Morphometric Analysis of Posterior Fossa and Foramen Magnum among Pediatric Age Group 6 to 16 Years

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ABSTRACT

Background

Configuration and size of the foramen magnum and posterior cranial fossa plays an important role in the pathophysiology of various disorders like Chiari malformations, basilar invagination etc. Thus, a fundamental knowledge of normal anatomy of this region is important to the clinician for diagnosis and treatment. However, we couldn't find any anatomical study related to the concerned topic among the pediatric population aged 6 to 16 years in Nepal to the best of our knowledge.

Objective

To attain the baseline results (volume of bony part of posterior cranial fossa and the surface area of foramen magnum) that will help in the better diagnosis, classification, and treatment of diseases related to posterior fossa and craniovertebral junction and serve as a future reference defining an anatomic range in our region.

Method

This is a retrospective prospective observational study conducted from 1st February 2021 to 31st January 2022 at Dhulikhel Hospital, Kathmandu University Hospital, Kavrepalanchowk, Nepal. We used convenient sampling technique to fulfil our sample size. We considered 68 patients, who got recruited either from our emergency and OPD departments and were fulfilling our criteria of inclusion. Upon the recruitment, 68 consecutive head CT scan of pediatric patients with normal reports (without any bony or soft-tissue abnormality) were studied. Volume of the posterior fossa was calculated with the help of inbuilt "advanced work station - 3D volume calculator" program in 128 slices - SOMATOM PERSPECTIVE CT Scanner from Siemens, Germany. The area of the foramen magnum was calculated using formula πr^2, where r is average radius calculated from obtained antero-posterior and transverse diameter.

Result

The age of the patients ranged between 6 and 16 years with the mean age of 10.56 ± 3.38 years with male to female distribution of 1: 1.125. The mean volume of the posterior fossa was 165.61 ± 8.52 mm^3. The mean AP diameter, transverse diameter, and the surface area of foramen magnum were 3.31 ± 0.12 mm, 2.72 ± 0.12 mm, and 28.60 ± 0.09 mm^2 respectively.

Conclusion

Normal ranges of volume of posterior cranial fossa and various dimensions and surface area of foramen magnum of pediatric population were determined using CT scans, which could serve as future reference in Nepal.

KEY WORDS

Chiari malformation, Foramen magnum, Posterior cranial fossa

INTRODUCTION

Shape and size of the posterior cranial fossa and foramen magnum plays an important role in the pathophysiology of various disorders like Chiari malformation, Dandy Walker syndrome, basilar invagination etc.[1] The posterior cranial fossa is the deepest cranial fossa and is bounded by dorsum sellae, clival part of occipital bone anteriorly, petromastoid part of temporal bone laterally, tentorium cerebelli superiorly, and the occipital bone posteroinferiorly. The foramen magnum in the occipital bone is the largest opening in the posterior fossa and transmits important neurovascular structures.[2] Stenosis of foramen magnum causes brainstem compression that might manifest as lower cranial nerve dysfunctions, alteration of muscle tone, upper and lower extremity weakness, gait disturbances and in severe cases cardiorespiratory compromise.[3]

Recent evidences supported by the computed tomography (CT) / Magnetic resonance Imaging (MRI) imaging of cranial structures suggested that the overcrowding of hindbrain due to underdevelopment of the posterior fossa is the main cause for the development of numbers of disorder in and around craniovertebral junction.[4] Thus, a fundamental knowledge of normal anatomy about the region is important to the clinician for diagnosis and treatment.

Various morphometric studies considering cranial bony details have been described till date, however there is no anatomical study regarding the concerned topic among pediatric population aged 6 to 16 years in Nepal to the best of our knowledge.[5-9] Hence, the results obtained from this study will help in the better diagnosis, classification, and treatment of diseases related to posterior fossa and craniovertebral junction and serve as a future reference defining an anatomic range in our region.

METHODS

This is a retrospective prospective observational study was conducted from 1st February 2021 till 31st January 2022 at Dhulikhel Hospital, Kathmandu University Hospital, Kavre, Nepal. We used convenient sampling technique to fulfil our sample size. Sample size was derived in accord to Cochran (1963) sample size equation, $N = Z^2 \times P \times (1-p) / E^2$

Considering,

Z (critical value for desired level of confidence) - 1.96 for alpha 0.05

P (estimated prevalence or proportion of event) - 0.039

E (precision or margin of error) - 0.05

This produced a total minimal sample size of 58 participants. Hence, we aim to consider at least 58 patients, to be recruited either from our emergency and OPD departments and were fulfilling our criteria of inclusion. Eligible subjects were Nepalese participants aged 6 to 16 years who had undergone computed tomographic evaluation of head during the course of management of their disease process. Within this study, eligible patients were recruited despite the nature of indication for computed tomography or severity of the issue, provided informed consent was obtained. Patients without CT scans of head available for study either during their stay for treatment or follow up were excluded. Also, those patients who sustained deforming skull injuries or have conditions that alter normal skull shape and configuration were also excluded.

