Clinical Anatomy

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This chapter describes the anatomy of the osseous skull base and the neurovascular structures in the anterior, middle, and posterior cranial fossa with special emphasis on the clinical and surgical meaning of their morphology.

Editor's Comment

Detailed anatomical knowledge is a basic precondition for planning and performing surgical procedures. Due to the complex anatomy and important functional areas, this is notably the case for skull base procedures.

The learning and consolidation of knowledge about the fascinating skull base anatomy is less complex when combining reading of anatomical descriptions and searching them on a bony human skull. Like in the famous scene of Shakespeare's Hamlet with the skull in one hand and the book in the other hand one can much easier learn human anatomy. Looking at the skull through the operating microscope as well as inspecting the skull base through an endoscope both give an insight and illustrate the microsurgical anatomy in three dimensions in the classical sense. Furthermore, to extend his or her knowledge, the skull base surgeon should study the microsurgical anatomical books of Wolfgang Seeger (*Anatomical Dissection for the Use in Neurosurgery*) that are rich in detail, the well-illustrated work of Gazi Yasargil (*Microsurgery* Volume 4), or the microsurgically oriented publication by Takanori Fukushima (*Manual of Skull Base Dissection*). In all of the books, one will recognize the direct clinical relevance of microsurgical skull base anatomy. For vascular lesions at the skull base the book *Neurovascular Surgery* by Robert Spetzler and for the anatomy of the cerebellopontine angle the book *Surgery of Cerebellopontine Lesions* by Madjid Samii are recommended.

The chapter about clinical anatomy of the skull base can, of course, only give an overview and should be stimulus for self-studying and reading the accompanying literature.

2.1 Anterior Cranial Fossa and Frontal Skull Base

2.1.1 Osseous Components

The os frontale (frontal bone) makes up the largest portion of the anterior cranial fossa and the osseous frontal base. It forms the predominant portion of the orbital roofs (Fig. 2.1). Only at the transition from the anterior to the middle cranial fossa (lateral) and in the orbital apex area (medial) portions of the orbital roofs consist of the os sphenoidale (sphenoid bone). The latter also forms the planum sphenoidale as the dorsal section of the median frontal base. The limbus sphenoidale separates the planum sphenoidale (anterior fossa) from the pre-chiasmatic sulcus (middle fossa) and continues laterally with the anterior roof of the optic canal (Fig. 2.2). The lamina cribrosa below the olfactory cortex area is formed by the os ethmoidale (ethmoid bone) [12].

2.1.2 Foramina and Their Contents

The lamina cribrosa (cribriform plate of the ethmoid bone) possesses multiple openings for the filia olfactoria of the olfactory nerve (CN I). The anterior meningeal artery, a branch of the anterior ethmoidal artery, runs intracranially through the lamina cribrosa. The anterior ethmoidal nerve, a branch of the nasociliary nerve (from the ophthalmic nerve [V1]), initially goes through the cribriform plate intracranially, and from there peters out extracranially to the nasal mucosa. The optic nerve (CN II) and the ophthalmic artery reach the inferior part of the orbital cavity through the optic canal (Figs. 2.1, 2.2, 2.3, and 2.4).

The oculomotor nerve originates from the anterior aspect of the midbrain. It runs anteriorly, passing below the posterior cerebral artery and above the superior cerebellar artery. The nerve pierces the dura mater and enters the lateral aspect of the cavernous sinus at the oculomotor triangle. This triangle consists of three ligaments as shown in Fig. 2.5: anterior petroclinoid ligament, posterior petroclinoid ligament, and interclinoid ligament. Opening and cutting these ligaments is necessary in different approaches to the cavernous sinus.

The ophthalmic artery is a branch of the supraclinoid portion of the internal carotid artery in most cases. This vessel follows the optic nerve into the optic canal and orbit and is responsible for the supply of the orbital structures. The origin of the ophthalmic artery is usually medial to the anterior clinoid process and below the optic nerve. At the level of the optic canal, this artery has passed to a position lateral

