Anterior, Posterior and Lateral Approaches to the Brainstem

(Ön, Arka ve Yandan Beyin Sapına Yaklaşımlar)

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Abstract: The aim of this study was to demonstrate posterior, postero-lateral, lateral, antero-lateral and anterior approaches to the brainstem, and to discuss the indications for each approach. Twenty cadaver head specimens (40 sides in total) were used bilaterally to demonstrate different approaches to the brainstem. The posterior approaches were supracerebellar, combined supra- and infratentorial-transsinus, subtonsillar-transcerebellomedullary, and midline transvermian approaches. The postero-lateral approaches were retrosigmoid, trans-sigmoid, and extreme lateral-transcondylar approaches. From the lateral direction, subtemporal-transzygomatic and petrosal approaches were studied. From the antero-lateral aspect of the skull, we performed orbitozygomatic-transsylvian approach, and the anterior approach studied was transmaxillary-transoral approach. Three-hundred and sixty degree visualization of the brainstem was achieved with all these approaches.. The instrument distance required to reach the brainstem via the anterior and posterior approaches was greater than that required with the antero-lateral, lateral, and postero-lateral approaches. A variety of neurosurgical approaches are used to access the brainstem. Good knowledge of the surgical anatomy and of the indications for each approach are essential. However, safely gaining access to the brainstem is always challenging, and further research is needed in this area.
Key Words: Brain stem, skull base, surgical approach

Özet: Bu çalışma, posterior, postero-lateral, lateral, antero-lateral ve anteriordan beyin sapına cerrahi yaklaşımları ortaya koymak ve cerrahi endikasyonlarını tartışmak amacı ile gerçekleştirildi. Çalışmada iki taraflı olarak 20 kadavra spesimeni kullanıldı. Posteriordan: Supraserebellar, kombine supra –ve infratentoryal-transsinüs, subtonsiller-transserebellomedüller, orta hat transvermian; postero-lateralden: retrosigmoid, transsigmoid, uzak lateral-transkondiler; lateralden: subtemporal-transzigomatik, petrozal; antero-lateralden: orbitozigomatik-transsylvian; ve anteriordan: transmaksiller-transoral yaklaşımlar uygulandı. Tüm yaklaşımlar kullanılarak kafatasının her yönünden beyin sapına 360 derece yaklaşım sağlandı. Anterior ve posterior yaklaşımlarda, antero-lateral, lateral ve postero-lateral yaklaşımlarla karşılaştırılınca, beyin sapına ulaşabilmek için daha uzun enstrüman mesafesine ihtiyaç olduğu gözlendi. Sonuç olarak, beyin sapına ulaşmak amacı ile farklı nöroşirürjik yaklaşımlar uygulanabilir. Her yaklaşım için cerrahi anatominin iyi bilinmesi ve endikasyonun doğru konulması gereklidir. Bununla birlikte, beyin sapına güvenli bir şekilde giriş yolları hala sorgulanmakta ve daha ileri çalışmaları gerektirmektedir.

Anahtar Kelimeler: Beyin sapı, cerrahi yaklaşım, kafa tabanı

INTRODUCTION

A variety of skull base approaches are used to access the surface of the brainstem (2, 13, 14, 24). To minimize morbidity and mortality, it is crucial to gain maximum exposure via the most direct route. The decision regarding which approach should be used must also take into account the neurosurgeon's knowledge of the anatomy involved, and whether he or she is prepared to perform the technique.

However, even when the surgeon has all the necessary anatomical information, it is always a challenge to access the brainstem safely (2, 6, 10, 22, 24). This report describes the important anatomy in several approaches to the brainstem, and discusses the various strategies for removing lesions in the brainstem.

MATERIAL AND METHOD

Twenty cadaver head specimens (a total of 40 sides) injected with microfil were used to demonstrate several approaches to the brain stem surface.

SURGICAL APPROACHES TO THE BRAINSTEM SURFACE

Approaches to the brainstem from the posterior, postero-lateral, lateral, antero-lateral and anterior aspects of the skull enable the surgeon to reach lesions in a variety of locations (Table 1) (Figure 1).

