

# A Morphometric Analysis of the Foramen Magnum and Occipital Condyle as it Relates to the Transcondylar Approach

Jefferson Pereira Sarmiento<sup>1</sup>, Ana Priscila Franca Correia<sup>1</sup>, Diego Furtado Rolim Lima<sup>1</sup>, Ícaro Magalhães<sup>1</sup>, Adára Maria de Holanda Melo Costa<sup>1</sup>, Carlos Augusto Menezes Vitorino<sup>1</sup>, Anaylle Vieira Lacerda de Oliveira<sup>1</sup>, Thales Henrique de Araújo Sales<sup>2</sup>, Jalles Dantas de Lucena<sup>1,3</sup>

<sup>1</sup>Medicine Course, Santa Maria University Center (UNIFSM), Cajazeiras, PB, Brazil

<sup>2</sup>Medical School Nova Esperança (FACENE/FAMENE). Department of Morphology, Medicine Course. Gramame, João Pessoa, PB, Brazil

<sup>3</sup>Medicine Course, INTA University Center (UNINTA), Itapipoca, CE, Brazil

**Disclose and conflicts of interest: none to be declared by all authors**

## ABSTRACT

**Introduction:** the posterior cranial fossa (PCF) is a part of the cranial cavity that contains important neurovascular structures. The anatomical knowledge of the foramen magnum (FM) and occipital condyle (OC) is essential to avoid damage to the PCF during lateral surgical approaches.

**Purpose:** to conduct a clinical and anatomical analysis of the FM and OC and its importance with the transcondylar approach.

**Methods:** 98 human skulls of individuals from Northeast Brazil were studied. Sexual dimorphism was evaluated according to the characteristics of Vanrell (2002). The longitudinal and transverse diameters of the FM and OC were measured with the help of a vernier caliper. The distance between the retrocondylar point (RP) and the basion was also measured. Student's t-test was applied to evaluate statistical difference between sexes on each side, using GraphPad Prism® for Windows version 6.0. Values of  $p < 0.05$  were considered significant.

**Results:** the transverse diameter of the FM is larger in men ( $p = 0.007$ ). Regarding the OC, the transverse diameter on the left side is statistically larger in men ( $p = 0.023$ ). The distance between the RP and the basion in men and women, was statistically insignificant ( $p > 0.05$ ). When comparing men and women, the longitudinal and transverse diameters of left OC were statistically larger in men ( $p = 0.004$  and  $p = 0.009$ , respectively). The distance from the RP to the basion is statistically insignificant between sexes.

**Conclusion:** we present unprecedented insights regarding the anatomy of the FM and OC in individuals from northeastern Brazil as well as its importance in the planning of lateral transcondylar approaches.

**Keywords:** Anatomy; Posterior cranial Fossa; Foramen magnum; Occipital condyle.

## Introduction

The posterior cranial fossa (PCF) is a part of the cranial cavity that contains several neurovascular structures, which enter and exit the neurocranium through the foramen magnum (FM), the hypoglossal canal (HC), the jugular foramen (JF) and the internal auditory canal (IAC)<sup>1</sup>. Various neural structures are in close vicinity to this area, such as the IX to XII cranial nerves, C1 and C2 spinal nerves, the caudal aspect of the medulla oblongata, the rostral aspect of the spinal cord, the inferior vermis, and the cerebellar tonsil. In addition, vascular structures such as vertebral, cerebellar, and meningeal arteries, as well as dural and venous sinuses, and also the internal jugular vein are also closely associated with this area<sup>1-3</sup>.

Anatomical and morphometric knowledge is essential to prevent damage to the PCF during lateral surgical approaches, which are used to treat pathologies that affect this region, as important neurovascular structures that are essential for life

maintenance pass through this area<sup>4</sup>. Additionally, understanding the morphology of structures within the PCF is crucial in craniovertebral surgeries, aiding in determining surgical zones and neurovascular boundaries, as errors in this region can result in high morbidity and mortality<sup>5</sup>.

The application of morphometric analysis of the FM is clinically relevant in the pathogenesis of various disorders that occur in the structures present in the PCF. For instance, the cervicomedullary junction may be compressed as a result of marked FM stenosis, resulting in neurologic manifestations<sup>6,7</sup>.

