The lowest four cranial nerves

HYPOGLOSSAL NERVE

The hypoglossal nerve (cranial nerve XII) contains somatic efferent fibers for the supply of the extrinsic and intrinsic muscles of the tongue. Its nucleus lies close to the midline in the floor of the fourth ventricle and extends almost the full length of the medulla (Figure 15.1). The nerve emerges as a series of rootlets in the interval between the pyramid and the olive. It crosses the subarachnoid space and leaves the skull through the hypoglossal canal. Just below the skull, it lies close to the vagus and spinal accessory nerves (Figure 15.2). It descends on the carotid sheath to the level of the angle of the mandible, then passes forward on the surface of the hypoglossus muscle where it gives off its terminal branches.

In the neck, proprioceptive fibers enter the nerve from the cervical plexus, to accept afferents from about 100 muscle spindles in the same half of the tongue.

Phylogenetic note

In reptiles, the lingual muscles, the geniohyoid muscle, and the infrahyoid muscles develop together from the uppermost mesodermal somites. The somatic efferent neurons supplying this hypobranchial muscle sheet form a continuous ribbon of cells extending from lower medulla to the third cervical spinal segment. In mammals, the hypoglossal nucleus is located more rostrally and its rootlets emerge separately from the cervical rootlets. However, the caudal limit of the hypoglossal nucleus remains linked to the cervical motor cell column by the supraspinal nucleus, from which the thyrohyoid muscle is supplied via the first cervical ventral root. In rodents, some of the intrinsic muscle fibers of the tongue receive their motor supply indirectly, from axons which leave the most caudal cells of the hypoglossal nucleus and emerge in the first cervical nerve to join the hypoglossal nerve trunk in the neck. Whether this arrangement holds for primates is not yet known.

Supranuclear supply to the hypoglossal nucleus

The hypoglossal nucleus receives inputs from the reticular formation, whereby it is recruited for stereotyped motor routines in eating and swallowing. For delicate functions including articulation, most of the fibers from the motor cortex cross over in the upper part of the pyramidal decussation; some remain uncrossed and supply the ipsilateral hypoglossal nucleus. Supranuclear, nuclear, and infranuclear lesions of the hypoglossal nerve are described together with lesions of the accessory nerve (see Clinical Panels 15.1–15.3).

SPINAL ACCESSORY NERVE

The spinal accessory nerve (cranial nerve XI) is a purely motor nerve attached to the uppermost five segments of the spinal cord. The nucleus of origin is a column of α and γ motoneurons in the basolateral anterior gray horn.

The nerve runs upward in the subarachnoid space, behind the denticulate ligament. It enters the cranial cavity through the foramen magnum and leaves it again through the jugular foramen. While in the jugular foramen, it shares a dural sheath with the cranial accessory nerve, but there is no exchange of fibers (Figure 15.3). Upon leaving the cranium, it crosses the transverse process of the atlas and enters the sternomastoid muscle, in company with twigs from roots C2 and C3 of the cervical plexus. It emerges from the posterior border of the sternomastoid and crosses the posterior triangle of the neck to reach the trapezius. It pierces the trapezius in company with twigs from roots C3 and C4 of the cervical plexus. In the posterior triangle, the nerve is vulnerable, being embedded in prevertebral fascia and covered only by investing cervical fascia and skin.

The spinal accessory nerve provides the extrafusal and intrafusal motor supply to the sternomastoid and trapezius. The branches from the cervical plexus are proprioceptive in function to the sternomastoid and to the craniocervical part of the trapezius. The thoracic part of the trapezius, which arises from the spines of all the thoracic vertebrae, receives its proprioceptive innervation from the posterior rami of the thoracic spinal nerves. Some of the afferents supplying muscle spindles in the thoracic trapezius do not meet up with the fusimotor supply before reaching the spindles. This is the only instance, in any muscle known, where the fusimotor and afferent fibers to some spindles travel by completely independent routes.

