Anatomical and Radiological study of the posterior cranial base in relationship to occipital condyles and Foramen magnum

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ABSTRACT

Detailed morphometric analysis is required for various surgical approaches in the craniovertebral junction. High mortality and morbidity are anticipated for the surgical procedures when undertaken without in-depth anatomical knowledge. With so much clinical importance in this area, our study will present a thorough understanding in terms of skull and CT values. The main aim of this study is to give the morphometric details of occipital condyles and foramen magnum in cadaveric skulls and CT scans. Seventy dried human skulls and 70 CT images on the three-dimensional volume-rendered reconstruction of the skull base was used for this study. The length and width of the occipital condyle of right and the left side was 22.21 ± 5.20 mm; 22.05 ± 4.83 mm; 12.57 ± 2.50 and 12.68 ± 2.92 mm respectively in cadaver skull. The length and width of occipital condyles in CT scans for right and left side was 21.61 ± 3.09 mm; 21.58 ± 3.50 mm; 13.04 ± 1.58 mm and 13.13 ± 2.54 mm respectively. The Anteroposterior and transverse diameters of the foramen magnum in cadaveric skulls and CT images was 33.17 ± 7.23; 29.22 ± 6.17; 34.15 ± 2.88 and 28.14 ± 2.43 mm respectively. Each surgical approach and the radiological diagnostic procedures have their limitations. Moreover, analysis of cranial base dimensions of occipital condyles and foramen magnum can be considered as a reliable method for sex determination. Hence this study will a useful guide for surgeons, radiologists, anthropologists and forensic experts.

INTRODUCTION

The base of the skull is such a complex region with numerous foramina through which several vital structures have access to the closed cranium. Awareness about the various foramina and the anatomical landmarks is essential while planning multiple surgical approaches for reaching the middle and posterior cranial base (Çiçekibaşi et al., 2004). However, the study of the foramina becomes an integral part of the anthropologist for the study of significant change in size and shape during the evolution (Bruner, 2007).

Tumours of the foramen magnum and other Craniovertebral junction surgeries can be approached...
both ventrally and dorsally, the safest of both these is the dorsal approach which is highly preferred at the craniocervical junction. The maximum extent of the condylar resection is unclear, ranging from suboccipital craniotomy to total occipital condyle removal. Hence dimensional anatomy of occipital condyle has a vital role in minimizing the complications of the surgical procedures (Kalthur et al., 2014).

The dimensions are not only crucial in establishing safe operational techniques but also to evaluate and analyze the age, gender, stature, and ethnicity. Discrimination functional analysis of foramen magnum is of great help in anthropologic and forensic techniques (Vinutha et al., 2018). This study aims to evaluate the morphometric analysis of occipital condyles and the Foramen magnum in the posterior skull base and its surgical importance.

MATERIALS AND METHODS

The study was carried out after getting Institutional Ethical committee clearance. Reference no:1162/IEC/2017. Adult cadaveric skulls 70 and 70 CT scans of patients who underwent an examination of the skull region for various reasons were used for these studies. Measurements were taken for both sides. All the cadaveric skulls were collected from the department of anatomy and the department of Forensic medicine. CT scan studies were obtained from the Department of Radiology SRM Medical college hospital and research centre Chennai. All the skulls selected were of south Indian origin, and the damaged skulls in the base were excluded for this study. CT skull images studied were of high resolution 0.6 mm slice thickness. Patients with a history of trauma, surgery, pathological lesions with poor image quality were excluded from this study.

Morphometric measurements of the occipital condyles were recorded for its length, width, Foramen magnum dimensions were measured for its anteroposterior diameter and transverse diameter. For skulls, measurements were taken using the digital image analysis program known as Digimizer Software version 4.3.0. The pictures captured were calibrated before measuring the parameters under the same position with a regular grid sheet. Figure 1. CT skull images obtained were of 0.6-mm-thin sections. The raw data collected were reformatted in the axial, coronal, and sagittal plane, and then three-dimensional images were created using the Radiant software version5.5.0. Figure 2.

Statistical analysis: Data analysis was done using SPSS software version 20.0 Student’s t-test was per-
formed to analyze between the right and left condylar parameters and comparison between the CT and the Skull values was also done. Significance was considered if p<0.05.

RESULTS AND DISCUSSION

The outcome of our study is summarized in the following tables (Table 1 and Table 2).

