Original Article

Morphometric analysis of posterior cranial fossa and surgical implications

ABSTRACT

Background: Posterior cranial fossa (PCF) is an important area in terms of anatomy and surgery. It is a common site of many neoplastic, vascular, and degenerative lesions. Craniovertebral surgeries require special attention regarding detailed information about the morphology and morphometry of this region. The aim of this study was to analyze the morphometric characteristics of PCF and distances between the inner base of the skull.

Materials and Methods: An observational, retrospective cross-sectional study was made. Fifty-five dry human skulls of unknown sex were measured ascertained using digital Vernier caliper with 0.01 mm precision.

Results: The morphometric analysis of the mean length and width of the FM was 34.51 mm and 29.85 mm, respectively. We found a significant difference ($P < 0.05$) among the distance between the posterior tip of occipital condyle and basion of the right and left sides.

Conclusion: According to our observations, the present study yielded detailed morphometry of the PCF and neurovascular relationship. It can facilitate successful instrumentation and minimize neurovascular injuries. Furthermore, it provides safe and suitable data for guiding neurosurgical procedures. The major limitation of this study was the lack of knowledge regarding the age and gender of the participants whose skull base was studied.

Keywords: Cranial morphometry, neuroanatomy, occipital condyle, posterior cranial fossa

INTRODUCTION

The posterior cranial fossa (PCF) is an important area in terms of anatomy and surgery. It is a common site of many neoplastic, vascular, and degenerative lesions.[1] Various neural structures are in close vicinity to this area, like IX to XII cranial nerves, C1 and C2 spinal nerves, caudal aspect of the medulla oblongata, rostral aspect of the spinal cord, inferior vermis, and tonsil of the cerebellum. In addition, vascular structures such as vertebral, cerebellar, meningeal arteries, dural venous sinuses, and internal jugular vein are also closely associated with it.[2,3]

Lateral approaches to the foramen magnum (FM) are frequently used to treat lesions located anteriorly to the brain stem and at the craniocervical junction (CCJ).[4] The occipital condyle (OC) represents the cranial portion of the cranial vertebral junction. Each OC is oriented obliquely, so that its anterior end lies closer to the midline. The OC is related to the hypoglossal canal directed laterally and slightly forwards, jugular foramen (JF) and internal auditory canal (IAC) is lateral to each condyle.

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Craniovertebral surgeries require special attention regarding detailed information about the morphology and morphometry of the OC and the structures surrounding it. Surgical mistakes in PCF may damage neurovascular structures and produce CCJ instability, increasing morbidity and mortality.[5] The fundamental goals of PCF surgery are to maximize bone removal and minimize brain retraction. Further, anatomic knowledge of the morphometry of this area can provide important benefits in determining safe surgical zones during surgical procedures.[6]

Although there are many studies determining the morphometry of the FM, OC, and HC, there are only a very few reports available of the distance between these intracranial foramina.[7-9]

The aim of this study was to accurately describe the anatomic morphometric parameters of the PCF and its relations with surrounding structures.

MATERIALS AND METHODS

The present study included 55 dry human skulls of unknown sex obtained from the department of anatomy of the Hospital Italiano de Buenos Aires. Skulls that were damaged or those with deformities, which may influence measurements, were excluded and only intact skulls in good condition were included. All linear measurements were ascertained using digital Vernier caliper with 0.01 mm precision.

Anatomical definitions

The anatomical key points were defined as follows:

- Length of the FM: Distance in a straight line from the end of the anterior border (basion) through the center of the FM until the end of the posterior border (opísthion), toward the median sagittal plane [Figure 1]
- Width of FM: Distance in a straight line from the end of the border right side, with the concavity stronger through the center of the FM to the opposite end of the lateral border of concavity more pronounced, with transverse direction [Figure 1]
- Length of OC: Maximum anteroposterior distance between the anterior and posterior tips of OC [Figure 1]
- Width of OC: Maximum transverse distance between the medial and lateral border of OC [Figure 1]
- Distance between the posterior tip of OC (POC) and basion [Figure 1]
- Distance between the POC and posterior tips of hypoglossal canal [Figure 2]
- Distance between the POC and the projection of the spine of the JF on the occipital bone [Figure 2]
- Distance between the POC and posterior tips of the IAC [Figure 2].