GLOSSOPHARYNGEAL, VAGUS, AND CRANIAL ACCESSORY NERVES

Especially relevant to nerves IX, X, and cranial XI are the solitary nucleus and the nucleus ambiguus. The solitary nucleus extends from the lower border of the pons to the level of the gracile nucleus. Its lower end merges with its opposite number in the midline; hence the term commissural nucleus for the lower part of the solitary nucleus.

Anatomically, the nucleus is divisible into eight parts. Functionally, four regions have been clarified (Figure 15.4):

1. The uppermost region is the gustatory nucleus, which receives primary afferents supplying taste buds in the tongue and palate.
2. The lateral midregion is the dorsal respiratory nucleus (see Ch. 19).
3. The medial midregion is the baroreceptor nucleus, which receives the primary afferents supplying blood pressure detectors in the carotid sinus and aortic arch.
The most caudal region, including the commissural nucleus, is the major **visceral afferent nucleus** of the brainstem. It receives primary afferents supplying the alimentary tract and respiratory tract.

From the nucleus ambiguus, **special visceral efferent** fibers supply the constrictor muscles of the pharynx, stylopharyngeus, levator palati, intrinsic muscles of the larynx, and (via the recurrent laryngeal nerve) the...
striated muscle of the upper one-third of the esophagus.

**Glossopharyngeal nerve**

The glossopharyngeal nerve is almost exclusively sensory. It carries no less than five different kinds of afferent fibers traveling to five separate afferent nuclei in the brainstem. The largest of its peripheral territories is the oropharynx, which is bounded in front by the back of the tongue; hence the name for the nerve.

The glossopharyngeal rootlets are attached behind the upper part of the olive. The nerve accompanies the vagus through the anterior compartment of the jugular foramen (the posterior compartment contains the bulb of the internal jugular vein). Within the foramen, the nerve shows small superior and inferior ganglia; these contain unipolar sensory neurons.

Immediately below the skull, the glossopharyngeal is in the company of three other nerves (*Figure 15.2*): the vagus, the spinal accessory, and the internal carotid (sympathetic) branch of the superior cervical ganglion. Together with the stylopharyngeus, it slips between the superior and middle constrictor muscles to reach the mucous membrane of the oropharynx.

**Functional divisions and branches**

- Before emerging from the jugular foramen, the IX nerve gives off a tympanic branch which ramifies on the tympanic membrane and is a potential source of referred pain (see later). The central processes of the tympanic branch synapse in the spinal nucleus of the trigeminal nerve (*Figure 15.1*).
- Some fibers of the glossopharyngeal tympanic branch are parasympathetic. They pierce the roof (tegmen tympani) of the middle ear as the lesser petrosal nerve, leave the skull through the foramen ovale, and synapse in the otic ganglion. Postganglionic fibers supply secretomotor fibers to the parotid gland (*Figure 10.3*).
- The branchial efferent supply to the stylopharyngeus comes from the nucleus ambiguus.
- Branches serving ‘common sensation’ (touch) supply the mucous membranes bounding the oropharynx (throat), including the posterior one-third of the tongue. The neurons synapse centrally in the commissural nucleus. The glossopharyngeal branches provide the afferent limb of the gag reflex – contraction of the pharyngeal constrictors in response to stroking the wall of the oropharynx. (The gag reflex is unpleasant because of

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**Figure 15.3** Course and distribution (in red) of special visceral efferent fibers derived from the nucleus ambiguus.

**Figure 15.4** Functional composition of the solitary nucleus.
Clinical Panel 15.1  Supranuclear lesions of the IX, X, and XI cranial nerves

Supranuclear lesions of all three are commonly seen following vascular strokes damaging the pyramidal tract in the cerebrum or brainstem.

