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Morphological analysis of the hypoglossal canal and its relationship with surrounding anatomical structures

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Abstract

Aim: The aim of this study was to investigate the hypoglossal canal morphologically and to emphasize the importance of its relation to the adjacent anatomical structures, which may affect some surgical procedures, such as the transcondylar surgical approach.

Methods: In the study, 25 adult human skulls belonging to Bursa Uludağ University Anatomy Laboratories were evaluated. The 19 parameters were measured on the skulls.

Results: The distance between the hypoglossal canal and the anterior border of the occipital condyle was found to be 15.8 ± 2.8 mm on the left side and 15.8 ± 3.1 mm on the right side. The external distance between the hypoglossal canal and the anterior border of the occipital condyle was found to be 11.5 ± 2 mm on the left and 11.6 ± 2 mm on the right. The distance between the hypoglossal canal and the posterior margin of the occipital condyle was 11.7 ± 1.8 mm on the left side and 12.2 ± 2.1 mm on the right side. Furthermore, the distance measured externally between the same anatomical structures was found to be 14.04 ± 1.89 mm and 14.4 ± 1.6 mm on the left and right, respectively. We also found a positive correlation between the length of the foramen magnum and the occipital condyle. In addition, the diameter of the foramen magnum and the distance between the hypoglossal canal and the anterior margin of the occipital condyle were positively correlated.

Conclusion: In the transcondylar approach, the locations of important anatomical structures must be well known to perform a safe occipital condyle resection without harming the neural tissue. Especially surgeons should pay attention to the distances between the hypoglossal canal and the anterior and posterior margins of the occipital condyle in order to prevent hypoglossal nerve injury. The operational success of a condylectomy may be affected by the length of the hypoglossal canal. A detailed anatomical assessment is needed before similar procedures to avoid surgical injuries.

Keywords: Morphological analysis, hypoglossal canal, transcondylar approach, occipital condyle

Introduction

The hypoglossal canal (HC) is located on the basis of the cranium nearby the craniovertebral junction, and the cranial nerve XII passes through it, which is named "Hypoglossal nerve." HC and the other anatomical structures make this region a problematic area for surgical approaches. The location, morphological features, and relations between the other bone structures of HC vary in the populations. Knowledge of the advanced bone anatomy of the HC and the condylar region is required for the technique named transcondylar approach used to reach the brainstem and cervicomedullary structures [1]. The objectives of modern skull base surgery, which include preservation of the anatomical and functional cranial nerves, protection of the major vessels, and microscopic gross total tumor excision, should be taken into account prior to undertaking any surgical procedure [2]. It is also known that the topographical relationship between neurovascular structures is also significant in craniovertebral surgery for tumors [3].

Three different approaches are defined as transcondylar, supracondylar, and paracondylar techniques, which are possible for the occipital condyle (OC) region. The transcondylar approach is related to atlantooccipital joint and adjacent parts of the condyle, the supracondylar approach is associated with the area on OC, and paracondylar approach is related primarily to HC lateral to the OC [4]. Keeping in mind the morphometric details of HC, foramen magnum (FM) and OC allow a safe surgical approach, and it is also necessary to review and analyze the literature knowledge for the foramen magnum, occipital condyle, and relationship between the HC.

This study aimed to investigate the morphology of HC in dry skulls and relationships between adjacent anatomical structures such as FM, OC, and jugular foramen.

Materials and Methods

In our study, 25 adult dry skulls of unknown gender belonging to the Anatomy Department of the Faculty of Medicine of Bursa Uludağ University were used. Skulls with any damage to the base or with significant deformities are excluded from the study.

The measurements obtained manually from bones were taken using Somet Inox (1/20) calipers, and the Image J software (LOCI, University of Wisconsin, Madison, WI, USA) was performed for the measurements on the taken photographs. The 19 parameters measured are shown in Table 1.

The length of the HC was measured using a wire and caliper. Measurements of the maximum-minimum diameters of the extracranial and intracranial orifice of HC were evaluated with the Image J. The other parameters were measured directly by caliper. The parameters measured are shown in Figures 1, 2, and 3.

Table 1. Measured parameters.

