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ORIGINAL ARTICLE

COMPUTED TOMOGRAPHY MEASUREMENTS OF OCCIPITAL BONE THICKNESS IN CHILDREN

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ABSTRACT

Background Data: The unique anatomy of the craniovertebral junction, the perceived high risk of vascular and neurological complications, and the anatomical variations require the morphological analysis of the occipital bone.

Purpose: The purpose of this study was to present morphometric analysis of the pediatric occipital bones and to provide guidance for pediatric occipitocervical fusion.

Materials - Methods: We retrospectively reviewed the records of pediatric patients who had undergone head CT scanning due to various reasons. Patients with traumatic fractures, congenital abnormality, tumor or other diseases and problematic CT images were excluded. Occipital bone thicknesses were determined at three levels (each level having 5 points) starting from the external occipital protuberance (EOP) (Level 0) and extending inferiorly for 2 cm by 1-cm decrements (Level 1 and Level 2).

Results: Among 300 CT scans, 70 were found to be suitable for the study. There were 50 males and 20 females, with a mean age of 9.9 ± 4.40 years (range 2–17 years). The external occipital protuberance (EOP) had the greatest thickness, with mean values of 10.3 ± 2.99 mm (range, 5.0-18.5 mm) in males and 9.9 ± 2.41 mm (range, 5.1–14.1 mm) in females. At each level, the midline was always thicker than the lateral regions at each age group ($p<0.001$). The midline thickness at Level 0, 1 and 2 were thicker in males compared to females ($p=0.011$, $p=0.045$ and $p=0.032$, respectively). Positive correlation was found between age and occipital bone thickness ($r=0.828$ and $p<0.001$ for EOP, $r=0.770$ and $p<0.001$ for midline at Level 1, $r=0.792$ and $p<0.001$ for midline at Level 2) and the other points showed similar findings.

Conclusion: Safe zones with thicknesses > 8 mm for screw insertion were found only at the midline in children older than 5 years of age and preoperative evaluation of occipital thickness should be performed in every patient considering the individual variability.

Keywords: Occipital bone, occipitocervical fusion, morphometric analysis

Level of evidence: Retrospective clinical study, Level III.

INTRODUCTION

The craniovertebral junction (CVJ) is the most cephalic portion of the spinal axis, and craniovertebral instability in children is a rare disorder with severe neurological and potentially life-threatening consequences. A wide variety of congenital, developmental, and acquired abnormalities can occur at the CVJ, and instability can manifest as disabling neck pain, occipital headaches, cranial nerve dysfunction, paralysis, or even sudden death (1). The same general principles that apply to adults also apply to children regarding the assignment of instability, spinal immobilization and surgical fusion, and the most common intervention for instability at the CVJ is occipitocervical fusion (2).

Several types of posterior approaches have been described for occipitocervical fusion and an increasing number of researchers recommend rigid posterior fixation systems utilizing screw-rod or screw-plate constructs that provides superior biomechanical stability and higher rates of fusion (3-5). However, the anatomical complexity of this area complicates instrumented stabilization and this necessitates detailed morphological anatomical knowledge about the thickness of the occipital bone in terms of both providing adequate bony purchase for screws and avoiding penetration of the dura, which is poorly documented in the literature. Although occipital bone thickness was investigated in a few previous anatomic or computed tomography (CT) studies in the adult population, to the best of our knowledge, there are no studies on pediatric patients in Turkish population [6].

The aim of this study was to perform a morphometric analysis of pediatric occipital bone using CT images of patients from different age groups.

MATERIALS AND METHODS

Ethical approval was not sought for this study because of retrospective nature of the study and consent was not obtained as no personal information was revealed.

We retrospectively reviewed the records of pediatric patients who had undergone head CT scanning (SIEMENS Sensation 64, Siemens Healthineers Headquarters, Erlangen, Germany) due to trauma, headache, or any other complaint requiring cranial investigation at our institution between January 1, 2015, and January 1, 2019. Patients with traumatic fractures, congenital abnormality, tumor or other diseases and problematic CT images were excluded. Among 300 CT scans, 70 were found to be suitable for the study. The children were divided into four groups according to age, Group 1 (2-5 years), Group 2 (6-9 years), Group 3 (10-13 years) and Group 4 (14-17 years).