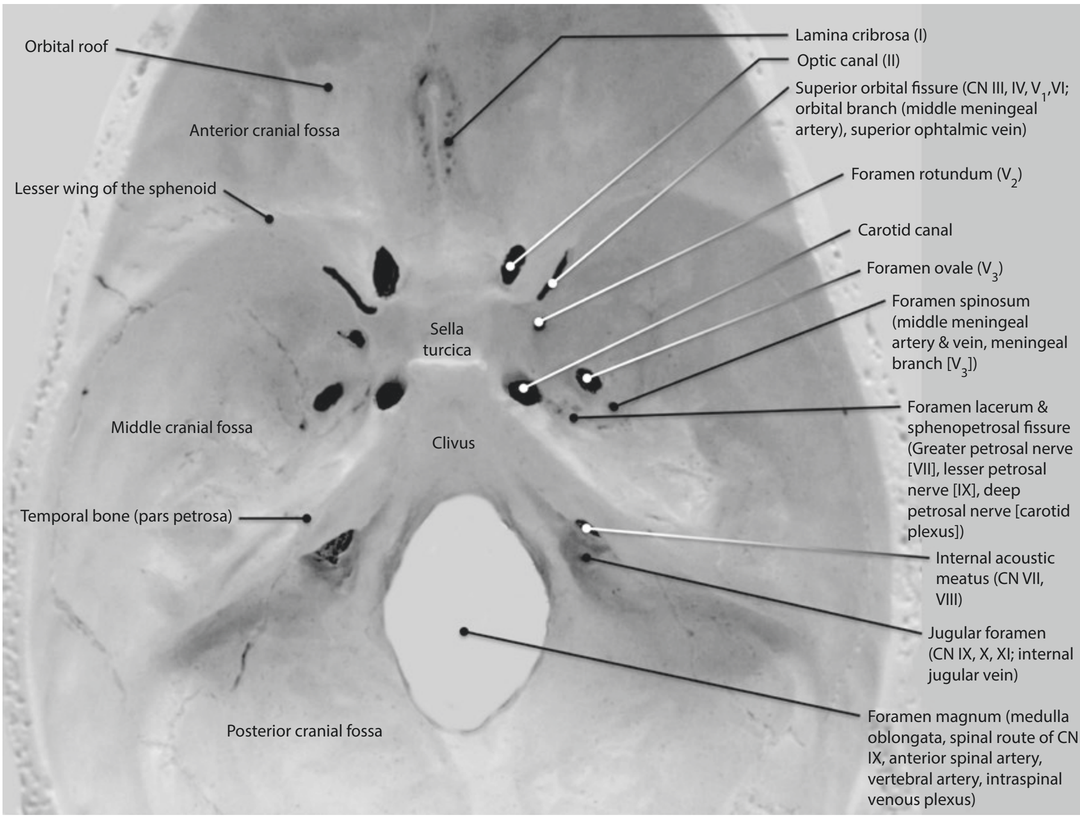

Fig. 2.1 Foramina of the osseous skull base specifying the pervading neurovascular structures

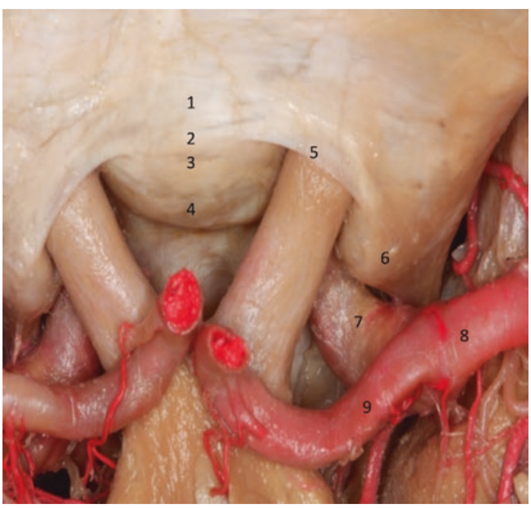

Fig. 2.2 Overview of the anterior-middle fossa junction and components: *1* planum sphenoidale, *2* limbus sphenoidale, *3* prechiasmatic sulcus, *4* tuberculum sellae, *5* falciform ligament, *6* anterior clinoid process, *7* internal carotid artery (supraclinoid segment), *8* middle cerebral artery (M1 segment), *9* anterior cerebral artery (A1 segment)

to the nerve. This anatomical fact must be kept in mind during the opening of the falciform ligament to avoid an iatrogenic lesion of this artery (Fig. 2.5b).

2.2 Middle Cranial Fossa, Sellar Region, and Temporal Base

2.2.1 Osseous Components

The middle cranial fossa is formed in its anterior portion by the greater and lesser wings of the sphenoid bone, whereby the lesser wing represents the border between middle and anterior cranial fossa. The temporal bone (os temporale) forms the major portion of the middle cranial fossa. The tip of the petrous part of the temporal bone represents the boundary to the posterior cranial fossa (Fig. 2.1).

The sella turcica is completely formed by the medial portions of the sphenoid bone. Important

