Cranial Nerve

5

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5.1 Introduction

Cranial nerves consist of 12 pairs and have several anatomical and functional peculiarities. Cranial nerves 3–12 have their nuclei within the brainstem or also in the cervical spinal cord. They can be distinguished as nuclear, parenchymatous, or having an intracranial course, a specific site of exit of the skull, or an extracranial distribution. The specificity of symptoms and signs and the combination of two or more CN lesions help to achieve a precise anatomical localization (Fig. 5.1).

This chapter helps describe the individual cranial nerves, in regard to the anatomical lesion and etiology.

Fig. 5.1 Cranial nerve anatomy. Anatomical preparation: showing the cranial nerve distribution below the base of the skull. The mandibula has been removed. In addition to imaging as CT and MR, several nerves can be demonstrated by ultrasound

5.2 Olfactory Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Clinical testing
	+	+		Smell/taste

Function Mediates olfaction, defined as the sense of smell.

Anatomy Olfactory receptors are present in the superior nasal conchae and nasal septum. The unmyelinated axons pass through the cribriform plate to synapse in the olfactory bulb. The olfactory bulb is located beneath the surface of the frontal lobe. Axons leave the olfactory bulb via the olfactory tract and connect to the prepyriform cortex.

Symptoms The term parosmia describes a qualitative change in smell, while the total loss of smell is known as anosmia. Disorders of smell usually develop slowly and insidiously (except in traumatic brain injury) and are commonly associated with impaired taste. Olfactory hallucinations may accompany seizures or psychosis.

Signs Altered smell is difficult to quantitate on examination. Each nostril is tested separately for the patient's ability to smell coffee, peppermint oil, oil of cloves, and/or camphorated oil. Ammonia provokes a painful sensation and can be used to diagnose fictitious anosmia. In acute trauma, nasal bleeding and swelling may impede examination.

Pathogenesis Parosmia and anosmia are most frequently due to trauma. Approximately 7 % of head injuries involve altered smell and taste. Impact from a fall causes anteroposterior brain movement, and olfactory fibers may be literally "pulled out." This may occur without or with a skull fracture. An anteroposterior skull fracture can cause tearing of the olfactory fibers that traverse the cribriform plate with loss of ipsilateral olfaction. Other traumatic etiologies include missile injuries and inadvertent postsurgical damage. Other less frequent causes are listed in Table 5.1.

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Table 5.1 Etiologies of parosmia and anosmia

Vascular	Metabolic	Toxic	Infection	Inflammatory	Degenerative and aging	Genetic
ACA giant cell aneurysm	Renal insufficiency	Drugs[a]	Meningitis	Granuloma[b]	Alzheimer's disease	Congenital and hereditary
	Diabetes		Herpes	TB	CJD (new variant)	
			Influenza			
	Hypothyroidism		Diphtheria	Syphilis	Huntington's disease	
			TB	Rhinoscleroma	Korsakoff syndrome	
			Postinfections		Parkinson's disease	

[a]Drugs include allopurinol, analgesics, antibiotics (amphotericin B, ampicillin, ethambutol, lincomycin, tetracycline), antihelminthic, local anesthetics, chemotherapy (doxorubicin, methotrexate, carmustine, vincristine), colchicine, diuretics, immunosuppressants (azathioprine), muscle relaxants, opiates, and statins

[b]Wegener's granulomatous, sarcoid. Mass lesions can also produce parosmia and anosmia, including abscesses, aesthesioneuroepithelioma (blastoma), craniopharyngioma, meningiomas, mucocele, nasopharyngeal tumors, olfactory meningioma, olfactory neuroblastoma, tuberculum sellae tumors

Diagnosis is based on history, signs upon clinical testing, and in rare cases olfactory evoked potentials. If loss of taste accompanies loss of smell, electrogustometry is used. Smell charts are increasingly used, also for the assessment of neurodegenerative disorders.

Differential Diagnosis The perception of loss or altered smell may be actually due to altered taste secondary to dysfunction in CN IX.

Therapy Therapy depends upon etiology and in cases of trauma is usually supportive.

Prognosis When the loss of smell is due to trauma, more than one third of individuals have full recovery within 3 months.

5.3 Optic Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Other clinical tests
	+	Aquaporin	+	+
	VEP	abs	MRI, ultrasound	Color vision
				ERG

Quality Special sensory: visual information from the retina.

Anatomy Light energy is transduced into electrical signals in the posterior layer of the retina by receptor cells called rods and cones. Primary sensory neurons called bipolar cells receive signals from the rods and cones. Bipolar cells pass these signals onto secondary sensory neurons called ganglion cells, which are found in the most anterior layer of the retina. The axons of the ganglion cells traverse the retina and converge at the optic disc near the center of the retina. The macula contains no traversing ganglion cell axons, in order to diminish interference with the central vision. At the optic disc, the axons turn posteriorly through the lamina cribriformis of the sclera and exit the eyeball as the optic nerve. The optic nerve leaves the orbit through the optic canal (lesser wing of the sphenoid bone), in close proximity to the ophthalmic artery and the cavernous sinus. The optic nerve enters the middle cranial fossa and joins the optic nerve from the other eye to form the optic chiasm.

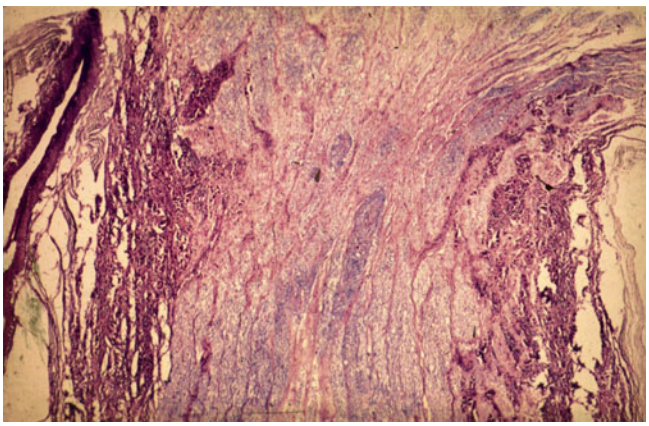

Fig. 5.2 Optic neuropathy: (photomicrograph of a histological slide). The nerve is compressed by tumor cells ("cuffed") in meningeal carcinomatosis, resulting in blindness of the patient

Location of Lesions Lesions of the optic nerve can be divided into three categories:

- Anterior to the chiasm (monocular field defect or blindness)
- Medial and temporal compression of the chiasm (hemianopia)
- Posterior to the chiasm

Central lesions and papillary dysfunction will not be discussed here.

Symptoms Loss of vision.

Signs While direct pupillary reaction to light is absent, the pupillary reaction can be evoked indirectly.

Pathogenesis

- *Compression:* Apoplexy of the pituitary (associated with headache), carotid aneurysm, endocrine orbitopathy.
- *Inflammatory causes of compression:* Arachnitis optochiasmatica-cisterna optochiasmatica, syphilis, tuberculosis.

- *Hereditary:* Optic atrophy 1, Leber's hereditary optic neuropathy, lysosomal disease, mitochondrial myopathy, Kearns-Sayre syndrome, storage disease (Tay-Sachs), spinocerebellar disease. Ataxias: Friedreich's ataxia; mitochondrial (NARP syndrome (neuropathy, ataxia, retinitis, pigmentosa)); posterior column ataxia + retinitis pigmentosa.
- *Iatrogenic:* Pressure on the eye bulb caused by anesthesia (ischemic optic nerve neuropathy), blepharoplasty, fractures of the orbit, or surgery of the nasal sinus.
- *Immune mediated:* Optic neuritis in Devic syndrome, multiple sclerosis (MS).
- *Infectious:* Meningitis, sarcoid, syphilis, tuberculosis.
- *Focal infection:* Granulomatous disease, orbital tumors, sinusitis.
- *Inflammatory:* Devic syndrome, optic neuritis due to demyelinating diseases (MS, neuromyelitis optica).
- *Metabolic:* Diabetes, thyrotoxicosis, uremia.
- *Nutritive:* Alcohol ingestion, B12 anemia, Cuban neuropathy, methylol toxicity, Strachan's syndrome.
- *Paraneoplastic:* Rarely involved in paraneoplastic dysfunction – CAR antibodies (carcinomatous retinopathy).
- *Radiation:* Radiation therapy of brain tumors, pituitary tumors, metastases, or ENT tumors can cause uni- or bilateral loss of vision with long latencies. Progressive optic nerve atrophy is seen within 6 weeks of exposure to 70 Gy.
- *Toxic optic neuropathy:* Alcohol, amoproxan, aniline dye, ara-C (high dose), arsenic, aspidium (antihelminthic drug), Cafergot, carbon disulfide, carbon tetrachloride, chinin, chinoline derivates, chlorambucil (edema of the retina), chloramphenicol, digitalis, disulfiram, paclitaxel/docetaxel – may cause visual sensations ("visual field flash") – ethambutol, isoniazid, lead, mercury (Hg), nitrosourea and radiation, nitrous oxide (N_2O), thallium, vincristine.
- *Vascular:* Ischemic optic neuropathy due to amyloidosis, arteritis cranialis, herpes zoster, retrobulbar optic neuropathy, systematic lupus.
- *Trauma:* "Blowout" fractures, gunshot wounds, penetrating trauma, trauma of the orbit, traumatic optic neuropathy (TON).
- *Tumors:* Metastasis, melanocytoma, meningeal carcinomatosis, nasopharyngeal tumor that can compress the nerve and chiasm, neurofibromatosis (NF 1), orbital tumors, optic nerve glioma, retinal infiltration (leukemia).
- *Compression* of the optic chiasm by tumors in the sella results in visual field defects and a swollen optic disc. Compression occurs in 50 % of pituitary adenomas; other potential causes include craniopharyngioma (in childhood), meningioma of the tuberculum sellae, aneurysm, tumors of the chiasm itself (spongioblastoma, meningioma, neurinoma, or retinoblastoma).

Diagnosis Diagnosis is based on X-ray, CT, or MRI imaging, visual function and color discrimination tests, ophthalmoscopic exam, visual evoked potentials, and electroretinogram. Also special ultrasound techniques allow a partial identification of the optic nerve.

Differential Diagnosis Other causes of papilledema should be considered, including increased intracranial pressure and pseudotumor cerebri.

Therapy Treatment depends upon the cause of the lesion.

Prognosis Depending on the etiology.

5.4 Oculomotor Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Lee screen
		+	+	

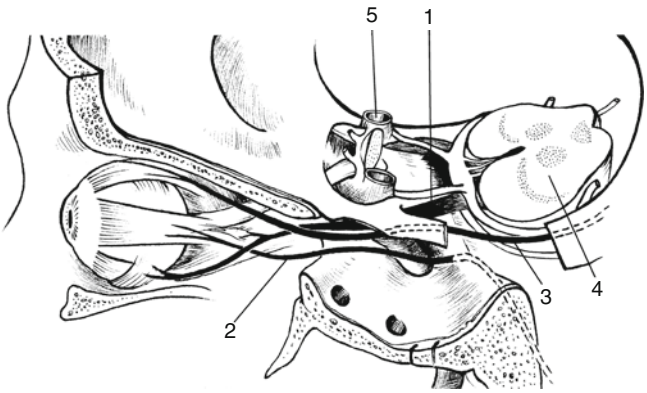

Fig. 5.3 Anatomy of oculomotor nerve: *1* Oculomotor nerve, *2* abducens nerve, *3* trochlear nerve, *4* cross section through brainstem, *5* internal carotid artery

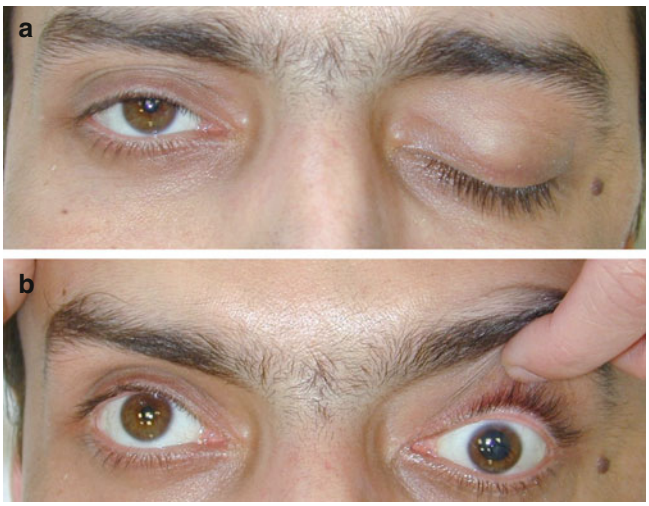

Fig. 5.4 Oculomotor nerve paresis: (**a**) complete ptosis, (**b**) Upon lifting of the lid lateral deviation of left bulbus. Mydriasis signals affection of the parasympathetic fibers for the sphincter pupillae

Table 5.2 Oculomotor nerve structures: from the nuclei to the orbit

CN III	Brain parenchyma	Intracranial and CSF	Exit of cranial vault	Extracranial lesion
III	Nuclei (see neuro-ophthalmology)	Clivus (pressure)	Fissura orbitalis superior	Orbital
	Fascicle	Cavernous sinus tumors, meningeal carcinomatosis		Orbital neuroma
	Brainstem syndromes			
		Aneurysms		
Autonomic	Edinger-Westphal nucleus	Inferior portion		Ciliary ganglion

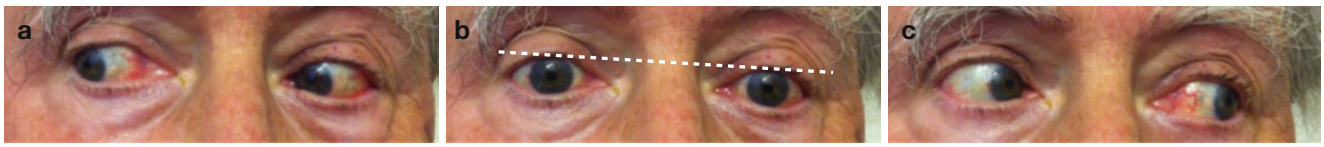

Fig. 5.5 Lymphoma of the left lacrimal gland. The patient presented with blurred vision, then diplopia. (**a**) Normal look to the left. In (**b**) the left eye is lower than the right, (**c**) also at glance to the left

Qualities *Somatic motor:* extraocular eye muscles except superior oblique muscle and lateral rectus muscle. *Visceral motor:* parasympathetic to the constrictor pupillae and ciliary muscles.

Anatomy The nucleus of the oculomotor nerve is located in the midbrain, ventral to the cerebral aqueduct. The nerve fibers course ventrally in the tegmentum, through the red nucleus and the medial aspect of the peduncles, emerging in the fossa interpeduncularis. The nerve passes the posterior cerebral and superior cerebellar arteries as it courses anteriorly. It pierces through the dura and enters the cavernous sinus, where it runs along the lateral wall superior to the trochlear nerve. The nerve then passes the superior orbital fossa and through the tendinous ring. In the orbit, it divides into a superior portion (innervating the superior rectus and levator palpebrae superioris) and inferior portion (innervating the inferior rectus, inferior oblique, and medial rectus). The visceral fibers (originating in the Edinger-Westphal nucleus of the oculomotor nucleus complex) are also found in the inferior portion and terminate in the ciliary ganglion.

Topographical Location of Lesions Brain parenchyma:

- *Nuclear lesions:* Nuclear lesions are rare and usually of vascular etiology.
- *Fascicular lesions:* Occur during the passage through the mesencephalon and concomitant with lesions of the pyramidal tract and cerebellar fibers.
- *Intracranial pathway:* Posterior communicating aneurysm – often with pupillary involvement. However, the pupil can be spared.
- *Transtentorial herniation:* Impairment of consciousness and other signs of raised intracranial pressure.
- *Clivus and plica petroclinoidea:* In herniation or local tumors.
- *Cavernous sinus:* Associated with other CN involvement (IV, V1, VI). The pupil can be spared. "Pseudo-pupillary sparing" means that pupillary involvement by an oculomotor nerve lesion is masked by a concomitant Horner's syndrome.
- *Extracranial pathway/orbit:* Passage through the superior orbital fissure – superior division (levator and superior rectus) and inferior division (inferior oblique, inferior rectus, medial rectus, pupillary muscle).
- *Orbital lesion:* Often associated with proptosis and optic nerve dysfunction.

Symptoms Patients with third nerve palsies have diplopia and unilateral ptosis. Complete ptosis may alleviate diplopia. Patients have difficulty viewing near objects because convergence is impaired.