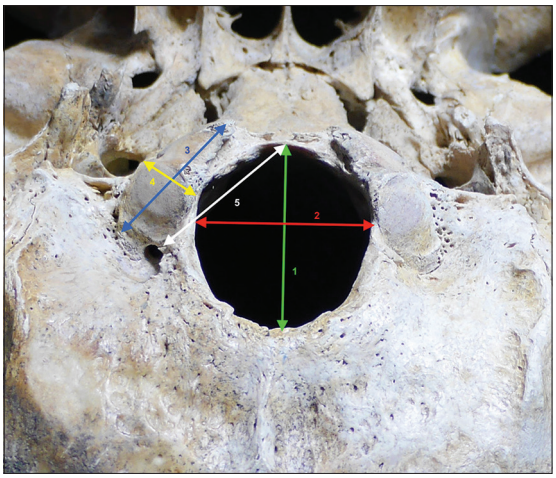

Figure 1: Inferior view of base of dry skull. Showing the length (1) and width (2) of the foramen magnum, the length (3) and width (4) of the occipital condyle and the distance between the posterior tips of the occipital condyle and the basion (5)

Statistical analysis

An observational retrospective cross-sectional study was made. All analyses were performed using the StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP (Stata for Macbook version 13.0). The Shapiro–Wilk test was used to test the normality assumption. Relative frequencies were calculated for the categorical data. Continuous data were expressed as mean ± standard deviation. The two-tailed independent sample *t*-test was performed to compare means between groups. $P < 0.05$ was considered to be statistically significant.

RESULTS

Morphometric study

The range, mean, and associated standard deviation of each parameter evaluation from right and left OC and the distance between the posterior tips of the OC to the HC, JF, and IAC, together with the FM are summarized in Table 1. We found no significant differences in laterality in any of the measurements, except between the distance of the POC and the basion ($P < 0.05$).

The mean length and width of the FM were 34.51 ± 2.53 mm and 29.85 ± 2.94 mm, respectively.

The mean length and width of the OC were 24.15±2.83 mm and 12.94 ±2.67 mm, respectively. The dimensions of both sides were comparable.

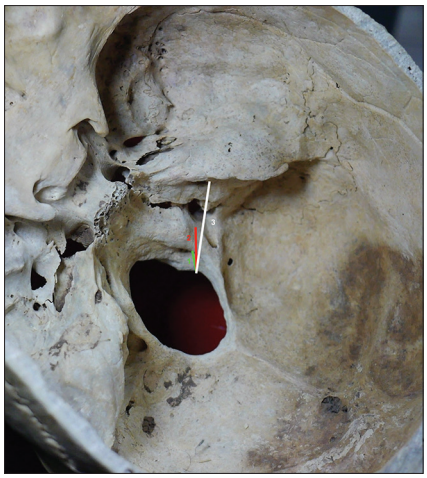

Figure 2: Superior view of posterior cranial fossa. Distance between the posterior tips of the occipital condyle and the hypoglossal canal (1), jugular foramen (2) and internal auditory canal (3)

Figure 3: Posterior view of the right pontocerebellar angle with upper cerebellar retraction. The vestibulocochlear nerve (1), the glossopharyngeal nerve (2), the vagus nerve (3), the accessory nerve (4), the hypoglossal nerve (5), the posteroinferior cerebellar artery (6) and the vertebral artery (7)

The mean distance of both sides between the posterior tips of the OC and the basion were 24.24 ± 1.94 and 24.98 ± 1.59 mm, respectively. We found a significant difference ($P < 0.05$) among the distance between the posterior tip of OC and basion of the right and left sides.