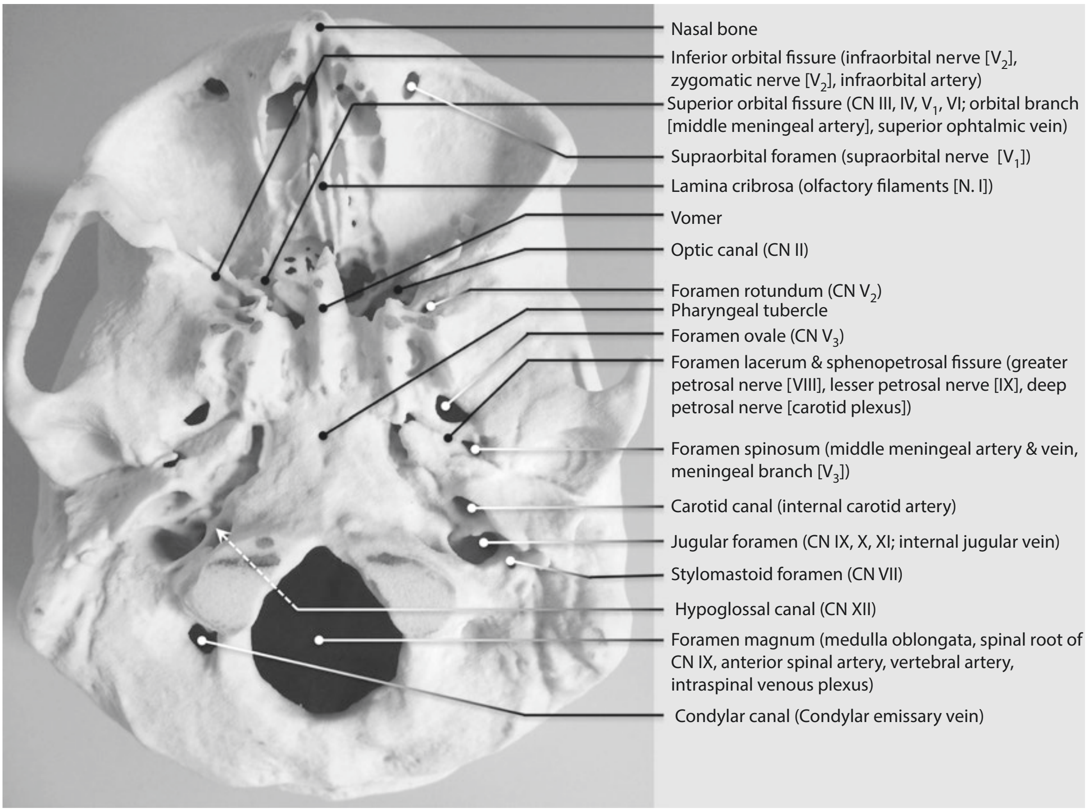

Fig. 2.3 Osseous skull base, inferior view, with foramina

landmarks here are the anterior, middle, and posterior clinoid processes (Figs. 2.2, 2.5, and 2.6) [4, 9, 17].

The middle clinoid process is an osseous prominence that arises from the body of the sphenoid bone at the anterolateral margin of the sella turcica. It is identifiable in 60% of the normal population (bilateral in 35%). Recognition of this structure, especially when there is a caroticoclinoid ring, is very important in the surgical planning of endoscopic endonasal surgeries in the perisellar region (Fig. 2.6) [7].

The prechiasmatic sulcus is a groove on the upper surface of the sphenoid bone running transversely between the optic canals bounded anteriorly by the sphenoidal limbus and posteriorly by the tuberculum sellae; the optic chiasm is located just above the prechiasmatic sulcus (Figs. 2.2 and 2.6) [2].

2.2.2 Foramina and Their Contents

Numerous structures permeate the superior orbital fissure (Figs. 2.1 and 2.4):

- Oculomotor nerve (CN III)
- Trochlear nerve (CN IV)
- Abducens nerve (CN VI)
- Nasociliary nerve (branch from CN V_1)
- Lacrimal nerve (branch from CN V_1)
- Frontal nerve (branch from CN V_1)
- Superior ophthalmic vein

The cranial nerves III, IV, and VI control the oculomotor system, while cranial nerve III also controls the pupillomotor system. The branches from the ophthalmic nerve (V_1) have sensory fibers from the cornea and upper facial area. The lacrimal nerve additionally has attached sympathetic and parasympathetic fibers for the lacrimal gland.

