

SKULL BASE ANATOMY IN NEUROSURGICAL APPROACHES**Soliyeva Minora Yulbarsova**

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Abstract: The skull base is one of the most complex anatomical regions of the human body, containing critical neurovascular structures and forming the main corridor for intracranial neurosurgical procedures. A thorough understanding of its anatomy is fundamental to ensuring surgical precision, minimizing complications, and optimizing patient outcomes. This article provides a comprehensive overview of skull base anatomy, focusing on the relationships of cranial fossae, foramina, major blood vessels, and cranial nerves, and highlights their relevance in modern neurosurgical approaches such as endoscopic endonasal surgery, pterional craniotomy, suboccipital approaches, and transpetrosal routes. The integration of advanced imaging, microsurgical techniques, and endoscopic methods is also discussed to emphasize the evolution of neurosurgical access to the skull base.

Keywords: Skull base anatomy; neurosurgical approaches; cranial fossae; cavernous sinus; internal carotid artery; cranial nerves; transpetrosal approach; endoscopic skull base surgery; posterior fossa.

Introduction

The skull base forms the inferior boundary of the cranial cavity and serves as the structural interface between the brain and multiple extracranial regions. Due to its anatomical density—housing cranial nerves I–XII, major arteries including the internal carotid and vertebrobasilar systems, venous sinuses, and numerous foramina—the skull base is central to neurosurgical practice. Lesions involving this region, including tumors, vascular malformations, traumatic fractures, and infectious processes, frequently require highly specialized surgical exposure.

Over the past decades, the development of microsurgical instruments, neuronavigation, and endoscopic techniques has significantly expanded the range of safe neurosurgical approaches. However, the success of these interventions relies on intimate knowledge of skull base anatomy, including its three cranial fossae, bony landmarks, foraminal pathways, and neurovascular corridors. This study aims to synthesize essential anatomical insights relevant to neurosurgeons and to analyze their implications for commonly used skull base approaches.

Materials and Methods

This work is based on an in-depth analysis of anatomical textbooks, cadaveric dissection reports, neurosurgical atlases, and clinical studies published between 1995 and 2024. Data were derived from microsurgical dissections performed in neuroanatomy laboratories, high-resolution CT and MRI imaging studies, and operative notes from skull base surgeries involving pituitary tumors, meningiomas, vestibular schwannomas, aneurysms, and petroclival lesions.

Emphasis was placed on identifying the most relevant bony structures, foramina, sulci, emissary pathways, arterial channels, and venous sinuses critical in neurosurgical orientation. The study also included the evaluation of different surgical routes—endonasal, subfrontal, retrosigmoid, presigmoid, transpetrosal, and far-lateral approaches—correlating them with specific anatomical

landmarks. The objective was to correlate structural relationships with operative accessibility and risk assessment.

Results

The analysis of anatomical, radiological, and microsurgical data reveals that the skull base possesses an exceptional structural and functional complexity crucial for neurosurgical access. The anterior cranial fossa is characterized by its thin bony floor, the presence of the cribriform plate, and close proximity to the frontal lobes, making it vulnerable to cerebrospinal fluid leakage and olfactory impairment during surgical manipulation. The middle cranial fossa demonstrates the highest concentration of neurovascular elements, including the cavernous sinus, internal carotid artery, trigeminal ganglion, and multiple cranial nerves, which collectively create narrow surgical corridors that require precise dissection. The posterior cranial fossa, containing the brainstem and cerebellum, presents deep and tightly confined spaces where critical structures such as the vertebral arteries, basilar artery, and cranial nerves VII–XII must be navigated carefully during surgical exposure.

Radiological evaluation shows considerable anatomical variability across the skull base. Pneumatization patterns of the sphenoid sinus, orientation of the carotid canal, configuration of the jugular foramen, and the dominance of venous sinuses differ significantly among individuals. These variations directly influence the trajectory, visibility, and safety of neurosurgical approaches. For instance, extensive sphenoid pneumatization provides wider endonasal access to the sella and clivus, whereas a narrow or septated sphenoid sinus complicates safe entry and elevation of the mucosa. Similarly, lateral displacement or prominence of the sigmoid sinus affects the feasibility of presigmoid and retrosigmoid approaches.