The CT scan parameters included: 120 kV, 260 MA, DFOV 20 x 20 cm, layer thickness of 1.2 mm, collimation of 200 × 0.600 mm, pitch of 0.8 mm. Bone windows were used for analysis. The external occipital protuberance (EOP) was used as a reference point to measure the thickness of the occipital bone on arbitrary CT slices. When measuring, a McRae line was drawn as the base line on the images, then find the center of EOP (Level 0) and through it make a line with the McRae's line into an angle about 45°. Two parallel lines were drawn by 1-cm decrements extending inferiorly for 2 cm (Level 1 and Level 2). The surface was divided into 1-cm segments extending bilaterally for 2 cm (R2, R1, Midline, L1, L2). Therefore, 3 × 5 sites were created in each patient (Figure-1).

Statistical analysis

All statistical analyses were performed using SPSS version 22.0 (IBM Inc.). Continuous variables were expressed as mean ± standard deviation (SD). The Student t-test was used to compare parameters between males and females, and statistical significance was accepted with a p-value <0.05. The relationship between age and the thickness of the occipital bone were estimated using Spearman's rank correlation.

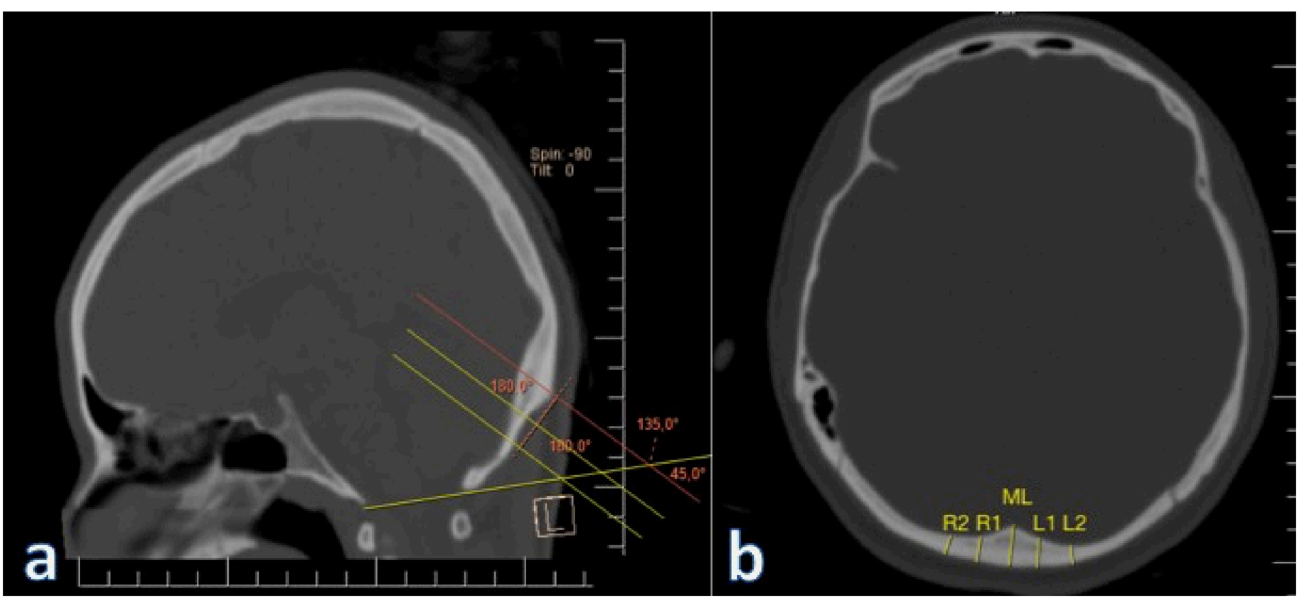

Figure-1. Computed tomography measurements of the occipital bone. a) Sagittal plane showing the lines representing 1-cm segments using the external occipital protuberance as a reference, for a distance up to 2 cm. b) Axial plane showing points created at each level in 1-cm segments laterally in both directions using the external occipital as a reference, for a distance up to 2 cm.