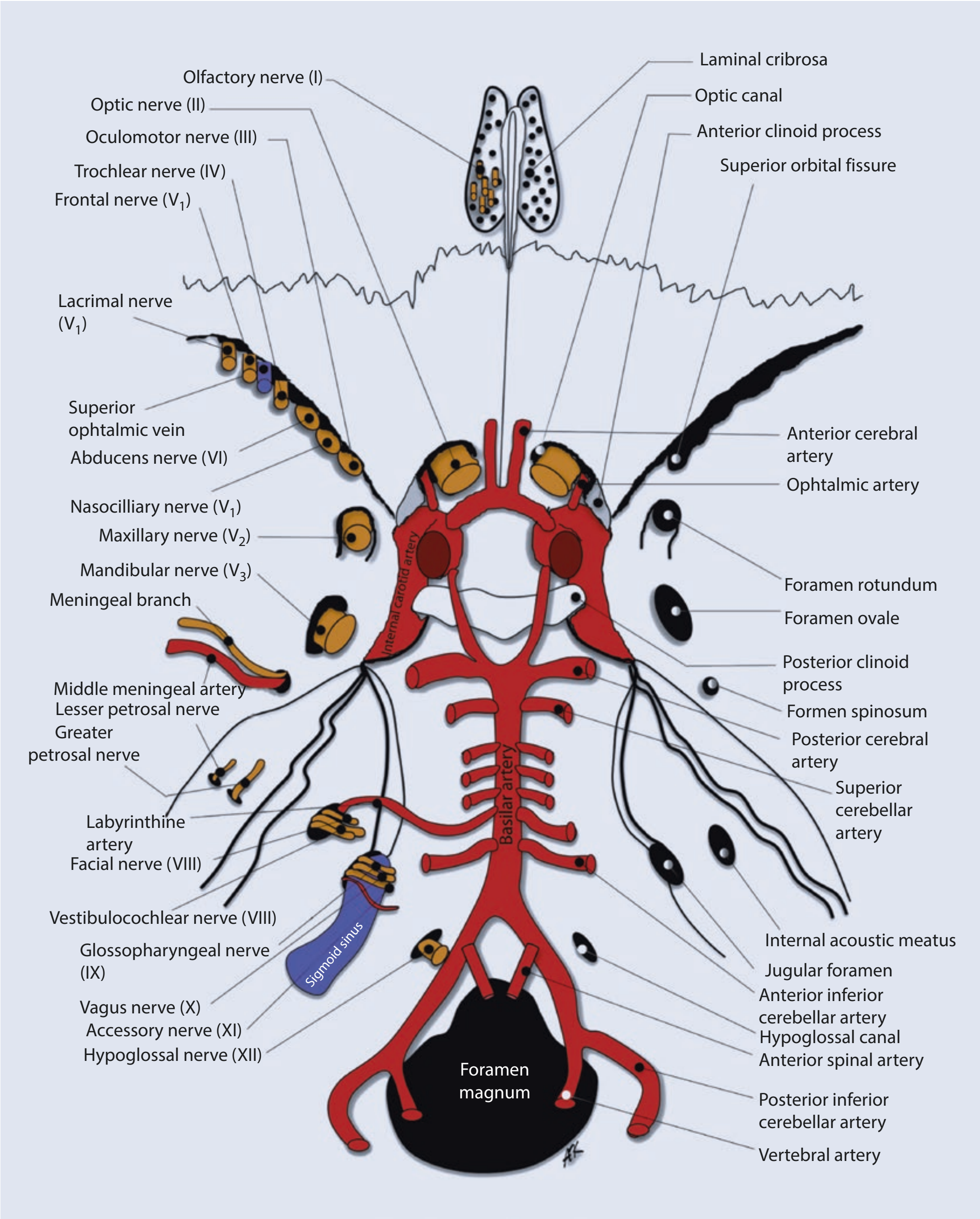

Fig. 2.4 Schematic drawing of the most important neurovascular structures of the skull base

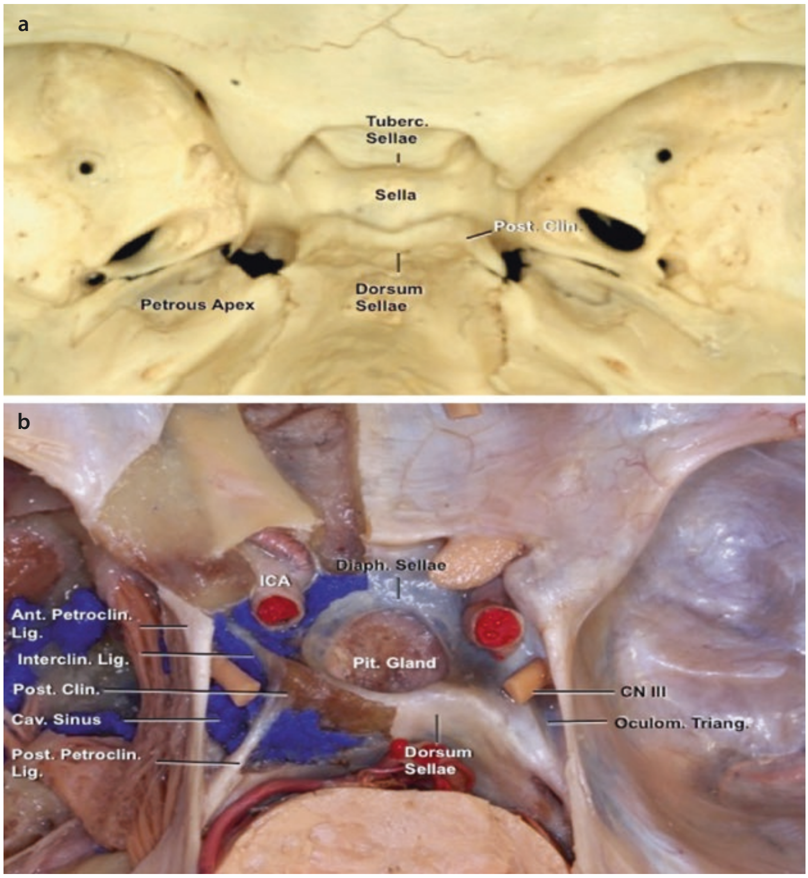

Fig. 2.5 Overview of the cavernous sinus, oculomotor triangle, and their correlations. **a** Bony structures, **b** anatomical structures: pay attention to the ophthalmic artery origin from the internal carotid artery at the left side and its correlation to the optic nerve