Signs Partial or complete ipsilateral ptosis occurs. The pupil can be dilated and poorly reactive or nonreactive to light and accommodation. Examination reveals ipsilateral adduction, elevation, and depression deficit of the bulbus. If the deficit of adduction is significant, there will be a primary position exotropia that is worse when the gaze is directed toward the paretic medial rectus muscle. If the levator muscles (e.g., superior rectus or inferior oblique muscles) are involved, ipsilateral hypotropia occurs. If the inferior rectus muscle is involved, ipsilateral hypertropia occurs. Complete paresis of both inferior and superior divisions of the nerve causes ptosis, downward and outward deviation of the eye, and mydriasis (with preserved consensual pupillary reaction contralaterally). Internal ophthalmoplegia involves the parasympathetic pupillary fibers exclusively. External ophthalmoplegia involves only the extraocular eye muscles while sparing the parasympathetic fibers.

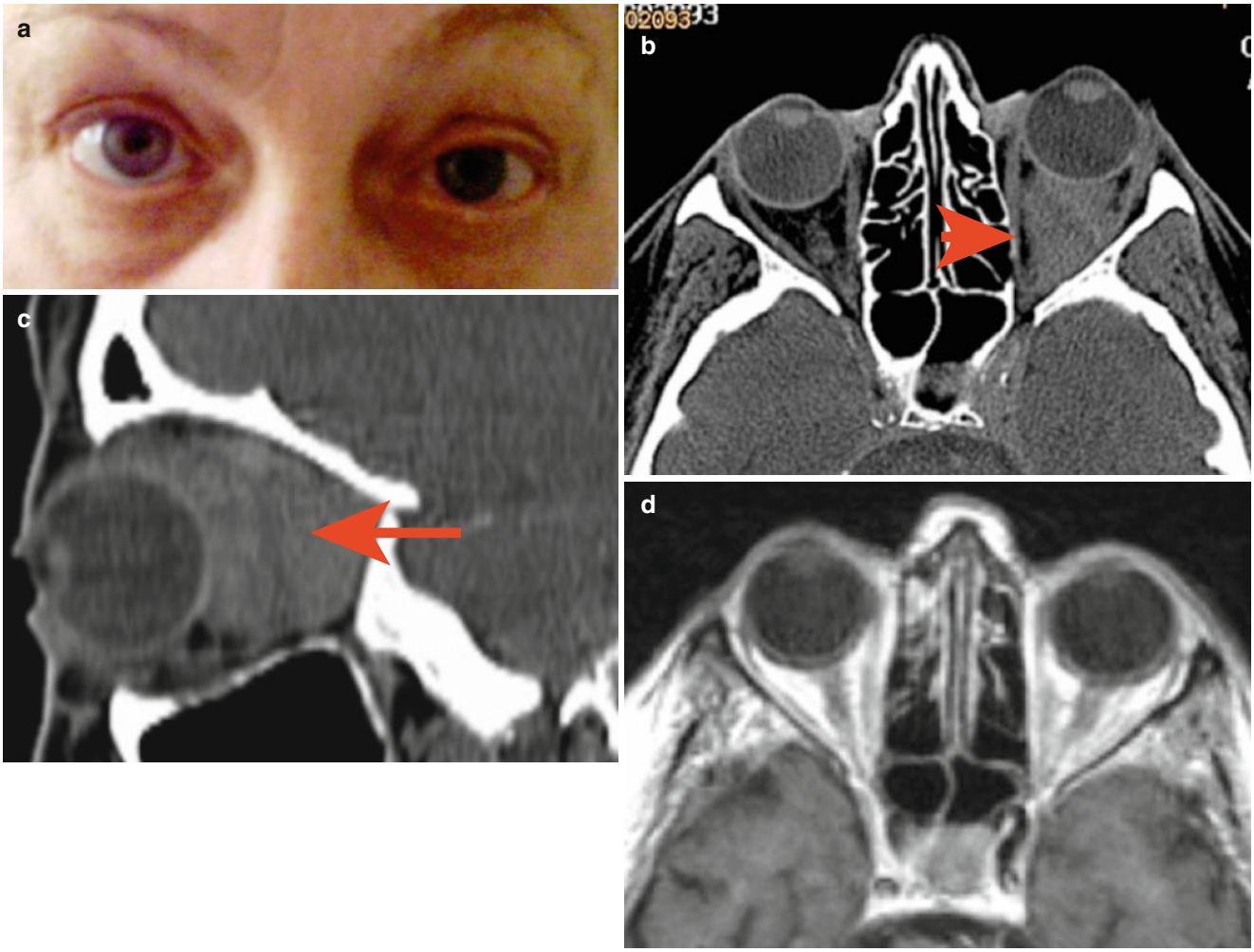

Fig. 5.6 This patient presented with orbital pain and diplopia; the left eye is hypotropic (**a**). (**b**, **c**) Mass in the orbit (*arrows*). The diagnosis of lymphoma was made at a different site (abdomen). (**d**) Regression of the lymphoma after chemotherapy

Pathogenesis Cranial nerve III is the second most frequently affected of the ocular cranial nerves. Incomplete lesions are more common. Sixty to seventy percent of lesions are isolated, the rest being associated with lesions of IV and/or VI.

- *Congenital* (nucleus usually unilateral).
- *Compressive:* Herniation of the temporal lobe, neurosurgical procedures, pathologic conditions in the cavernous sinus.
- *Idiopathic:* 20–25 % in adults, in pediatric cases up to 40 %.
- *Infections:* Botulismus, herpes zoster, mumps, syphilis, TBC, or tetanus.
- *Inflammation:* GBS (rare), meningitis – with other cranial nerve involvement.
- *Metabolic causes:* Diabetes – often painful – with sparing of the pupil. Usually self-limiting with a recovery in 4 months.
- *Toxic:* Alcohol, arsenic, carbon monoxide, and lead; carbon disulfide or dinitrophenol poisoning; or diabetes mellitus.
- *Neoplastic:* Leptomeningeal carcinomatosis, multiple myeloma, neurinoma.
- *Trauma:* Cranial trauma with or without fracture, blowout fractures, traumatic aneurysm. Differential diagnosis may be confused with impairment of orbital movements due to generalized swelling. Regeneration after trauma may be aberrant, and posttraumatic innervation may cause erroneous innervation of adjacent muscles; e.g., upper lid may

retract on attempted downward gaze (pseudo-von Graefe sign). Also, the pupil can restrict on adduction.
- *Vascular:* Aneurysm: often painful and involves the pupil. Diabetes mellitus.
- *Nuclear, fascicular:* In combination with brainstem infarcts.
- *Others:* Migraine – ophthalmoplegic migraine. Pediatric oculomotor lesions: congenital, traumatic, and inflammatory causes are most common. Isolated third nerve palsy in adults may be due to aneurysm, vascular, or undetermined causes.

Diagnosis Laboratory (exclude diabetes). Imaging, to exclude aneurysm, MR techniques (hrMRI) identifies nerve lesions.

Differential Diagnosis Botulism (involvement of pupil), brainstem disorders, CANOMAD syndrome, chronic progressive external ophthalmoplegia, congenital lesions, Miller Fisher syndrome, myasthenia gravis, and myopathy.

Therapy Long duration of defects may require prism therapy or strabismus surgery.

Prognosis Depends on the treatment of the underlying pathology. If the lesion is of vascular etiology, resolution occurs usually within 4–6 months.

5.5 Trochlear Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Biopsy
			+	

Qualities Somatic motor to the superior oblique muscle.

Anatomy The trochlear nucleus is located in the tegmentum of the midbrain at the inferior colliculus level, near the midline and ventral to the aqueduct. Axons leave the nucleus and course dorsally around the aqueduct and decussate within the superior medullary velum (thus, each superior oblique muscle is innervated by the contralateral trochlear nucleus). The axons exit from the midbrain on its dorsal surface and travel around the cerebral peduncle, emerging between the posterior cerebral and superior cerebellar arteries with the oculomotor nerve. The trochlear nerve pierces the dura at the angle between the free and attached borders of the tentorium cerebelli. It then enters the lateral wall of the cavernous sinus, along with V1, CN III, and sometimes V2. It enters the superior orbital fissure and passes above the tendinous ring, crossing medially along the roof of the orbit and then diagonally across the levator palpebrae. The nerve breaks into three or more branches as it enters the superior oblique muscle.

Symptoms Patients experience vertical diplopia that increases when the gaze is directed downward and medially.

Signs The affected eye is sometimes extorted (although this may not be apparent to the observer) and exhibits poor depression during adduction. Hypertropia may occur if the weakness is severe.

Topographical Localization of Lesions Lesion sites include the midbrain, subarachnoid space, cavernous sinus, superior orbital fissure, and orbit.

Pathogenesis An isolated lesion of the trochlear nerve is rare, although it is the most common cause of vertical diplopia. More often trochlear nerve dysfunction is observed in association with lesions of CN III and VI.
- *Compression:* Cavernous sinus, orbital fissure lesions, inflammatory aneurysms (posterior cerebral artery, anterior superior cerebellar artery), tentorium.
- *Infection:* Mastoiditis, meningitis.
- *Inflammatory:* Ophthalmoplegia or diplopia associated with giant cell arteritis.
- *Metabolic:* Diabetes.
- *Neoplastic:* Carcinomatous meningitis, cerebellar hemangioblastoma, ependymoma, meningioma, metastasis, neurilemmoma, pineal tumors, trochlear nerve sheath tumors.
- *Pediatric:* Congenital, traumatic, and idiopathic.
- *Trauma:* Head trauma causing compression at the tentorial edge, lumbar puncture or spinal anesthesia, subarachnoid hemorrhage, surgery. The trochlear nerve is the most commonly injured cranial nerve in head traumas.
- *Vascular:* Arteriosclerosis, diabetes (painless diplopia), hypertension.
- *Another type of involvement:* Superior oblique myokymia.

Diagnosis Diagnosis can be facilitated by the Bielschowsky test:
- Hypertropia of the affected eye.
- Diplopia is exacerbated when the affected eye is turned nasally.
- Diplopia is exacerbated by gazing downward.
- Diplopia is improved by tilting the head away from the affected eye.

Also, when viewing a horizontal line, the patient sees two lines. The lower line is tilted and comes closest to the upper line on the side of the affected eye.

Differential Diagnosis Skew deviation, a disparity in the vertical positioning of the eyes of supranuclear origin, can mimic trochlear palsy. Myasthenia gravis, disorders of the extraocular muscles, thyroid disease, and oculomotor palsy

that affects the superior rectus can also cause similar effects.

Therapy The vertical diplopia may be alleviated by the patching of one eye or the use of prisms. Surgery could be indicated to remove compression or repair trauma.

Prognosis The recovery rate over 6 months was observed to be higher in cases of diabetic etiology than other nonselected cases.

5.6 Trigeminal Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Biopsy
	(+) SEP Reflexes: masseteric, blink reflex EMG of masseteric muscle		+	

Qualities *Branchial motor:* anterior belly of digastric muscle, mastication muscle, mylohyoid muscle, tensor tympani muscle, tensor veli palatini. *General sensory:* bulb of eye, conjunctiva, face, meninges of anterior and middle cranial fossa, mucous membranes of paranasal sinus, nasal and oral cavity, tongue, teeth, part of external aspect of the tympanic membrane, scalp.

Anatomy The trigeminal nuclei consist of a motor nucleus, a large sensory nucleus, a mesencephalic nucleus, the pontine trigeminal nucleus, and the nucleus of the spinal tract. The nerve emerges from the midlateral surface of the pons as a large sensory root and a smaller motor root. It ascends over the temporal bone to reach its sensory ganglion, the trigeminal or semilunar ganglion. The branchial motor branch lies beneath the ganglion and exits via the foramen rotundum. The sensory ganglion is located in the trigeminal (Meckel's) cave in the floor of the middle cranial fossa. The three major divisions of the trigeminal nerve, V1, V2, and V3, exit the skull through the superior orbital fissure, the foramen rotundum, and the foramen ovale, respectively. V1 (and in rare instances, V2) passes through the cavernous sinus (Figs. 5.7, 5.8, 5.9, and 5.10).

The extracranial pathway has three major divisions:

- *V1, the ophthalmic nerve:* The ophthalmic nerve is positioned on the lateral side of the cavernous sinus and enters the orbit through the superior orbital fissure. It has three major branches, the frontal, lacrimal, and nasociliary nerves. Intracranially, V1 sends a sensory branch to the tentorium cerebelli. The frontal nerve and its branches can be damaged during surgery and fractures
- *V2, the maxillary nerve:* The maxillary nerve has three branches: the infraorbital, zygomatic, and pterygopalatinal nerves. It passes below the cavernous sinus and gives off some meningeal branches. V2 is most frequently affected in trauma. Sensory loss of the cheek and lip is a common symptom. V2 can also be injured during facial surgery.
- *V3, the mandibular nerve:* The mandibular nerve's major branches are the auriculotemporal, inferior alveolar, and

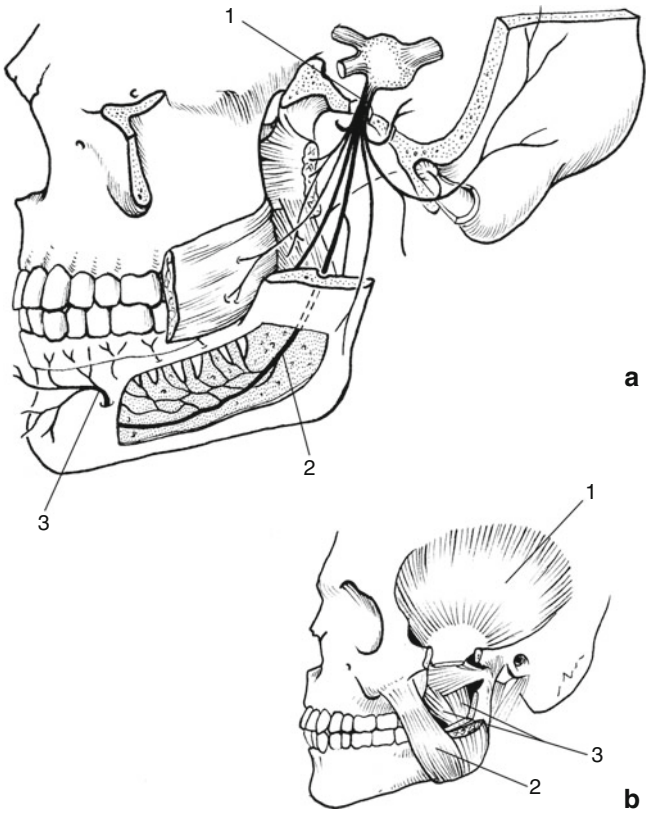

Fig. 5.7 Trigeminal nerve: Motor and sensory innervation. (**a**) *1* Mandibular nerve, *2* inferior alveolar nerve, *3* mental nerve. (**b**) *1* Temporal muscle, *2* Masseteric muscle, *3* pterygoid muscles

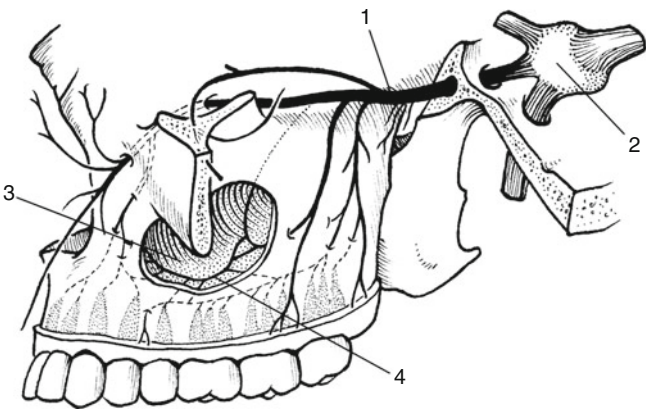

Fig. 5.8 Trigeminal nerve: sensory innervation of the maxilla. *1* Maxillary nerve, *2* trigeminal ganglion, *3* the maxilla (bone removed), *4* branch of superior alveolar nerve

lingual nerves. A separate motor division innervates the temporal and masseteric muscles and the tensor tympani, pterygoid, mylohyoid, and tensor veli palatini muscles. The mandibular nerve also has meningeal branches. Lesions of the V3 may result from dentistry, implantation, mandible resection, hematoma of the lower lip, or bites.

Symptoms The symptoms of trigeminal nerve lesions are predominately sensory and rarely motor. Pain in the distribution of the trigeminal nerve can vary widely from symptomatic pain to neuralgia.

Signs The corneal reflex may be absent. Complete sensory loss, or loss of pain and temperature, may lead to ulcers on the skin, mucous membranes, and the cornea. Sensory lesions in the trigeminal nerve distribution may be also caused by central (brainstem) lesions and follow an "onion skin" pattern. Some neuralgic trigeminal pain syndromes may be associated with redness of the eye or abnormal tearing during the attack. Motor lesions are rarely symptomatic and could cause a mono- or diplegia masticatoria. When the patient's mouth is opened widely, the jaw will deviate to the affected side.