Table-1. Thickness of the occipital bone in the study cohort

		2-5 years group (n=13)			6-9 years group (n=19)			10-13 years group (n=16)			14-17 years group (n=22)		
Mean age, years		3.4 ± 1.12			7.3 ± 1.11			11.4 ± 1.31			14.9 ± 0.83		
Female		4.3 ± 0.96			7.4 ± 1.14			12.3 ± 1.16			14.5 ± 0.76		
Male		3.0 ± 1.0			7.3 ± 1.14			11.2 ± 1.28			15.1 ± 0.83		
Female / Male		4 / 9			5 / 14			3 / 13			8 / 14		
Gender	**Point**	**Level 0**	**Level 1**	**Level 2**	**Level 0**	**Level 1**	**Level 2**	**Level 0**	**Level 1**	**Level 2**	**Level 0**	**Level 1**	**Level 2**
Male	**R2**	2.5±0.64	2.0±0.72	1.8±0.74	3.6±0.61	2.7±0.59	2.2±0.66	4.5±0.92	2.9±0.75	2.8±0.71	5.7±1.17	4.2±1.25	3.4±1.06
	R1	3.5±0.72	2.7±0.76	2.2±0.72	4.4±1.40	3.9±1.30	3.3±0.76	5.8±0.99	3.7±1.15	3.4±0.86	7.8±1.43	5.2±1.48	4.1±1.38
	ML	6.4±0.93	5.1±1.28	4.0±1.16	8.9±1.38	7.9±0.82	6.7±0.72	10.7±1.37	9.7±1.46	8.2±1.26	13.7±2.13	10.5±2.11	9.1±1.52
	L1	3.6±0.83	2.8±1.21	1.9±0.49	4.8±1.47	4.1±1.44	3.6±0.93	5.8±1.09	3.9±0.94	3.5±0.94	7.9±1.51	5.3±1.80	4.3±1.72
	L2	2.5±0.61	2.1±0.85	1.8±0.67	3.8±0.97	2.9±0.95	2.1±0.81	4.6±0.89	3.0±0.58	2.7±0.66	5.7±1.18	4.2±1.44	3.5±1.27
Female	**R2**	3.1±1.02	2.2±0.60	2.0±0.59	3.8±0.65	3.0±0.68	2.1±0.75	4.8±0.95	2.7±1.32	2.7±0.76	4.7±1.28	3.4±0.82	3.1±0.41
	R1	4.1±0.85	2.8±0.85	2.6±0.78	3.6±1.16	3.5±1.0	3.0±0.52	6.1±2.13	2.9±0.91	3.1±0.98	6.3±1.75	4.0±1.07	3.4±0.69
	ML	6.7±1.23	5.7±1.02	4.4±1.32	9.0±0.71	7.5±0.69	6.1±0.6	12.1±1.78	9.7±0.45	9.3±1.60	11.3±1.76	9.0±1.20	7.7±1.28
	L1	3.8±1.34	2.7±0.96	2.8±0.69	3.7±0.87	3.1±0.49	3.0±0.87	5.7±1.62	3.0±0.35	2.8±0.83	6.0±1.58	4.4±1.23	3.8±1.0
	L2	2.8±0.93	2.1±0.68	2.0±0.55	3.1±0.71	2.7±0.43	2.2±0.42	4.6±0.68	3.3±1.23	2.4±0.99	4.5±1.50	3.3±1.11	2.9±0.54
All	**R2**	2.7±0.79	2.1±0.67	1.9±0.68	3.6±0.62	2.8±0.61	2.2±0.66	4.5±0.90	2.8±0.82	2.8±0.7	5.3±1.29	3.9±1.16	3.3±0.88
	R1	3.7±0.77	2.7±0.75	2.3±0.73	4.2±1.36	3.8±1.21	3.2±0.71	5.9±1.18	3.6±1.13	3.4±0.86	7.3±1.69	4.8±1.46	3.8±1.21
	ML	6.5±0.98	5.3±1.19	4.1±1.17	9.0±1.22	7.8±0.79	6.5±0.72	11.0±1.49	9.7±1.32	8.4±1.34	12.8±2.29	10.0±1.94	8.6±1.57
	L1	3.6±0.96	2.8±1.10	2.1±0.68	4.5±1.40	3.8±1.32	3.4±0.93	5.8±1.14	3.7±0.91	3.4±0.93	7.2±1.78	5.0±1.65	4.1±1.49
	L2	2.6±0.70	2.1±0.78	1.8±0.62	3.6±0.94	2.8±0.84	2.2±0.72	4.6±0.83	3.0±0.71	2.7±0.70	5.2±1.39	3.9±1.36	3.3±1.08