The occipital condyle (OC) represents the cranial portion of the craniovertebral junction. The OC is related to the HC laterally and slightly forward, the JF and IAC are lateral to each OC<sup>1</sup>. Craniovertebral surgeries require special attention about the morphology and morphometry of the OC and the structures surrounding it. Surgical mistakes in PCF may damage neurovascular structures, increasing

morbidity and mortality<sup>8</sup>. Further, anatomic knowledge of the morphometry of this area can provide important benefits in determining safe surgical zones during surgical procedures<sup>5,9</sup>.

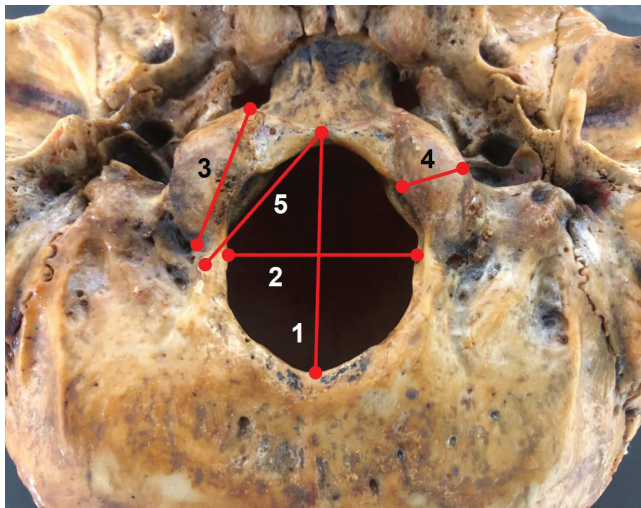
Although there are many studies determining the morphometry of the FM and OC<sup>10-13</sup>, there are only very few reports available regarding the clinical and anatomical importance of these structures in the perspective of the surgical transcondylar approach.

The objective of this study was to conduct a clinical and anatomical analysis of the FM and OC addressing their relation to the transcondylar approach.

## Material and Methods

A total of ninety-eight human skulls (60 males and 38 females) of individuals from northeastern Brazil, belonging to the Anatomy Department of the Federal University of Ceará (UFC) and the Nova Esperança Medical School (FAMENE) were analyzed. The skulls that were damaged or affected by pathological processes were excluded from the study. Sexual dimorphism was evaluated according to the characteristics shown in Vanrell's study<sup>14</sup>.

Linear measurements of FM and OC, i.e., longitudinal and transverse diameters (Figure 1), were taken with the help of a vernier caliper with



**Figure 1.** Inferior view of skull.

Legend: 1- longitudinal diameter of the FM; 2- transverse diameter of the FM; 3- longitudinal diameter of the OC; 4- transverse diameter of the OC; 5- distance of the RP and basion.

a minimum counting of 0.01 mm. The distance between the retrocondylar point (RP) and the basion was also measured.

For data analysis, the 2016 version of Word and Excel<sup>®</sup> were used to record the measurements and descriptions. Shapiro-Wilk test was used to verify the normal distribution of the data. The Student's t-test was applied to evaluate the existence of statistical

difference between the arithmetic mean on the right and left sides of the skulls. Also, it was analyzed the presence of gender differences in the cranium. It was used GraphPad Prism version 6.00 for Windows, La Jolla California USA. Values of  $p < 0.05$  were considered as statistically different.

The present study was elaborated in accordance with the Brazilian Federal Law 8.501 (November 30, 1992).

## Results

The mean longitudinal diameter of FM was found to be  $36.63 \pm 2.51$  mm and  $35.70 \pm 2.07$  mm in males and females, respectively, and the difference of the arithmetic mean was statistically insignificant ( $p > 0.05$ ). The obtained mean transverse diameter of FM was  $31.83 \pm 2.79$  mm and  $30.30 \pm 2.46$  mm in males and females, respectively, and in this case, difference of the arithmetic mean was statistically significant ( $p = 0.007$ ).

The mean longitudinal diameter of OC in males was  $21.99 \pm 2.84$  mm and  $22.18 \pm 2.91$  mm on the right and left sides, respectively, and the arithmetic mean difference was statistically insignificant ( $p > 0.05$ ). The mean transverse diameter of OC in males was  $11.50 \pm 1.24$  mm and  $12.12 \pm 1.71$  mm on the right and left sides, respectively, and the arithmetic mean difference was statistically significant ( $p = 0.023$ ). In female skulls, none of the OC measurements were statistically significant ( $p > 0.05$ ).