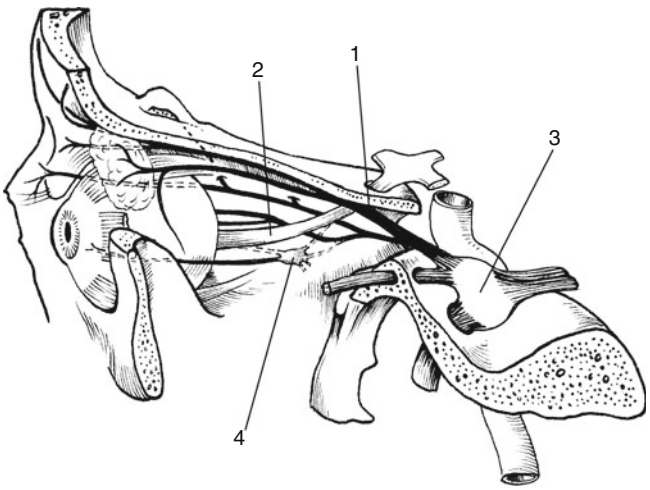

Fig. 5.9 Trigeminal nerve: sensory innervation of the eye and orbit. *1* Ophthalmic nerve, *2* optic nerve, *3* trigeminal ganglion, 4 ciliary ganglion

Pathogenesis

- *Compressive:* Compressive lesion of the trigeminal nerve in the intracranial portion by vascular loops (posterior inferior cerebellar artery, superior cerebellar artery, arteriovenous malformation) is considered to be a major cause of trigeminal neuralgia by some.
- *Iatrogenic:* Pressure and compression of infra- and supraorbital nerves by oxygen masks during operations. Excessive pressure during operating procedures on the mandibular joint may affect the lingual nerve. The infraorbital nerve may be damaged by maxillary surgery. The lingual nerve can be affected by dental surgery (extraction of the 2nd or 3rd molars from the medial side, and wisdom teeth). Bronchoscopy can rarely lead to lingual nerve damage. Abscesses and osteosynthetic procedures of the mandibula can affect the lingual nerve. Clinically, patients suffer from hypesthesia and hypalgesia of the tongue, floor of the mouth, and lingual gingiva. Patients have difficulties with eating, drinking, and their sense of taste.
- *Infectious:* Herpes zoster ophthalmicus may rarely be associated with corneal ulcer, iridocyclitis, retinal and arterial occlusions, optic nerve lesions, and oculomotor nerve lesions.
- *Inflammatory/immune mediated:* Characterized by abrupt onset, usually affecting one or two branches unilaterally; numbness (may disturb motor coordination of speech);

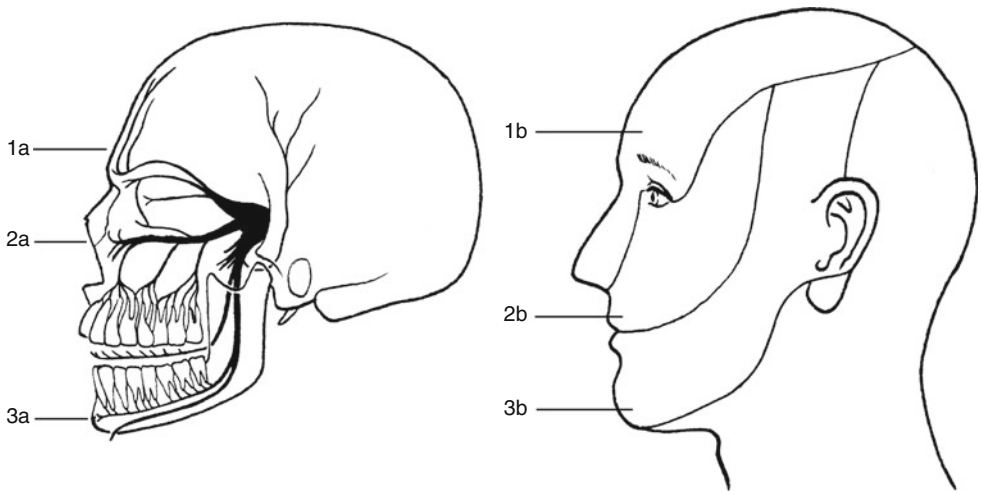

Fig. 5.10 Trigeminal nerve: 3 branches: *1a* Ophthalmic nerve, *2a* maxillary nerve, *3a* mandibular nerve, *1b–3b* sensory distribution

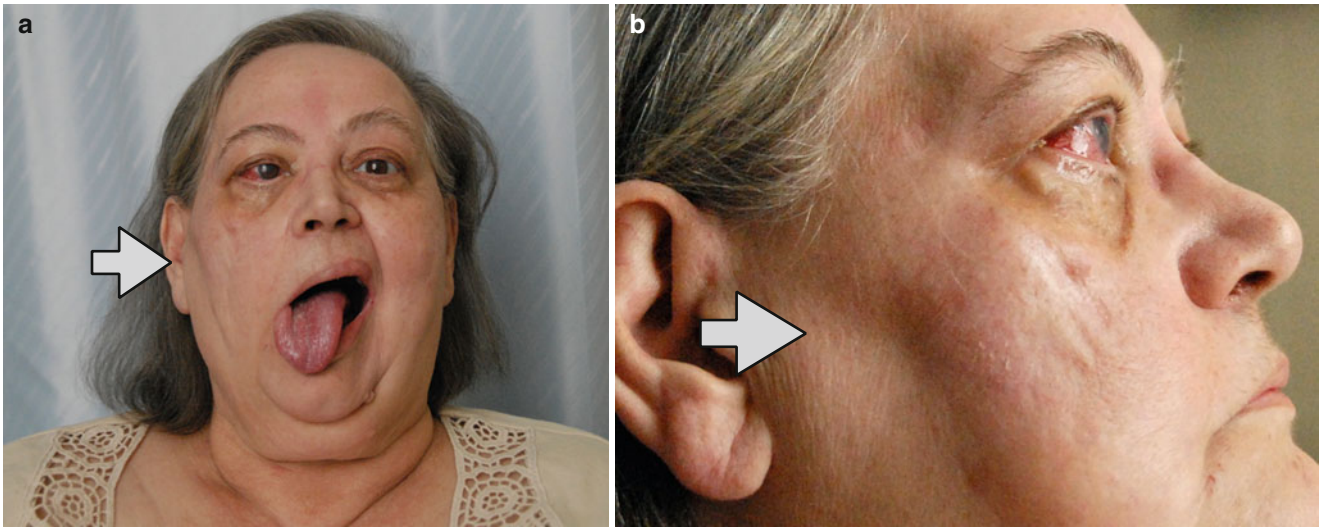

Fig. 5.11 Base of the skull metastasis with cranial nerve lesions and lesion of the trigeminal nerve: temporal and masseteric atrophy (*arrow*); in addition also VI, VII, and XII paresis occurred, due to the base of the skull metastasis

and pain. Etiologies include sensory trigeminal neuropathy, subacute sensory neuropathy, sensory trigeminal neuropathy (connective tissue disease), Sjögren syndrome, scleroderma, SLE, and progressive sclerosis. "Numb chin syndrome" or mental neuropathy has been described as an idiopathic neuropathy or resulting from mandibular metastasis.

- *Neoplastic:* "Amyloidoma" (gasserian ganglion syndrome); cholesteatoma; chordoma; leptomeningeal carcinomatosis that may compress or invade the nerve or trigeminal ganglion, either intracranially or extracranially; metastasis to the base of the skull.
- *Toxic:* Trichloroethylene (TCE).
- *Trauma:* Cranial fractures can cause local lesions of the supratrochlear, supraorbital, and infraorbital nerves (e.g., facial lacerations and orbital fractures). Trigeminal injury caused by fractures of the base of the skull is usually combined with injury to the abducens and facial nerves. Injury to the maxillary and ophthalmic divisions results in facial numbness, and involvement of the mandibular branch causes weakness of the mastication muscles.
- *Vascular:* Medullary infarction may cause trigeminal sensory deficits (e.g., "onion skin") and pain.
- *Other conditions*:
  - Association of the trigeminal nerve with polyneuropathy: Amyloidosis, diphtheria, leprosy, syphilis, thallium neuropathies, Waldenström's macroglobulinemia.
  - Cavernous sinus lesions: The ophthalmic nerve can be injured by all diseases of the cavernous sinus. Neoplastic lesions can be caused by lymphoma, metastases, myeloma, sphenoid tumors, and tumors of the nasopharynx. Typically, other cranial nerves, particularly the optomotor nerves, are also involved. The first and second divisions are also involved.
  - Gradenigo syndrome: Lesion of the apex of the pyramid (from middle ear infection) causes a combination of injury to V and VI and potentially VII.
  - Other conditions are the paratrigeminal (Raeder) syndrome, characterized by unilateral facial pain, sensory loss; Horner's syndrome; and optomotor motility disturbances.
  - An aneurysm of the internal carotid artery may also damage the cavernous sinus accompanied by concomitant headache, diplopia, and ptosis.

Trigeminal Neuralgia Idiopathic trigeminal neuralgia has an incidence of 4 per 100,000. The average age of onset is 52–58 years. The neuralgia affects mostly the second and third divisions. Clinically patients suffer from the typical "tic douloureux." Trigger mechanisms can vary but often caused by specific movements such as chewing, biting, or just speaking. The neurologic examination is normal, and ancillary investigations show no specific changes. Vascular causes, like arterial loops in direct contact with the intracranial nerve roots, have been implicated as causal factors. Therapies include medication (anticonvulsants), decompression or lesion of the ganglion, vascular surgery in the posterior fossa, and rarely medullary trigeminal tractotomy (Fig. 5.13).

Symptomatic trigeminal neuralgia may be caused by a structural lesion of the trigeminal nerve or ganglion and by surgical procedures, tumors of the cerebellopontine angle, meningitis, and MS. If the ophthalmic division is involved,

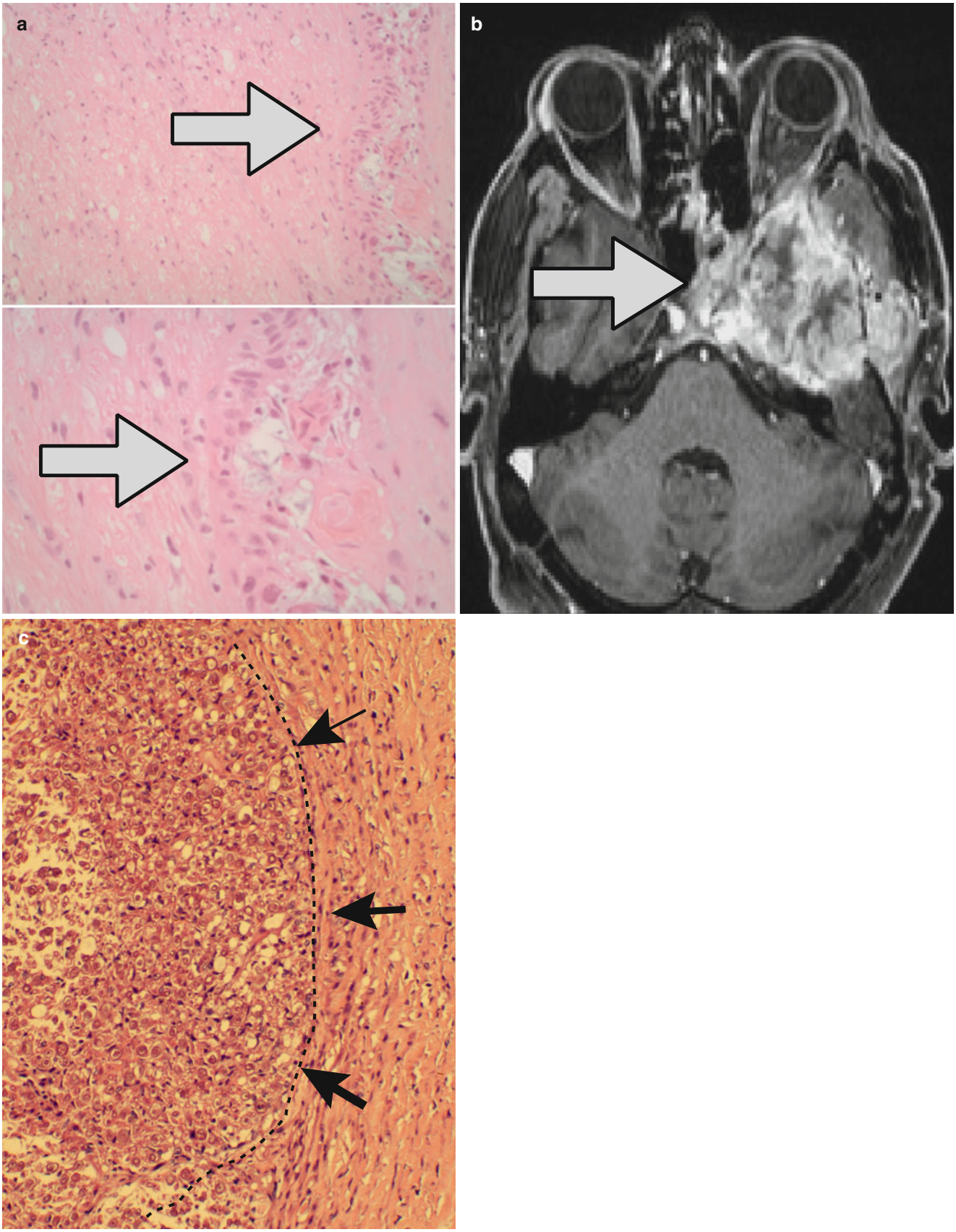

Fig. 5.12 Nerve infiltration. (**a**) Invasion of the facial nerve via the skin and retrograde spread of the tumor (*arrows*). (**b**) Malignant glioma, infiltration of the cavernous sinus. Neuropathic trigeminal pain and ophthalmoplegia due to intrasinusoidal nerve infiltration. (**c**) Nerve infiltration of a cranial nerve by a glioma in the cavernous sinus. *Dotted line:* circumference of the nerve. *Arrows:* invasion

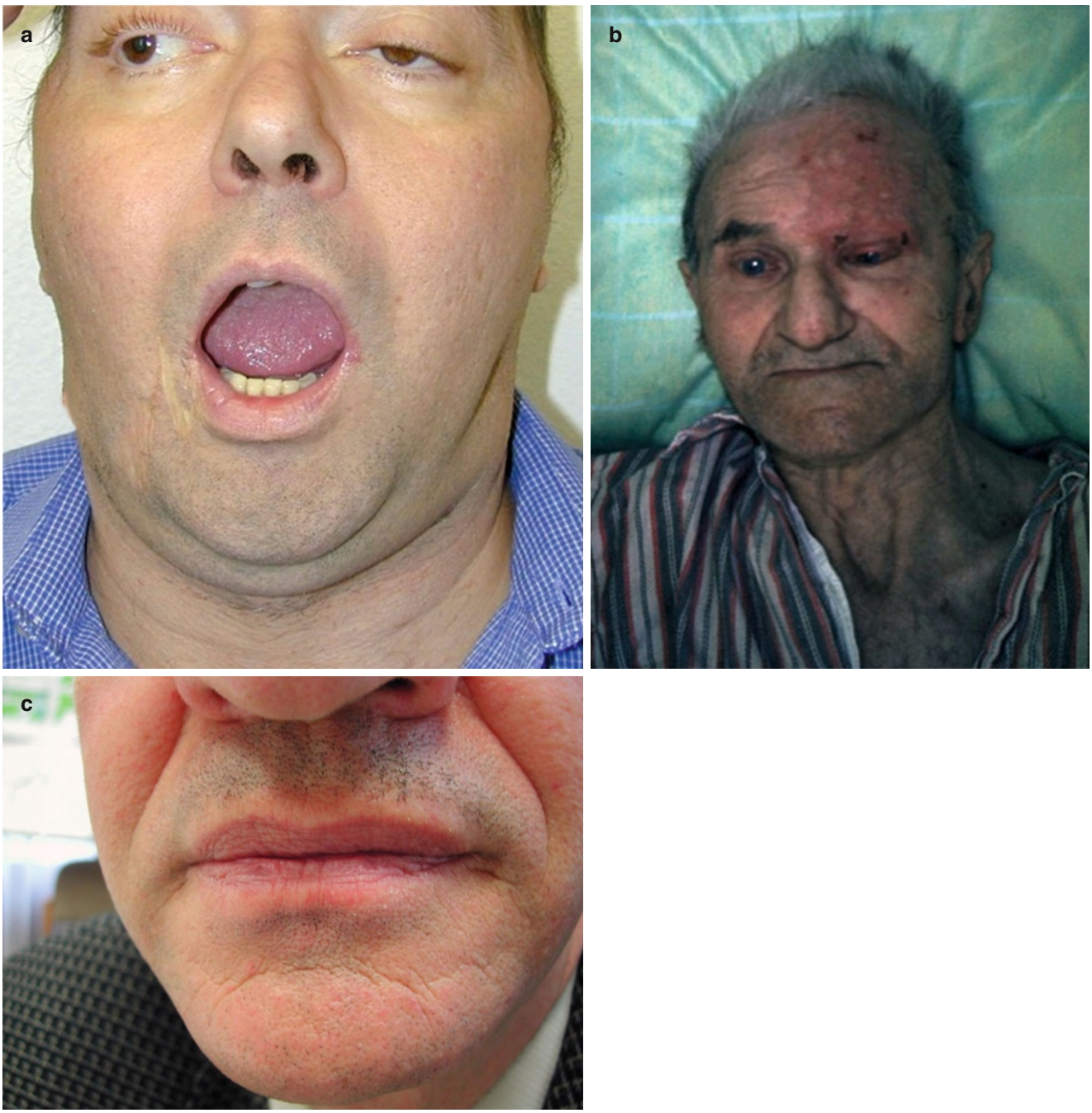

Fig. 5.13 Some features of trigeminal neuropathy. (**a**) Motor lesion of the right trigeminal nerve. The jaw deviates to the ipsilateral side upon opening the mouth. (**b**) Left ophthalmic zoster. (**c**) The patient suffers from trigeminal neuralgia. Shaving above the mouth induces attack. Note the unshaved patch that corresponds to the area, where the attack is elicited

keratitis neuroparalytica, hyperemia, ulcers, and perforation of the cornea may result.

