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Full Length Research Paper

Characterization of Occipital Condyles in Sudanese using Computerized Tomography

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The transcondylar approach has been used in surgeries to access lesions in areas close to the foramen magnum (FM) and is performed directly through the occipital condyle (OC). The objective of this study is to characterize the anatomical variations related to the (OC) with the relation to the morphometric parameters of the (FM) and head dimensions using computed tomography (CT). A total of 123 Sudanese patients (75 males and 48 females) with mean ages were 39.89 ± 15.75 , 41.02 ± 14.32 years respectively were examined using reformatted axial CT and three-dimensional CT. Characteristics of the head, and measures related to the (FM) and right and left occipital condyles were examined. The results showed no significant difference between the measurements obtained in the right and in left sides. The (OC) morphometric parameters had significant relationship with (FM) anteroposterior and transverse diameters. The study revealed a significant difference between the two genders with no significant relations between (OC) and head characteristics. The data obtained by three-dimensional CT images are important in assessing the morphometric variations of (OC) for Sudanese patients. As the (OC) is the main bony eminences impeded the anterolateral surface of the brainstem, neurosurgeons should be familiar with variations of the (OC) and structures surrounding the (FM) in order to achieve the safest surgical procedure.

Keywords: Foramen magnum, Occipital condyle, Anatomical variations

INTRODUCTION

The occipital bone can be described as being pierced by the foramen magnum (FM), condylar parts laterally and the basilar part in front. The anterolateral aspect of the FM is one of the most complex areas of the skull base (Avci et al., 2011).

The occipital condyles (OC) are located with the superior articular facets of the atlas vertebra and form an important junction between the cranium and the vertebral column (Bozbuga et al., 1999; Muthukumar et al., 2005; Naderi et al., 2005). Each (OC) is oriented obliquely so that its anterior end lies nearer the midline. It is convex anteroposteriorly, transversely, and its medial aspect is abraded by ligamentous attachments (Schwaber et al., 1990). Its reliability is of vital importance for the stability of the craniovertebral junction (Mehmet et al., 2011).

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The transcondylar surgical approach has been used to access lesions in areas close to the (FM) and it is performed directly through the (OC) (George et al., 1988), therefore the anatomical landmarks of the (FM) should be well known in order to make a safe occipital condyle resection (Barut et al., 2009).

The surgical errors in this region may result in injury to the vascular structures and cranial nerves and result in craniocervical instability. Consequently, neurosurgeons should be more familiar with the anatomy and variations of this region. Therefore, radiological (Osborn et al., 1978) and anatomical morphometric studies (Bozbuga et al., 1999; De Oliveira et al., 1985; Prescher, 1997) were performed to contribute to the knowledge of this area.

To the best of our knowledge, no similar studies were performed for Sudanese in the open literature concerning that issue. Therefore, we analyze important morphometric parameters of the FM, OC region and head dimensions, in particular, its variations, which may affect the surgical route taken to perform lesions involving this region using computed tomography (CT).

MATERIALS AND METHODS

Materials:-

The study was done prospectively during the period from August 2012 up to August 2014. The studied sample consisted of 123 Sudanese patients (75 males and 48 females) with mean ages were 39.89 ± 15.75 , 41.02 ± 14.32 respectively; They were referred to the Radiology Department in IBN ALHYTAM MEDICAL CENTER, Khartoum-Sudan, for the purpose of imaging the brain for numerous reasons. The study was approved by the Ethics Committee of the College of Medical Radiological Science, Khartoum-Sudan. Patients with history of trauma, surgery or pathological lesions in the region of the (FM) congenital or acquired disease causing probable cranial deformities were excluded from the study. Measurements were obtained using Asteion, TX-021B Toshiba multislice CT scanner 120Kvp and 200 mAs. Slice thickness 5mm and 2mm for reformatted images. All measurements were taken from reformatted images (axial, and 3D volume rendering), by the measurement function available in the CT system.

Methods:-

The Foramen Magnum (FM) measurements were taken as follows:-

Foramen magnum length (maximum internal length of the foramen magnum along the midsagittal plane), Foramen magnum width (maximum internal width of the foramen magnum along the transverse plane). The measurements of foramen magnum, area and circumference by tracing the bony border in the 3D volume rendering reformatted images.