Table 1: Anterior, posterior and lateral approaches to the brainstem

Anterior, Posterior and Lateral Approaches to the Brainstem
Posterior
- Supracerebellar
- Combined Supra and Infratentorial - Transsinus
- Subtonsillary Transcerebellomedullary
- Midline Transvermian
Postero-Lateral
- Retrosigmoid
- Transsigmoid
- Extreme Lateral, Transcondylar
Lateral
- Subtemporal Transzygomatic
- Petrosal
Partial Labyrinthectomy
Retrolabyrinthine
Translabyrinthine
Antero-Lateral
- Orbitozygomatic-Transsylvian
Anterior
- Transmaxillary-Transoral
- Transbasal

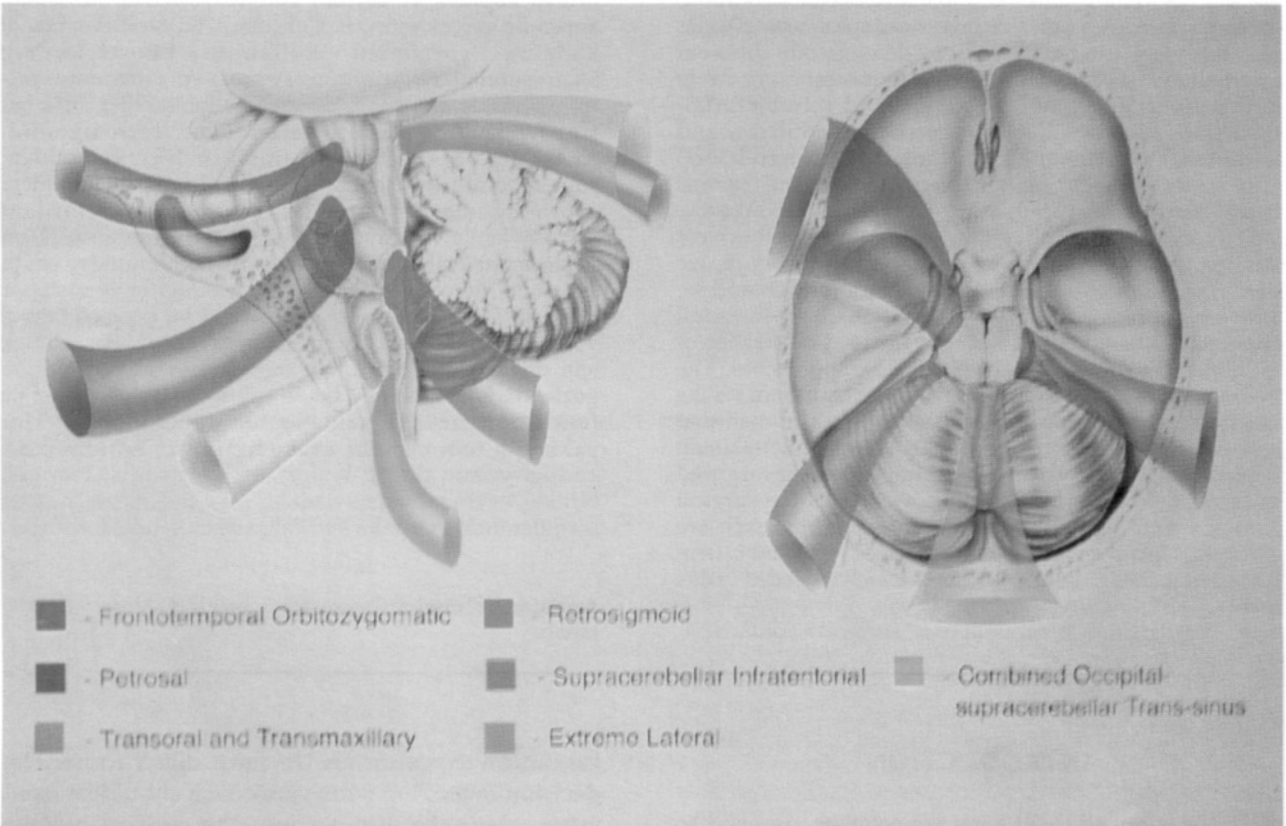

Figure 1: Surgical approaches to the brainstem

Posterior Approaches:

Posterior approaches to the brainstem are used when the lesion is situated in the collicular plate, or close to the pial surface of the fourth ventricle. For lesions of the dorsal mesencephalon and collicular plate, the supracerebellar infratentorial approach (6, 19, 21), the occipital transtentorial approach (7, 8), or the combined supra- and infratentorial transsinus approach (Figure 2) may be used (17, 28). For lesions at the midline or in the fourth ventricle, a transvermian approach (4, 15) is necessary. However, excessive splitting of the vermis may lead to permanent truncal ataxia. For lesions of the ponto-medullary junction and the medulla that are located

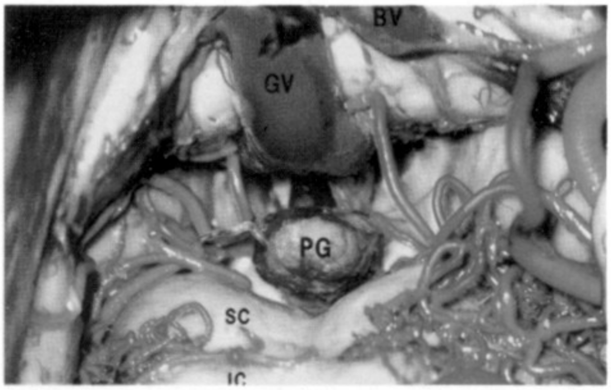

Figure 2: The superior and inferior colliculi after a combined supra/infratentorial-transsinus approach (BV: basal vein of Rosenthal, GV: Galen's vein, PG: pineal gland, SC: superior colliculus, IC: inferior colliculus)

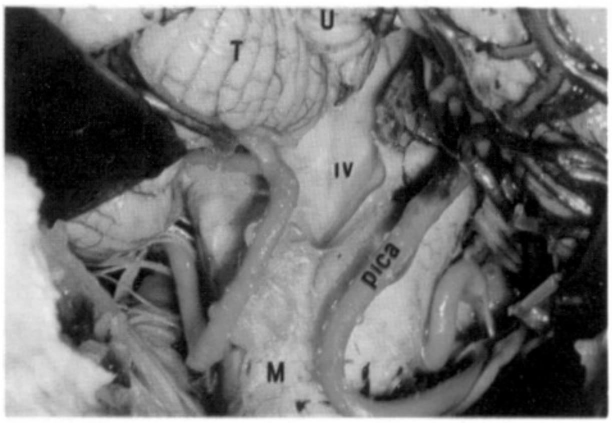

Figure 3: In the subtonsillary transcerebellomedullary approach, the cerebello-medullary fissure was opened, the right tonsil was resected, and the left tonsil was retracted. This wide exposure allowed visualization of the distal segments of the PICA, the lateral recess of the fourth ventricle and the posterior part of the brainstem (U: uvula, T: tonsil, IV: fourth ventricle, pica: posterior inferior cerebellar artery, M: medulla)

in the lateral part of the fourth ventricle, the best method is the subtonsillar-transcerebellomedullary approach (Figure 3) (2, 11, 22, 23). In this technique, the cerebellar tonsils are mobilized and the cerebello-medullary fissure is opened, but there is no splitting of the cerebellar vermis. In some cases, it may be necessary to resect one tonsil (23).

Postero-Lateral Approaches:

For ponto-medullary lesions that present in the middle or inferior cerebellar peduncles, or in the olivary area, a far-lateral retrosigmoid approach is optimal. Extreme-lateral transcondylar or retrocondylar approaches (16, 27) can be used to reach the lateral and antero-lateral surface of the medulla, and the cervico-medullary junction (Figure 4A and B). A combined retro- and pre-sigmoid approach (26) with sectioning of a non-dominant, well collateralized sigmoid sinus (the transsigmoid approach) may be useful for accessing some lesions (Figure 5A and B). However, when the lesion is located in the cervico-medullary area and is anterior in the midline, the exposure provided may still be inadequate.

Lateral Approaches:

The petrosal approach (1, 20, 26) (retrolabyrinthine, partial labyrinthine or translabyrinthine) can be used to expose lesions of the pons that are situated anteriorly and anterolaterally. This technique is also used to expose lesions on the lateral aspect of the midbrain (Figure 6A and B).