Effects of unilateral supranuclear lesions
1. The supranuclear supply to the hypoglossal nucleus is mainly crossed. The usual picture following a hemiplegic stroke is as follows: during the first few hours or days, the tongue, when protruded, deviates toward the paralyzed side because of the stronger pull of the healthy genioglossus. Later, the tongue does not deviate on protrusion. However, normal hypoglossal nerve function is not restored. Electrophysiological testing has revealed that tongue movement, in response to stimulation of the crossed monosynaptic corticonuclear supply to the hypoglossal nucleus, is both delayed and weaker than normal. This, together with comparable deficiency in the corticonuclear supply to the facial nerve (which includes a motor supply to the lips), accounts for the dysarthria (slurred speech) which persists after a hemiplegic stroke.

2. Damage to the supranuclear supply to the nucleus ambiguous may cause temporary interference with phonation and swallowing.

3. On testing the power of trapezius by asking the patient to shrug the shoulders against resistance, the muscle on the affected side is relatively weak. This accords with expectation. But on testing sternomastoid (SM) by asking the patient to turn the head against resistance applied to the side of the jaw, the SM on the unaffected side appears to be relatively weak. Given that electrical stimulation applied to the supranuclear supply for SM has shown that the crossed supply is strong and monosynaptic and the uncrossed is weak and disynaptic, there appears to be a ‘sternomastoid paradox’. However, the authors’ parsimonious explanation is that the prime mover for the ‘No’ headshake is not the contralateral SM but is the ipsilateral inferior oblique, a muscle within the suboccipital triangle passing from spine of axis to transverse process of atlas. Supplementary ipsilateral muscles include splenius capitis and longissimus capitis. All three are typical spinal muscles and would be expected to share in the general muscle weakness on the affected side.

During the head rotation test the functionally intact contralateral SM does contract strongly. However, the head rotators, with the exception of inferior oblique, also have a tilting function at the atlanto-occipital joint. The laterally placed insertion of SM has strong leverage potential and is well placed to counter the tilting action of the four ipsilateral muscles inserting onto the skull.

Effects of bilateral supranuclear lesions
The supranuclear supply to the hypoglossal nucleus and nucleus ambiguous may be compromised bilaterally by thrombotic episodes in the brainstem in patients suffering from arteriosclerosis of the vertebrobasilar arterial system. The motor nuclei of the trigeminal nerve (to the masticatory muscles) and of the facial nerve (to the facial muscles) may be affected as well. The characteristic picture, known as pseudobulbar palsy, is that of an elderly patient who has spastic (tightened) oral and pharyngeal musculature, with consequent difficulty with speech articulation, chewing, and swallowing. The gait is slow and shuffling because of involvement of corticospinal fibers descending to the spinal cord.

Clinical Panel 15.2  Nuclear lesions of the X, XI, and twelfth cranial nerves

Lesions of the hypoglossal nucleus and nucleus ambiguous occur together in progressive bulbar palsy, a variant of progressive muscular atrophy (Ch. 13) in which the cranial motor nuclei of the pons and medulla are attacked at the outset. The patient quickly becomes distressed by a multitude of problems: difficulty in chewing and articulation (mandibular and facial nerve nuclei) and difficulty in swallowing and phonation (hypoglossal and cranial accessory nuclei).

Unilateral lesions at nuclear level may be caused by occlusion of the vertebral artery or of one of its branches (see Lateral Medullary Syndrome in Ch. 16). The distribution of motor weakness is the same as for infranuclear lesions (see Clinical Panel 15.3).
Jugular foramen syndrome
The last four cranial nerves, and the internal carotid (sympathetic) nerve nearby, are at risk of entrapment by a tumor spreading along the base of the skull. The tumor may be a primary one in the nasopharynx, or a metastatic one within lymph nodes of the upper cervical chain. In the second case, the primary tumor may be in an air sinus or in the tongue, larynx, or pharynx. In either case, a mass can usually be felt behind the ramus of the mandible. The symptomatology varies with the number of nerves caught up in the tumor, and the degree to which they are compromised.