The Occipital Condyles (OC) measurements were taken as follows:-

Right occipital condyle maximum width –taken along the articular surface perpendicular to the right occipital condyle length .Right occipital condyle length – maximum length taken along the articular surface perpendicular to the right occipital condyle width. Left occipital condyle maximum width –taken along the articular surface perpendicular to the left occipital condyle length .Left occipital condyle length – maximum length taken along the articular surface perpendicular to the left occipital condyle width .Maximum distance between occipital condyles – maximum distance between the lateral edges of the articular surfaces of the occipital condyles perpendicular to the mid sagittal plane .Minimum distance between occipital condyles – minimum distance between the medial edges of the articular surfaces of the occipital condyles perpendicular to the midsagittal plane .Maximum internal distance of the occipital condyles – maximum distance between the medial margins of the occipital condyles, perpendicular to the mid sagittal plane.

Head diameter including sagittal and transverse diameter was obtained from axial reformatted images.

Data analyses:-

The measured data were analyzed and presented in tables as mean and standard deviation, maximum and minimum values; SPSS programme version 16 was used.

RESULTS

Table 1. Descriptive statistics of the studied variables (Mean± SD, Maximum and Minimum values)

**Measured Variables	Mean± S.D (mm)	Maximum (mm)	Minimum (mm)
LRC(mm)	21.2±2.1	26.1	16.2
WRC(mm)	13.1±1.2	16.3	9.0
LLC(mm)	20.1±2	25.4	13.1
WLC(mm)	12.4±1.15	14.7	9.1
MnLC(mm)	13.3±2.4	18.6	5.4
Mic(mm)	27.1±2.4	34.9	16.9
MDC(mm)	45.7±3.4	56	30.4
TDH(mm)	120.1±7.6	141	101.6
SDH(mm)	153.8±9.8	175	121
LFM(mm)	34.1±3.1	42.1	25.8
WFM(mm)	29.4±2.6	39.5	23
AFM(mm ²)	774.3±120.7	1102	463.5
CFM(mm ²)	104±12.1	147.3	74.7

** Right occipital condyle length (LRC), Right occipital condyle maximum width (WRC), Left occipital condyle length (LLC), Left occipital condyle maximum width (WLC), Minimum distance between occipital condyles (MnLC), Maximum internal distance of the occipital condyles (Mic) Maximum distance between occipital condyles (MDC), Transverse head Diameter (THD), Sagittal head Diameter (SHD), Foramen Magnum length (LFM), Foramen Magnum width (WFM), Area of The foramen Magnum (AFM), Circumference of the foramen Magnum (CFM)

Table 2. Morphometric measurements of the Occipital condyles.

Group Statistics	Independent Samples Test	
**Measured Variables	Mean	P-value
LRC(mm)	21.21	0.000**
LLC(mm)	20.10	
WRC(mm)	13.13	0.000**
WLC(mm)	12.49	

** Right occipital condyle length (LRC), Left occipital condyle length (LLC), Right occipital condyle maximum width (WRC), Left occipital condyle maximum width (WLC).

**Significance at level 0.01

Table 3. Morphometric measurements of the Occipital condyles related to gender (mean ± standard deviation, min, max,p-value).

Group Statistics			Independent Samples Test T-test for Equality of Means			
	Gender	N	Mean ± S. D	Min	Max	P-value
LRC (mm)	Male	75	21.84±2.08	16.20	26.1	.000**
	Female	48	20.21±1.73	16.8	23.6	
WRC (mm)	Male	75	13.26±1.18	9	16.3	.104
	Female	48	12.90±1.21	9.7	15	
LLC (mm)	Male	75	20.70±1.84	15.2	25.4	.000**
	Female	48	19.16±1.93	13.1	22.3	
WLC (mm)	Male	75	12.67±1.16	9.1	14.7	.027*
	Female	48	12.20±1.08	9.6	14.4	
MnLC (mm)	Male	75	13.45±2.38	8.8	18.6	.396
	Female	48	13.06±2.61	5.4	18.2	
Mic (mm)	Male	75	28.14±2.66	21.3	34.9	.000**
	Female	48	25.57±2.76	16.9	30	
MDC (mm)	Male	75	46.96±2.98	35	56	.000**
	Female	48	43.90±3.28	30.4	54.7	
TDH (mm)	Male	75	122.68±7.17	104	141	.000**
	Female	48	116.29±6.88	101.6	136	
SDH (mm)	Male	75	157.08±8.48	136	175	.000**
	Female	48	148.76±9.73	121	167	
AFM (mm ²)	Male	75	835.20±98.23	646.1	1102	.000**
	Female	48	679.31±86.74	463.5	892	
CFM (mm ²)	Male	75	109.36±11.04	88	147.3	.000**
	Female	48	95.75±8.84	74.7	125	