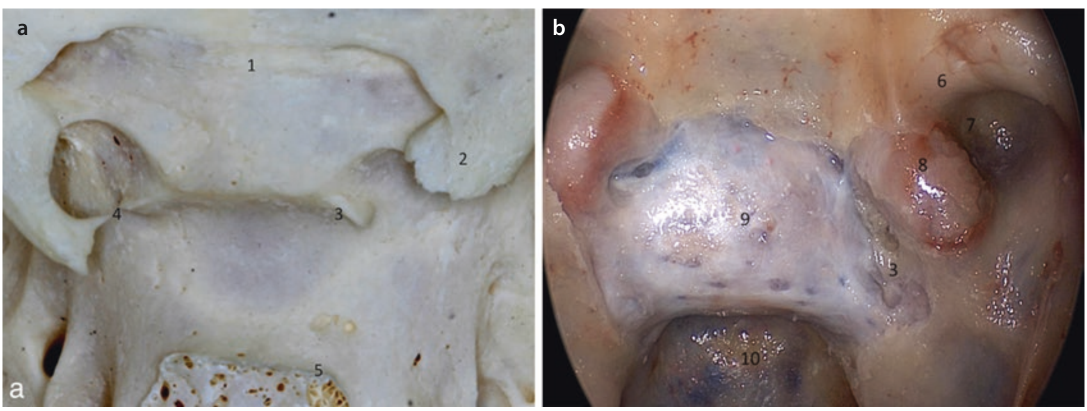

Fig. 2.6 Intracranial **a** and transnasal endoscopic **b** view of the middle clinoid process. *1* prechiasmatic sulcus, *2* anterior clinoid process, *3* middle clinoid process, *4* carotidoclinoid ring, *5* posterior clinoid process, *6* optic nerve, *7* lateral opticocarotid recess, *8* internal carotid artery (supraclinoid segment), *9* sella turcica, *10* clivus recess

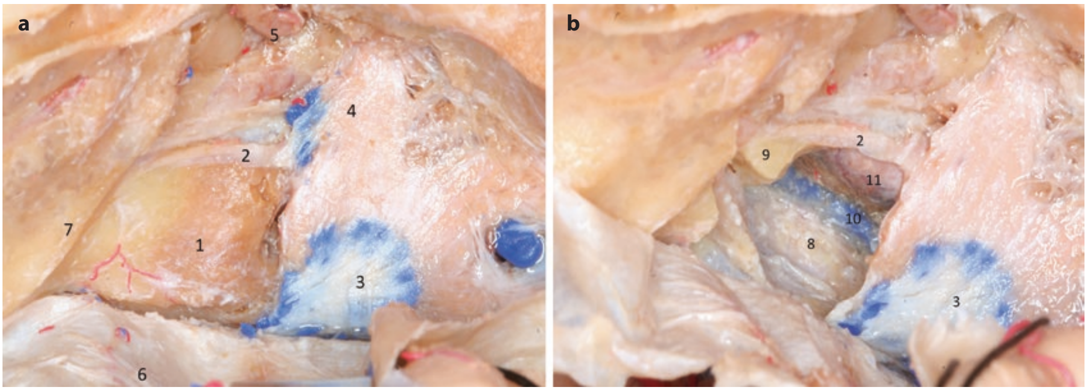

Fig. 2.7 Extradural exposure of the middle fossa floor and Kawase triangle **a**. Exposure of the posterior fossa dura after drilling the Kawase triangle **b**. *1* Kawase triangle (KT), *2* greater petrosal nerve (lateral border of KT), *3* Gasserian ganglion, *4* V_1 nerve (anterior border of KT), *5* middle meningial artery, *6* middle fossa dura, *7* arcuate eminence (posterior border of KT), *8* posterior fossa dura, *9* cochlea, *10* inferior petrosal sinus, *11* internal carotid artery (intrapetrosal part)

The inferior orbital fissure contains:

- Infraorbital nerve (branch from V_2)
- Zygomatic nerve (branch from V_2)
- Infraorbital artery
- Parasympathetic fibers from the pterygopalatine ganglion

Both nerve branches from V_2 are the sensory provision for the middle facial region. The zygomatic nerve receives parasympathetic fibers at the pterygopalatine ganglion for the lacrimal gland, which it passes on to the lacrimal nerve.

The maxillary nerve (V_2) and mandibular nerve (V_3) each possess their own foramina in the middle cranial fossa — foramen rotundum and foramen ovale (Figs. 2.1, 2.3, and 2.4).

The maxillary nerve is the sensory provision for the middle third of the face, as well as the gums and teeth of the upper jaw.

The mandibular nerve is the sensory provision for the lower facial region and tongue, as well the motor provision for the masticatory muscles, portions of the muscles in the base of the mouth, the tensor tympani muscle, and the tensor veli palatini muscle [5, 10, 13].

The greater petrosal nerve leaves the petrous portion of the temporal bone at its anterior side (Figs. 2.4 and 2.7) and draws on the floor of the middle cranial fossa toward the foramen lacerum, through which it reaches the outer cranial base. Beyond the synapses of its parasympathetic fibers in the pterygopalatine ganglion, it reaches the lacrimal gland and the glands of the nasal mucosa, gums, and epipharynx via branches of the maxillary nerve [8, 15]. This nerve is especially of importance during the anterior transpetrosal approach as a reliable lateral landmark of the Kawase triangle (Fig. 2.7) [3].

The lesser petrosal nerve (Jacobson anastomosis) leads parasympathetic fibers from the glossopharyngeal nerve and leaves the petrous portion of the temporal bone at its anterior surface (Fig. 2.4). It leaves the middle cranial fossa via the foramen lacerum and the sphenopetrosal fissure and draws through the infratemporal fossa to the otic ganglion (switching of the parasympathetic fibers). It reaches the parotid gland via anastomoses with the auriculotemporal nerve (from V_3) and with the facial nerve (CN VII) [18].