Antero-Lateral Approaches:

Lesions located close to the anterior surface of the midbrain are best removed via fronto-temporal, orbito-zygomatic (9, 18), pterional-transsylvian(21) or anterior subtemporal approaches (Figure 7).The transsylvian approach is preferred for lesions that are antero-medial to the cerebral peduncles, and the transtentorial subtemporal approach is best for those located anterolaterally at the level of the medial (spinal) lemniscus and lateral geniculate body. The sixth cranial nerve in the ambient cistern is the only clearly identifable structure on the surface of the mesencephalon.

Anterior Approaches:

Both transmaxillary and transoral approaches (12, 25) can be used to access lesions of the medulla and pons that are located anteriorly and on the midline (Figure 8A and B). Due to the high risk of cerebrospinal fluid (CSF) leakage and infection, these approaches should only be used when no other option is available. Careful dural closure or repair, and protracted lumbar CSF drainage are necessary to promote healing. When attempting to reach the anterior brainstem, the transbasal approach (5) is another optional corridor (Figure 9A and B).

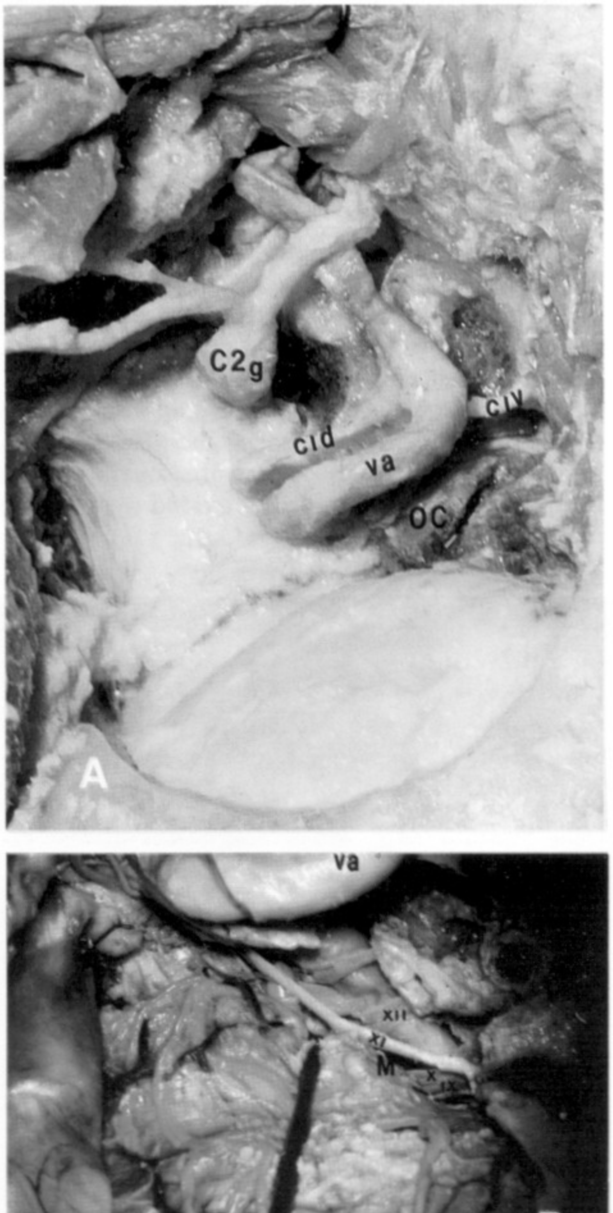

Figure 4A and B: Extreme lateral transcondylar or retrocondylar approaches can be used to reach the lateral and antero-lateral surfaces of the medulla, and the cervico-medullary junction (C2g: C2 ganglion, va: vertebral artery, OC: occipital condyle, cıd: cı dorsal root, cıv: cı ventral root, M: medulla, IX-X-XI and XII: lower cranial nerves).