The mean distance between the RP and the basion in males was  $23.87 \pm 2.31$  mm and  $23.54 \pm 2.30$  mm on the right and left sides, respectively, and mean difference was statistically insignificant ( $p > 0.05$ ). In female skulls, this measure was also statistically insignificant ( $p > 0.05$ ).

In this study, none of the measures analyzed in the right OC between males and females were statistically different. In the left OC, the mean longitudinal and transverse diameter were statistically different between males and females,  $p = 0.004$  and  $p = 0.009$ , respectively.

The mean distance from the RP to the basion between males and females was found to be statistically insignificant ( $p > 0.05$ ).

**Table 1.** Foramen magnum (FM) dimensions in skulls in relation to gender. (Number: Male= 60; Female= 38)

Dimensions	Male (mean $\pm$ SD)	Female (mean $\pm$ SD)	P value
Longitudinal diameter of FM	$36.63 \pm 2.51$ (29.0-42.0)	$35.70 \pm 2.07$ (32.0-41.0)	$p > 0.05$
Transverse diameter of FM	$31.83 \pm 2.79$ (25.50-38.0)	$30.30 \pm 2.46$ (25.50-38.0)	$p = 0.007$

Legend: FM- Foramen magnum.

**Table 2.** Occipital condyle (OC) and retrocondylar point (RP) dimensions in skulls in relation to gender. (Number: Male= 60; Female= 38)

Dimensions	Male (mean $\pm$ SD)		Female (mean $\pm$ SD)		P value
	Right	Left	Right	Left	
Longitudinal diameter of OC	21.99 $\pm$ 2.84 (14.15-27.0)	22.18 $\pm$ 2.91 <sup>†</sup> (12.72-29.37)	20.85 $\pm$ 2.66 (14.98-28.50)	20.55 $\pm$ 2.20 <sup>†</sup> (14.48-25.0)	<sup>†</sup> 0.004
Transverse diameter of OC	11.50 $\pm$ 1.24* (8.79-14.0)	12.12 $\pm$ 1.71* <sup>†</sup> (8.0-15.43)	11.0 $\pm$ 1.46 (8.0-15.0)	11.22 $\pm$ 1.45 <sup>†</sup> (8.0-14.0)	*0.023; <sup>†</sup> 0.009
RP and basion	23.87 $\pm$ 2.31 (18.0-28.87)	23.54 $\pm$ 2.30 (20.0-29.0)	23.11 $\pm$ 2.40 (20.0-29.77)	22.95 $\pm$ 2.94 (13.0-29.40)	p>0.05

**Legend:** OC- occipital condyle; RP- retrocondylar point.

\*- Statistically significant difference intragroup.

<sup>†</sup>- Statistically significant difference between groups.

## Discussion

The knowledge of morphometry of the posterior cranial fossa is a prerequisite for surgical interventions in this region, especially with a transcondylar approach<sup>4</sup>.

The anteroposterior and transverse lengths of the FM are clinically important for calculating the surgical area. In this study, only the transverse diameter of the FM is statically different between men and women (p=0.007). This information differs from a previous study performed by our study group, where the anteroposterior and transverse diameters were found to be statically different between sexes<sup>11</sup>.

The transverse diameter was 31.83 $\pm$ 2.79 mm in men and 30.30 $\pm$ 2.46 mm in women. In other studies, the mean transverse diameter was reported differently, from 29.5 mm to 31.6 mm in men and from 27.1 to 29.4 in women; the reported diameters are larger in men than in women<sup>15-26</sup>.

Due to deep locations of some tumors anterior to the brainstem, a detailed anatomy analysis of this region is important before any surgery, to aid in the proper planning of the management. Variations in the morphology of FM should be considered during radiological diagnostic procedures and surgical approaches in the area. Previous studies have shown that this variability may be due to sexual dimorphism, differences in population types, and ethnic groups<sup>23,27</sup>.

In this study, none of the measures analyzed in the right OC between men and women were statistically different (p>0.05). Concerning the left OC, the mean longitudinal and transverse diameters were found to be statistically larger in men (p=0.004 and p=0.009, respectively). This result differs from another study performed by our research group<sup>13</sup>, which showed that upon comparing the genders, the longitudinal

diameter on both right and left side was larger in men (p<0.0001). Regarding the transverse diameter, the OC in males are larger only on the right side (p<0.0013).

The distances between the RP and the basion are also important anatomical features. In this study, it was found no statistical difference in the measurement of the RP to the basion between men and women (p>0.05).