The greater superficial and deep petrosal nerves join to form the vidian nerve at the level of the foramen lacerum around the ICA. The vidian nerve enters the sphenoid bone, passes through the pterygoid canal, and ends in the pterygopalatine ganglion, where the parasympathetic fibers synapse. Sympathetic and parasympathetic fibers exit the ganglion and join the nerves that supply the orbit, nasal cavity, and palate. The vidian nerve has an important role in maintaining normal lacrimation and nasopharyngeal physiology.

The vidian nerve is a landmark for safe identification of the petrous internal carotid artery during endoscopic endonasal approaches (EEAs) to the skull base (Fig. 2.8) [1, 14].

The pterygosphenoidal fissure (curved line in Fig. 2.8) is the best landmark to find the foramen lacerum segment of the internal carotid artery.

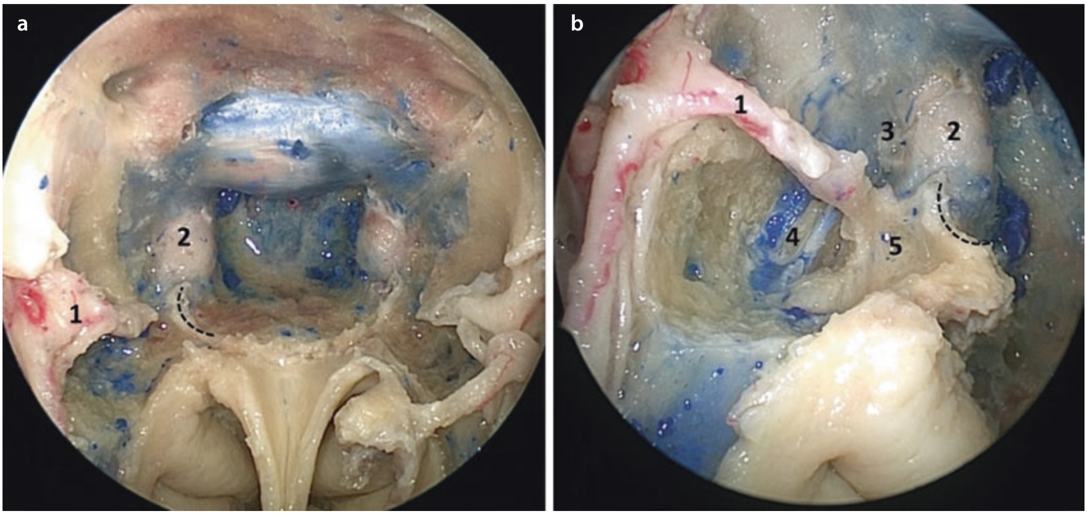

Fig. 2.8 Transsphenoidal transpterygoid exposure of the vidian nerve along with other anatomical landmarks **a**, **b**. *1* vidian nerve; *2* paraclival internal carotid artery, curved line, pterygosphenoidal fissure; *3* lingual process of the sphenoid bone; *4* mandibular strut; *5* foramen lacerum fibrocartilaginous

2.3 Cranial Base of the Posterior Cranial Fossa

2.3.1 Osseous Components

The posterior cranial fossa, including the foramen magnum and the caudal clivus, is primarily formed by the occipital bone. The posterior surface of the petrous bone is part of the temporal bone and anterolateral border of posterior fossa.

2.3.2 Foramina and Their Contents

The foramen magnum represents the connection of the intracranial space with the spinal canal (Figs. 2.4, 2.9, 2.10, and 2.11). It contains the medulla oblongata, the spinal roots of CN XI, the anterior spinal artery, the vertebral arteries, and the marginal sinus.

The hypoglossal canal enables the hypoglossal nerve (XII) to pass through the cranial base. Its function is the motor innervation of the tongue.

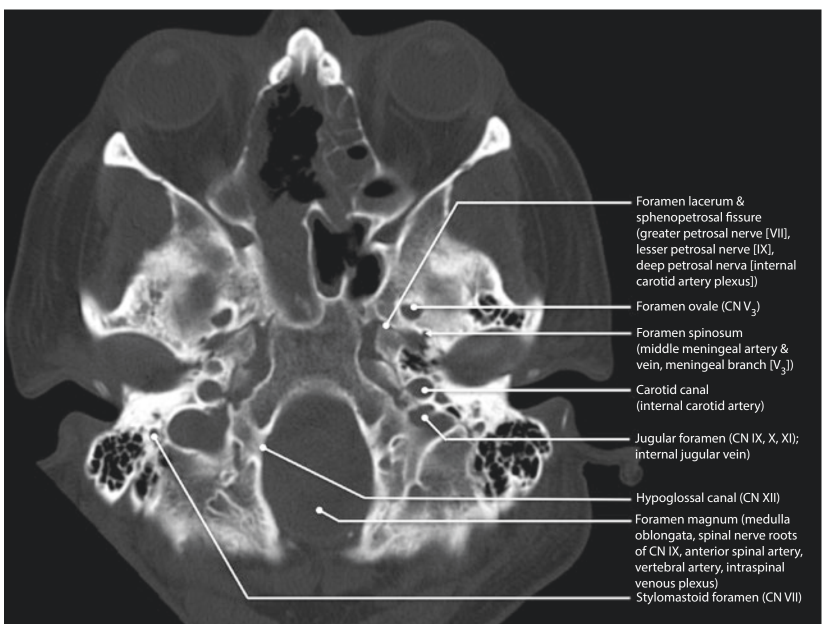

Fig. 2.9 Osseous skull base in a CT scan with important foramina for the passage of neurovascular structures