**Significance at level 0.01,*Significance at level 0.05

** Right occipital condyle length (LRC),Right occipital condyle maximum width (WRC), Left occipital condyle length (LLC), Left occipital condyle maximum width (WLC), Minimum distance between occipital condyles (MnLC), Maximum internal distance of the occipital condyles (Mic),Maximum distance between occipital condyles (MDC),Transverse head Diameter (THD),Sagittal head Diameter (SHD),Area of The foramen Magnum (AFM),Circumference of the foramen Magnum (CFM)

Table 4. Statistical measurements of the variables correlated with the age classes (mean ± standard deviation, min, max,p-value)

Descriptive Statistics						
	Age classes	N	Mean ± S. D	Min	Max	P-value
<i>Right occipital condyle length</i> LRC(mm)	20-35	56	21.2±2.00	16.80	26.10	.755
	36-50	39	21.2±2.25	16.20	24.40	
	51-65	18	21.2±2.07	18.00	25.40	
	>66	10	20.5±2.30	16.90	23.00	
	Total	123	21.2±2.10	16.20	26.10	
<i>Right occipital condyle width</i> WRC(mm)	20-35	56	12.9±1.31	9.00	16.30	.606
	36-50	39	13.3±1.01	10.40	15.00	
	51-65	18	13.2±1.38	10.40	16.30	
	>66	10	13.1±.96	11.60	14.80	
	Total	123	13.1±1.20	9.00	16.30	
<i>Left occipital condyle length</i> LLC(mm)	20-35	56	20.0±2.01	15.00	25.40	.875
	36-50	39	20.3±1.97	15.20	23.80	
	51-65	18	19.8±2.31	13.10	24.30	
	>66	10	19.9±1.87	17.50	22.40	
	Total	123	20.1±2.01	13.10	25.40	

Table 4 continue

<i>Left occipital condyle maximum width (WLC) (mm)</i>	20-35	56	12.3±1.28	9.10	14.70	.481
	36-50	39	12.5±1.02	9.60	14.40	
	51-65	18	12.5±1.14	9.70	14.70	
	>66	10	12.8±.84	11.70	14.20	
	Total	123	12.4±1.15	9.10	14.70	
<i>Minimum distance between occipital condyles MnLC(mm)</i>	20-35	56	12.9±2.6	5.40	17.50	.269
	36-50	39	13.8±2.46	7.80	18.60	
	51-65	18	13.0±1.87	10.30	17.30	
	>66	10	13.9±1.93	10.20	16.40	
	Total	123	13.3±2.47	5.40	18.60	
<i>Maximum internal distance of the occipital condylesMic(mm)</i>	20-35	56	27.3±3.17	21.30	34.90	.492
	36-50	39	27.3±2.32	22.80	34.30	
	51-65	18	26.1±3.96	16.90	32.20	
	>66	10	26.8±1.81	23.30	29.80	
	Total	123	27.1±2.97	16.90	34.90	
<i>Maximum distance between occipital condylesMDC(mm)</i>	20-35	56	45.7±3.23	35.00	52.00	.839
	36-50	39	46.0±2.60	41.90	54.70	
	51-65	18	45.1±5.14	30.40	55.20	
	>66	10	45.7±4.02	41.90	56.00	
	Total	123	45.7±3.43	30.40	56.00	
<i>Transverse head Diameter TDH(mm)</i>	20-35	56	121.1±8.08	102.00	140.00	.452
	36-50	39	119.6±8.08	101.60	141.00	
	51-65	18	117.9±6.94	104.00	126.40	
	>66	10	120.6±4.42	111.30	127.30	
	Total	123	120.1±7.69	101.60	141.00	
<i>Sagittal head Diameter SDH(mm)</i>	20-35	56	154.2±9.10	132.00	169.80	.560
	36-50	39	154.1±10.65	121.00	175.00	
	51-65	18	150.9±10.02	132.50	168.50	
	>66	10	155.8±10.70	135.70	166.50	
	Total	123	153.8±9.83	121.00	175.00	
<i>Area of The foramen Magnum AFM(mm²)</i>	20-35	56	779.0±124.40	463.50	1102.00	.984
	36-50	39	771.3±116.3	510.60	992.00	
	51-65	18	768.6±133.65	598.00	1005.60	
	>66	10	769.9±109.00	605.40	919.40	
	Total	123	774.3±120.75	463.50	1102.00	
<i>Circumference of the foramen Magnum (CFM) (mm²)</i>	20-35	56	104.6±12.53	74.70	147.30	.969
	36-50	39	103.7±12.13	79.80	137.50	
	51-65	18	103.5±13.79	87.00	132.40	
	>66	10	102.9±8.27	89.60	116.00	
	Total	123	104.0±12.18	74.70	147.30	