Symptoms
• Pain in or behind the ear, attributable to irritation of the auricular branches of the IX and X nerves. Whenever an adult complains of constant pain in one ear, without evidence of middle ear disease, a cancer of the pharynx must be suspected.
• Headache, from irritation of the meningeal branch of the vagus.
• Hoarseness, owing to paralysis of laryngomotor fibers.
• Dysphagia (difficulty in swallowing) owing to paralysis of pharyngomotor fibers.

Signs (Figure CP 15.3.1)
• Horner’s syndrome (ptosis of the upper eyelid, with some pupillary constriction) from interruption of the sympathetic internal carotid nerve.
• Infranuclear paralysis of the hypoglossal nerve, with wasting of the affected side of the tongue and deviation of the tongue to the affected side on protrusion.
• When the patient is asked to say ‘Aahh’, the uvula is pulled away from the affected side by the unopposed healthy levator palati.
• Sensory loss in the oropharynx on the affected side.
• On laryngoscopic examination, inability to adduct the vocal cord to the midline.
• Interruption of the spinal accessory nerve produces weakness and wasting of the sternomastoid and trapezius.

A jugular foramen syndrome may also be caused by invasion of the jugular foramen from above, for instance by a tumor extending from the cerebellopontine angle (Ch. 17). In this case, the sympathetic and spinal accessory nerves will be out of reach, and unaffected.

Isolated lesion of the spinal accessory nerve
The surface marking for the spinal accessory nerve in the posterior triangle of the neck is a line drawn from the posterior border of the sternomastoid one-third of the way down to the anterior border of the trapezius two-thirds of the way down. It may be injured in this part of its course by a stab wound, or during a surgical procedure for removal of cancerous lymph nodes. The trapezius is selectively paralyzed, whereupon the scapula and clavicle sag noticeably because trapezius normally helps to carry the upper limb. Shrugging of the shoulder is weakened because the levator scapulae must work alone. Progressive atrophy of the muscle leads to characteristic scalloping of the contour of the neck (Figure CP 15.3.2).
Gustatory neurons supply the taste buds contained in glomus component has a huge territory which includes the lingual muscle spindles. Supranuclear paralysis of XII is characterized by temporary deviation to the paralyzed side on protrusion. Nuclear/infranuclear paralysis is characterized by wasting and fasciculation as well as deviation.

Spinal accessory nerve
Spinal XI is purely motor. From motor neurons of spinal segments C1–C5, the axons enter the foramen magnum and exit the jugular foramen; they pierce and supply sternomastoid, then pass deep to trapezius and supply it. Proprioceptive connections are received from cervical and thoracic spinal nerves. Supranuclear lesions are characterized by weakness of the contralateral trapezius and contralateral head rotators; nuclear/infranuclear lesions by ipsilateral wasting of the two muscles and drooping of the scapula.

Vagus and cranial accessory nerves
X and cranial XI rootlets emerge behind the olive and unite in the jugular foramen. Cranial XI fibers arise in nucleus ambiguous and utilize laryngeal and pharyngeal branches of X to supply the intrinsic muscles of larynx and pharynx, and levator palatii.

Preganglionic fibers from the dorsal nucleus of X travel to intramural ganglia in the walls of heart, bronchi, and alimentary tract. Visceral afferents from these regions, and from larynx and pharynx, have unipolar cell bodies in the nodose ganglion and project to the commissural nucleus.

Hypoglossal nerve
XII contains somatic efferent neurons supplying extrinsic and intrinsic muscles of the tongue. Its nucleus is close to midline and is innervated by reticular neurons for automatic/reflex movements and by (mainly crossed) corticonuclear neurons for speech articulation. XII emerges beside the pyramid, exits the hypoglossal canal and descends on the carotid sheath where it collects cervical proprioceptive fibers for the supply of lingual muscle spindles. Supranuclear paralysis of XII is characterized by temporary deviation to the paralyzed side on protrusion. Nuclear/infranuclear paralysis is characterized by wasting and fasciculation as well as deviation.