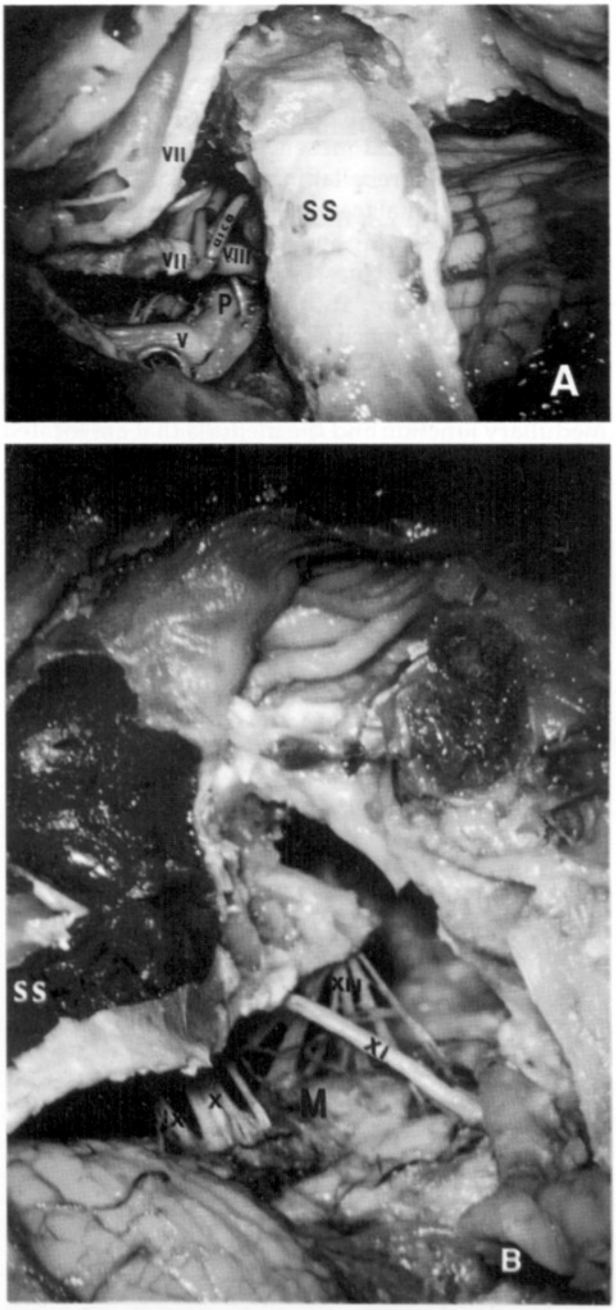

Figure 5A and B: A combined retro- and presigmoid approach with the sectioning of a non-dominant, well collateralized sigmoid sinus (the trans-sigmoid approach) may be useful for accessing some lesions. The figures of a laterally placed specimen's right side show presigmoid and retrosigmoid areas without (A) and with (B) sectioning of the transverse sinus. The relationship of lower cranial nerves with the brainstem and their exit through the juguler foramen and the hypoglossal canal is demonstrated on Figure 5B. (SS: sigmoid sinus, P: pons, V: trigeminal nerve, VII: facial nerve, VIII: vestibulocochlear nerve, aica: anterior inferior cerebellar artery, M: medulla, IX-X-XI and XII: lower cranial nerves).