The mean distance of the posterior tips of OC to the HC, JF, and IAC were 9.87 ± 1.53 mm, 17.22 ± 2.02 mm, and 30.2 ± 2.84 mm, respectively.

Foramen jugular septation was observed in 6 skulls, 4 on the right sided, and 2 on the left sided.

DISCUSSION

This study describes the morphometric anatomy features of the PCF foraminas and its relationship. A clear understanding of the relationship of lesion at the PCF and the adjacent complex neurovascular structures is important for safe and accurate dissections to avoid injury of the surrounding structures [Figures 3 and 4].

Lesions located in the anterior aspect of FM, extending from the clivus to the upper spinal cord, have posed a surgical challenge to neurosurgeons.[10] Understanding the dimensions of the morphometry of the CCJ has clear implications to decrease morbidity and mortality in surgery of this region, especially when the lateral approaches and its variations are used.[11-13]

Different reports about the mean length of the OC length have been done.[14-16] These variations may be due to different methods of data or population. Knowing the precise location of the OC and the foramina in the inner skull is important to understand the relationship between the neurovascular structures surrounding the area and in the approach to lesions lying close to or within the canals itself.

In the present study, the results obtained from the length and width of the FM were 34.51 ± 2.53 mm and 29.85 ± 2.94 mm, respectively. Our results are comparable to the mean length reported by Kanodia G *et al*. (34.1 mm) and Saluja *et al*. 34.8 mm.[16,17] Due to deep locations of tumors anterior to the brainstem, detailed anatomy analysis of this region must be reviewed and knowed prior to any surgery, to proper planning of the management.

The overall mean and standard deviation of OC length and width were 24.15 ± 2.83 mm and 12.94 ± 2.67 mm, respectively. The measures are according to Kizilkanat *et al*.[6] (24.5 mm and 13.1 mm) and Ozer *et al*.[18] (23.95 mm and 11.3 mm), both realized in Turkish population, but differ the length of the OC from Suluja *et al.* (22.75 mm and 12.97 mm), Salih *et al*. (20.66 mm and 12.81 mm) which was realized in the Indian and Sudanese population and observed shorter results.[16,19]

The distances between the posterior tips of OC and basion are also essential anatomical features. The overall mean and standard deviation in the present study was 24.61 ±1.74 mm. We found a significant difference between the distance of both sides ($P< 0.05$), it was according to the results obtained by Saluja *et al*.[16] The results obtained by Kalthur *et al*. 27.5 ±2.4 mm[14] are comparable with our study. The findings observed of Ozer *et al*. 29.4 mm and and Suluja *et al.* 27.54 mm were smaller.[16,18]

Table 1: Morphometric parameters (*n*=55)

Parameters	Range	Mean±SD (mm)	*P*
Occipital condyle			
Length			
Right	20.55-31.33	24.34±2.57	0.6
Left	20.31-31.24	23.96±3.09	
Mean	20.31-31.33	24.15±2.83	
Width			
Right	9.93-17.55	13.2±3.47	0.32
Left	10.39-17.34	12.67±1.87	
Mean	9.93-17.55	12.94±2.67	
Foramen magnum			
Length	29.08-40.95	34.51±2.53	-
Width	24.05-38.27	29.85±2.94	-
Distance between POC and basion			
Right	20.2-28.09	24.24±1.94	0.03
Left	21.04-28.47	24.98±1.59	
Mean	20.02-28.47	24.61±1.74	
Distance between POC and hypoglossal canal			
Right	6.68-12.87	9.79±1.32	0.75
Left	6.38-12.54	9.95±1.75	
Mean	6.38-12.87	9.87±1.53	
Distance between POC and Jugular foramen			
Right	13.52-22.54	17.14±1.96	0.66
Left	12.47-22.58	17.31±2.08	
Mean	12.47-22.58	17.22±2.02	
Distance between POC and internal auditory canal			
Right	21.73-34.78	29.96±3.42	0.63
Left	22.59-34.87	30.43±2.22	
Mean	21.73-34.87	30.2±2.84	