Table 5. Correlation between the foramen magnum (FM) measurements (Length and width) and the occipital condyles morphometric measurements

Correlations		LFM(mm)	WFM(mm)
LRC (mm)	Pearson Correlation	.325**	.347
	P-value	.000	.000
	N	123	123
WRC (mm)	Pearson Correlation	.137	-.036
	P-value	.131	.692
	N	123	123
LLC (mm)	Pearson Correlation	.290**	.258**
	P-value	.001	.004
	N	123	123
WLC (mm)	Pearson Correlation	.103	-.087
	P-value	.258	.339
	N	123	123
MnLC (mm)	Pearson Correlation	.215*	.184*
	P-value	.017	.042
	N	123	123
Mic (mm)	Pearson Correlation	.436**	.664**
	P-value	.000	.000
	N	123	123
MDC (mm)	Pearson Correlation	.370**	.407**
	P-value	.000	.000
	N	123	123

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

** Right occipital condyle length (LRC), Right occipital condyle maximum width (WRC), Left occipital condyle length (LLC), Left occipital condyle maximum width (WLC), Minimum distance between occipital condyles (MnLC), Maximum internal distance of the occipital condyles (Mic), Maximum distance between occipital condyles (MDC).

Table 6. Correlation between the head dimensions (transverse and sagittal diameter) and the occipital condyles morphometric measurements.

Correlations		THD(mm)	SHD(mm)
LRC(mm)	P-value	.075	.084
	N	123	123
WRC(mm)	P-value	.191	.082
	N	123	123
LLC(mm)	P-value	.082	.065
	N	123	123
WLC(mm)	P-value	.367	.256
	N	123	123
MnLC(mm)	P-value	.077	.082
	N	123	123
Mic(mm)	P-value	.098	.087
	N	123	123
MDC(mm)	P-value	.187	.257
	N	123	123

** Correlation is significant at the 0.01 level (2-tailed).

** Right occipital condyle length (LRC), Right occipital condyle maximum width (WRC), Left occipital condyle length (LLC), Left occipital condyle maximum width (WLC), Minimum distance between occipital condyles (MnLC), Maximum internal distance of the occipital condyles (Mic), Maximum distance between occipital condyles (MDC), Transverse head Diameter (THD), Sagittal head Diameter (SHD)

DISCUSSION

The occipital condyle (OC), is an important area in craniovertebral surgery, but neither its anatomical features, nor the procedures concerning the (OC) for Sudanese have been studied yet. The morphological analyses of the structures were made in totally 246 sides of the occipital bones of adult Sudanese craniums by 3D-CT images. The length and width of the (OC) were found to be 21.2 ± 2.1 mm (right), 20.1 ± 2.0 mm (left) and 13.1 ± 1.2 mm (right), 12.4 ± 1.15 mm (left), respectively..