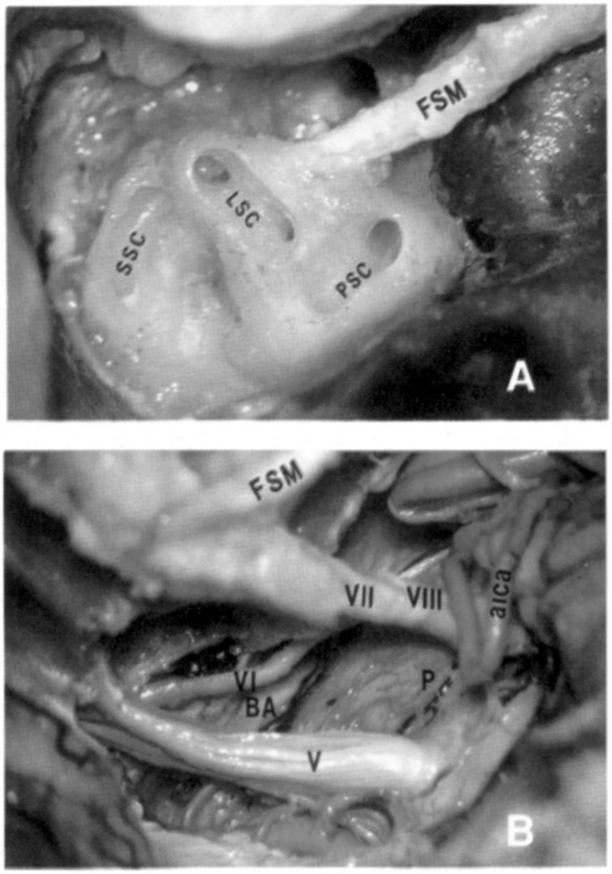

Figure 6A and B: A petrosal approach (retrolabyrinthine, partial labyrinthine or trans-labyrinthine) can be used to expose lesions involving the pons. Figure A shows the labyrinth and Figure B shows the wide exposure achieved after removal of labyrinth (FSM: mastoid segment of the facial nerve, SSC-LSC and PSC: superior, lateral and posterior semicircular canals, P: pons, V: trigeminal nerve, VI: abducens nerve VII: facial nerve, VIII: vestibulocochlear nerve, BA: basilar artery, aica: anterior inferior cerebellar artery).

RESULTS

In each of the different approaches, we achieved 360-degree visualization of the brainstem. The instrument distance required in the anterior and posterior approaches was greater than that required in the antero-lateral, lateral and postero-lateral approaches. Table 2 summarizes the strategies and zones that have been investigated for accessing lesions in the brainstem.

DISCUSSION

Treatment of brainstem lesions requires two major steps. First, the surgeon must select the approach that will best expose the affected area. Several important anatomical structures will be encountered in any of the techniques. To avoid damaging these structures, and to be able to visualize the appropriate surface of the brainstem, the path to the lesion should be as direct as possible, and should allow maximum exposure of the area of interest. As noted above, we found that the antero-lateral, lateral and postero-lateral approaches were more direct than the anterior and posterior approaches. Even among variations of any given approach, skin-brainstem distances may differ. For example, of the various anterior approaches, the transbasal approach involves a longer skin – brainstem distance than the transoral approach. However, the transbasal approach for brainstem lesions is very complicated and, although it is theoretically possible, this method is rarely necessary.

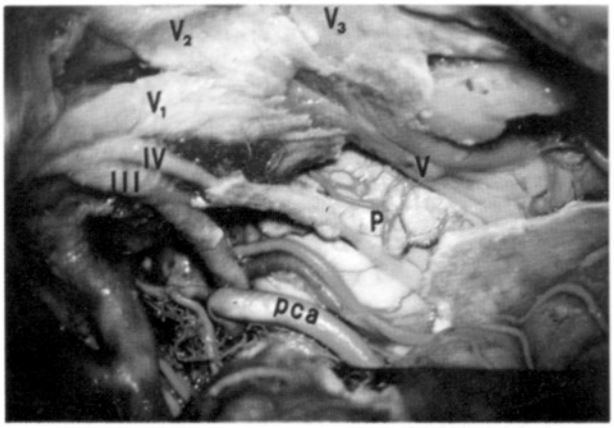

Figure 7: Lesions located on or near the anterior surface of the midbrain are best removed by fronto-temporal, orbito-zygomatic, transsylvian or anterior subtemporal approaches. The figure shows the combination of the orbito-zygomatic and subtemporal approaches at the righ side of the specimen. Anterior part of the tentorium is cut and removed. The relationship of cranial nerves III and V with the brainstem are demonstrated.(Cranial nerves: III, IV, V and V1-V2-V3, P: pons, pca: posterior cerebral artery) .

The second step is removal of the lesion, which may be deep or superficial in the brainstem. If the lesion is on the surface, tissue manipulation is easier and safer. Hovewer, it is difficult to expose deep-seated lesions without causing morbidity. Regarding brainstem anatomy, it is generally considered that motor tracts remain in the anterior portion; sensory tracts, cranial nerves and the vestibular nuclei occupy the posterior and lateral aspects; and the tegmentum

