Comparative Analysis of Endoscopic Endonasal Far-Medial, Far-Lateral Transcondylar and Combined Approaches to the Foramen Magnum Region: Volumetric Analysis and Quantitative Insights on Surgical Exposure and Maneuverability

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BACKGROUND

Surgical access to the anterior craniovertebral junction (CVJ) and foramen magnum region remains technically challenging due to dense neurovascular anatomy and limited working corridors. Although the far-lateral transcondylar and endoscopic far-medial approaches are both employed clinically, direct quantitative comparisons of maneuverability and volumetric exposure are still wanting.

OBJECTIVE

To quantitatively assess and compare surgical maneuverability, anatomic limits and volume of exposure of the endoscopic far-medial, far-lateral, and combined approaches.

METHODS

Five latex-injected cadaveric heads underwent dissection via an endoscopic endonasal far-medial approach (EEFM), contralateral far-lateral transcondylar approach (FL), and a combined approach. Surgical freedom, horizontal and vertical angles of attack, and volumetric exposure were measured using neuronavigation and 3D CT-based segmentation. Site-specific measurements were obtained at the hypoglossal canal, jugular foramen, and vertebrobasilar junction. Statistical comparisons were made using Wilcoxon rank-sum tests.

RESULTS

The FL demonstrated significantly greater surgical freedom (363 mm² vs. 6.8 mm², *P* = .01), horizontal angle of attack (99° vs. 8.1°, *P* = .01), and vertical angle of attack (78° vs. 15.4°, *P* = .01) compared to the EEFM. The EEFM yielded the smallest mean total volume (5.53 ± 2.01 cm³), primarily concentrated in the anteromedial compartment (4.70 ± 1.67 cm³). The FL offered a significantly larger mean total exposure (15.12 ± 1.93 cm³, p < 0.001), dominated by posterolateral access (12.60 ± 2.16 cm³, p < 0.001). The combined approach provided the greatest overall exposure volume (18.76 ± 3.58 cm³), with substantial access to both the posterolateral (12.90 ± 2.32 cm³) and anteromedial (5.86 ± 1.95 cm³) compartments.

CONCLUSION

The far-lateral approach offers superior surgical freedom and posterolateral exposure, while the far-medial endoscopic approach provides a direct but limited midline corridor predominantly anteromedial foramen magnum lesions. The combined approach maximizes volumetric access and should be considered for extensive foramen magnum lesions particularly engulfing or anterior to neurovascular structures.

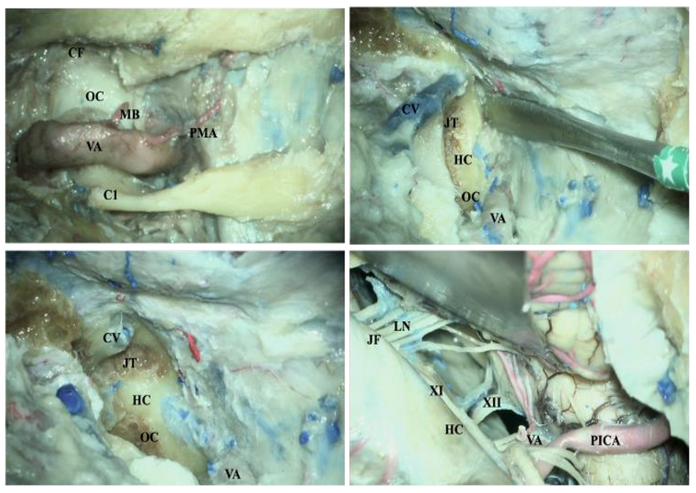

Figure 1. Far Lateral Cadaveric Anatomical Dissection. CF: Condylar Fossa, OC: Occipital Condyle, MB: Muscular Branch, VA: Verterbral Artery, PMA: Posterior Meningeal Artery, CV: Condylar Vein, JT: Jugular Tubercle, HC: Hypoglossal Canal, JF:Jugular Foramen, LN: Lower Cranial Nerves, XI: Cranial Nerve 11, XII: Cranial Nerve 12