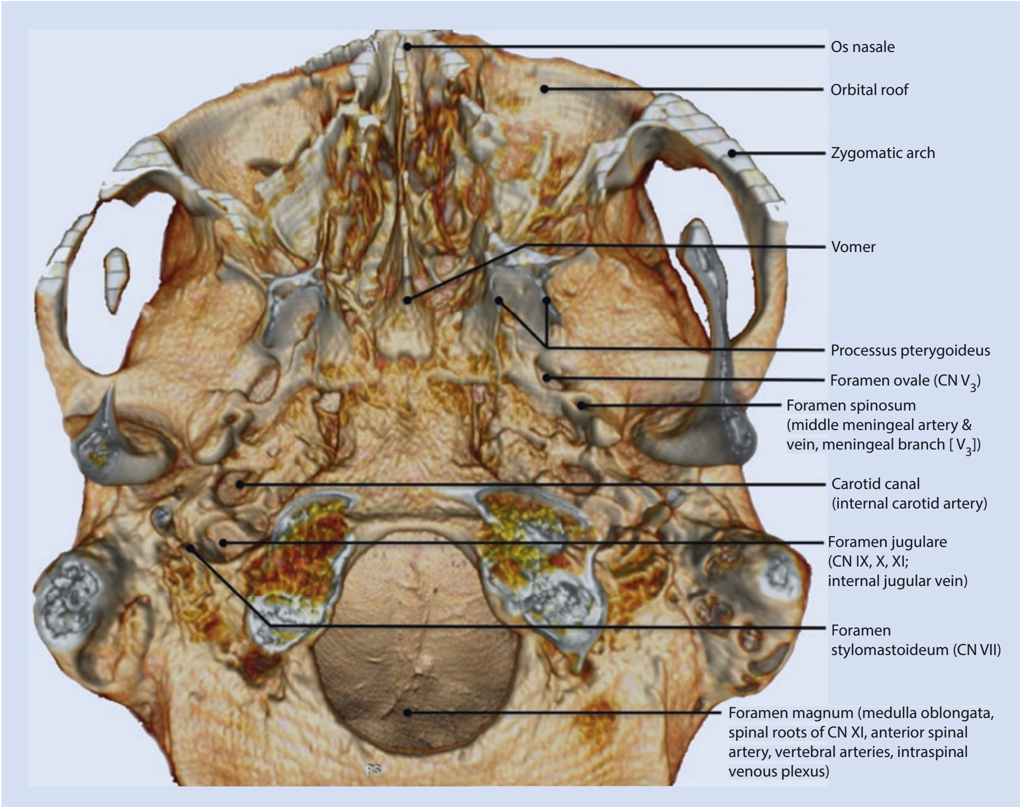

Fig. 2.10 Inferior view of the osseous skull base with anatomical landmarks and the most important openings for the passage of neurovascular structures (3D reconstruction of a skull base CT scan)

The internal jugular vein, the glossopharyngeal nerve (IX), the vagus nerve (X), and the accessory nerve (XI) leave the intracranial space via the jugular foramen, while the posterior meningeal artery (arises from the ascending pharyngeal artery) enters the skull base here [10, 11, 13].

The glossopharyngeal nerve leads sensory, motor, and parasympathetic fibers for the tongue, pharynx, and parotid gland. Impulses from pressoreceptors run from the carotid sinus to the medulla oblongata via this nerve.

The vagus nerve (CN X) is the most important nerve of the parasympathetic nervous system, ensuring extensive vegetative control of internal organs. It operates on a motor, sensory, viscerosensory, and visceromotor basis. It is involved in the innervation and control of the following organs: larynx, pharynx, upper esophagus, heart, trachea, bronchia, stomach, proximal intestine, liver, spleen, and kidneys.

The accessory nerve (CN XI) provides innervation for the voluntary motor control of the sternocleidomastoid and trapezius muscles.

2.3.3 Anatomy in the Cerebellopontine Angle

The cerebellopontine angle possesses great clinical importance, because it is the origin for a series of pathologies and their clinical manifestations. Various types of tumors can be found here, e.g., vestibular schwannomas (acoustic neuromas), epidermoids, and meningiomas arising from the posterior surface of the petrous bone or tentorium or even neurovascular conflicts such as trigeminal neuralgia, hemifacial spasms, or glossopharyngeal neuralgia [6, 12].

The drainage patterns of the superior petrosal venous complex are defined on the basis of the relationship between their site of entry into the superior petrosal sinus, Meckel's cave, and the internal acoustic meatus.