Parameters
1- The distance between the HC and basion
2- The distance between the HC and opisthion
3- The distance between the HC and the jugular foramen
4- The length of the OC
5- The width of the OC
6- The anteroposterior diameter of the FM
7- The transverse diameter (right-left) of the FM
8- The distance between internal orifice of the HC and the anterior tip of the OC
9- The distance between internal orifice of the HC and the posterior tip of the OC
10- The distance between external orifice of the HC and the anterior tip of the OC
11- The distance between external orifice of the HC and the posterior tip of the OC
12- The maximum internal transversal diameter of the HC
13- The minimum internal (superoinferior) diameter of the HC
14- The distance between internal side of the HC and the inferior-median tip of the OC
15- The distance between internal side of the HC and superior-median tip of the OC
16- The height of the OC
17- The maximum external (transverse) diameter of the HC
18- The minimum external (superoinferior) diameter of the HC
19- The distance between the external side of the HC and the inferior-median tip of the OC

Statistical analysis

Statistical analyses were performed using IBM SPSS 22.0 software (IBM, Armonk, New York, USA).

Mean and standard deviation (Mean ± SD) values were analyzed for descriptive statistics of the data. The Shpario-Wilk normality test was applied to check whether the data were normally distributed.

Student's t-test was applied to compare the parameters between the right side and the left side (since all data were normally distributed).

Pearson correlation analysis was applied to examine the relationship between parameters. $p < 0.05$ was accepted as statistical significance.

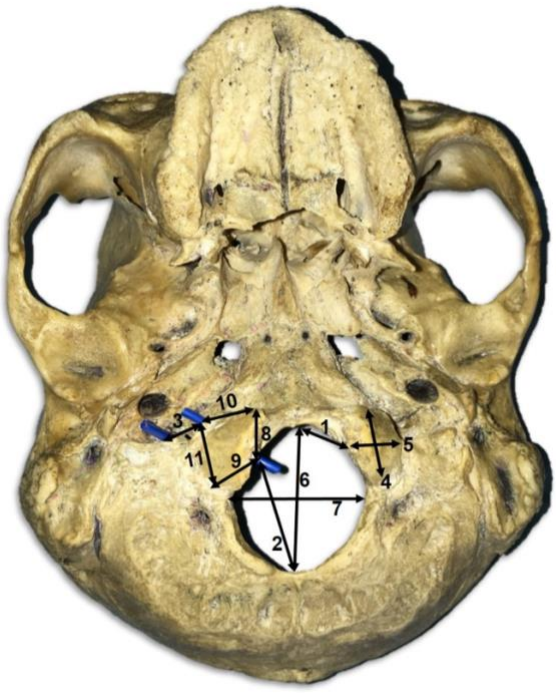

Figure 1. Parameters of basis cranii externa. According to the numbers next to the arrows; **1st -** the distance between the HC and basion, **2nd -** The distance between the HC and opisthion, **3rd -** The distance between the HC and the jugular foramen, **4th -** The length of the OC, **5th -** The width of the OC, **6th -** The anteroposterior diameter of the FM, **7th -** The transverse diameter (right-left) of the FM, **8th -** The distance between internal orifice of the HC and the anterior tip of OC, **9th -** The distance between internal orifice of the HC and the posterior tip of OC, **10th -** The distance between external orifice of the HC and the anterior tip of the OC, **11th -** The distance between external orifice of the HC and the posterior tip of the OC.

Figure 2. Parameters on the medial aspect of the hypoglossal canal. According to the numbers next to the arrows; **12th -** The maximum internal transversal diameter of the HC, **13th -** The minimum internal (superoinferior) diameter of the HC, **14th -** The distance between internal side of the HC and inferior-median tip of the OC, **15th -** The distance between internal side of the HC and superior-median tip of the OC, **16th -** The height of the OC.

Figure 3. Parameters on the lateral aspect of the hypoglossal canal. According to the numbers next to the arrows; **17th -** The maximum external (transverse) diameter of the HC, **18th -** The minimum external (superoinferior) diameter of the HC, **19th -** The distance between the external side of the HC and the inferior-median tip of the OC.

Results

The distance between the HC and the anterior tip of the OC was found as 15.8 ± 2.8 mm (mean ± standard deviation) on the internal orifice left side and 15.8±3.1 mm on the right side, and for the external orifice results were 11.5±2 mm on the left and 11.6 ± 2 mm on the right.