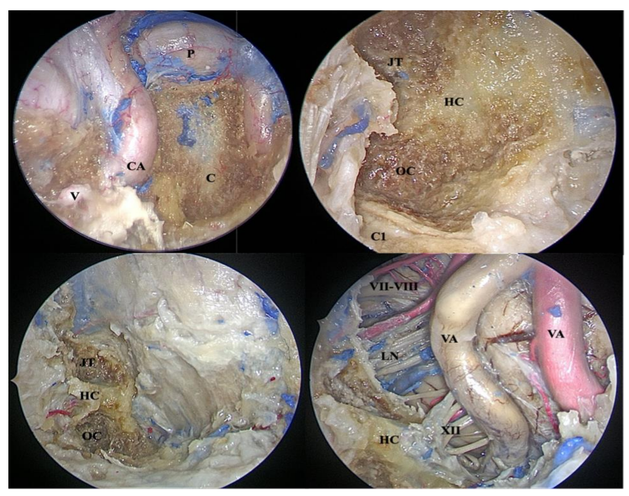

Figure 2. Far Medial Cadaveric Anatomical Dissection. P: Pituitary, CA: Carotid Artery, V: Vidian Nerve, C: Clivus, JT: Jugular Tubercle, HC: Hypoglossal Canal, OC: Occipital Condyle, VII-VIII: Cranial Nerves 7-8, LN: Lower Cranial Nerves, VA: Vertebral Artery, XII: Cranial Nerve 12

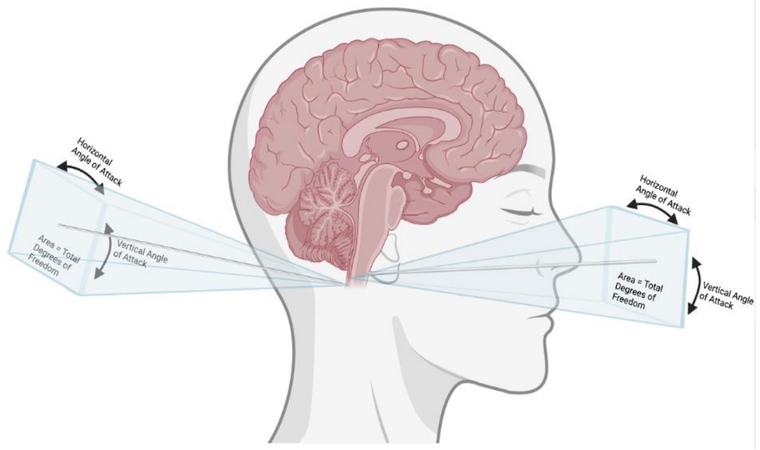

Figure 3. Surgical freedom and angles of attack in EEFM and FL approaches. The vertical and horizontal angles of attack define the limits of maneuverability and instrument reach at a fixed target point. The projected working envelope represents the total degrees of freedom, serving as a surrogate for surgical freedom. These parameters were quantitatively measured using neuronavigation for both far-medial endoscopic and far-lateral approaches to evaluate access to key anatomical targets

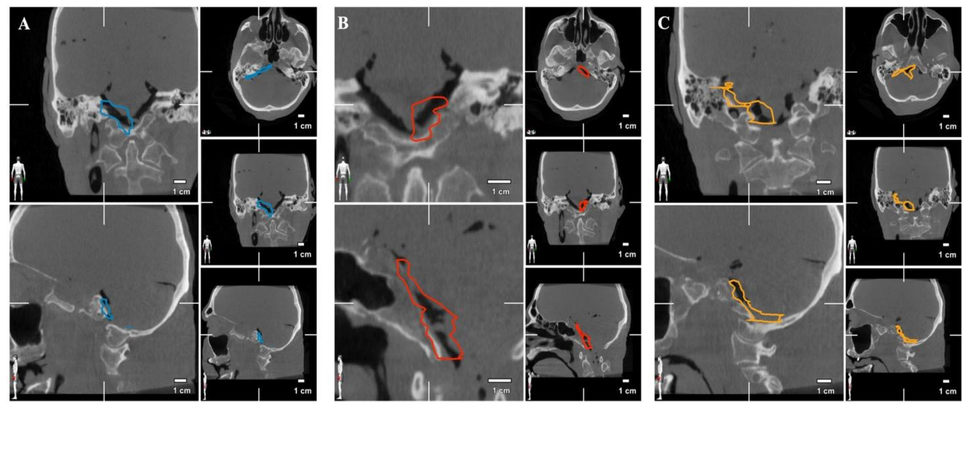

Figure 4. Brain Lab 3D volumetric exposure between the Far Lateral exposure (A), Endoscopic Endonasal Far Medial exposure (B) and Combined exposure (C).

