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ON ENTERING THE FORTRESS:
Surgical Approaches to Brainstem Lesions

A Comprehensive Review of Safe Entry Zones for Neurosurgical Access to the Brainstem

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I INTRODUCTION

The brainstem has historically been regarded as a surgical fortress—a densely packed structure harboring critical nuclei and fiber tracts within a volume roughly the size of the human thumb. Intrinsic brainstem lesions, including cavernous malformations, focal gliomas, and hemangioblastomas, have long been considered inoperable by many neurosurgeons[1,2]. However, the development of complex skull base approaches, advances in neuroimaging, and the identification of anatomical safe entry zones have progressively transformed this paradigm[3,4]. Safe entry zones represent specific points on the brainstem surface where eloquent structures and perforating arteries are sparse, allowing neurotomy with minimal damage to surrounding neural tissue[5]. A total of thirteen safe entry zones have been described and validated across the three brainstem regions—midbrain, pons, and medulla oblongata—each accessible through specific surgical corridors[5,6]. Understanding these zones is essential for reducing morbidity in the surgical management of intrinsic brainstem pathology.

M METHODS

We conducted a comprehensive review of the literature on brainstem safe entry zones, with particular emphasis on cadaveric morphometric studies and clinical surgical series. Ten major surgical approaches were analyzed for their ability to expose specific brainstem surfaces and provide access to the thirteen described safe entry zones: orbitozygomatic, subtemporal, subtemporal transtentorial, anterior petrosectomy, suboccipital telovelar, median supracerebellar infratentorial, extreme lateral supracerebellar infratentorial, retrosigmoid, far lateral, and retrolabyrinthine[3]. Additionally, twenty cadaveric brainstem specimens were examined to validate the morphometric parameters of the lateral pontine entry zone (the Roman Triangle), measuring three distinct lines (X, Y, Z) forming a triangular safe corridor on the lateral aspect of the pons[7]. All measurements were correlated with intraoperative neurophysiological monitoring data.

Z THE 13 BRAINSTEM SAFE ENTRY ZONES

#	Safe Entry Zone	Abbreviation	Anatomical Description	Key Boundaries	Surgical Approach(es)
MIDBRAIN (3 zones)					
1	**Anterior Mesencephalic Zone**	AMZ	Limited area on the cerebral peduncle within the interpeduncular cistern	CN III medially, CST laterally, PCA superiorly, SCA inferiorly	Orbitozygomatic, Subtemporal
2	**Lateral Mesencephalic Sulcus**	LMS	Sulcus separating peduncular and tegmental surfaces; avg. length 9.6mm	Substantia nigra anterolaterally, medial lemniscus posteriorly	Subtemporal, Subtemporal transtentorial
3	**Intercollicular Region**	ICR	Area between superior and inferior colliculi on the quadrigeminal plate	Superior colliculi (visual), inferior colliculi (auditory)	Median & extreme lateral supracerebellar
PONS (6 zones)					
4	**Peritrigeminal Zone**	PTZ	Anterolateral pons, anterior to CN V; mean depth 11.2mm to trigeminal nuclei	CN V laterally, CST medially (4.64mm distance)	Retrosigmoid, Anterior petrosectomy, Retrolabyrinthine
5	**Supratrigeminal Zone**	STZ	Above CN V root entry zone on middle cerebellar peduncle	Pontine transverse fibers, posterior to CST	Retrosigmoid
6	**Lateral Pontine Zone**	LPZ	Junction of middle cerebellar peduncle and pons, between CN V and CN VII/VIII	CN V superiorly, CN VII/VIII inferiorly	Retrosigmoid, Retrolabyrinthine
7	**Supracollicular Zone**	SCZ	Suprafacial triangle on 4th ventricle floor, above facial colliculus	Facial nerve caudally, cerebellar peduncles laterally, MLF medially	Suboccipital telovelar
8	**Infracollicular Zone**	ICZ	Infrafacial triangle, below facial colliculus; 9.2mm vertical extent	Striae medullaris caudally, facial nerve laterally, MLF medially	Suboccipital telovelar
9	**Median Sulcus of 4th Ventricle**	MS	Midline approach between CN VI and CN III nuclear projections	MLF laterally (risk of extraocular movement disorders)	Suboccipital telovelar
MEDULLA OBLONGATA (4 zones)					
10	**Anterolateral Sulcus**	ALS	Lateral to pyramid, between CN XII rootlets and C1 nerve	CST decussation; paramedian oblique dissection	Far lateral
11	**Posterior Median Sulcus**	PMS	Below obex, restricted laterally by clava covering gracile nucleus	Similar to intramedullary spinal cord approach	Suboccipital telovelar
12	**Olivary Zone**	OZ	Through the olive; safe depth 4.7–6.9mm, vertical length 13.5mm	CN XII & medial lemniscus medially, spinothalamic tract posteriorly	Far lateral
13	**Lateral Medullary Zone**	LMZ	Through inferior cerebellar peduncle via foramen of Luschka	Inferior to cochlear nuclei, posterior to CN IX/X origins	Retrosigmoid