The distance between the posterior tip of the OC and the internal orifice was measured as 11.7±1.8 mm on the left and 12.2±2.1 mm on the right side, and for the outer orifice 14.1±1.8 mm on the left and 14.4±1.6 mm on the right side. There was no significant difference between the right and left sides. The other results of the measurements were presented in Table 2.

Additionally, positive correlations were found between the distance between the external orifice of the HC and the anterior tip of the OC - the transverse diameter (right-left) of the FM. Correlative data were shown in Table 3. According to the correlation analysis, the FM transverse (right-left) diameter is the most effective factor in the region.

Table 2. The statistical results of parameters measured in millimeters.

Parameters	Left	Right	*p*-value
The length of HC	10.15 ± 2	9.41 ± 2.32	0.326
The maximum transverse (external) diameter of the HC	4.7 ± 1.09	4.53 ± 1.06	0.538
The minimum internal (superoinferior) diameter of the HC	3.06 ± 0.92	2.97 ± 0.88	0.794
The maximum transverse diameter of the HC	5.19 ± 1.48	5.02 ± 1.1	0.699
The minimum external (superoinferor) diameter of the HC	3.51 ± 1.08	3.69 ± 0.87	0.604
The distance between the HC and basion	16.91 ± 3.24	15.85 ± 3	0.334
The distance between the HC and opisthion	31.71 ± 3.97	31.29 ± 3.01	0.732
The distance between internal orifice of the HC and the anterior tip of the OC	15.78 ± 2.87	15.8 ± 3.04	0.986
The distance between internal orifice of the HC and the posterior tip of the OC	11.76 ± 1.79	12.21 ± 2.12	0.507
The distance between internal side of the HC and inferior-median tip of the OC	12.31 ± 2.08	13.12 ± 2.13	0.270
The distance between internal side of the HC and superior-median tip of the OC	7.89 ± 0.84	8.01 ± 0.89	0.736
The distance between external orifice of the HC and the anterior tip of the OC	11.49 ± 1.99	11.61 ± 1.98	0.864
The distance between external orifice of the HC and the posterior tip of the OC	14.04 ± 1.89	14.41 ± 1.6	0.554
The distance between external side of the HC and the inferior-median tip of the OC	13.74 ± 2.39	13.82 ± 2.54	0.929
The distance between the HC and the jugular foramen	2.87 ± 1.04	2.54 ± 0.92	0.328
The length of the OC	22.33 ± 3.05	22.99±3.08	0.543
The width of the OC	14.31 ± 1.22	14.21 ± 1.48	0.831
The height of the OC	9.1 ± 1.13	9.35 ± 1.1	0.516
The anteroposterior diameter of the FM	37.17 ± 3.38		
The transverse diameter (right-left) of the FM	29.81 ± 2.72		

Table 3. The relationship between the hypoglossal canal and nearby anatomical structures.

Correlated parameters	Pearson correlation coefficient
The maximum transversal diameter of the HC - The transverse diameter (right-left) of the FM	0.629
The minimum internal (superoinferior) diameter of the HC - The transverse diameter (right-left) of the FM	0.629
The distance between the HC and basion - The transverse diameter (right-left) of the FM	0.689
The distance between external orifice of the HC and the anterior tip of the OC - The transverse diameter (right-left) of the FM	0.781

Table 4. The comparison of the diameters of HC.

	The maximum external diameter		The maximum internal diameter		The minimum external diameter		The minimum internal diameter	
Muthukumar et al. (2005)	7.9 mm		7.2 mm					
Barut et al. (2009)	Right 5.6 ± 0.95 mm	Left 5.7±0.80 mm	Right 5.7 ± 1.17 mm	Left 5.6 ± 1.18 mm				
La Marca et al. (2011)	6.2 mm				4 mm			
Osunwoke et al. (2014)	Male Right 3.78 ± 0.68 mm	Male Left 3.45 mm	Male Right 3.78 ± 0.68 mm	Male Left 3.45 ± 1.21 mm	Male Right 2.25 ± 1.09 mm	Male Left 2.67 ± 1.35 mm	Male Right 2.00 ± 1.17 mm	Male Left 2.33 ± 0.80 mm
	Female Right 3.45 ± 1.16 mm	Female Left 3.50 ± 1.02 mm	Female Right 3.45 ± 1.16 mm	Female Left 3.50 ± 1.02 mm	Female Right 2.67 ± 1.21 mm	Female Left 3.17 ± 1.97 mm	Female Right 2.10 ± 0.95 mm	Female Left 2.70 ± 2.03 mm

Table 5. The comparison of the morphometric traits belonging OC.