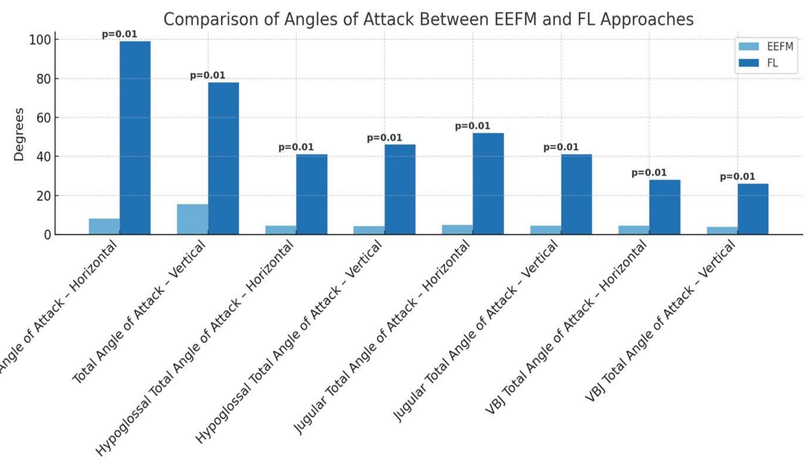

Figure 5. Comparison of angles of attack between far-medial endoscopic (EEFM) and far-lateral (FL) approaches. Bar graph illustrates the mean horizontal and vertical angles of attack (in degrees) at the hypoglossal canal, jugular foramen, and vertebrobasilar junction ($p < 0.05$, bolded).

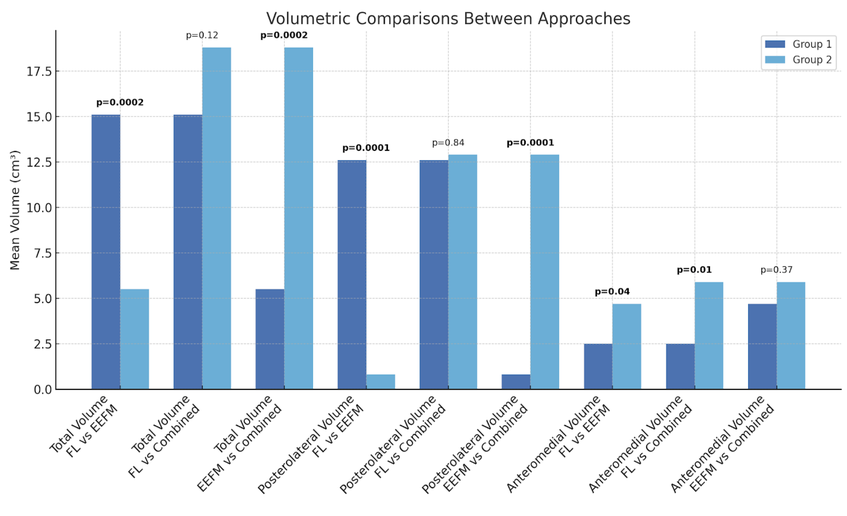

Figure 6. Volumetric comparison of surgical exposure between approaches to the foramen magnum region. Bar graphs display mean volumetric exposure for three key anatomical regions including total volume, posterolateral volume, and anteromedial volume across pairwise comparisons of far-lateral (FL), endoscopic endonasal far-medial (EEFM), and combined approaches. Blue bars represent mean values for each group. Statistically significant differences ($p < 0.05$) are annotated above each pairwise comparison and highlighted in bold.