Diagnosis Neuroimaging is guided by the clinical symptoms and may include CT to detect boney changes and MR to investigate intracranial and extracranial tissue spaces. Neurophysiologic techniques rely on sensory conduction velocities and reflex techniques (masseteric, blink reflex). Trigeminal SEP techniques can also be used. Motor impairment of the temporal and masseteric muscles can be confirmed by EMG.

Therapy Treatment is dependent upon the underlying cause. Neuralgias are usually treated with drugs and sometimes surgery. Symptomatic care is required when protective reflexes, like the corneal reflex, are impaired and may lead to ulceration.

5.7 Abducens Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Biopsy	CSF
		+	+ Angiography		(+)

Quality Somatic motor, lateral rectus muscle.

Anatomy The abducens nucleus is located in the pontine tegmentum close to the midline and ventral to the IV ventricle. Axons from cranial nerve VII loop around the abducens nucleus, forming the bulge of the IV ventricle. Axons from the abducens nucleus course ventrally through the pontine tegmentum to emerge from the ventral surface of the brainstem at the junction of the pons and the pyramid of the medulla. The nerve runs anteriorly and laterally in the subarachnoid space of the posterior fossa, by piercing the dura lateral to the dorsum sellae of the sphenoid bone. The nerve continues forward between the dura and the apex of the petrous temporal bone. Here it takes a sharp right angle, bending over the apex of the temporal bone to enter the cavernous sinus. The nerve lies laterally to the carotid artery and medially to III, IV, V1, and V2. The abducens nerve enters the orbit at the medial end of the superior orbital fissure.

Fig. 5.14 Bilateral abducens nerve paresis. Inward gaze of bulbi. This patient suffered a fall from a bicycle with a subsequent head trauma

Table 5.3 Abducens nerve structures: from the nuclei to the orbit

CN VI	Brain parenchyma	Intracranial and CSF	Exit of cranial vault	Extracranial lesion
VI	Nucleus: pons, vicinity to VII fibers	Clivus pressure	Superior orbital tissue	Orbit
	Brainstem syndromes	Cavernous sinus		
		Meningeal carcinomatosis		
		Aneurysms		

Symptoms Patients report binocular horizontal diplopia that worsens when looking in the direction of the paretic lateral rectus muscle. The diplopia is also reported to be worse when looking at distant objects.

Signs An isolated paralysis of the lateral rectus muscle causes the affected eye to be adducted at rest. Abduction of

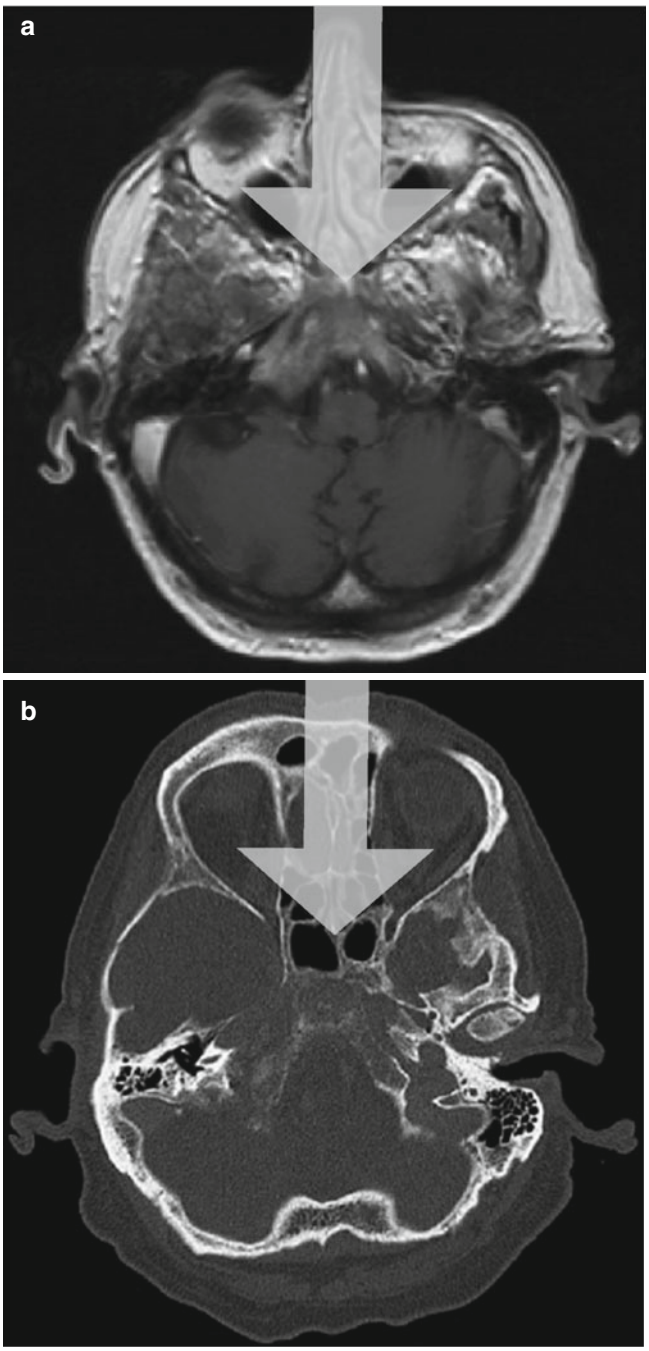

Fig. 5.15 Bilateral VIth nerve palsy caused by clivus metastasis. Bilateral VI nerve palsy in a patient with prostate carcinoma. Clinically a leptomeningeal carcinomatosis was excluded. Destruction of the sella (**a**), also visible in the image of the bone (**b**, *arrows*)

the affected eye is highly reduced or impossible, while gaze to the unaffected side is normal.

Pathogenesis Lateral rectus paralysis is the most frequently encountered paralysis of an extraocular muscle. Eighty percent of cases exhibit isolated paralysis of the lateral rectus, while 20 % of cases are in association with lesions of CN III or IV.

- *Brain:*
  - Nuclear: Fascicular lesion: demyelination, infarction, tumor, Moebius and Duane's syndrome, Wernicke's disease.
  - Intracranial course: Petrous apex: mastoid infection, raised ICP, skull fracture, trigeminal schwannoma. Subarachnoid space: basilar aneurysm, cavernous sinus, clivus tumor (chordoma, meningioma), hemorrhage, meningitis, trauma. Uncertain: microvascular infarction, migraine.
- *Causes:*
  - Compressive: Abducens palsy is a common sign of increased cranial pressure caused by hydrocephalus, pseudotumor cerebri, tumors, and lesions of the cavernous sinus (e.g., thrombosis).
  - Congenital: Duane's syndrome.
  - Infections: CMV encephalitis, cryptococcal and other meningitis, cysticercosis, HIV, Lyme disease, syphilis, tuberculosis, ventriculitis of the IV ventricle.
  - Inflammatory/immune mediated: Sarcoidosis, systemic lupus erythematosus, vasculitis.
  - Metabolic: Rarely diabetes.
  - Neoplastic: Abducens nerve tumor, cerebellopontine angle tumor, clivus tumor, leukemia, metastatic, leptomeningeal carcinomatosis.
  - Toxic: Vincristine therapy.
  - Vascular: Aneurysms of the posterior inferior cerebelli or basilar or internal carotid arteries.
  - Trauma: Fractures of the base of the skull.
  - Most frequent causes: MS, syphilis, undetermined cause, vascular disease, and diabetes.
  - Most frequent causes in pediatric cases: Neoplasm (39 %), trauma (20 %), inflammation (18 %).
  - Bilateral VI palsy: GBS, meningitis, pontine glioma, trauma, Wernicke's encephalopathy.

Diagnosis Diagnosis is achieved by assessing the patient's metabolic situation, imaging for tumors or vascular conditions, and checking the CSF and serology for signs of infection.

Differential Diagnosis Convergence spasm, Duane's retraction syndrome, internuclear ophthalmoplegia, myasthenia gravis, pseudo VI nerve palsy (lesion in the thalamic and subthalamic region), thyroid disease.

Therapy Treatment is dependent upon the underlying cause.

Prognosis The most frequent "idiopathic" type in adults usually remits within 4–12 weeks.

5.8 Facial Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Clinical exam
				Taste Hearing
	+	+	+	+

Qualities

- Branchial motor: Stapedius, stylohyoid, posterior belly of digastric, muscles of facial expression, including buccinator, platysma, and occipitalis muscles.
- Visceral motor: Lacrimal, submandibular, sublingual glands, as well as mucous membrane of the nose and hard and soft palate.
- General sensory: Skin of concha of the auricle, small area of skin behind the ear, possibly supplements the trigeminal nerve – V3 – which supplies the wall of the acoustic meatus and external tympanic membrane.
- Special sensory: Taste of anterior two thirds of the tongue and hard and soft palate.
- Major branches: Chorda tympani: taste. Large petrosal: salivation and lacrimation, motor branches, nerve to the stapedius muscle. Sensory: ear.

Anatomy Branchial motor fibers originate from the facial motor nucleus in the pons, lateral and caudal to the VIth nerve nucleus. The fibers exit the nucleus medially and wrap laterally around the VIth nucleus in an arc called the internal genu. The superior salivatory nucleus is the origin of the preganglionic parasympathetic fibers. The spinal nucleus of the trigeminal nerve is where the small general

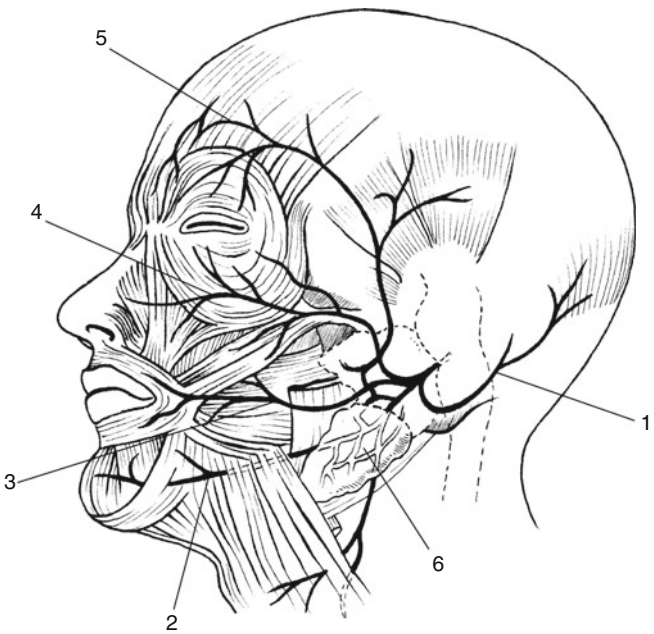

Fig. 5.16 Facial nerve: *1* Posterior auricular nerve, *2* mandibular branch, *3* buccal branch, *4* zygomatic branch, *5* temporal branch, *6* parotid gland

sensory component synapses. Taste fibers synapse in the rostral gustatory portion of the nucleus solitarius. All four groups of fibers leave the brainstem at the base of the pons and enter the internal auditory meatus. The visceral motor, general sensory, and special sensory fibers collectively form the nervus intermedius. Within the petrous portion of the temporal bone, the nerve swells to form the geniculate ganglion (the site of the cell bodies for the taste and general sensory fibers). The nerve splits within the petrous portion of the temporal bone. First, the greater petrosal nerve carries the parasympathetic fibers to the lacrimal gland and nasal mucosa (the pterygopalatine ganglion is found along its course). The chorda tympani nerve exits through the petrotympanic fissure and brings parasympathetic fibers to the sublingual and submandibular salivary glands, as well as the taste sensory fibers to the tongue. The nerve to the stapedius innervates the stapedius muscle. The remaining part of the facial nerve, carrying branchial motor and general sensory fibers, exits via the stylomastoid foramen. The motor fibers branch to innervate the facial muscles, with many branches passing through the parotid gland.

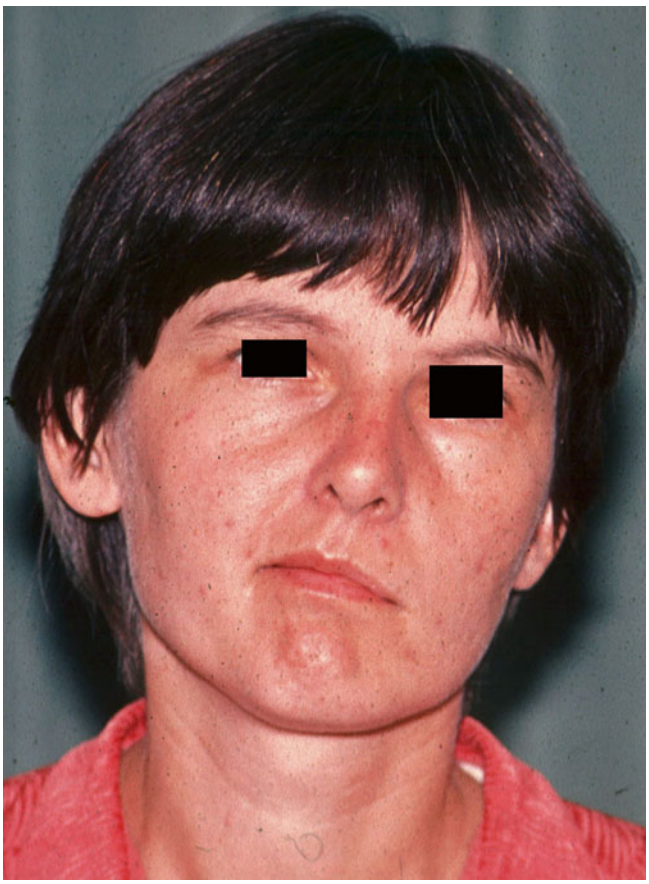

Fig. 5.17 Facial nerve palsy: this patient suffered from a right-sided Bell's palsy, which resulted into a contracture of the facial muscles. Note the deviated mouth

Topographical Lesions

- Supranuclear lesion
- Nuclear and brainstem lesions
- Cerebellopontine angle lesions
- Canalis of the facial nerve
- Exit of cranial vault and peripheral twigs

Symptoms Lesion of the facial nerve results predominantly in loss of motor function characterized by acute onset of facial paresis, sometimes associated with pain and/or numbness around the ear. Loss of visceral functions results in loss of tearing or submandibular salivary flow (10 % of cases), loss of taste (25 %), and hyperacusis (though patients rarely complain of this).

Signs

- *Central lesions:* Supranuclear: because the facial motor nuclei receive cortical input concerning the upper facial muscles bilaterally, but the lower face muscles unilaterally, a supranuclear lesion often results in paresis of a single lower quadrant of the face (contralateral to the lesion). Pyramidal facial weakness: lower face paresis with voluntary motion. Emotional: face paralysis with emotion (dorsolateral pons – anterior cerebellar artery). Pontine lesion: neighboring structures: CN VI, conjugate ocular movements, hemiparesis, extrapyramidal facial: Parkinson's syndrome.
- *Peripheral lesions:* Mimic and voluntary movements of the facial muscles are impaired or absent. Drooping of the corner of the mouth, lagophthalmos. Patients are unable to whistle, frown, or show their teeth. Motor function is assessed by the symmetry and degree of various facial movements. With paralysis of the posterior belly of the digastric muscle, the jaw is deviated to the healthy side. With pterygoid paralysis, the opposite is true.