The right and left side measurements were tested for significance, and no significant differences were noted. Similarly, there is no significant difference between the skull and CT measurements (p>0.05).

The Trans condylar approach is a complex skull base approach that is used to reach the craniocervical junction (CVJ), the foramen magnum and the brainstem. CVJ is in close relationship with vital structures, and therefore, surgeries involved in this area include potential complications (Agnihotri et al., 2014). Detailed knowledge of condylar and foramen magnum dimensions helps the surgeon in making important decisions for deciding the type of approach and the extent of condylar drilling to be carried out to minimize the injury of neural structures. The condylar width plays an important factor in assessing the screw placement in occipital condylectomy.

In our study, the sagittal length of cadaver skull right and left side was 22.21 ± 5.20, and 22.05 ± 4.83 mm which coincides with the values of Saluja et al. (2017) and Ilhan et al. (2017) with results of 22.90±3.11; 22.60±2.72 and 23.44±2.60; 23.49±2.71 mm. Notably, this value was even higher than the length of 19.43±3.27 mm, 19.28±3.57 mm as reported by Bayat et al. (2014).

In our study, the width of right occipital condyles for the cadaveric skull was 12.57 ± 2.50 and left occipital condyles were 12.68 ± 2.92 mm. These values correspond to the study of Saluja et al. (2017) of 12.98±1.62 mm and 12.97±1.46 mm and George et al. (2019) of 12.39 mm and 12.37 mm, respectively. Whereas Lyrtzis et al. (2017) observed the width of occipital condyles as 11.77±1.52 mm and 11.85±1.63 mm, which is slightly lower than our study. Besides, it coincides with Cheruiyot et al. (2018) of 12.2±1.25 mm and 12.2±1.33 mm. However, our values highly contradicted with Bayat et al. (2014) with much lower values of 9.21±1.97 and 9.40±1.87 mm right and left side respectively with a higher value observed in Agnihotri et al. (2014) study of 13.72±1.56 and 13.96±1.82 mm.

The mean condylar length for right and left side on CT scans in our study was 21.61 ± 3.09 and 21.58 ± 3.50 mm, which was slightly lower when compared to values reported by Foxx et al. (2017) and Srivastava et al. (2017) of 18.7 ± 1.7, 18.6 ± 1.7, 18.6 and 19.9±2.4, 19.4±2.7 mm. Highly coincides with the study of El-Barrany et al. (2016) with 21.41±2.05, 21.50±2.19 mm and Agnihotri et al. (2014) of 22.61±2.3, 22.36±2.3 mm. There are not many variations observed in the width of occipital condyles in our study, and by the authors mentioned above. The main focus for extensive investigation of the morphometry of occipital condyles was for

Table 1: Measurements of parameters for cadaveric skull and CT scan

| Parameter | Skull(n70) Mean and SD in mm | CT(n70) Mean and SD in mm | P-value |
|-----------|-------------------------------|---------------------------|---------|
| OC-length-R | 22.21 ± 5.20 | 21.61 ± 3.09 | 0.409 |
| OC-length-L | 22.05 ± 4.83 | 21.58 ± 3.50 | 0.515 |
| OC-width-R | 12.57 ± 2.50 | 13.04 ± 1.58 | 0.186 |
| OC-width-L | 12.68 ± 2.92 | 13.13 ± 2.54 | 0.335 |
| FM-AP | 33.17 ± 7.23 | 34.15 ± 2.88 | 0.295 |
| FM-T | 29.22 ± 6.17 | 28.14 ± 2.43 | 0.175 |

OC-occipitalcondyles; FM-Foramen Magnum; AP-anteroposterior; T-transverse diameter; R-Right; L-left

Table 2: Comparison of cadaveric skull and CT scan for right and left side

| Parameters | Skull (mm) | Left | P | CT(mm) | Right | Left | P |
|------------|------------|------|---|--------|--------|------|---|
| OC-L | 22.21 ± 5.20 | 22.05 ± 4.83 | 0.852 | 21.61 ± 3.09 | 21.58 ± 3.50 | 0.963 |
| OC-W | 12.57 ± 2.50 | 12.68 ± 2.92 | 0.816 | 13.04 ± 1.58 | 13.13 ± 2.54 | 0.811 |
the placement of occipital condylar screws (Le et al., 2011).