The maximum distance between occipital condyles, and minimum distance between inter condyles, and maximum internal distances of the occipital condyles were measured as 45.7 ± 3.4 and 13.3 ± 2.4 mm and 27.1 ± 2.4 , respectively. The sagittal and transverse head diameter were observed to be 153.8 ± 9.8 and 120.1 ± 7.6 mm respectively. The foramen magnum area, and circumference were measured as 774.3 ± 120.7 and 104 ± 12.1 mm² respectively. These were presented in table 1, and these findings were considered less than the measurements done previously (Mehmet et al., 2011)

The significance for transcondylar surgical procedure needs information regarding the morphometric aspects of the OC and surrounded structures (Muthukumar et al., 2005; Naderi et al., 2005; De Oliveira et al., 1985). The main issues to be countered in the pre-operative decision-making process is whether the measurements of the OC may affect surgical technique, therefore our study was planned to determine the length, and width of the OC which is important in cases requiring craniovertebral surgery. When we measured the right and left occipital condyle maximum length and width, no significant differences were detected between the two sides at p value = 0.000. Similar findings were detected (Mehmat et al., 2011), this was noticed in table 2

The radiological evaluation using 3D CT to the anatomical measurement, strengthens the accepted view that preoperative radiological evaluation is of greatest importance for attaining successful surgical achievement. The study, showed that there are significant differences at p value = 0.000, between the males and females regarding the variables. The Sudanese males were found to have greater measurements than females. The variables including right occipital condyle length (LRC), left occipital condyle maximum width (WLC), left occipital condyle length (LLC), maximum distance between occipital condyles (MDC), maximum internal distance of the occipital condyles (Mic), transverse head diameter (THD), sagittal head diameter (SHD), area of the foramen magnum (AFM), circumference of the foramen magnum (CFM). No significant difference were detected between right occipital condyle maximum width (WRC) and minimum distance between occipital condyles (MnLC) with genders this was observed in table 3 as well as the correlations between all of the variables and different age groups as seen in table 4.

The morphologic variations, including area, circumference, length and width of the (FM) are important, because the ability of the surgeon to adequately expose the anterior portion of the (FM) might be difficult. In our study, the area, circumference, length and width of the FM were found to be 774.3 ± 120.7 (mm²), 104 ± 12.0 (mm²), 34.1 ± 3.1 (mm), and 29.4 ± 2.6 (mm) respectively, this was presented in table 1.

The (FM) measurements, including length and width and its correlation with the occipital condyles characteristics, including right occipital condyle length (LRC), left occipital condyle length (LLC), maximum distance between occipital condyles (MDC), minimum distance between occipital condyles (MnLC), maximum internal distance of the occipital condyles (Mic), were found to be significant at $p=0.01$, and no significant relations were detected between right and left occipital condyle maximum width (WRC, WLC) with the length and width of the foramen magnum (LFM, WFM), these were noticed in table 5.

(FM) measurements, and the length of the (OC) are important factors because protrusion of the (OC) into (FM) may indicate more extensive bony removal during surgery and the amount of partial condylectomy may cause greater occipitocervical instability in short (OC) (Barut et al., 2009). This also was discussed by (Muthukumar et al., 2005).

The differences between the OC Sudanese measurements, and other previous studies measurements, (Mehmet et al., 2011) proved that there are anatomical variations detected regarding the OC.

(Naderi et al., 2005), have done the first study which made a systematic and detailed classification of the (OC), based on its shape. Shapes have been described, including two-semicircles, oval type, and rhombus, bean-shaped, prismatic, flattened, convex, flattened-convex, short and broad, flat and long, small and convex types. (Bozbuga et al., 1999; Muthukumar et al., 2005; Acikbas et al., 1997) but our study didn't characterize its shape but did comprehensive measurements for the (FM), (OC) and surrounding structures, as well as, the head sagittal and transverse diameters. Table 6 shows the correlations between the transverse head diameters (THD) and sagittal head diameter (SHD) and the occipital condyles measurements for Sudanese, the presented data showed no significant relationship between the variables and similar results were found by (Naderi et al., 2005)

The importance of that fact and studying that area comprehensively; is that the surgeon should not decide about the achievement of condylectomy based on the head transverse and sagittal diameters. One has to be familiar with the anatomical structures of the skull base, (FM) and (OC) and the probable variations of the structures in order to achieve the best surgical outcome. Our study revealed that the radiological measurements of that anatomical region using CT scan helps to organize the presurgical preparations for Sudanese patients.

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