Table 5.4 Course of the facial nerve

CN	Brain parenchyma	Intracranial and CSF	Exit of cranial vault	Extracranial lesion	Multiple
VII	Central paresis: hemisphere, pons (nuclear and fascicular)	Cerebellopontine angle, meninges	Facial canal See anatomy	Parotid gland Each twig can be damaged Neoplastic retrograde infiltration	Leptomeningeal carcinomatosis, granulomatous

- *Location of peripheral lesion:*Internal auditory meatus: Geniculate ganglion – reduced salivation and lacrimation. Loss of taste on anterior 2/3 of tongue. Hyperacusis.
  - Between internal auditory meatus and stapedius nerve: Facial paralysis without impairment of lacrimation; however, loss of and salivation, taste, and hyperacusis.
  - Between stapedius nerve and chorda tympani: Facial paralysis, intact lacrimation, reduced salivation and taste. No hyperacusis.
  - Distal to the chorda tympani: Facial paralysis, no impairment of salivation, lacrimation, or hyperacusis.
  - After exit from the stylomastoid foramen: Lesions of singular branches.
  - Muscle disease: Myopathic face (facies myopathica) in several conditions.
- *Partial peripheral lesion:* Symptoms and signs depend upon the site of the lesion. Perifacial nerve twigs can be damaged with neurosurgical procedures. Parotid surgery may damage one or several twigs, and a paresis of the cauda perioral muscle is seen in carotid surgery. Retrograde infiltration by skin tumors of the face can occur.

Pathogenesis *Bell's palsy:* Prevalence is 6–7/100,000 to 23/100,000 and increases with age. Paralysis progresses from 3 to 72 h. About half of the patients have pain in the mastoid or ear, and some (30 %) have excess tearing and dysgeusia. Facial weakness is complete in 70 % of cases. Stapedius dysfunction occurs in 30 % of cases. Mild lacrimation and taste problems are rare. Some patients complain of ill-defined sensory symptoms in the trigeminal distribution. Improvement occurs in 4–6 weeks, for about 80 %. Symptoms may persist and contractures or synkineses may develop. Pathogenesis is not clear, but may be viral or inflammatory. Associated diseases: diabetes, hypertonia.

Therapy: Corticosteroids are effective in Bell's palsy (Salinas RA). Acyclovir, steroids, and surgery were compared: Pooled results from I and II studies showed better outcome from steroid-treated vs. non-steroid-treated patients. Steroids are probably effective, and steroids with acyclovir are possibly effective. High-quality evidence showed no significant benefit from anti-herpes simplex antivirals compared with placebo in producing complete recovery from Bell's palsy. Surgery: 104 cases were evaluated. Seventy-one showed complete recovery, 84 % with near-normal function. However a Cochrane review showed no improvement. Physical therapy was not effective in Bell's palsy. Important additional measures to consider are eye care, eyelid surgery, facial rehabilitation, and botulinus in symptomatic synkineses.

Differential diagnosis for Bell's palsy:

- Birth trauma: Cardiofacial syndrome, congenital dysfunction, hemifacial microsomia, Moebius syndrome. Prenatally: face compression against mother's sacrum, abnormal posture.
- Genetic conditions: Amyloid: gelsolin, Tangier disease.
- Granulomatous disease: Heerfordt's syndrome, sarcoid, and other granulomatous disease.
- Iatrogenic: Oxygen mask used in anesthesia (mandibular branch).
- Infection: Botulism, leprosy, Lyme disease (bilateral), otitis media, poliomyelitis, Ramsay Hunt syndrome (Fig. 5.18), syphilis, tetanus.
- Neoplastic: Acoustic neurinoma, base of the skull tumors (dermoids, large meningiomas, cholesteatoma), cerebellopontine tumors, leptomeningeal carcinomatosis, metastasis at the base of the skull.
- Trauma: Extracranial: carotid endarterectomy, gunshot, knife wound, parotid surgery. Intratemporal: motor vehicle accidents – 70–80 % from longitudinal fractures. Temporal bone fractures: In about 50 % of cases of transverse temporal bone fractures, the facial nerve within the internal auditory canal is damaged. Facial nerve injury occurs in about 50 % of cases, and the labyrinth is usually damaged by the fracture. Sixty-five to eighty percent of fractures have been reported to be neither longitudinal nor transverse, but rather oblique. Severe head injury can also avulse the nerve root from the brainstem. Intracranial: surgery.
- Other conditions: Myeloma, Paget's disease, porphyria.
- Regeneration may result in involuntary movements and similar conditions: Blepharospasm, contracture (postparalytic facial dysfunction), facial myokymia, hemifacial spasm, synkinesis, tick.
- Association of CN VII palsy with neuropathies: Guillain-Barré, Lyme disease, polyradiculopathies, sarcoid.
- Periocular weakness, without extraocular movement disturbance: Congenital myopathies, FSH, muscular dystrophies (myotonic, oculopharyngeal muscle dystrophy), polymyositis.
- MND/ALS: ALS, bulbospinal muscular atrophy, motor neuron syndromes.
- Bilateral facial paralysis: AIP, leprosy, Lyme disease, Melkersson-Rosenthal syndrome, MND, Moebius syndrome, myopathies, sarcoid.

Diagnosis Aside from clinical examination, laboratory tests that may be helpful include ANA, angiotensin converting enzyme (for sarcoidosis), BSR, glucose, HIV, RA Lyme serology, microbial tests, serology, virology. CSF should be examined if an intracranial inflammatory lesion is suspected. Other tests include CT, blink reflex, EMG (facial nerve CMAP, needle EMG), magnetic stimulation, and MRI. Based on Cochrane review and conslusion of studies with steroid treatment:

Therapy Cochrane Bell and Steroids Authors' conclusions: The available evidence from randomized controlled trials shows significant benefit from treating Bell's palsy with corticosteroids.

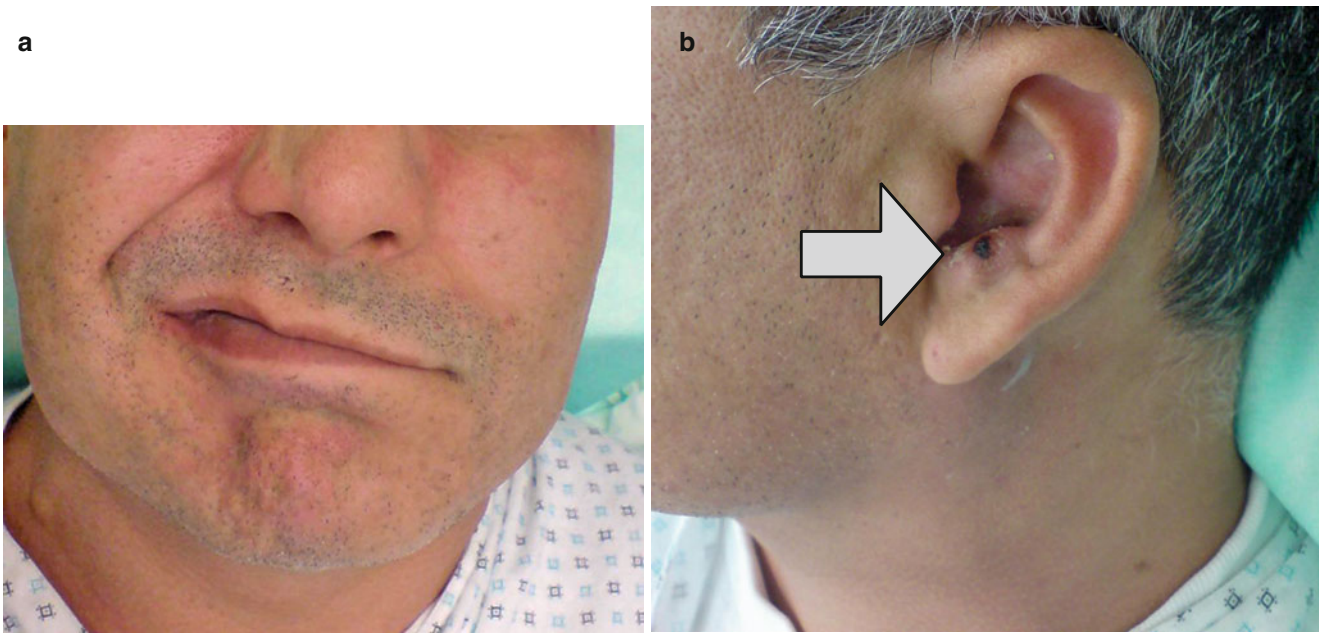

Fig. 5.18 Ramsey Hunt syndrome. This patient suffered from a left-sided peripheral facial nerve palsy (**a**). In the ear herpes sores can be seen (**b**, *arrow*)

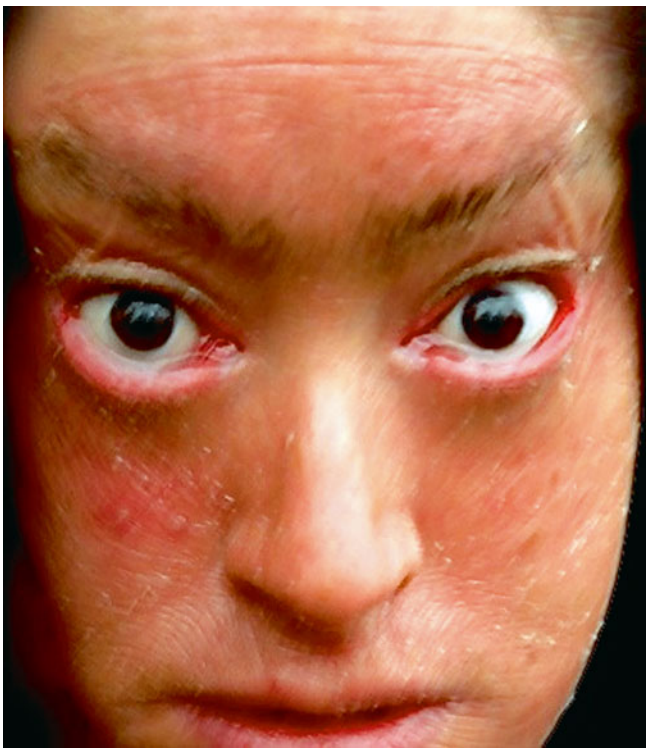

Fig. 5.19 Scleroderma mimicking bilateral "facial" paralysis. Inability to close eyes and masklike face

Prognosis In Bell's palsy, improvement typically occurs 10 days to 2 months after onset. Plateau is reached at 6 weeks to 9 months. Recurrence is possible in up to 10 %.

The prognosis can be based on electrophysiologic tests: CMAP in comparison side-to-side – good. Blink reflex: uncertain. Needle EMG: Limited. Magnetic stimulation in side-to-side relation: good.

Qualities associated with a better prognosis for Bell's palsy include early improvement, incomplete paralysis, normal salivary flow, normal taste, slow progression, and younger age. Residual signs may occur with Bell's palsy. These include contracture (20 %), crocodile tears (6 %), facial weakness (30 %), and synkinesis (50 %).

5.9 Acoustic Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Biopsy	Hearing tests
Familial	+ Auditory evoked potentials (AEP)		+ MR		+

Quality Special sensory: auditory information from the cochlea.

Anatomy Cell bodies of afferent neurons are located in the spiral ganglia in the inner ear and receive input from the cochlea. The central processes of the eighth nerve travel through the internal auditory meatus with the facial nerve. The eighth nerve enters the medulla just at the junction of the pons and lateral to the facial nerve. Fibers of the auditory nerve bifurcate on entering the brainstem, sending a branch to

both the dorsal and ventral divisions of the cochlear nucleus. From here, the path to the auditory cortex is not well understood and includes several pathways: superior olivary complex, nuclei of the lateral lemniscus, the trapezoid body, the dorsal acoustic striae, and the inferior colliculi. A small number of efferent axons are found in the eighth nerve, projecting from the superior olivary complex to the hair cells of the cochlea bilaterally. The function of this projection is not clear.

Symptoms Hearing loss predominates (slow onset or acute), possibly associated with tinnitus.

Signs Damage can cause hearing loss ranging from mild to complete deafness.

Pathogenesis

- Compressive: Tumors at the cerebellopontine angle.
- Congenital: Rubeola embryopathy, thalidomide toxicity.
- Infectious: Herpes, mumps, otitis, sarcoid.
- Inflammatory/immune mediated: Cogan syndrome, paraneoplastic (anti-Hu) (very rare).
- Hereditary: Congenital hearing loss. Hereditary motor-sensory neuropathies: CMT, HMSN, and others including CMT 1A, CMT 1B, Coffin-Lowry syndrome, Connexin 31, Duane's syndrome, HMSN X (Connexin 32), neuroaxonal dystrophy (late infantile), neurofibromatosis-2, and X-linked. Dilated cardiomyopathy with sensorineural hearing loss (CMD1J; CMD1K).
- Metabolic: Diabetes, hypothyroidism.
- Neoplastic: Cholesteatoma, meningeal carcinomatosis, metastasis.
- Trauma: Temporal bone fractures.
- Toxic: Antibiotics, benzoles, carbon monoxide, cytostatic drugs, salicylate.
- Tinnitus: Sensation of noise caused by abnormal excitation of acoustic apparatus (continuous, intermittent, uni- or bilateral). Tinnitus is often associated with sensorineural hearing loss and vertigo. Only 7 % of patients with tinnitus have normal hearing. Causes: arteriosclerosis, conducting apparatus, degeneration of cochlea, drugs (including amyl nitrate, quinine, salicylates, streptomycin), hemifacial spasm, ischemia, labyrinthitis, otosclerosis.

Diagnosis Diagnosis is made by hearing tests and auditory evoked potentials, genetic testing for known deafness genes, and imaging for traumatic or neoplastic causes.

5.10 Vestibular Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Biopsy
	+ Vestibulometry	+	+	

Quality Special sensory: balance information from the semicircular canals.

Anatomy The vestibular apparatus consists of the saccule, the utricle, and the semicircular canals. The semicircular canals perceive angular movement of the head in space. The saccule and utricle perceive the position of the head with respect to gravity. Hair cells within the apparatus synapse with peripheral processes of the primary sensory neurons, whose cell bodies constitute the vestibular ganglion. Central processes from the vestibular ganglion cells form the vestibular part of the VIII nerve. The nerve runs with the cochlear division and the VII nerve through the internal acoustic meatus and terminates in the vestibular nuclear complex at the floor of the IV ventricle. A limited number of axons terminate in the flocculonodular lobe of the cerebellum. The secondary sensory neurons, whose cell bodies form the vestibular nuclei, send axons mainly to the cerebellum and lower motor neurons of the brainstem and spinal cord (modulating muscle activation for keeping balance). In the lateral vestibular nucleus, axons project ipsilaterally and caudally into the spinal cord and vestibulospinal tract (to lower motor neurons which control antigravity muscles). The medial and inferior vestibular nuclei have reciprocal connections with the cerebellum (vestibulocerebellar tract), which allows the cerebellum to coordinate balance during movement. All nuclei in the vestibular complex send fibers into the medial longitudinal fasciculus (MLF), which serves to maintain orientation in space. Connections here between III, IV, and VI allow the eyes to fixate on an object while the head is moving. Vestibular axons in the descending part of the MLF are referred to as the medial vestibulospinal tract and influence lower motor neurons in the cervical spinal cord bilaterally.

Symptoms Patients experience dizziness, falling, vertigo, and nausea/vomiting.

Signs Lesions result in abnormal eye movements and problems with stance, gait, and equilibrium.

Pathogenesis

- *Congenital and hereditary:* Aplasia; Arnold-Chiari; atrophy of VIII; chromosomal aberrations; Cockayne, Hallgren, and Alström syndrome; Refsum's disease; HSMN; Kearns-Sayre; OPCA; retinitis pigmentosa; sensorineural deafness; SMA; thyroid disease.
- *Cupulolithiasis* (benign paroxysmal positional nystagmus). Several subtypes have been described.
- *Immunologic disorders:* Demyelinating neuropathies, Hashimoto, leukodystrophies, MS, periarteritis nodosa, sarcoid.

- *Infection:* Labyrinthitis, specific and unspecific. Suppuration reaches inner ear by either blood or direct invasion (meningoencephalitis).
  - Bacterial: Streptococcal pneumoniae, hemophilus, Lyme disease, petrositis, syphilis.
  - Viral: AIDS may cause sensorineural hearing loss, herpes zoster oticus, Ramsey Hunt syndrome, vestibular neuronitis.
  - Mycotic: Coccidiomycosis, cryptococcosis, rickettsial infection.
- *Metabolic:* Diabetes, uremia.
- *Neoplastic:* Acoustic nerve neuroma, metastases, neurofibromatosis, schwannoma.
- *Toxic:* Alcohol, aminoglycosides, chemotherapy (cisplatin, cyclophosphamide, hydroxyurea, vinblastine), heavy metals (lead, mercury); quinine salicylate.
- *Trauma:* Blunt, penetrating, or barotrauma. Transverse fractures are often associated with additional CN VII lesion. The less common transverse fractures damage both facial and vestibulocochlear nerves. These fractures involve the otic capsule, passing through the vestibule of the inner ear, tearing the membranous labyrinth, and lacerating both vestibular and cochlear nerves. Vertigo is the most common neurologic sequel to head injury, and it is a positional vertigo.
- *Vascular:* AICA aneurysm, large vascular loops, posterior communicans artery aneurysm, unruptured aneurysms, vascular lesions of the spiral ganglion, vertebrobasilar circulation (history of diabetes, hypertension).
- *Others:* Hyperviscosity syndromes (hypergammaglobulinemia, polycythemia vera, Waldenström's macroglobulinemia).