The anteroposterior and transverse diameter of the foramen magnum for the cadaveric skull in our study was noted as 33.17 ± 7.23 and 29.22 ± 6.1 mm. All the metric variables assessed in the present study for foramen magnum were found to have similar values with the previous studies as reported by Muthukumar et al. (2005) of 33.3 and 27.9 mm and Ganapathy et al. (2014) of 33.9 and 28.7 mm. However, the transverse diameter was noted to be smaller in our study to that of Singh et al. (2019) which described values of 33.57 and 27.49 mm. Sahoo et al. (2015) observed the anteroposterior diameter as 35.3 and transverse diameter as 29.49 mm, which is very close to our values. Nevertheless, Veeramani et al. (2018) reported more extensive areas of the foramen magnum in the transverse diameter of 32 mm significantly when compared to our study.

Similarly, the CT scan results of our study for anteroposterior and transverse diameters were 34.15 ± 2.88 mm and 28.14 ± 2.43 mm, respectively. Notably, these values were even higher than the mean anteroposterior and transverse diameters as observed by Vinutha et al. (2018) and El-Barrany et al. (2016) as 31.64 ± 2.8 and 26.13 ± 2.6 mm. And 38.5 ± 3.22, 31.57 ± 2.62 mm, respectively. Similar values were found with Gopalrao et al. (2013) of 33.9 ± 2.61, 28.05 ± 2.22 mm and Kanodia et al. (2012) of 33.1 ± 2.61, 28.05 ± 2.22 mm.

The difference in morphometric measurements of different studies could contribute to the different angulations of the occipital condyles relative to the sagittal plane. The larger the sagittal intercondylar angles, the more considerable intercondylar distances were noted (Verma et al., 2016). Moreover, the difference could also be associated with the varying prevalence of Occipital condyle overriding into the foramen magnum. The presence of wider intercondylar distances is advantageous in accessing ventral craniovertebral junction lesions, which demands less extensive bony resection for both suboccipital and occipital condylectomy.

CONCLUSION

Analysis of the various parameters from this study concludes that there is no significant difference between the cadaveric skulls and CT skull measurements. Besides, the data obtained from anatomical and radiological studies did not differ statistically in the sides also. Understanding the knowledge of anatomy simplifies the understanding of underlying pathological lesions. Moreover, the dimensions of the foramen magnum and occipital condyle can be used for performing transcondylar approaches for reaching the middle and posterior cranial base surgeries. Hence, this study concludes that preoperative morphometric assessment is mandatory for knowing the feasibility of occipital condyle in screw fixation. To add up these dimensions will also throw light for the sex determination, thus contributing to new research in the field of anthropology and forensic sciences.

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Conflict of Interest

None declared.

REFERENCES

Agnihotri, G., Mahajan, D., Sheth, A. 2014. An Anatomical Perspective Of Human Occipital Condyles And Foramen Magnum With Neurosurgical Correlates. Journal of Evolution of Medical and Dental Sciences, 3(17):4497–4503.
Bayat, P., Bagheri, M., Ghanbari, A., Raoofi, A. 2014. Characterization of Occipital Condyle and Comparison of its Dimensions with Head and Foramen Magnum Circumferences in Dry Skulls of Iran. International Journal of Morphology, 32(2):444–448.
Bruner, E. 2007. Cranial shape and size variation in human evolution: structural and functional perspectives. Child’s Nervous System, 23(12):1357–1365.
Cheruiyot, I., Mwachaka, P., Saidi, H. 2018. Morphometry of Occipital condyles: Implications for transcondylar approach to craniovertebral junction lesions. Anatomy Journal of Africa, 7(2):1224–1231.
Çiçekibaşi, A. E., Murshid, K. A., Ziylan, T., Şeker, M., Tuncer, I. 2004. A morphometric evaluation of some important bony landmarks on the skull base related to sexes. Turkish Journal of Medical Sciences, 34(1):37–42.
El-Barrany, U. M., Ghaleb, S. S., Ibrahim, S. F., Nouri, M., Mohammed, A. H. 2016. Sex prediction using foramen magnum and occipital condyles computed tomography measurements in Sudanese
population. *Arab Journal of Forensic Sciences and Forensic Medicine*, 230(3950):1–9.