These quantitative data are important during a condylectomy procedure, as shorter OC may be more susceptible to occipitocervical instability, while long OC may require a more extensive resection for better visualization<sup>28,29</sup>.

Techniques such as partial and far lateral transcondylar approaches may require partial or complete removal of the OC<sup>28,30,31</sup>. Kizilkanat *et al.*<sup>9</sup>, mention the importance of knowing the length and width of the OC during surgery to remove the posterior third of this structure. The dimensions and orientation of the OC may affect the surgical approach to craniocervical injuries<sup>31</sup>. Different studies state that variable morphometry of the OC may result from distinct genetic characteristics of among populations<sup>9,32</sup>.

## Conclusion

We present unprecedented insights regarding the anatomy of the FM and OC in individuals from northeastern Brazil. The understanding of the morphometric differences in the transverse diameter of the foramen magnum and left occipital condyle in male and female skulls is essential in the planning of lateral suboccipital approaches, retrocondylar or transcondylar, to access ventral lesions at the craniocervical junction without injuring neurovascular structures, such as the hypoglossal nerve.

## References

1. Standring S, editor. Gray's Anatomy. The Anatomical Basis of Clinical Practice. 40<sup>th</sup> ed. Edinburg: Churchill & Livingstone; 2008. p. 423-34.
2. Wen HT, Rhoton AL, Jr, Katsuta T, de Oliveira E. Microsurgical anatomy of the transcondylar, supracondylar, and paracondylar extensions of the far-lateral approach. J Neurosurg 1997;87:555-85.