Diagnosis Diagnosis is based on vestibular testing, laboratory testing (including genetics for hereditary causes), and imaging.

5.11 Glossopharyngeal Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Biopsy
	+		+ Videocinematography	

Quality Branchial motor: stylopharyngeus muscle. Visceral motor: otic ganglion, fibers to stimulate the parotid gland. Visceral sensory sensation (subconscious): carotid body and sinus. General sensory: posterior one third of the tongue, skin of the external ear, and the internal surface of the tympanic membrane. Special sensory: taste, from the posterior third of the tongue.

Anatomy The nuclei consist of several parts: the nucleus ambiguus, inferior salivatory nucleus, and nucleus solitarius. The nerve emerges from the medulla oblongata at the dorsal border of the inferior olive. A dural isthmus separates the nerve from the vagus nerve. It leaves the cranial vault through the jugular foramen (jointly with the vagus and accessory nerves) and passes in the upper neck between the carotid artery and jugular vein. Then it passes superficially to the internal carotid artery behind the styloid process. The nerve follows the posterior inferior part of the stylopharyngeus muscle, between the constrictors of the pharynx, and finally reaches the deep hypoglossus muscle. Its extracranial course includes several ganglia (superior and petrous ganglia). It contains sensory fibers (posterior third of the tongue, pharynx, tonsils, middle ear, and carotid body). The parasympathetic fibers supply the parotid gland (via the ganglion oticum) and motor fibers to the stylopharyngeal muscle. There is a communicating nerve to the vagus nerve. The CN IX is involved in swallowing by innervation of the stylopharyngeal muscle, which elevates and pulls the larynx forward during the pharyngeal stage of swallowing.

Functions: It receives sensory fibers from the posterior one third of the tongue, the tonsils, the pharynx, the middle ear, and the carotid body. It supplies parasympathetic fibers to the parotid gland via the otic ganglion. It supplies motor fibers to the stylopharyngeus muscle, and it contributes to the pharyngeal plexus.

Symptoms Lesions can cause minor swallowing difficulties, disturbance of taste, glossopharyngeal neuralgia (rare – pain behind the angle of the jaw, deep within the ear, and side of throat). Abnormal lacrimation ("crocodile tears," "Bogorad" syndrome) may occur but may also be a complication of Bell's palsy with lesions proximal to the geniculate ganglion.

Signs Taste on the soft palate, pharynx, fauces, and posterior third of the tongue is disturbed (taste evaluation on posterior third of the tongue). The gag reflex is reduced or absent, which may result in aspiration problems. Salivary production of the parotid gland can be reduced. Acute sectioning bilaterally may cause hypertension.

Pathogenesis Lesions are rarely isolated and more often associated with vagus nerve lesions.

- Topographical: Brainstem: vascular brainstem lesions (e.g., Bonnier's syndrome) – medulla oblongata, pons, pontine tumors, Wallenberg's syndrome.
- Intracranial: Inflammatory: GBS, meningitis, "polyneuritis cranialis." Tumors: neurinoma – cerebellopontine angle, meningeal carcinomatosis, venous thrombosis.
- Exit from the cranial vault: Jugular foramen syndrome (with CN X, XI; Vernet's syndrome) caused by chordoma, fracture of base of the skull, metastasis, neurinoma.

- Neck (iatrogenic): Carotid operations, neck dissection (ENT and neurosurgical procedures), resection of aneurysms. Tonsillectomy is rarely a cause (0.1 %), by lesions of the lateral pharynx wall.

Other Pathogenetic Mechanisms

- *Infectious:* Diphtheria, herpes zoster, poliomyelitis.
- *Inflammatory/immune mediated:* Cryoglobulinemia, GBS, Miller Fisher syndrome, panarteritis nodosa, sarcoid, serum sickness, SLE.
- *Metabolic:* Amyloid deposition, porphyria.
- Motor neuron disease
- Myasthenia gravis
- *Neoplastic:* Leptomeningeal carcinomatosis, leukemia, myeloma, vagal rootlet neuroma.
- *Surgery:* Tonsillectomy (rare).
- *Tardive dyskinesia:* Can involve the swallowing function.
- *Toxic:* Tetanus toxin, nitrofurantoin, salvarsan intoxication.
- *Vascular:* Brainstem lesions; see topographical lesions.
- *Trauma:* Basal fracture of the skull.
- *Association with neuropathies:* Diphtheria, GBS, paraneoplastic.

Other Syndromes

- Baroreceptor may be affected in tabes and diabetes.
- Glossopharyngeal neuralgia is a rare occurrence, much less frequent than trigeminal neuralgia. Several trigger points have been described. Pain radiates into the ear, pharynx, neck, and the base of the tongue. The attacks are brief but can be associated with excruciating pain. Glossopharyngeal neuralgia can be associated with fainting (reflex association with vagal nerve, which can cause syncope, and bradycardia).

Diagnosis Diagnosis is made by examination and subsequent imaging and laboratory tests that may be helpful in identifying suspected causes.

Differential Diagnosis Bulbar muscular disorder, motor neuron disorders, myasthenia gravis, pain, trigeminal neuralgia.

Therapy For neuralgia: amitriptyline, carbamazepine, gabapentin.

5.12 Vagus Nerve

Genetic testing	NCV/EMG Autonomic testing	Laboratory	Imaging	Biopsy
	+		+	

Qualities

- *Branchial motor:* Pharynx (except stylopharyngeus and tensor veli palatini), larynx, tongue.
- *General sensory:* Auditory meatus, skin on the back of the ear, external tympanic membrane, pharynx.

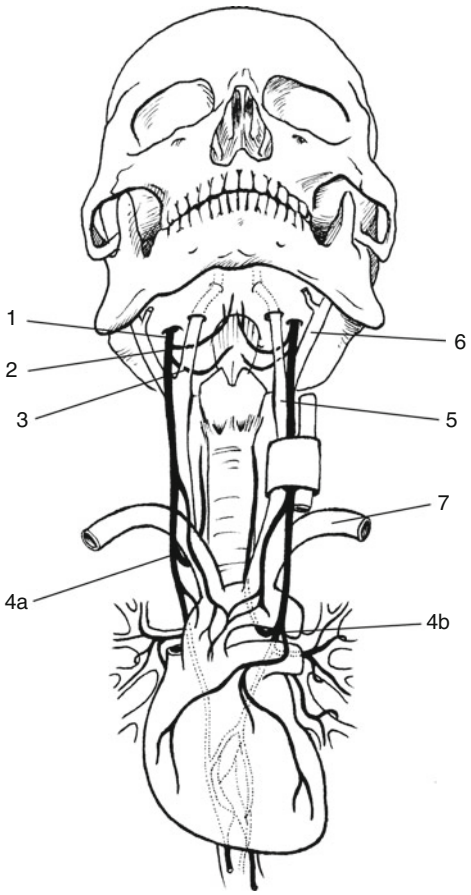

Fig. 5.20 *1* Vagus nerve, *2* pharyngeal branch, *3* internal laryngeal branch, *4a* right recurrent laryngeal nerve (across the subclavian artery), *4b* left recurrent laryngeal nerve (across the arch of the aorta), *5* internal carotid artery, *6* external carotid artery, *7* left subclavian artery

- *Visceral sensory:* Larynx, trachea, esophagus, thoracic and abdominal viscera, stretch receptors in the wall of the aortic arch, chemoreceptors in the aortic body.
- *Visceral motor:* Smooth muscle and glands of pharynx, larynx, thoracic, and abdominal viscera.

Anatomy The vagus nerve is the longest cranial nerve, with the widest anatomical distribution. The vagus nuclei consist of a branchial motor component (nucleus ambiguus), a visceral motor component (dorsal motor nucleus of the vagus), a visceral sensory component (nucleus solitarius), and a general sensory component (spinal trigeminal tract). Most of the fibers are sensory and parasympathetic.

Intracranial pathway: The vagus nerve emerges from the medulla with several rootlets and exits through the jugular foramen (within the same dural sleeve as accessory nerve). Two external ganglia, the superior and inferior vagal ganglia, are found along the nerve's course within the jugular fossa of the petrous temporal bone.

Extracranial pathway: In the neck region, the nerve branches into the pharyngeal rami and the superior laryngeal nerve (internal and external rami). The pharyngeal rami innervate all the muscles of the pharynx except the stylopharyngeus and the tensor veli palatini muscles. The superior laryngeal nerve divides into the internal and external laryngeal nerves. The external laryngeal branch supplies the inferior constrictor muscles. The vocal cords are innervated by the superior laryngeal nerve and the external and internal rami of the inferior laryngeal nerve.

Motor divisions: The three motor divisions have a bilateral upper motor neuron innervation and consist of three branches: (1) pharyngeal branch supplying muscles of the soft palate and pharynx, (2) the superior laryngeal nerve (inferior pharyngeal constrictor and cricothyroid muscles of the pharynx), and (3) recurrent laryngeal branches innervating all other intrinsic muscles of the pharynx. The recurrent laryngeal nerve passes under the subclavian artery on the right side and the aortic arch on the left side and then returns to the larynx to innervate all of its muscles, except the cricothyroid muscle (superior laryngeal nerve). Both recurrent nerves are located between the trachea and esophagus and emit visceral branches. Visceral fibers of the vagus nerve innervate the cardiac, pulmonary, esophageal, and gastrointestinal structures.

Symptoms Patients with vagus damage experience swallowing difficulty and hoarseness of voice.

Signs Vagus damage can cause paralysis of the palate, pharynx, and larynx according to the site of the lesion and cause hoarse voice and dysphagia. Bilateral lesions can lead to nasal voice and regurgitation through the nose. The gag reflex can be absent and the uvula deviates away from the side of the lesion as a failure of palate elevation occurs.

Pathogenesis

- *Iatrogenic:* Mediastinal tumors, mediastinoscopy, operations of the trachea and esophagus, thoracotomy, thyroid surgery (recurrent nerve).
- *Infectious:* Botulism, diphtheria, herpes, meningitis, poliomyelitis, tetanus.
- *Inflammatory/immune mediated:* Dermato- and polymyositis.
- *Neoplastic:* Jugular foramen tumor, meningeal carcinomatosis, metastasis (with CN IX involvement).
- *Metabolic:* Hyperpotassemia, hypophosphatemia.
- *Trauma:* Fractures that affect the jugular foramen (uncommon). Hyperextension neck injuries are also sometimes associated with injury to these nerves at the craniocervical junction.
- *Toxic:* Alcoholic polyneuropathy, thallium.
- *Vascular:* Medullary infarction.
- *Others:* Familial hypertrophic polyneuropathy; myopathies (Chronic progressive external ophthalmoplegia, oculopharyngeal muscle dystrophy); polyneuropathies (amyloid (some types), diphtheria, alcohol). Tardive dyskinesia can involve laryngeal muscles.
- *Special segments:*
  - *Focal superior and recurrent laryngeal neuropathies: Peripheral lesions affecting the recurrent laryngeal nerve, with or without involvement of the superior laryngeal nerve, are most common from trauma, surgery, thyroidectomies, carotid endarterectomies, or idiopathic causes. Clinically, laryngeal* neuropathy leads to the inability to cough forcefully and hoarseness of voice. If the superior laryngeal nerve is affected in addition and the cricothyroid is no longer functional, the vocal cords will remain in an intermediate position. This causes a breathy and weak voice and constant clearing of the throat as with a lodged foreign body or aspiration. Causes of focal damage of the recurrent laryngeal nerve include diseases of the lungs, tumors in the thoracic cavity (lung cancer), aneurysm of the aortic arch, enlarged lymph nodes, and thyroid surgery. About 25 % of cases are idiopathic.
  - *Recurrent laryngeal nerve lesions:* Hoarseness is observed in local anesthetic procedures, presumably due to excessive local anesthetic spread.
- *Other entities:*
  - Focal laryngeal dystonia, gag reflex which can be diminished in patients with schizophrenia, obesity treatment, sexual dysfunction in women after spinal cord injury, spastic dystonia, vagal nerve stimulation which has been used in the treatment of epilepsy and major depression.
  - Neuralgia of the laryngeal nerve (rare).
  - Idiopathic vocal cord paralysis: Other causes must be excluded.

Diagnosis Diagnosis can be facilitated with ENT examination and vocal cord inspection (with endoscopy), imaging, and video swallowing studies. EMG of the cricothyroid muscle (superior laryngeal nerve) or thyroarytenoid muscle (recurrent nerve) can be done but is uncommon.

Differential Diagnosis Bulbar disorders, motor neuron diseases, neuromuscular transmission disorders.

Therapy Treatment depends upon the etiology.

Prognosis Prognosis depends upon the etiology.

5.13 Accessory Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Biopsy
	+		+	

Quality *Branchial motor:* innervation of the sternocleidomastoid and trapezius muscles.

Anatomy/Distribution The cell bodies of the motor neurons are located in the spinal cord. Their axons emerge as rootlets

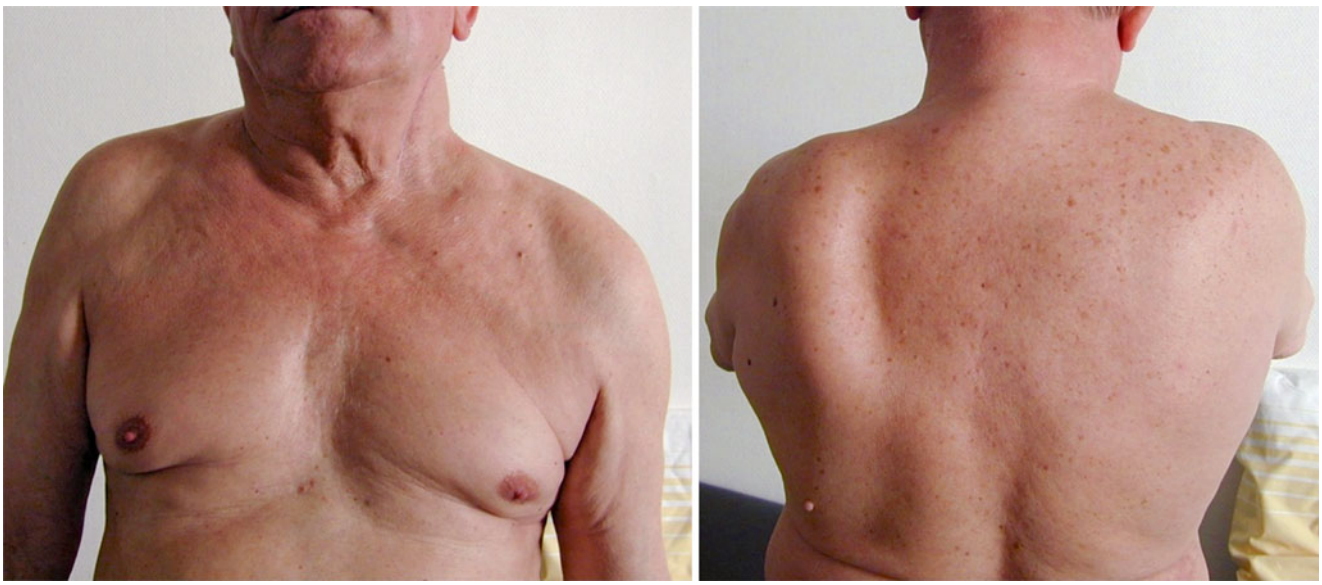

Fig. 5.21 Left accessory nerve palsy, following carotid resection: note the unilaterally missing profile of the trapezoid muscle (diagnostic clue) and the winging of the scapula with the abduction of the medial scapular border

anterior to the dorsal roots of the cord (C1–6) and form a trunk that extends rostrally and laterally to the foramen magnum and posterior to the vertebral artery to enter the posterior cranial fossa. The trunk joins with fibers of the vagus nerve, then separates from them within the jugular foramen. Anatomically a distinction between the brainstem and spinal fibers is made, and the term of an additional "transitional nerve" has been proposed, which divides the nerve into a cranial and a spinal portion. The "transitional nerve" is involved in laryngopharyngeal innervation. Outside the jugular foramen, the nerve passes posteriorly and medially to the styloid process, then descends obliquely to enter the upper portion of the sternocleidomastoid muscle, which has a prominent role in optomotor tracking. The nerve crosses the posterior triangle of the neck, closely associated to lymph nodes. Above the clavicle it passes the deep anterior border of the trapezius to supply this muscle.