RESULTS

Seventy patients, composed of 50 males and 20 females, with a mean age of 9.9 ± 4.40 years (range 2–17 years), were the subjects of this analysis. The mean thickness ± SD of the pediatric occipital bones in different age groups is presented in Table 1.

The external occipital protuberance had the greatest thickness, with mean values of 10.3 ± 2.99 mm (range, 5.0-18.5 mm) in males and 9.9 ± 2.41 mm (range, 5.1–14.1 mm) in females. At each level, the midline was always thicker than the lateral regions at each age group ($p<0.001$). Occipital bone thickness showed no significant difference between males and females in all age groups, except for 14-17 year group. The midline thickness at Level 0, 1 and 2 were thicker in males compared to females ($p=0.011$, $p=0.045$ and $p=0.032$, respectively).

Positive correlation was found between age and occipital bone thickness ($r=0.828$ and $p<0.001$ for EOP, $r=0.770$ and $p<0.001$ for midline at Level 1, $r=0.792$ and $p<0.001$ for midline at Level 2) and the other points showed similar findings.

DISCUSSION

Occipitocervical fusion is an effective surgical method to treat various CVJ pathologies. While semi-rigid fixation using a rod and wire construct was the preferred method, the fusion techniques have shifted to the more rigid modern fixation modalities over the past several decades [7]. Occipital plate and rod constructs eliminated the need for prolonged postoperative immobilization and the high incidence of dural laceration during sublaminar passage of wires, and also provided lesser number of spinal segments to be fixed more stiffness to the implant assembly by three-column purchase of the cervical screws, thus offering a minimal disturbance to the motion of the cervical spine [8,9].

However, besides these advantages, occipitocervical fusion using screw-rod or screw-plate constructs are challenging due to the slope of the occipital bone and the angle it makes with the cervical spine [10, 11] and these may lead to poor occipital screw purchase, screw loosening, pullout, breakage, dural laceration, cerebrospinal fluid leakage, or dural venous sinus injury. Therefore, choosing the appropriate screw length and fixation points is of great importance.

Stable fixation of the occipital bone requires screws 8 mm or more in length [12, 13]. A few authors have measured occipital bone thickness using CT or morphologic studies in cadavers [6, 13-17]. The thickness of the occiput was reported to be maximum at the median of the occipital bone in these studies. Similar to these studies, the thickest points in the occiputs were mostly at the EOP in our study, namely 6.5 mm in 2-5 years group, 9.0 mm in 6-9 years group, 11.0 mm in 10-13 years group and 12.8 mm in 14-17 years. Although occipital screws in the midline have greater pull-out strength and midline screw placement has been recommended in the literature, the plates with only midline screw options have weaker torsional strength and most of the recent occipital plates also incorporate holes for lateral screw insertion. Paramedian safe zones with thicknesses > 8 mm were reported as follows: up to 2 cm lateral from the midline at the level of the EOP, 1 cm from the median crest at a level 1 cm inferior to the protuberance, and 0.5 cm from the crest at a level 2 cm inferior to the protuberance by Ebraheim et al. [17], up to 1 cm lateral to the EOP at the level of the superior nuchal line and 2 cm inferior to the EOP by Hertel and Hirschfelder [15] and Naderi et al [6]. However, in our study, safe zones with thicknesses > 8 mm remained only at the midline in children older than 5 years of age.

CONCLUSION

Although rare, occipitocervical fusion in children is challenging and preoperative evaluation of occipital thickness should be performed in every patient considering the individual variability.

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