	The height of OC		The length of OC		The width of OC	
Zhou et al. (2016)	9.39 ± 1.50 mm		22.22 ± 1.69 mm		12.12 ± 1.03 mm	
Le et al. (2011)	9.9 ± 1.3 mm		22.4 ± 2.2 mm		11.2 mm ± 1.4	
La Marca et al. (2008)	9.3 mm		24.2 mm		9.9 mm	
Lyrtzis et al. (2017)	Right 10.09 ± 1.66 mm	Left 10.03 ± 1.45 mm	Right 23.66 ± 2.84 mm	Left 23.66 ± 2.67 mm	Right 11.77±1.52 mm	Left 11.85 ± 1.63 mm
El-Gaidi et al. (2014)	Right 10.8 ± 1.9 mm	Left 10.5 ± 2.1 mm	Right 24.24 ± 4 mm	Left 24.1±3.8 mm	Right 14.15 ± 2.0 mm	Left 14.15 ± 1.8 mm
Naderi et al. (2005)	9.2 mm		23.4 mm		10.6 mm	
Ozer et al. (2011)			Right 23.9±3.4 mm	Left 24 ± 3.3 mm	Right 11.9 ± 2.3 mm	Left 10.7 ± 2.3 mm
Barut et al. (2009)			Right 23.3 ± 2.91 mm	Left 22.9± 3.17 mm	Right 11.9 ± 1.42 mm	Left 11.7 ± 1.43 mm

Discussion

Various interventions in the craniovertebral compartment are performed by neurosurgeons because of the lesions, such as tumors or vascular pathologies. The current approaches, such as the transcondylar have enabled the safe and effective treatment of these lesions [1,4]. The transcondylar approach can be achieved in the clivus regions of the medulla by making a hole through the OC between the occipital joint and the HC. The supracondylar approach provides access to the HC and medial side of the canal [3, 4].

Because of differences in the shape, size, and location of HC, many authors have proposed a careful radiological analysis of the OC and its surroundings before attempting the procedure [1, 5, 6].

OC was surrounded by the atlantooccipital joint, the FM at the medial side, the jugular foramen at the lateral side, and the HC at rostral side. The location of the HC and other anatomical structures are essential in the condylar approaches. The distance between the internal orifice of HC and the posterior tip of the OC was reported as 11.76±1.79 mm on the left, 12.2±2.12 mm on the right; the distance between the external orifice and the posterior tip of the OC was measured as 14.04±1.89 mm on the left, 14.41±1.6 mm on the right in our study. This distance represents the safe distance that the OC can penetrate without encountering HC. According to Muthukumar et al. [1] the safe entrance distance is 12 mm. La Marca et al. [7] reported that the distance between the internal orifice and the caudal tip of OC ranges from 11 to 13 mm. Barut et al. [3] declared that the measurement was 12.5±1.65 mm on the right and 12.6±1.71 mm on the left. Kumar et al. [8] determined the distance between the internal orifice of the HC and the posterior tip of OC as 10.66±2.7 mm on the right and 11.89±2.9 mm on the left side and the distance between the external orifice of HC and the posterior tip of OC as 13.83±2.9 mm on the right and 15.02±1.9 mm on the left side. The data provide the basis for the safe distance for the OC approaches providing the damages the HC, and the results of our study were similar to the other studies in the literature.

In our study, we obtained the distance between the internal orifice of the HC and the anterior tip of OC as 11.76±1.79 mm on the left and 12.21±2.12 mm on the right side. The values of our study were similar to the results declared by Barut et al. [3] as 11.2±1.50 mm on the right and 11.2±1.71 mm on the left and the result obtained by Naderi et al. [5] as 10.1 mm.

The distance between HC and the middle tip of OC obtained as 12.31±2.08 mm on the left side and 13.12±2.13 mm on the right side internally and 13.74±2.39 mm on the left side, 13.82±2.54 mm on the right side externally. Parvindokht et al. [9] reported the distance between HC and the middle tip of OC obtained as 8.95±4.00 mm in their study.