Symptoms Damage to the accessory nerve can cause shoulder pain of variable severity, paresthesias over the shoulder and scapula, weakness of the shoulder, and shoulder drop.

Signs Lesion causes weakness of head rotation to the opposite side and trapezius weakness that results in the inability to lift the shoulder and raise the arm above horizontal. Dropping of shoulder and moderate winging of the scapula is also observed.

Pathogenesis

- *Topo*graphical lesions:
  - Intracranial part: Rare, intracranial tumors.
  - At the jugular foramen: Lesions here occur in association with the glossopharyngeal and vagus nerves – Vernet's syndrome, local tumors, schwannomas, metastasis, sarcoidosis, Siebmann syndrome, Collet-Sicard syndrome.
  - Injury to the neck: Biting, blunt trauma, carotid endarterectomy, coronary bypass surgery, radiation, shoulder blows, shoulder dislocation, stretch/hyperextension injury, variant of neuralgic amyotrophy.
- *Other pathogenetic mechanisms:*
  - Iatrogenic: Surgery in the neck (posterior cervical triangle), deep cervical lymph node extirpation, "neck dissection procedures," shunt implantation, fibrosis following radiotherapy, shoulder support in the Trendelenburg position.
  - Neoplastic: ENT tumors, base of skull metastases (all tumors, in particular multiple myeloma, prostate, ENT). Collet-Sicard syndrome, spinal tumors, retrograde infiltration from adjacent tumors.
  - Others: Motor neuron disorders, neck surgery; spinal – tumors and syringomyelia, trauma.
  - Dystonia: A cervical lesion of the CN XI can result in cervical dystonia or torticollis (in addition to the more common cause of centrally caused dystonia).

Diagnosis

- *Sternocleidomastoid muscle:* Impaired head rotation.
- *Trapezius muscle:* Upper, middle, and lower parts of the trapezius muscle must be examined separately. Upper and middle part lesions may produce winging of the scapula.
  - Test: Abduct the arm through 180° from its resting position. The trapezius muscle is responsible for the upper 90° of movement above shoulder level.
  - NCV: Stimulation of the nerve at the posterior aspect of the sternocleidomastoid muscle.
  - EMG: Sternocleidomastoid, trapezoid upper, middle, and lower part.

Differential Diagnosis Acute idiopathic onset may resemble acute brachial plexopathy.

Therapy Nerve grafting (bridge); no operation is effective in long-standing scars; orthotic devices are not effective.

Prognosis Uncertain: recovery is slow and often incomplete. Further exploration is warranted if no improvement occurs after closed trauma.

5.14 Hypoglossal Nerve

Genetic testing	NCV/EMG	Laboratory	Imaging	Biopsy
	+		+	

Quality Somatic motor intrinsic and extrinsic muscles of the tongue except the palatoglossus muscle.

Anatomy *Intracranial:* The nerve originates in the hypoglossal nucleus, beneath the floor of the IVth ventricle, and extends caudally to the lower limit of the medulla. In the brainstem the fibers traverse the reticular formation and medial part of olive, then exits the medulla in the lateral sulcus. The nerve emerges in two bundles which pass separately through the dura as it enters the anterior condyloid foramen (hypoglossal canal).

Extracranial: Some dural fibers leave the nerve at the exit of the foramen. Outside the skull the nerve passes downward, to the level of the angle of the jaw, where it innervates the thyrohyoid muscle and the extrinsic and intrinsic muscles of the ipsilateral side of the tongue. The descending portion has anastomoses with the glossopharyngeal, vagus, and accessory nerves. Fibers from the first and second cervical nerve join the hypoglossal nerve close to its exit from the skull, but leave the nerve shortly after this as a descending branch that turns around the occipital artery.

Symptoms Unilateral loss of hypoglossal function causes mild difficulties with speaking, but swallowing is not

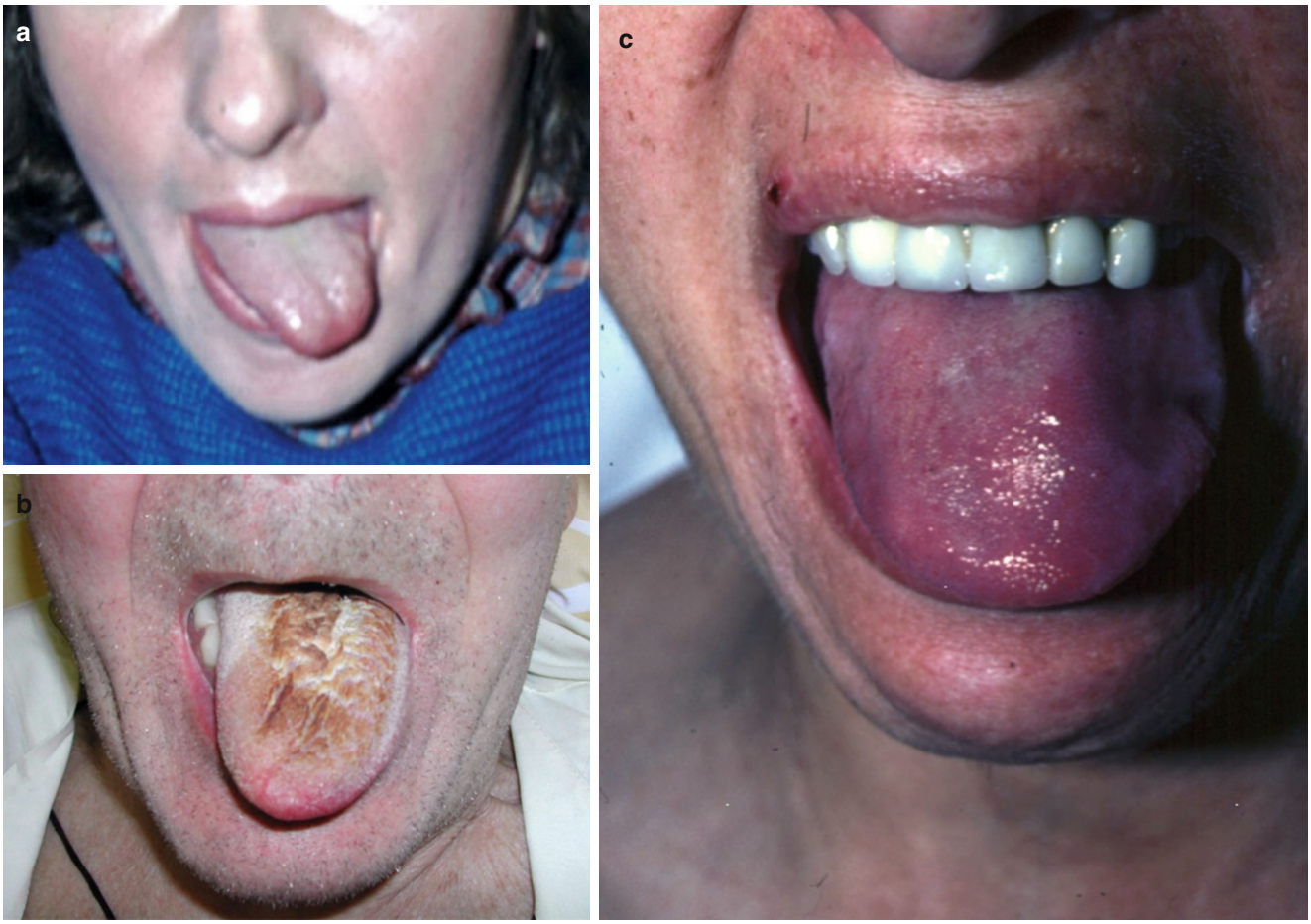

Fig. 5.22 (**a**) Left hypoglossal peripheral paresis. Note deviation of the tongue to the left. (**b**) Right-sided hypoglossal paresis, in a patient with meningeal carcinomatosis. Midline of the tongue shifted to the right. (**c**) Amyloid tongue in a patient with multiple myeloma. Patient's subjective impression was that the tongue was "too big"

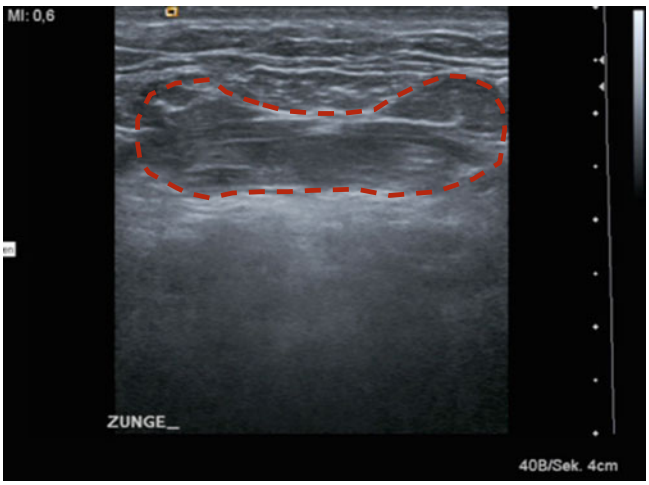

Fig. 5.23 Tongue in ultrasound. Mickey Mouse (*dotted red line*) appearance of the tongue and oral cavity in ultrasound. This technique allows a painless investigation of the tongue tissue and can detect movements as fasciculations

impaired. Bilateral impairment leads to speech difficulties and severe difficulty in swallowing. Tipping of the head is necessary for swallowing. Headache may occur in hypoglossal lesions due to its connection with the ansa cervicalis.

Signs Unilateral upper motor neuron lesion results in mild contralateral tongue weakness. Bilateral spasticity (e.g., ALS) in impairment of tongue movements. Unilateral peripheral lesion leads to wasting of the ipsilateral side of the tongue and excessive furring (wrinkling). Deviation occurs toward the side of the lesion when the tongue is protruded. Bilateral lesions cause difficulty in tongue protrusion, speech, and the ability to move food in the oral cavity. Patients are hardly able to eat and have difficulty pronouncing "d" and "t."

Pathogenesis This cranial nerve is rarely affected, except in disorders of the base of the skull and neck.

- *Iatrogenic:* Surgery of the oral cavity and neck, carotid endarterectomy, radiotherapy, in association with other cranial nerves, compression of the lateral part of the tongue (with lingual nerve) (laryngoscopy, etc.), following intubation, tooth extraction.
- *Idiopathic:* Isolated unexplained pathogenesis, usually reversible.
- *Infection:* Basal meningitis, infections: mononucleosis, granulomatous meningitis, postvaccination mononeuropathy, toxoplasmosis.
- *Inflammatory/immune mediated:* Rheumatoid arthritis: subluxation of odontoid process in rheumatoid arthritis, Paget's disease.
- *Neoplastic:* Schwannoma, primary nerve tumors (neurofibroma, neurinoma), metastasis to the base of the skull, meningeal carcinomatosis, clivus metastasis (can be bilateral as nerves are close to the midline), affection of hypoglossal canal by glomus jugulare tumors, meningioma, chordoma (sometimes in association with other cranial nerves). Tongue carcinoma may infiltrate the nerve and lymph nodes with Hodgkin's disease and Burkitt's lymphoma, amyloid nerve deposition in myeloma, radiation of neck tumors.
- *Trauma:* Head injury, penetrating head wound (often with other CN injuries), or dental extraction. Hyperextension of the neck. Hypoglossal tubercle or occipital condyle.
- *Vascular:* Vertebral basilar aneurysm, dissection of internal carotid artery.
- *Other causes:*
  - Malformation: Chiari malformation.
  - Bilateral CN XII lesions: Motor neuron disorders appear as bilateral hypoglossal nerve lesions. Iatrogenic: Intubation, multiple sclerosis, neoplasm – posterior tongue.

Other Syndromes

- Glossodynia: Burning pain in tongue and also oral mucosa, usually occurring in middle-aged or elderly persons.
- Burning tongue: Vitamin B12 deficiency and several internal medical diseases.

Differential Diagnosis Motor neuron disease (ALS), pseudobulbar involvement, local tumors affecting the tongue.

Therapy Treatment is based on the underlying cause.

5.15 Oral Cavity

The oral cavity is one of the most distinct entrance gates of the body. Its innervation is a combination of sensory, somatosensory, autonomic, and motor functions which is regulated both by voluntary and involuntarily controls. A brief bedside test with the patient pronouncing the consonants will help to get an impression on the function of the oral cavity regarding closure, transport of food, and initiation of swallowing.

- "**B**" entrance to the oral cavity: mouth and lips
- "**T**" the oral cavity:
  - Within: tongue, gums, mucous membranes, glands
  - Sensory motor innervation and feedback: chewing
- "**G**" posterior part: gag and swallowing

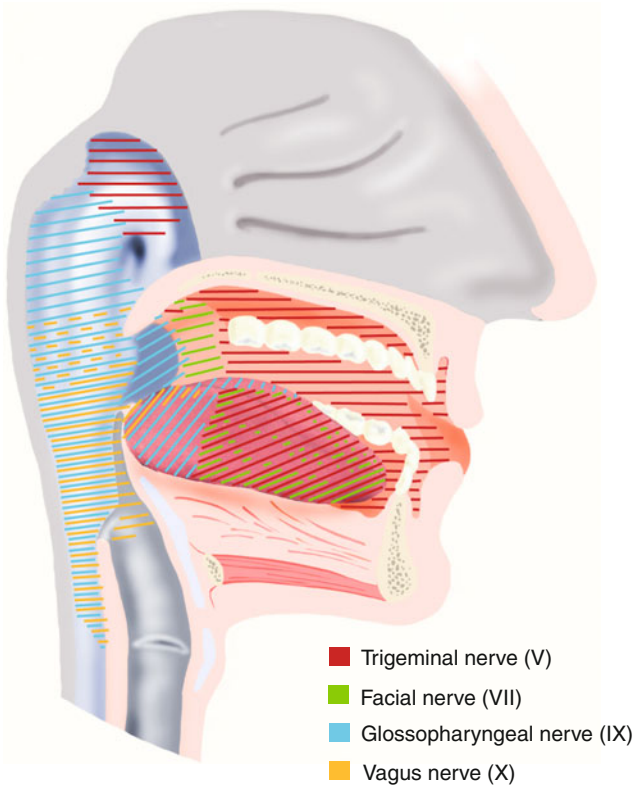

Fig. 5.24 Oral cavity. The image illustrates the innervation of the oral cavity and tongue. The taste perception of the anterior two thirds of the tongue is transmitted by the facial nerve, the posterior third by the glossopharyngeal nerve. The sensory innervation by the trigeminal nerve V3 overlapping in the buccal area with V2. The buccinator muscle, which innervates the cheeks, is innervated by the facial nerve

5.15.1 Ventral Part and Closure

The muscles of the entrance of the oral cavity are innervated by the facial nerve, and the sensory innervation comes from the trigeminal nerve. The lips are innervated in particular by the orbicularis oris muscle; the sensory innervation comes from the mental and infraorbital nerve. The closure of the oral cavity is a step in feeding; the precise lip movement and closure is as important in drinking as the movement of the lips in speaking, which is another important aspect. Both motor dysfunction (facial nerve) and sensory dysfunction (mental nerve) are reducing the ability of lip function. The causes can be central, peripheral, and within the muscle.

5.15.2 Middle Part, Oral Cavity and Tongue

The vestibule is the slit-like space between the mouth and the cheeks, lips, teeth, and gingivae. The boundaries of the oral cavity are the cheeks and lips, the hard palate, and posteriorly the oropharynx. The cheeks' sensory innervation comes from the mental and maxillary nerves; the muscle is predominantly the buccinator muscle. Both the tongue and the cheeks act as a functional unit during sucking, blowing, and chewing and act as an oral sphincter. The tongue fills the oral cavity. It consists of a root, body, and tip and is divided into an oral and a pharyngeal part. Its functions are mastication, taste (lingual papillae and taste buds), deglutition (swallowing), articulation (speech), and cleansing of the oral cavity. Squeezing food into the pharynx when swallowing and forming words during speech are its main functions. The muscle is innervated by the hypoglossal nerve, with the exception of the palatoglossus muscle, which is supplied by the pharyngeal branch of the vagus nerve. It has several intrinsic muscles. The tongue is also linked with extrinsic muscles as the genioglossus, hypoglossus, styloglossus, and palatoglossus. The sensory innervation is generated by the lingual nerve (anterior 2/3) and the glossopharyngeal nerve (posterior 1/3) and the special sensory innervation by the chorda tympani (anterior 2/3) and the glossopharyngeal nerve (posterior 1/3). The dome of the oral cavity is composed of the maxillary hard palate (2/3) and the soft palate, which is the posterior curtain-like part, composed of a fibromuscular fold, which separates the naso- and oropharynx. Posteriorly and inferiorly it extends to a curved free margin from which hangs the uvula. The muscles of the soft palate are the levator veli palatini (CN X), tensor veli palatini (medial pterygoid nerve – a branch of the mandibular nerve), palatoglossus (CN X, XI), palatopharyngeus (CN X, XI), and uvula muscle (CN X). The sensory innervation of the hard palate are branches from the ganglion pterygopalatinum. The greater palatine nerve supplies the gingivae, whereas the lesser palatine nerve, the soft palate. The anterior part of the hard palate is innervated by the nasopalatine nerve. The posterior part of the oral cavity prepares for swallowing and the gag reflex. The glossopharyngeal and vagal nerve innervate this part of the oral cavity. The function is the food passage propelling the food bolus through the pharynx, and the airway protection during food passage.