Upon the selection of eligible subjects, patients and care givers were explained about the objectives of the study. Informed consent was obtained and participants were enrolled in our study. Sixty-eight consecutive head CT scans of pediatric patients with normal reports (without any bony or soft-tissue abnormality) were studied. Those with a fracture of skull bone or bony deformity of skull were excluded from the study. Volume of the posterior fossa was calculated with the help of inbuilt “advanced work station - 3D volume calculator program” in 128 slices -SOMATOM PERSPECTIVE CT Scanner from Siemens, Germany. The area of selection was done with superior margin considered as the line joining dorsum sellae to anterior margin of tentorium cerebelli and inferior margin as McRae’s line. The anteroposterior (AP) selection was considered including all areas between the dorsum sellae, clivus bone anteriorly and tentorium, inferior parts of occipital bone posteriorly (Fig. 1) while the transverse selection was done including all areas between the points just below the base of petrous temporal bone in the groove for sigmoid sinus (Fig. 2,3). The area of the foramen magnum was calculated using formula πr^2, where r is average radius calculated from obtained AP and transverse diameter.

Figure 1. Showing sagittal section in Head CT and performing Antero-posterior and Supero-Inferior selection for posterior cranial fossa volume measurement

Data entry and analysis were performed using the Statistical Package For The Social Sciences (SPSS) version 16.0. Descriptive statistics were reported using means and standard deviations (SD) for continuous variables and frequency with percentages for categorical variables. Normality of data was assessed using Shapiro-Wilk test. Independent sample t test was used to compare between means of two variables. All statistical tests were two-sided, and the significant level was set at 0.05.

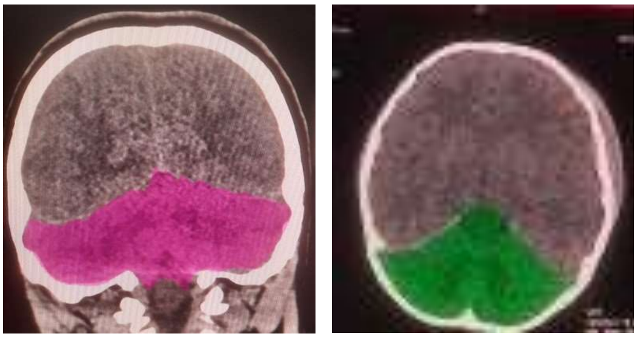

Figure 1 and 3. **Showing coronal and axial section in Head CT and performing transverse diameter selection for posterior cranial fossa volume measurement**

RESULTS

The volume of the posterior cranial fossa and the various dimensions of the foramen magnum were recorded from 68 CT scans done in pediatric patients fulfilling our inclusion criteria. The age of the patients ranged from 6 to 16 years with a mean of 10.56 ± 3.39 years (Fig. 4). There were 32 male and 36 female patients belonging to Aryan and Mongol ethnicity.

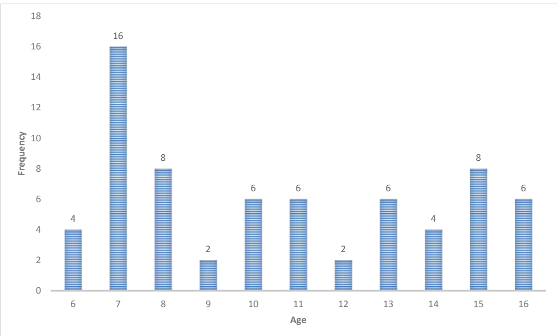

Figure 4. **Frequency distribution of age patients (years)**

The mean volume of the posterior fossa was 165.61 ± 8.52 mm^3. The maximum and minimum posterior cranial fossa volume noted was 189.45 mm^3 and 150.61 mm^3 respectively with the range of 38.84. Mean posterior cranial fossa volume among female was 165 ± 7.70 and among male was 165 ± 9.48. Considering the ethnicity, mean posterior fossa volume among Mongol was 164 ± 7.79 and among Aryan was 166 ± 9.19. The mean AP diameter, transverse diameter, and the surface area of the foramen magnum were 3.31 ± 0.12 mm, 2.72 ± 0.12 mm, and 28.60 ± 0.09 mm^2, respectively (Table 1).