3. Liu JK, Rao G, Schmidt MH, Couldwell WT. Far lateral transcondylar transtuberular approach to lesions of the ventral foramen magnum and craniovertebral junction. *Contemp Neurosurg* 2007;29:1-7.
4. Oberman DZ, Zabala PJ, Tomás L. Morfometría de la fosa craneal posterior: Importancia en los abordajes retrocondíleos. *Rev Argent Anat Online* 2015;6(2):87-92.
5. Oberman DZ, Baldoncini M, Rabelo NN, Ajler P. Morphometric analysis of posterior cranial fossa and surgical implications. *J Craniovertebr Junction Spine* 2021;12(2):178-82.
6. Hecht JT, Bodensteiner JB, Butler IJ. Neurologic manifestations of achondroplasia. *Handb Clin Neurol* 2014;119:551-63.
7. Samara OA, Amarín JZ, Badran DH, Al-Khayat OW, Suradi HH, Shatarat AT, Hadidi MT. Morphometric analysis of the foramen magnum. *Int J Morphol* 2017;35(4):1270-75.
8. Funaki T, Matsushima T, Peris-Celda M, Valentine RJ, Joo W, Rhoton AL, Jr. Focal transnasal approach to the upper, middle, and lower clivus. *Neurosurgery* 2013;73:ons155-90.
9. Kizilkanat ED, Boyan N, Soames R, Oguz O. Morphometry of the hypoglossal canal, occipital condyle, and foramen magnum. *Neurosurg Q* 2006;16:121-5.
10. Damiani D, Borelli NS, Melo HJF, Lima RS, Nobeschi L. Morphometry and spatial correlation of the foramen magnum and spinal cord through the magnetic resonance in normal young adults – anatomical and clinical aspects. *J Morphol Sci* 2012;29:87-90.
11. Lucena JD, Sanders JVS, Brito HM, *et al.* Morphometric Analysis of the Foramen Magnum in Dry Human Skulls in Northeastern Brazil. *J Morphol Sci* 2019;36:97-104.
12. Gumussoy I, Duman SB. Morphometric analysis of occipital condyles using alternative imaging technique. *Surg Radiol Anat* 2020;42(2):161-9.
13. Cavalcante LL, Soares CVA, Borba SDF, *et al.* Morphological Analysis of Occipital Condyles in Dry Human Skulls in Northeast Brazil. *J Morphol Sci* 2023;40:31-36.
14. Vanrell JP. *Odontología legal e antropología forense*. 1ª ed. Rio de Janeiro: Guanabara Koogan; 2002.
15. Sendemir E, Savci G, Cimen A. Evaluation of the foramen magnum dimensions. *Kaibogaku Zasshi* 1994;69(01):50-2.
16. Murshed KA, Çiçekbaşı AE, Tuncer I. Morphometric evaluation of the foramen magnum and variations in its shape: a study on computerized tomographic images of normal adults. *Turk J Med Sci* 2003;33:301-6.
17. Uysal S, Gokharman D, Kacar M, Tuncbilek I, Kosa U. Estimation of sex by 3D CT measurements of the foramen magnum. *J Forensic Sci* 2005;50(06):1310-14.
18. Manoel C, Prado FB, Caria PHF, Groppo FC. Morphometric analysis of the foramen magnum in human skulls of Brazilian individuals: its relation to gender. *Braz J Morphol Sci* 2009;26:104-8.
19. Gapert R, Black S, Last J. Sex determination from the foramen magnum: discriminant function analysis in an eighteenth and nineteenth century British sample. *Int J Legal Med* 2009;123(01):25-33.
20. Tubbs RS, Griessenauer CJ, Loukas M, Shoja MM, Cohen-Gadol AA. Morphometric analysis of the foramen magnum: an anatomic study. *Neurosurgery* 2010;66(02):385-8.
21. Burdan F, Umlawska W, Dworzański W, *et al.* Anatomical variances and dimensions of the superior orbital fissure and foramen ovale in adults. *Folia Morphol (Warsz)* 2011;70(04):263-71.
22. Burdan F, Szumilo J, Walocha J, *et al.* Morphology of the foramen magnum in young Eastern European adults. *Folia Morphol (Warsz)* 2012;71(04):205-16.
23. Chethan P, Prakash KG, Murlimanju BV, *et al.* Morphological analysis and morphometry of the foramen magnum: an anatomical investigation. *Turk Neurosurg* 2012;22(04):416-9.
24. Raghavendra Babu YP, Kanchan T, Attiku Y, Dixit PN, Kotian MS. Sex estimation from foramen magnum dimensions in an Indian population. *J Forensic Leg Med* 2012;19(03):162-7.
25. Shanthi CH, Lokanadham S. Morphometric Study on Foramen Magnum of Human Skulls. *Med Sci* 2013;2:792-8.
26. Jain D, Jasuja OP, Nath S. Evaluation of foramen magnum in sex determination from human crania by using discriminant function analysis. *El Med J* 2014;2:89-92.
27. Singh D, Patnaik P, Gupta N. Morphology and morphometric analysis of the foramen magnum in dried adult skulls in North Indian region. *Int J Health Sci Res* 2019;9:36-42.
28. Naderi S, Korman E, Citak G, *et al.* Morphometric analysis of human occipital condyle. *Clin Neurol Neurosurg* 2005;107(3):191-9.
29. Kalthur SG, Padmashali S, Gupta C, Dsouza AS. Anatomic study of the occipital condyle and its surgical implications in transcondylar approach. *J Craniovertebr Junction Spine* 2014;5(2):71-7.
30. Yu Z, Ma X, Jiang J, *et al.* Feasibility of screw placement in the occipital condyle of Chinese patients for occipitocervical arthrodesis: a cadaveric study. *Turk Neurosurg* 2015;25:559-65.
31. Demir BT, Eşme S, Patat D, Bilecenoğlu B. Clinical and anatomical importance of foramen magnum and craniovertebral junction structures in the perspective of surgical approaches. *Anat Cell Biol* 2023;56(3):342-9.
32. Saluja S, Das SS, Vasudeva N. Morphometric analysis of the occipital condyle and its surgical importance. *J Clin Diagn Res* 2016;10:AC01-4.

### Mini Curriculum and Author's Contribution

1. Jefferson Pereira Sarmiento: discussion of the results and writing of the manuscript.
2. Ana Priscila Franca Correia: discussion of the results and writing of the manuscript.
3. Diego Furtado Rolim Lima: discussion of the results and writing of the manuscript.
4. Ícaro Magalhães: discussion of the results and writing of the manuscript.
5. Adára Maria de Holanda Melo Costa: discussion of the results and writing of the manuscript.
6. Carlos Augusto Menezes Vitorino: discussion of the results and writing of the manuscript.
7. Anaylle Vieira Lacerda de Oliveira: writing of the manuscript and orthographic revision of the manuscript.
8. Thales Henrique de Araújo Sales: discussion of the results and writing of the manuscript.
9. Jalles Dantas de Lucena: discussion of the results and writing of the manuscript, conception and design of the study.

Received: March 15, 2024

Accepted: April 7, 2026

Corresponding author

Jalles Dantas de Lucena

E-mail: jalledantas@gmail.com