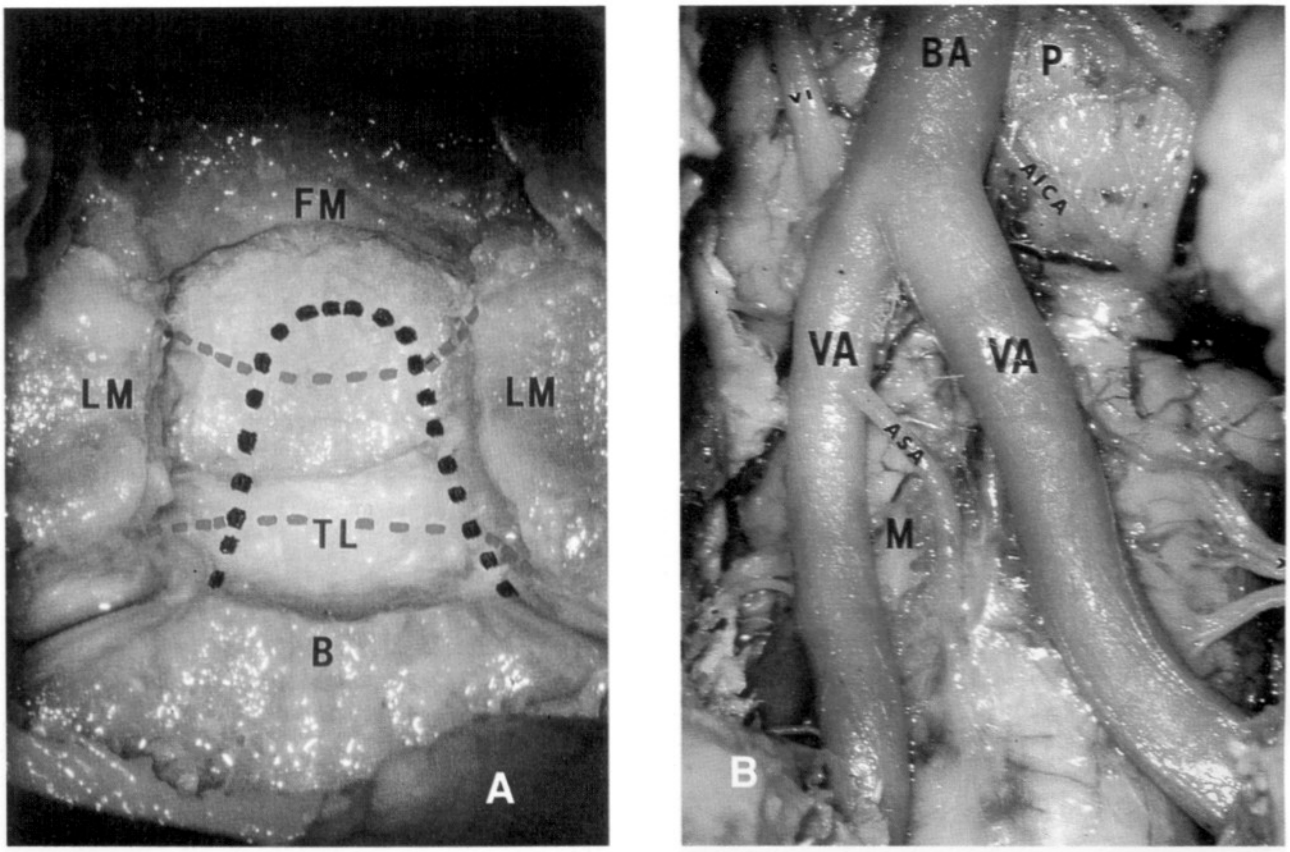

Figure 8A and B: A: Using the transoral approach, after removal of the C1 vertebral arch (red dotted line) and the odontoid process (black dotted line), the transvers ligament (TL) is exposed (FM: foramen magnum, LM: lateral mass of C1, B: body of C2). B: The transoral approach can be used for lesions of the medulla and pons that are located anteriorly in the midline. The figure demonstrates the pons and the medulla after opening of the clivus dura. (P: pons, M: medulla, BA: basilar artery, VA: vertebral artery, AICA: anterior inferior cerebellar artery, ASA: anterior spinal artery, VI: abducens nerve, XI: accessory nerve) .