The drainage pattern of the superior petrosal vein appears to vary among the different CP angle pathologies. In general, preservation of the superior petrosal vein is not always achiev-

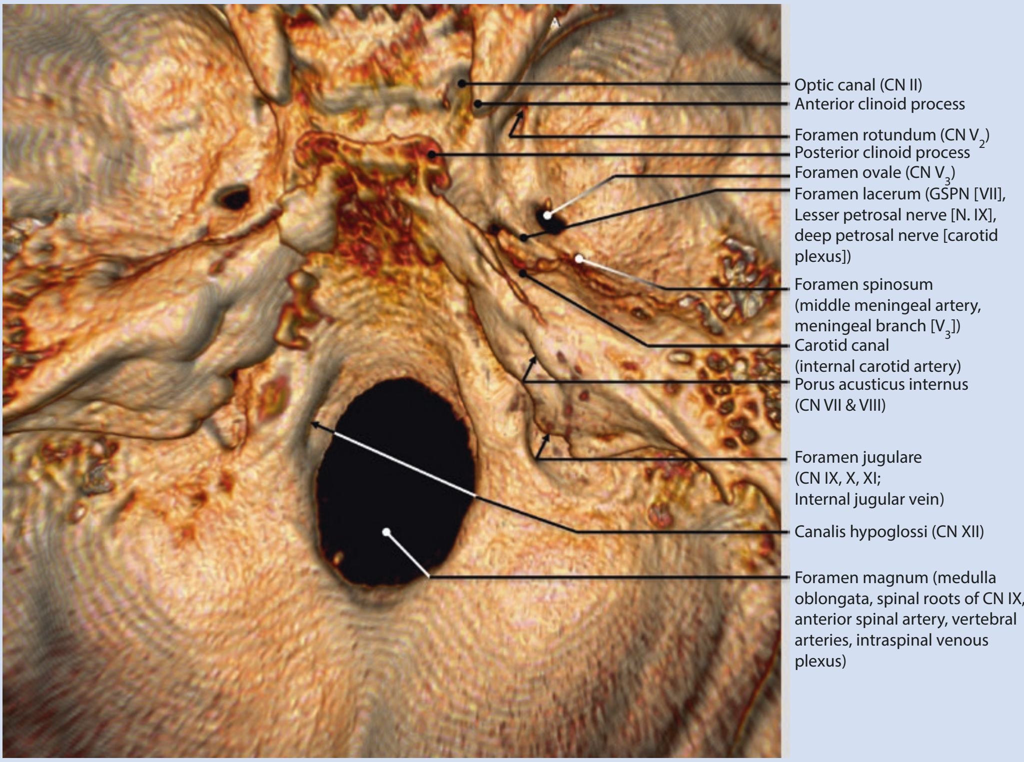

Fig. 2.11 Interior view of the skull base with the most important openings for the passage of neurovascular structures (3D reconstruction of a skull base CT scan)

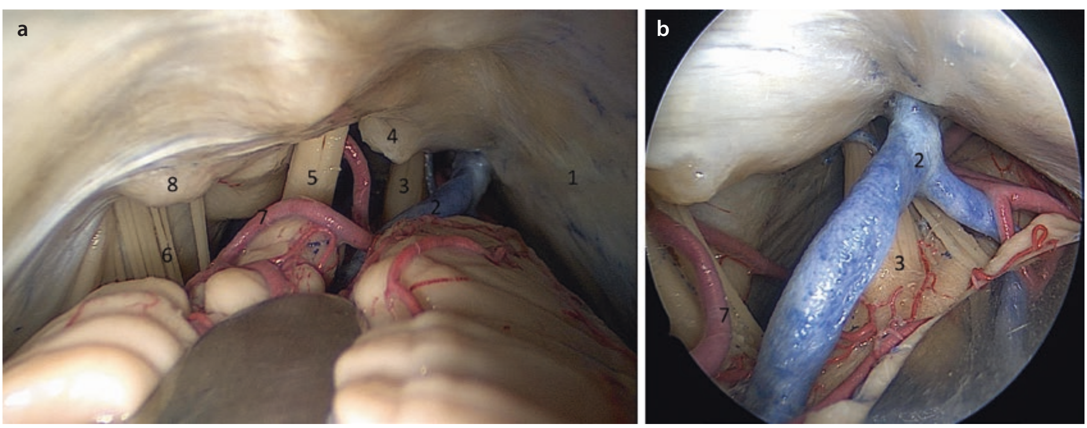

Fig. 2.12 Anatomy of the cerebellopontine angle, overview **a** and close up view on the superior petrosal vein (Dandy's vein) **b**. *1* tentorium; *2* superior petrosal vein; *3* trigeminal nerve (CN V); *4* suprameatal tubercle; *5* CN VII/VIII complex; *6* CN IX, X, XI complex entering the jugular foramen; *7* anterior-inferior cerebellar artery (AICA); *8* jugular tubercle

able in neurosurgical procedures, especially when the standard suboccipital approach is modified with suprameatal and/or supratentorial extension [16].

The retrosigmoidal access is considered as the standard surgical approach to the CPA. Here, the cranial nerves and vessels represented in Fig. 2.12 can be identified [6, 11, 12].

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