The length of HC was measured as 10.15±2 mm on the left, 9.41±2.32 mm on the right side in the current study. The results of our study were similar to the results given by Muthukumar et al. [1] as 12.6 mm, Barut et al. [3] as 10.5±1.58 mm on the right side, 10.6±1.49 mm on the left side and Lyrtzis et al. [10] as 8.89±1.50 mm on the right side, 9.03±1.53 mm on the left side.

The distance between the HC and the jugular foramen was obtained as 2.87±1.04 mm on the left side and 2.54±0.92 mm on the right side. Parvindokht et al. [9] reported the result as 3.5±1.52 mm. This distance was strongly emphasized by many authors because of

that it was a determining factor in regional approaches [1].

The distance between HC and basion was determined as 16.91±3.24 mm on the left and 15.85±3 mm on the right side in our study. In Parvindokht et al. [9]'s research, this distance was reported as 12.5±2.35 mm. The distance between HC and the opisthion was measured as 31.71±3.97 mm on the left and 31.29±3.01 mm on the right in the current study. Parvindokht et al. [9] obtained the distance between the HC and opisthion as 33.88±2.82 mm in their HC analysis study. Also, the comparison of the diameters of HC was given in Table 4.

In the current study, 20% double HC was encountered in the examined skulls. The incidence of double HC was similar to the results of the studies of Muthukumar et al. [1], 30%, Barut et al. [3] 25%, Jacob et al. [11] 23%, Osunwoke et al. [12] 25%, Vasantha Kumar et al. [13] 20%. Wyosocki et al. [14] reported the incidence of double or divided HC as 43. 5% in their study. The existence of dual or split forms of HC may cause unexpected nerve injury.

The relationship between OC and HC is significant for transcondylar approaches. The craniovertebral junction can be reached by OC resection, and the exact size of the resection should be determined. In the current study, the height of the OC was measured as 9.1±1.13 mm on the left side, 9.35±1.1 mm on the right side; the length of OC was reported as 22.33±3.05 mm on the left side, 22.9±3.08 mm on the right side; the width of OC was obtained as 14.31±1.22 mm on the left side and 14.21±1.48 mm on the right side. The similar results of some other studies were given in Table 5 to compare the results of the current study and the others.

As Naderi et al. [5] and Ozer et al. [15] declared in their studies, the diameter of HC was half of the length of the length of OC. In our study, the safe interval of the interventions can be considered as half of the OC length when we evaluate the distance between the internal orifice of the HC and the posterior tip of OC and the length of OC data together.

The diameter of the FM was found as 37.17±3.38 mm in the current study, which is the anteroposterior diameter. Barut et al. [3] measured that distance as 35.6±2.45 mm, Chethan et al. [16] measured it as 31 ± 2.4 mm (15), Naderi et al. [5] declared it as 34.7 mm (4) and Parvindokht et al. [9] reported 31.65±0.854 mm.

The transverse diameter of the FM was measured as 29.81±2.72 mm in our study. Barut et al. [3] reported this distance as 30.3±4.70 mm, Chethan et al. [16] declared as 25.2±2.4 mm, and Parvindokht et al. [9] defined as 25.45±2.32 mm.

The CC opens into the base of the condyles, through which the posterior condylar emissary vein. These veins are associated with sigmoid sinus. For this reason, it must be considered during the surgical processes of this region. Muthukumar et al. [1], La Marca et al. [7], Le et al. [6], and Ozer et al. [15], declared the incidence of CC as 82.3% and Barut et al. [3] defined as 71%. In the current study, the incidence of CC was found as 80%, and the frequency of dual CC was noticed as 5%.

We accept some constraints in this study: although the sample size, age, and gender information of the measured material were not sufficient for normative research, the focus of our study was not to give a reference value but to draw attention to the morphology of HC.

Conclusion

The anatomical features of the HC are essential for anatomists and clinicians. The location of the critical anatomic formations must be well known to make a safe OC resection without impinging the HC and the hypoglossal nerve. The distance between the borders of the HC and the OC should be considered in order to avoid damaging the hypoglossal nerve. The length of OC may affect the success of the condylectomy.

An extensive anatomical evaluation should be considered during surgical processes such as those related to the atlantooccipital joint to avoid unexpected injuries of the hypoglossal nerve. We believe that examining the anatomical features adverted in the current study in preoperative imaging can help the surgeon choose the right approach and decide the degree of bone resection.

Disclosures

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