Glossopharyngeal nerve
IX emerges behind the olive and exits the jugular foramen where it shows two unipolar-cell ganglia and gives off a tympanic branch which is partly sensory to the middle ear, partly parasympathetic to the parotid gland via the otic ganglion. IX then passes between superior and middle constrictors to gain the oropharynx, where it supplies sensation to that mucous membrane including the posterior third of tongue (hence the name), and taste fibers to the circumvallate papillae. A carotid branch supplies the carotid sinus and carotid body.

accompanying nausea. To test the integrity of the IX nerve, it is usually sufficient to test sensation on the pharyngeal wall.) Generalized stimulation of the oropharynx elicits a complete swallowing reflex, through a linkage between the commissural nucleus and a specific swallowing center nearby (Ch. 21).

• Gustatory neurons supply the taste buds contained in the circumvallate papillae of the tongue; they terminate centrally in the gustatory nucleus (Figure 15.4).

• An important carotid branch descends to the bifurcation of the common carotid artery. This branch contains two different sets of afferent fibers. One set ramifies in the wall of the carotid sinus (at the commencement of the internal carotid artery), terminating in stretch receptors responsive to systolic blood pressure; these baroreceptor neurons terminate centrally in the medial part of the nucleus solitarius (Figure 15.4).

• The second set of afferents in the carotid branch supplies glomus cells in the carotid body. These nerve endings are chemoreceptors monitoring the carbon dioxide and oxygen levels in the blood. The central terminals enter the dorsal respiratory nucleus (Figure 15.4).

Vagus and cranial accessory nerves
The vagus is the main parasympathetic nerve. Its preganglionic component has a huge territory which includes the heart, the lungs, and the alimentary tract from esophagus through transverse colon (Ch. 10). At the same time, the vagus is the largest visceral afferent nerve; afferents outnumber parasympathetic motor fibers by four to one. Overall, the vagus contains the same seven fiber classes as the glossopharyngeal, and they will be listed in the same order.

The rootlets of the vagus and cranial accessory nerves are in series with the glossopharyngeal, and the three nerves travel together into the jugular foramen. At this point, the cranial accessory nerve shares a dural sheath with the spinal accessory, but there is no exchange of fibers (Figure 15.3). Just below the foramen, the cranial accessory is incorporated into the vagus. The vagus itself shows a small, jugular (superior) and a large, nodose (inferior) ganglion; both are sensory.

Functional divisions and branches
• An auricular branch supplies skin lining the outer ear canal, and a meningeal branch ramifies in the posterior cranial fossa. Both branches have their cell bodies in the jugular ganglion; the central processes enter the spinal trigeminal nucleus.

• The parasympathetic neurons for the heart, and respiratory and alimentary tracts originate from the dorsal nucleus of the vagus. (Some cardiac neurons are probably embedded in the nucleus ambiguus.)

• Special visceral efferent neurons of the nucleus ambiguus constitute the motor elements in the
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pharyngeal and laryngeal branches of the vagus. They supply the pharyngeal and laryngeal muscles already noted, and levator palati. They also supply the striated musculature of the upper third of the esophagus.

- General visceral afferent fibers from the heart, and from the respiratory and alimentary tracts have their cell bodies in the nodose ganglion and synapse centrally in the commissural nucleus. They serve important reflexes including the Bainbridge reflex (cardiac acceleration brought about by distension of the right atrium); the cough reflex (stimulation of a coughing center (Ch. 21) by irritation of the tracheobronchial tree); and the Hering–Breuer reflex (inhibition of the dorsal respiratory center by pulmonary stretch receptors). In addition, afferent information from the stomach (in particular) is forwarded to the hypothalamus and influences feeding behavior (Ch. 23).

- A few taste buds on the epiglottis report to the gustatory nucleus.
- Baroreceptors in the aortic arch are supplied.
- Chemoreceptors in the tiny aortic bodies are supplied; these supplement the corresponding receptors at the carotid bifurcation.

Supranuclear, nuclear, and infranuclear lesions of the IX, X, and XI nerves are described in the Clinical Panels.

REFERENCES