Table 1. **Showing various measurements of the foramen magnum obtained in the study.**

Parameters	Minimum (cm)	Maximum (cm)	Mean (cm)	Std. Deviation
AP diameter	3.02	3.79	3.3068	.12417
Transverse diameter	2.46	2.93	2.7253	.11941
Surface area	24.72	33.18	28.6045	1.78276
Mean radius	2.80	3.25	3.0160	.09362

DISCUSSION

Important concepts about posterior cranial fossa and foramen magnum including their standard sizes and ranges are crucial clinically for correct radiological diagnosis and planning of various surgical interventions. Normal variations in both entities were seen among various races, body habitus, gender, geographical, and genetic factors.[10] Several studies were conducted throughout the globe on the topic, however information available among the Nepalese pediatric population was very limited. Hence, our study contributes to decreasing the deficit to a certain extent.

Most of the discussion regarding foramen magnum and posterior cranial fossa anatomy and volume focuses around the pathophysiology of Chiari malformations, basilar invaginations or craniosynostosis. Mostly these studies point to some form of developmental error during phases of embryology for such pathologies to occur. Most commonly proposed theories dictate 'the poor development of occipital endochondrium, possibly due to the abnormal growth of occipital somites originating from paraxial mesoderm' as the primary issue.[8,11] And to conclude all of these studies states hypoplastic posterior cranial fossa and foramen magnum to be the primary issue in causation of common craniovertebral junction pathologies like Chiari malformation, syringomyelia and basilar invagination. Further, it has been noted that decrease in AP and transverse diameters of the foramen magnum portends to be an independent risk factor for early development of severe symptoms in patients with cranio-cervical anomalies.[12,13]

Further studies from Goel et al. and Muthukumar et al. also suggested the path of management of such disease process varies according to the various measurements and volume of the posterior cranial fossa, foramen magnum and adjacent structures.[14,15] Hence it is of utmost importance to have a detailed knowledge about the issue among our population to whom we are providing neurosurgical service.

In our study we selected pediatric population from 6 to 16 years being based on paper from Birmingham Children's Hospital by Sgouros et al. on skull base growth in childhood where they concluded more than 90% of the skull base growth change occurs during the first 5 years of life and rest of the modifications occurs till age of 5-7 years.[16] And as per Rule of Nepal, age limit for pediatric population is 16 years.[17]

Concordant with Nishikawa et al. and Milhorat et al. we used a built-in-software to calculate posterior fossa volume (PFV).[8,11] They have reported that the mean posterior fossa volume as 186 mL and 166 ± 8 mL respectively, using both CT and MRI-based studies which was greater volume in comparison to our findings of 165.61 ± 8.52 mm^3. The difference observed is most possibly due to the difference in race and also age group of study population.

Concerning foramen magnum dimensions, in our study the mean AP diameter, transverse diameter, and the surface area of the foramen magnum were 3.31 ± 0.12 mm, 2.72 ± 0.12 mm, and 28.60 ± 0.09 mm^2, respectively which was similar to findings in Tubbs et al. series.[6] However The variation in surface area calculated among two papers could be due to the difference in races, habitus, geographical, and genetic factors. Lang et al. classified the shapes of foramen magnum into five groups: (a) two semicircles, (b) an elongated circle, (c) egg-shaped, (d) rhomboidal, and (e) rounded. He found that the average AP and transverse diameter of the foramen were 3.5 and 3 cm, respectively. Our findings were consistence with the Lang et al. series as well.[18]

Additionally, with respect to the local ethnic variation, we looked into two major ethnic group in our locality 'Aryan and Mongols'. Each group had 34 children. We found the mean posterior fossa volume among Mongol children was 1.64 ± 7.79, which was smaller in comparison to 1.66 ± 9.19 among Aryan children, however statistically insignificant. Most possibly due to a greater number of children above 12 years of age in Aryan group created this disparity.

This is a single center study with limited sample size and focused on single method of calculation i.e., CT based. Hence, our study missed the opportunity to study the details that could have been appreciated in dry skull-based measurements or MRI based measurements. It is recommended that multi centered study with multimodal approaches to detail the topic of interest will result in concrete data for in-depth knowledge.

Further among pediatric population also, we have only considered age group of 6 years or more for evaluation. So, the sample is not representative for age groups below 6 years. Additionally, in growing skull, it is difficult to make any remark on final stage that skull will attain. Growth of skull beyond age of 6 years may have altered the mean results in our study.

CONCLUSION

Normal ranges of volume of posterior cranial fossa and various dimensions and surface area of foramen magnum among pediatric population were determined using CT based calculation which could serve as future reference in Nepal. These findings will be useful in decision making while treating various congenital malformations like Chiari malformation and in surgical procedures of involving foramen magnum and posterior cranial fossa decompression.

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