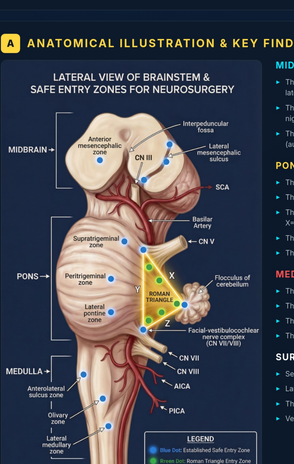
13 TOTAL SAFE ENTRY ZONES

3 zones MIDBRAIN

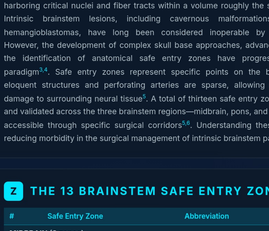
6 zones PONS

4 zones MEDULLA OBLONGATA

D DATA OVERVIEW



A ANATOMICAL ILLUSTRATION & KEY FINDINGS



MIDBRAIN ENTRY ZONES

- The **Anterior Mesencephalic Zone** provides access through the cerebral peduncle, bounded by CN III medially and the corticospinal tract laterally, between the PCA and SCA
- The **Lateral Mesencephalic Sulcus** (avg. 9.6mm length) separates peduncular from tegmental surfaces, running between the substantia nigra and medial lemniscus
- The **Intercollicular Region** on the quadrigeminal plate offers a corridor through sparse fibers between the superior (visual) and inferior (auditory) colliculi

PONTINE ENTRY ZONES

- The **Peritrigeminal Zone** provides the deepest working corridor (11.2mm) on the anterolateral pons, with 4.64mm clearance from the CST
- The **Supratrigeminal** and **Lateral Pontine Zones** offer access above and below CN V, respectively, through the middle cerebellar peduncle
- The **Roman Triangle** (infratrigeminal supraflocculer zone) is delimited by CN V, CN VII/VIII, and the flocculus, with mean measurements: X=14.41mm, Y=13.1mm, Z=3.0mm, area=20.1mm²
- The **Supracollicular** and **Infracollicular Zones** on the 4th ventricle floor provide dorsal access above and below the facial colliculus
- The **Median Sulcus** of the 4th ventricle allows midline entry but carries risk of MLF damage

MEDULLARY ENTRY ZONES

- The **Anterolateral Sulcus** provides access lateral to the pyramids between CN XII rootlets and C1
- The **Olivary Zone** allows entry through the olive with a safe depth of 4.7–6.9mm over 13.5mm vertical length
- The **Posterior Median Sulcus** below the obex mirrors the intramedullary spinal cord approach
- The **Lateral Medullary Zone** through the inferior cerebellar peduncle accesses dorsolateral lesions via the foramen of Luschka

SURGICAL PLANNING PRINCIPLES

- Selection of approach depends on lesion location relative to the brainstem surface and the closest safe entry zone
- Large lesions may distort safe entry zones; **neurophysiological monitoring** is a critical adjunct
- The **retrosigmoid approach** provides the most versatile access, reaching 4 different safe entry zones
- Ventral approaches are often avoided due to rich motor tracts, but may be used in select anterior midbrain cases

C CONCLUSIONS

The brainstem, once considered an impenetrable fortress, can be safely approached through thirteen well-defined safe entry zones distributed across the midbrain, pons, and medulla oblongata. Each zone has specific anatomical boundaries, morphometric parameters, and is accessible through one or more of ten major surgical approaches. The lateral pontine triangle (Roman Triangle), delimited by the trigeminal nerve, the flocculus of the cerebellum, and the vestibulocochlear complex, represents a particularly reliable entry zone with consistent anatomical landmarks present in 100% of specimens studied[7]. A detailed understanding of the anatomy, area of exposure, and safe entry zones for each major approach allows for improved surgical planning and dissemination of the techniques required to successfully resect intrinsic brainstem lesions, transforming what was once considered inoperable into a manageable surgical challenge[5,8].

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