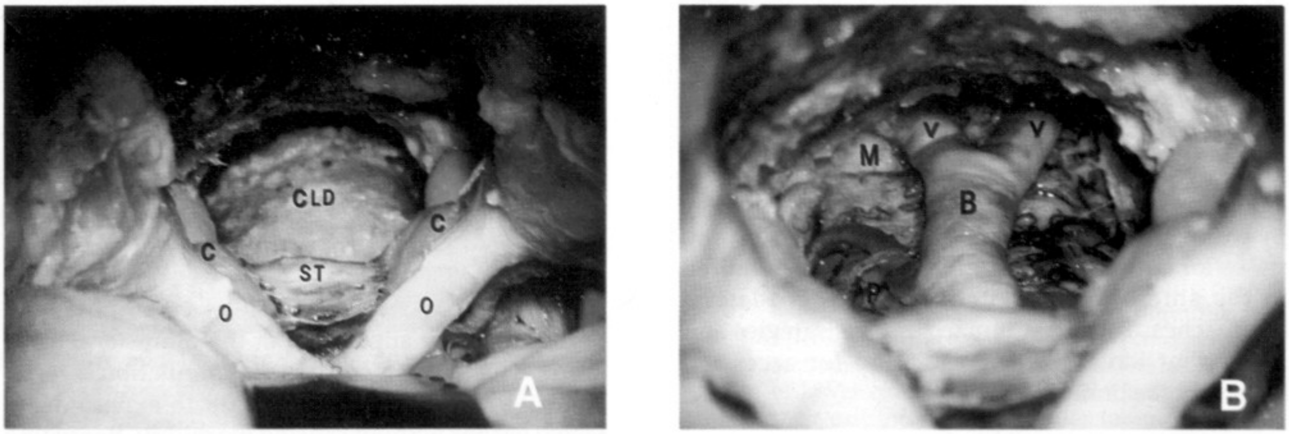

Figure 9A and B: A: After a bifrontal craniotomy and orbital osteotomy, and having passed through the ethmoid and sphenoid sinuses, the clivus is drilled anteriorly and the clivus dura is exposed (transbasal approach) (CLD: clivus dura, ST: sella turcica, C: carotid artery, O: optic nerve). B: The clivus dura is then opened and the basilar artery (B), vertebral arteries (V), medulla (M) and pons (P) are exposed.

and the medial longitudinal fasciculus occupy the middle and posterior portions. The majority of the brainstem vasculature enters and exits through the anterior and lateral surfaces, and damage to these vessels may have severe long-term effects.

Even though several reports have focused on this second step (2, 3, 10, 24), there is still controversy about how to minimize the brainstem damage, and more research is needed. Cantore et.al. divided the brainstem into six distinct areas around the reticular formation, which is located roughly at the center of the structure. The six divisions were the dorsal medulla, ventral medulla, dorsal pons, ventral pons, dorsal mesencephalon, and ventral mesencephalon (3). Kyoshima et.al. reported safe entry via sites in the floor of the fourth ventricle. These zones preserved the nuclei of the pairs of cranial nerves VI and VII, as well as the medial longitudinal fasciculus. The authors described two triangular sites, and named these zones the supra- and infrafacial triangles (10). Bricolo and Turazzi suggested entry through the floor of the fourth ventricle through the median sulcus at a point between the abducens and the oculomotor nuclei, as long as the two medial longitudinal fasciculi had no crossing fibers at that level (2). A summary of the findings regarding

Table 2: Methods of entering various parts of the brainstem (2, 3, 10, 24)

Part of the Brain Stem	Strategy and Entry Zone
Dorsal Medulla	Posterior medullotomy
Ventral Medulla	The paramedian oblique route a the level of the anterior latera sulcus between the radicles of th XII. cranial nerves and of C1 cervical root.
Dorsal Pons	Trans-fourth-ventricular approach (suprafacial and infrafacia triangles)
Ventral Pons	In front of the exit point of the V and/or VII-VIII cranial nerve pairs.
Dorsal Mesencephalon	Median intercollicular approach Trans-third ventricular approach (mesencephalic floor of the third ventricle)
Ventral Mesencephalon	Window bordered above by the posterior cerebral artery, below by the superior cerebellar artery medially by the emergence of II cranial nerve and the basilar artery and laterally by the pyramidal trac

options for brainstem entry sites is presented in Table 2.

In conclusion, this report describes several approaches that can be used to reach the brainstem surface; however, as mentioned, gaining entry to the brainstem is always challenging, and further investigation is needed to determine which techniques are safest.

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