base and upper neck.

Vocal Cord Paralysis

The vagus nerve (CN X) supplies visceral sensation to the pharynx, larynx, and viscera, and a small twig of general sensation supplies the ear. Branchial motor branches innervate muscles of the pharynx and larynx, whereas visceral motor branches play a predominant role in parasympathetic supply to the thorax and abdomen [3,5,83]. The vagus nerve boasts the longest course in the body of any cranial nerve and is therefore vulnerable to a wide range of pathologies occurring throughout its trajectory from the posterior fossa and skull base to the neck, thorax, and abdomen [4,14]. Intracranial processes such as meningiomas, schwannomas, metastases, granulomatous disease, ischemia, vascular conditions, and infection may affect the vagal nuclei and the nerve as it exits the medulla. Paragangliomas, schwannomas, and metastases involving the skull base may affect the nerve and the neighboring glossopharyngeal nerve (CN IX) by infiltration of fibers or by compression. Within the neck, trauma may also affect the vagus nerve in addition to masses, vascular lesions, thyroid conditions, infection, or inflammation [86]. Viral neuropathy may be one of the most common causes of idiopathic vagal palsies [86].

One of the most troubling symptoms of vagus dysfunction is vocal cord paralysis. Because lesions anywhere in the long course of the nerve may potentially cause paralysis, the imaging protocol must visualize the full extent of the nerve from the skull base to the mid-chest. With its rapid scanning time and availability, CT provides an excellent means of examining the lower course of the nerve [87]. Moreover, thoracic causes of paralysis, such as lung cancer, tuberculosis, and thoracic aortic aneurysm, are common [88]. Although chest radiographs may detect many of these causes, chest CT is more sensitive especially for lesions concealed in the aortopulmonary window [88-89]. For imaging of the upper course of the nerve including the skull base, MRI is preferred [90-91]. For the mid-neck and larynx, CT and MRI complement one another [92-93]. For example, CT may differentiate traumatic arytenoid dislocation from neurogenic paralysis [94]. Rapid multislice CT scanning, including functional 3D applications, also allows the patient to perform phonation and breathing maneuvers during imaging to augment diagnosis [95-99]. US may also have a role in imaging of the neck [86-87]. Although imaging is essential in the evaluation, it only supplements the physical examination and may not detect all lesions [100]. Moreover, PET imaging used for evaluating head and neck malignancy may yield false positive findings in the larynx for patients with vocal cord paralysis [101-102].

Weakness or Paralysis of the Sternocleidomastoid and Trapezius Muscles

The spinal accessory nerve (CN XI) supplies the sternocleidomastoid muscle and the upper portion of the trapezius muscle as its sole branchial motor function [3,5,83]. Palsy is clinically manifested by weakness and atrophy of these muscles and may be accompanied by evidence of involvement of the glossopharyngeal (CN IX) and vagus (CN X) nerves in combined syndromes [83]. Loss of volume and fatty infiltration of the sternocleidomastoid and trapezius muscles may be noted on imaging. CT and MRI are complementary in diagnosing conditions such as posterior fossa and skull base infarctions, vascular lesions, Chiari malformations, paragangliomas, schwannomas, meningiomas, and metastases, or in recognizing nerve involvement from prior neck surgeries [14,83,86].

Weakness or Paralysis of the Tongue

The hypoglossal nerve (CN XII) supplies somatic motor innervation to the intrinsic and extrinsic muscles of the tongue, except the palatoglossus muscle [3,5,83]. Palsy of this nerve is recognized by dysarthria and deviation of the tongue to the affected side on protrusion. Atrophy and fatty infiltration of the tongue may be noted on imaging. Lesions of the posterior fossa, skull base, upper neck, and floor of mouth may affect the hypoglossal nerve. They include infarctions, meningiomas, schwannomas, paragangliomas, carcinomas, metastases, subarachnoid hemorrhage, Chiari malformations, basilar invagination, and fractures [14,83]. As with the other lower cranial nerves, MRI is the preferred modality for CN XII, and CT provides complementary information on the integrity of the bony structures and foramina [103].

Combined Cranial Neuropathy Syndromes and Perineural Spread of Tumor

Because of the complex anatomy of the head and neck and the close proximity of several cranial nerves, many clinical presentations of cranial neuropathy involve multiple nerves. As in syndromes of combined neuropathy of the upper cranial nerves, such as those related to vision and the extraocular muscles (which are covered in other Appropriateness Criteria®), syndromes involving the lower cranial nerves are also grouped primarily by the proximity of the involved cranial nerves. For example, Gradenigo's syndrome involves CNs V and VI as they travel in the vicinity of the petrous apex, whereas Vernet's syndrome involves CNs IX, X, and XI as they travel within the jugular foramen. Imaging protocols should be tailored to evaluate the suspected region of anatomy when the syndrome is identified by the clinician.

A difficult problem for the surgeon is the perineural spread of head and neck malignancy. The trigeminal (CN V) and facial (CN VII) are the most common nerves involved; however, any cranial nerve traveling in the vicinity of a malignancy may become involved [104]. MRI has emerged as the preferred imaging method for evaluating perineural spread of tumor, although CT may be very useful for visualizing the neural foramina [104-110]. PET imaging may also be helpful [109,111]. Perineural spread of tumor along the facial nerve may evade even the most meticulous imaging [112]. Subtle clues such as nerve enhancement, nerve enlargement, foraminal expansion, or muscle volume loss may indicate cranial nerve involvement with tumor [113]. For example, asymmetry of facial musculature may be useful in detecting perineural tumor spread along the facial nerve or predicting return of function after nerve grafting [79,113].

Summary

- Imaging is useful in identifying the primary pathology causing cranial neuropathy, such as mass or inflammation, and is also helpful in noting secondary signs of cranial nerve involvement, such as

fatty infiltration or volume loss in denervated muscles.
- MRI is the preferred imaging modality for evaluating the cranial nerves. CT remains a useful complement for visualizing the skull base and neural foramina.
- Imaging protocols must be carefully tailored to reflect the complex anatomy and function of the cranial nerves.
- Effective imaging requires a collegial working alliance between the referring clinician and the imaging specialist.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (ie, <30 mL/min/1.73m^2), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73m^2. For more information, please see the ACR *Manual on Contrast Media* [114].

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document.

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as NS (not specified).

Supporting Document(s)

- ACR Appropriateness Criteria® Overview
- Procedure Information
- Evidence Table

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