5.15.3 Posterior Part, Gag and Swallowing

Pharyngeal stage: The food is propelled by the tongue to the oropharynx. In the pharyngeal stage the two issues are (1) the passage of the food bolus through the pharynx and (2) the airway protection. The soft palate elevates and closes the nasopharynx. The base of the tongue pushes the bolus against the pharyngeal walls. The pharyngeal wall muscles contract sequentially to press the bolus downward. Several airway protection mechanisms are involved in the closure of the vocal cords; the contraction of the suprahyoid muscles and the thyrohyoid muscles pull the larynx and hyoid bone upward. The epiglottis tilts backward to seal the laryngeal vestibule. Opening of the upper esophageal sphincter (UES) (pharyngeal

Table 5.5 Cranial nerves and painful conditions

CN	Base of the skull	Cavernous sinus	Neuralgic pain	Others
II				Temporal arteritis, headache
III, IV, VI	Metastases, meningeal carcinomatosis	+	Tolosa-Hunt syndrome	Aneurysms, diabetes, giant cell arteritis, metastasis, leukemia, lymphoma, infection Orbital disease: pseudotumor, sinusitis Others: ophthalmoplegic migraine
V	Ganglion gasseri syndrome, meningeal carcinomatosis, base of the skull tumors	V1 < V2	Neuropathic pain in nerve distribution Trigeminal neuralgia	Masticatory claudication Retrograde nerve infiltration, Tolosa-Hunt syndrome
VII				Ramsey Hunt syndrome Retrograde nerve infiltration
IX	+		+ Rare "glossopharyngeal neuralgia"	
X			+ Glossopharyngeal and vagal neuralgia	
XI				Lesions in the neck region, "shoulder arm" syndrome
XII	+			Pain, anastomosis with cervical plexus (ansa cervicalis)
Multiple CN	Orbital, middle fossa, jugular foramen, occipital condyle syndrome (XII)	Parasellar		Calvarial metastasis
Cervical plexus			+	

constrictor muscles, cricopharyngeus muscle, and the most proximal part of the esophagus) is essential for the bolus entry into the esophagus. The UES is closed at rest by tonic muscle contraction. Preceding the opening of the UES, the cricopharyngeus muscle relaxes; the suprahyoid and thyrohyoid muscles contract by the force of the descending bolus. Neurologic involvement in the oral cavity manifests as burning of the tongue. Buccal alterations in DM, taste misperceptions in chemotherapy, and several pathologic conditions caused by individual lesions of the structures are involved (see above).

5.16 Cranial Nerves and Painful Conditions: A Checklist

See Table 5.5.

Other Conditions Associated with Painful Cranial Nerve Lesions

- *Neoplastic:* Chondroma, chordoma, craniopharyngioma, epidermoid tumors, giant cell tumor, meningeal carcinomatosis, meningioma. Metastases: lymphoma, multiple myeloma, nasopharyngeal, neurofibroma, squamous cell carcinoma.
- *Vascular causes:* Carotid artery aneurysm, carotid cavernous fistula, intracerebral venous occlusion, PCA, thrombosis.
- *Infections:* Fungal: mucocele, mucormycosis, periostitis, sinusitis.
- *Viral:* Herpes zoster.
- *Bacterial:* Mycobacterial, spirochetal.
- *Others:* Eosinophilic granuloma, sarcoid, Wegener's granulomatosis.

5.17 Cranial Nerve Examination in Coma

Genetic testing	NCV/EMG	Laboratory	Imaging	Biopsy
	+ Blink reflex Brainstem evoked potentials Motor evoked potentials Somatosensory evoked potentials	+ Electrolyte Endocrine Toxicity	++ Structural changes, edema	

CN examination in coma	
Pupil	Metabolic and toxic causes often spare the light reflex. Nonreacting "pinpoint pupils" point to either structural damage (pontine) or opiate intoxication. Midbrain lesions can produce large, fixed unresponsive pupils. Lids must be passively held open: anisocoria, consensual light reaction. Early manifestation of herniation syndrome – decline of pupillary reaction, usually on the side of the mass, followed by an ipsilateral mydriatic pupil. DD: miotic eye drops, organophosphates

Perception within the visual field	Can be tested by examining if the patient "blinks to threat"
Oculovestibular reflexes are dependent on the functions of VIII, III, IV, and VI	Extraocular movements are more sensitive to toxic and metabolic influences. Quick and saccadic eye movements are absent. Clinical test: oculocephalic maneuver, caloric testing. Doll's head reflex. Deviation of eyes to one side. Eye movements in resting position: conjugate, dysconjugate, roving, bobbing, inverse ocular bobbing (dipping), nystagmus retractorius, convergence nystagmus. Lesions of the MLF with internuclear ophthalmoplegia
Palatal and gag reflex	Relatively well preserved reflex: absent gag is a severe sign. Imminent danger of aspiration
Corneal reflex	Needs localizing if unilaterally absent. Bilateral absence not particularly a sign of structural lesion but of metabolic or toxic influence
Pain	Pain can be elicited in the trigeminal nerve distribution. The "ciliospinal" reflex evokes a dilatation of the pupil by noxious cutaneous stimulation. Pain in the limbs and body may induce mimic changes and ipsilateral dilatation of the pupil
Trismus	Lesion above midpons
Acoustic startle reflex	The acoustic startle reflex is usually present in superficial coma. Exaggerated acoustic startle reflex can be a sign of disinhibition, as observed in hypoxic brain damage

5.18 Pupil

Genetic testing	NCV/EMG	Laboratory	Imaging	Pharmacologic
		+	+	testing

- *Innervation:* 2 antagonistic muscles: circular muscle of iris (cervical sympathetic) and pupillary sphincter (CN III).
- *Paralysis of sphincter pupillae:* Lesion between Edinger-Westphal nucleus and the eye: widens due to unantagonized action of sympathetic iris dilator muscle.
- *Paralysis of dilatator pupillae:* Ocular sympathetic paralysis, as in Horner's syndrome.
- *Paralysis of accommodation:* Drugs: antidepressants, atropine, eserine, homatropine, pilocarpine, psychotropics. Cocaine causes dilatation by stimulating sympathetic nerve endings.
- *Pupillary size and equality:* Anisocoria.
- *Light reflex:* Direct/indirect.
- *Horner's syndrome:* See Horner's syndrome.
- *Ciliospinal reflex:* See CN and coma.
- *Pinpoint pupils:* May be a sign of opioid intoxication or a structural lesion of the pons (pontine hemorrhage).
- *Botulism:* Foodborne: CN paralysis appears first, then dilated fixed pupils (not always present).
- *Reflex iridoplegia:* Argyll Robertson pupil (syphilis).
- *Optic nerve lesions:* Swinging flashlight test.
- *Adie tonic pupils*
- *Unilateral dilatation:* Raised ICP.

Pharmacological Testing Cocaine, apraclonidine, hydroxyamphetamine, and pilocarpine are used in testing various dysfunctions of the pupil.

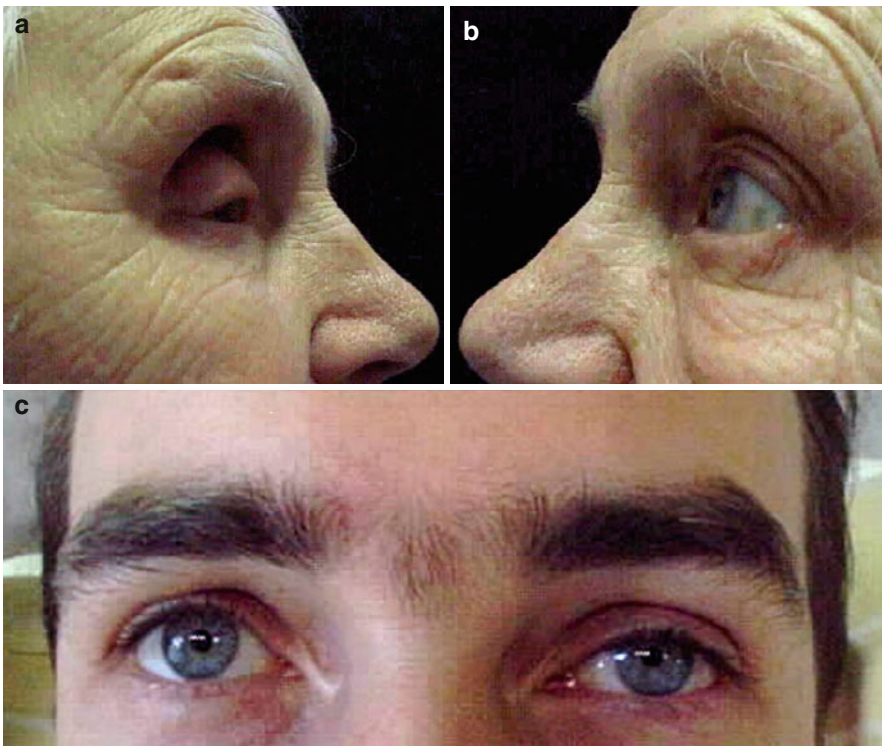

Fig. 5.25 Horner's syndrome. (**a**) Horner's syndrome of 10 y (years) duration, characterized by mild ptosis and enophthalmos, compared to normal side (**b**). (**c**) Horner's syndrome with mild ptosis and miosis

5.19 Multiple and Combined Oculomotor Nerve Palsies

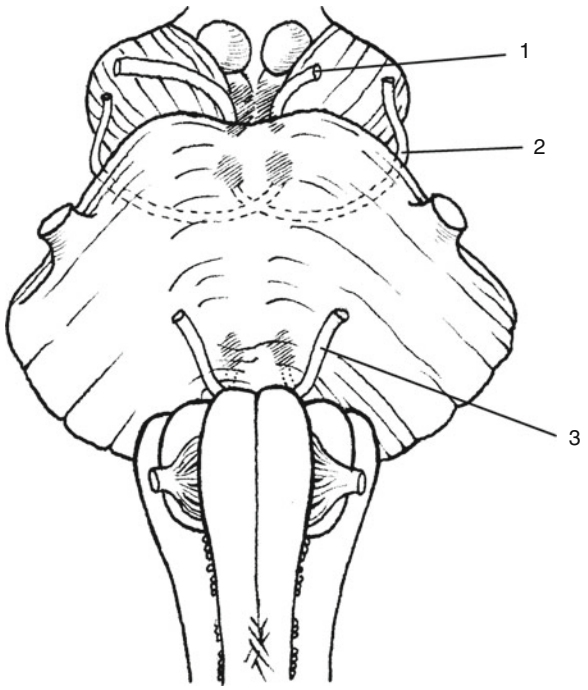

Fig. 5.26 *1* Oculomotor nerve, *2* trochlear nerve, *3* abducens nerve

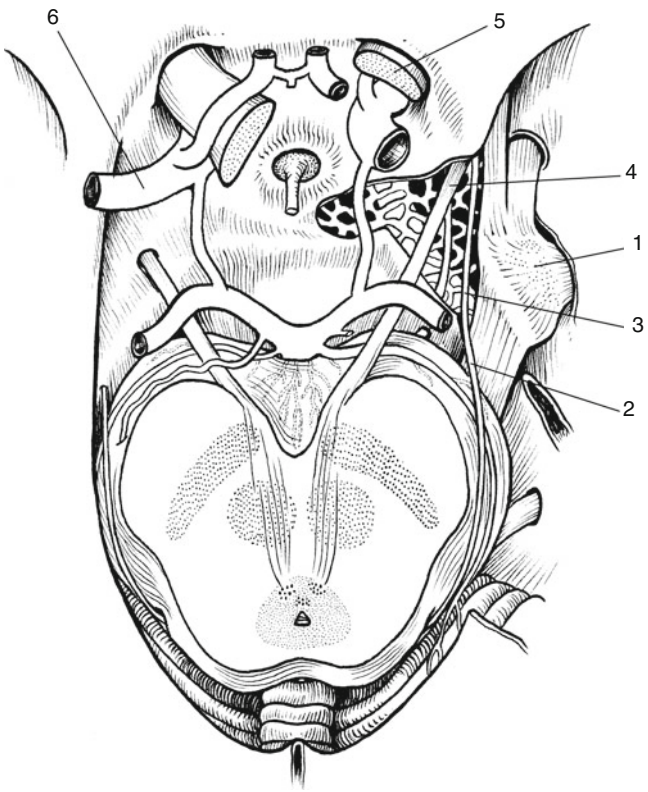

Fig. 5.27 *1* Trigeminal ganglion, *2* trochlear nerve, *3* abducens nerve, *4* oculomotor nerve, *5* optic nerve, 6 internal carotid artery

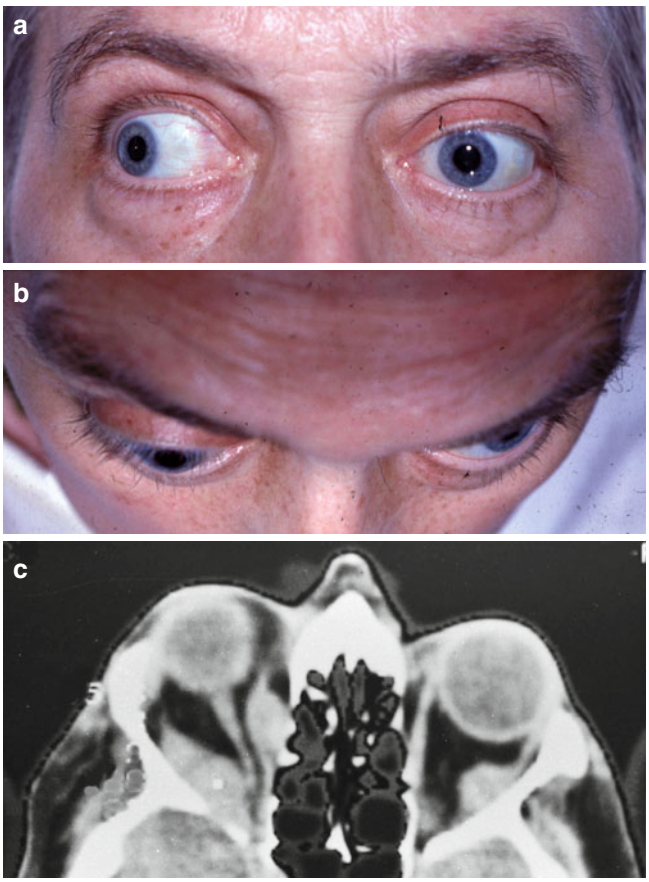

Fig. 5.28 Orbital metastasis. (**a**) Atypical optomotor function; (**b**) exophthalmos, best seen from above; (**c**) CT scan of orbital metastases

Table 5.6 Site of multiple cranial nerve lesions

CN III, IV, VI		
Site of lesion	Cause	Associated findings
Brainstem	Infarction Encephalitis Leigh syndrome Mental changes Paraneoplastic brainstem Tumor (e.g., glioma) Wernicke's disease	Brainstem signs
Subarachnoid space	Aneurysm Clivus tumor Cerebellopontine tumors LC Meningitis Trauma	Often multiple cranial nerves involved
Base of the skull	Base of the skull syndromes (Greenberg) Retrograde nerve infiltration from outside of the cranial vault, e.g., neck, sinus Infections: TBC meningitis, granulomatous diseases	

(continued)

Table 5.6 (continued)

CN III, IV, VI		
Site of lesion	Cause	Associated findings
Cavernous sinus	Aneurysm	Often V1, V2 involved
	Carotico-cavernous fistula	Orbital swelling
	Fistula	
	Herpes zoster	
	Infection	
	Mucormycosis	
	Mucocele	
	Nasopharyngeal carcinoma	
	Pituitary apoplexy	
	Tolosa-Hunt syndrome	
	Tumor: meningioma	
Fissura orbitalis superior (apex of the orbit)	Tumors, metastasis	
Orbital	Orbital cellulitis	Proptosis (particularly in advanced age)
	Orbital dysthyroid eye disease	
	Pain and vision loss: consider anterior optic pathways	
	Pseudotumor	
	Trauma	
	Tumor	
Uncertain	Cranial arteritis	Pain, polymyalgia
	Miller Fisher syndrome	Ataxia
	Oculomotor nerve palsies	Vincristine
	Toxic	
Differential diagnosis: orbital muscle disease including dysthyroid disease, MG, botulism, rare ocular myopathies		

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