SD - Standard deviation; POC - Posterior tip of occipital condyle

In the present study, the overall mean and standard deviation between the posterior tips of the OC and HC was 9.87 ±1.53 mm. These measurements are similar to the values obtained by Kalthur *et al*.[14] 9.05 ±1.8 mm. However, these distances differ and are lower according to the measurements obtained by Muthukumar *et al*. and Barut *et al*. 12.6 mm and 12.5 mm, respectively.[20,21] Knowing the distance between the OC and HC is crucial to perform a transcondylar approach. Knowing the observations above, it suggests that surgical approaches with OC drilling may be undertaken to within 9.57 mm, to prevent hypoglossal nerve damage. Notwithstanding these suggestions, the detailed individual anatomy of this region should be assessed using the morphometric methods prior surgical intervention.

In procedures such as exposure through the lateral transcondylar approach, perforation of the jugular tubercle is necessary.[22] Injuries to neurovascular structures adjacent to JF may occur if the anatomy of this region is not fully understood. The overall mean distance and standard deviation between posterior tips of the OC and the JF in the present study were 17.22 ± 2.02 mm. These measurements were not found in other studies. It has been reported that by removing the JT a gap can be created, sufficient for the surgical manipulation of neurinomas, epidermoid cysts, or similar noninvasive lesions,[2] without the need to drill into the petrous part of the temporal bone. Consequently, data on the distance between the JT and the HC are of clinical importance.

We found the mean distance between the posterior tips of OC and the IAC 30.2 ± 2.84 mm, which differ from Rock *et al*. 35.51 ± 2.5 mm.[23] Awareness of these findings can prevent injury to the adjacent neurovascular structures.

CONCLUSION

In conclusion, the present study yielded detailed morphometry of the PCF and neurovascular relationship. It can facilitate successful instrumentation and minimize the neurovascular injuries. Furthermore, it provides safe and suitable data for guiding neurosurgical procedures. Preoperative assessment of the structural features of PCF morphometric analysis facilitate safe drilling of these structures, increasing the operative

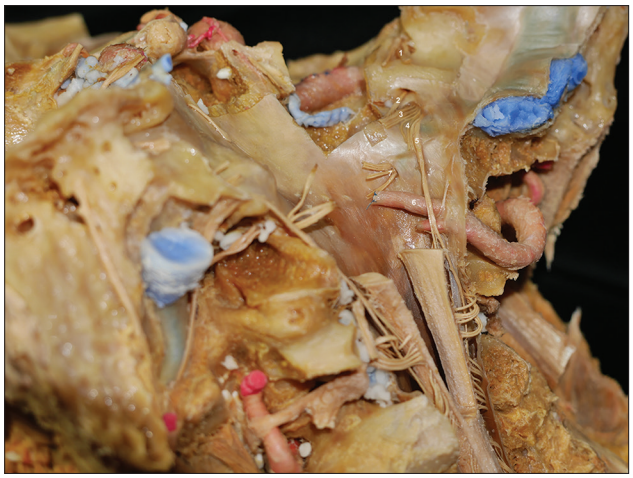

Figure 4: Posterior view of posterior cranial fossa and surrounding structures. The facial and vestibulocochlear nerve (1) emerging from the internal auditory canal, the glossopharyngeal (2), vagus (3), and bulbar (4) and spinal (5) nerve roots of the accessory nerve emerging from the jugular foramen. The intradural portion of the vertebral artery (6). Forward, the hypoglossal nerve (7) in the hypoglossal canal

space, and minimizing brain retraction. The major limitation of this study was the lack of knowledge regarding the age and gender of the participants whose skull base was studied.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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