Foxx, K. C., Uribe, J. S., Ikpeze, T. C., Omar, A., Mesfin, A. 2017. Occipital Condyle Morphology: a CT-Based Analysis of 500 Condyles. *The Spine Journal*, 17(10):S197–S198.

Ganapathy, A., Sadeesh, T., Rao, S. 2014. Morphometric analysis of foramen magnum in adult human skulls and CT images. *International Journal of Current Research and Review*, 6(20):11–15.

George, J. R., Francis, T., Francis, J., Samuel, J. E. 2019. Morphometric Study Of Dry Human Occipital Bone And Its Clinical Relevance. *Int J Anat Res*, 7(1.2):6230–6263.

Gopalrao, S. R., Solanke, P., Ugale, M., Balsurkar, S. 2013. Computed tomographic scan study of morphometry of foramen magnum. *International Journal of Current Research and Review*, 5(19):41–48.

Ilhan, P., Kayhan, B., Erturk, M., Sengu, G. 2017. Morphological Analysis of Occipital Condyles and Foramen Magnum as a Guide for Lateral Surgical Approaches. *MOJ Anat & Physiol*, 3(6):188–194.

Kalthur, S., Padmashali, S., Dsouza, A., Gupta, C. 2014. Anatomic study of the occipital condyle and its surgical implications in transcondylar approach. *Journal of Craniovertebral Junction and Spine*, 5(2):71–71.

Kanodia, G., Parihar, V., Yadav, Y. R., Bhatele, P. R., Sharma, D. 2012. Morphometric analysis of posterior fossa and foramen magnum. *Journal of Neurosciences in Rural Practice*, 03(03):261–266.

Le, T. V., Dakwar, E., Hann, S., Effio, E., Baaj, A. A., Martinez, C., Vale, F. L., Uribe, J. S. 2011. Computed tomography–based morphometric analysis of the human occipital condyle for occipital condyle–cervical fusion. *Journal of Neurosurgery: Spine*, 15(3):328–331.

Lyrtzis, C., Piagkou, M., Gkioka, A., Anastasopoulos, N., Apostolidis, S., Natsis, K. 2017. Foramen magnum, occipital condyles and hypoglossal canals morphometry: anatomical study with clinical implications. *Folia Morphologica*, 76(3):446–457.

Muthukumar, N., Swaminathan, R., Venkatesh, G., Bhanumathy, S. P. 2005. A morphometric analysis of the foramen magnum region as it relates to the transcondylar approach. *Acta Neurochirurgica*, 147(8):889–895.

Sahoo, S., Giri, S. K., Panda, S. K., Panda, P., Sahu, M. C., Mohapatra, C. 2015. Morphometric analysis of the foramen magnum and the occipital condyles. *Int J Pharm Sci Rev Res*, 33(2):198–204.

Saluja, S., Das, S. S., Vasudeva, N. 2017. Morphometric analysis of the occipital condyle and its surgical importance. *Journal of clinical and diagnostic research: JCDR*, 10(11):1–4.

Singh, D., Patnaik, P., Gupta, N. 2019. Morphology and Morphometric Analysis of the Foramen Magnum in Dried Adult Skulls in North Indian Region. *International Journal of Health Sciences and Research*, 9(4):36–42.

Srivastava, A., Nanda, G., Mahajan, R., Nanda, A., Mishra, N., Karmaran, S., Batra, S., Chhabra, H. S. 2017. Computed Tomography-Based Occipital Condyle Morphometry in an Indian Population to Assess the Feasibility of Condylar Screws for Occipitocervical Fusion. *Asian Spine Journal*, 11(6):847–853.

Veeramani, R., Manjunath, K. Y., Amirthalingam, U. 2018. Morphological and Morphometric Study of Variations in the Shape and Size of the Foramen Magnum of Human Skulls. *International Journal of Anatomy Radiology and Surgery*, 7(2):1–8.

Verma, R., Kumar, S., Rai, A., Mansoor, I., Mehra, R. 2016. The anatomical perspective of human occipital condyle in relation to the hypoglossal canal, condylar canal, and jugular foramen and its surgical significance. *Journal of Craniovertebral Junction and Spine*, 7(4):244–244.

Vinutha, S. P., Suresh, V., Shubha, R. 2018. Discriminant Function Analysis of Foramen Magnum Variables in South Indian Population: A Study of Computerised Tomographic Images. *Anatomy Research International*, 2018:1–8.