Microsurgical findings confirm that each skull base region has distinct neurovascular relationships that dictate operative strategies. The cavernous sinus area demonstrates the most intricate arrangement, with cranial nerves III, IV, V1, V2, and VI closely associated with the internal carotid artery, making this region particularly prone to iatrogenic injury. In contrast, the posterior fossa offers more direct exposure to vascular structures but requires careful handling of the lower cranial nerves and brainstem perforators. The proximity of the vertebrobasilar system to the clivus and foramen magnum further restricts surgical freedom in this region.

Observations of surgical corridors indicate that modern approaches utilize natural anatomical pathways to minimize brain retraction and preserve function. The endoscopic endonasal approach provides direct access to midline structures of the anterior and middle skull base, including the pituitary gland, clivus, and cribriform region, without external incisions. Lateral approaches such as the pterional, subtemporal, and transpetrosal routes rely on bony landmarks including the zygomatic arch, sphenoid ridge, and petrous temporal bone to safely reach vascular and neural targets. The far-lateral approach enables lower clival and foramen magnum exposure while respecting vertebral artery anatomy. Across all approaches, the preservation of venous sinuses, cranial nerve bundles, and perforating arteries is consistently identified as the most influential factor determining postoperative neurological outcomes.

Overall, the results emphasize that skull base anatomy combines delicate bony architecture, dense neurovascular networks, and significant anatomical variations, all of which must be precisely mapped before surgical intervention. The success of neurosurgical procedures strongly depends on individualized anatomical assessment, detailed understanding of local landmarks, and careful adaptation of surgical corridors based on patient-specific structural features.

Table. Key Skull Base Structures and Their Neurosurgical Relevance

Structural Region	Critical Elements	Neurosurgical Importance
Anterior fossa	Cribriform plate, ethmoid roof	Risk of CSF leak, olfactory preservation
Middle fossa	Cavernous sinus, ICA, cranial nerves III–VI	Aneurysm surgery, pituitary tumors
Posterior fossa	Foramen magnum, jugular foramen, VA/BA system	Brainstem and cerebellar tumor access
Temporal bone	Internal acoustic meatus	Preservation of hearing and facial nerve
Clivus	Basilar artery, abducens nerve	Endonasal or transpetrosal routes

Discussion

The skull base is a surgical region where millimeters determine the difference between success and catastrophic complications. Fine anatomical details—such as the depth of the sella, curvature of the clivus, variations in the carotid canal, and venous sinus positioning—directly affect surgical orientation and maneuverability.

Modern neurosurgery increasingly relies on endoscopic and minimally invasive techniques, which require sophisticated three-dimensional anatomical understanding. The endonasal approach, for example, demands precise identification of the sphenoid sinus septations, opticocarotid recess, clival recess, and pituitary landmarks. In contrast, lateral approaches require detailed knowledge of mastoid cells, sigmoid sinus position, and facial nerve trajectory.

Anatomical variations play a crucial role. Differences in the size of the jugular foramen, dominance of venous sinuses, carotid artery dehiscence, or pneumatization of the sphenoid sinus must be recognized on preoperative imaging to avoid complications such as vascular injury, cranial neuropathy, or cerebrospinal fluid leakage.

Thus, mastery of skull base anatomy remains the cornerstone of safe and effective neurosurgical practice.

Conclusion

The skull base represents one of the most anatomically complex regions of the human body, comprising dense neurovascular networks and essential bony structures that form the framework for neurosurgical interventions. Successful access to skull base lesions requires precise interpretation of anatomical landmarks, comprehensive understanding of arterial and venous pathways, and advanced surgical planning tailored to individual anatomical variations. As neurosurgical technology evolves toward minimally invasive and endoscopic approaches, detailed knowledge of skull base anatomy becomes increasingly indispensable. A thorough anatomical foundation significantly reduces the risk of intraoperative injury, improves surgical outcomes, and enhances the safety and effectiveness of modern neurosurgical care.

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