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A morphometric and morphological analysis of the foramen magnum, hypoglossal canal and occipital condyles in a select South African population

Seth Hendricks et al., Morphometric and morphological analysis of the foramen magnum, hypoglossal canal and occipital condyles

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ABSTRACT

Background: The foramen magnum is a centralised structure found at the base of the skull. This orifice is a passageway that allows secondary structures, such as the medulla oblongata and meninges, to pass through. The occipital condyles is a small structure on either side of the foramen magnum, forming the craniovertebral joint. The hypoglossal canal is an orifice located on the occipital canal, providing a passageway for hypoglossal nerves. The study aimed to document the morphology and morphometry of the foramen magnum, occipital condyles and hypoglossal canals within a South African population.

Materials and methods: Fifty skulls (n=50) were randomly selected from the Department of Clinical Anatomy, School of Laboratory Medicine and Medical Sciences, University of KwaZulu-Natal. This study investigated the morphological and morphometric parameters of the foramen magnum, occipital condyles and hypoglossal canal. The morphometric parameters were measured using a digital Vernier calliper. The data was statistically analysed using SPSS, and a p-value of <0.05 was deemed statistically significant.

Results: The mean length and width of the foramen magnum was found to be 35.19mm and 27.77mm, respectively. The mean index of the foramen magnum was 1.3, which indicated that the foramen magnum was predominantly oval-shaped within the selected sample. The occipital condyles have a mean length and width of 21.73mm and 12.87mm, respectively. Furthermore, the most prevalent shape of the occipital condyles was oval. The mean length and width of the hypoglossal canals were 5.14mm and 3.87mm, respectively. While the most prevalent shape of the hypoglossal canal was oval and round on the right and left sides, respectively.

Conclusions: The findings of this study may assist in reducing the risk of injury and mortalities during trans-condylar approach procedures.

Keywords: foramen magnum, occipital condyle, hypoglossal canal, morphological, morphometric, trans-condylar approach

INTRODUCTION

The foramen magnum, occipital condyles and the first two cervical vertebrae are commonly referred to as craniovertebral junction [1]. The foramen magnum is a large orifice located in the base of the skull, which provides a passageway for the medulla oblongata, spinal cord and neurovascular structures that leave the skull [2]. The foramen magnum is surrounded by different parts of the occipital bone, i.e., two condylar, squamous and occipital parts [1, 2]. Variations in the shape of the foramen magnum exist, this variation may be due to fetal development, as the foramen, magnum is one of the ossification centres [1]. The irregular shape of the foramen magnum may cause developmental anomalies of the bone and soft tissues at the craniovertebral junction [1]. According to literary reports, the most common foramen magnum shapes were round [3, 4]; oval [5], hexagonal [3] and tetragonal [1]. Farid and Fattah [6] found an association between the oval morphology and a mean length and width of 35.00mm and 29.40mm.

The occipital condyle is a distinctive skull structure containing superior articular facets. The structure and location of the occipital condyle are developed so that the position is slightly oblique, with the anterior region situated more medially. The medial aspect of the occipital condyle is relatively roughened; this is primarily due to the attachments of ligaments [7]. The occipital condyles connect the vertebral column and the cranium, forming the craniovertebral joint. Associated structures of the occipital condyles include cranial nerves, glossopharyngeal and hypoglossal nerves, spinal nerves C1 and C2 and meninges. Generally,

the shape of the occipital condyles is described as oval-shaped; however, Bayat et al. [8] described the occipital condyles as kidney-shaped. Farid and Fataah [6] found that the occipital condyles had a mean length and width of the occipital condyles to be 23.05mm and 14.90mm in their Egyptian sample, respectively. While in the Indian population, the mean length and width were recorded to be 23.60mm and 14.70mm, respectively [9]. Hence, these studies denote that population-specific differences regarding the morphology and morphometry of the occipital condyle exist [6].

The hypoglossal canal is a crucial structure located near the occipital condyles at the anterolateral border of the foramen magnum [10]. Kizilkanat et al. [10], when observing Turkish skulls, found the mean length of the hypoglossal canal to be 9.90mm. However, Muthukumar et al. [9] recorded the mean length of the hypoglossal canal to be 12.60mm, while the intracranial and extracranial diameters were 7.20mm and 7.90mm, respectively.

Transcondylar surgery is a type of approach that involves the location and resection of lesions in the area of the foramen magnum. This surgery is usually performed through the atlantooccipital joint or the occipital condyles [11]. In addition, the hypoglossal canal may also be linked to the transcondylar approach, as in certain instances, lesions are found within or around the hypoglossal canal [10]. Hence, knowledge of the morphometry of the canal and its surrounding structures may assist during surgical procedures [10]. Therefore, this study aimed to document the morphology and morphometry of the foramen magnum, occipital condyles and hypoglossal canals within a South African population of KwaZulu-Natal.

MATERIAL AND METHOD

Study design and selection criteria

This study was conducted on fifty dry adult cadaveric skulls (n=50) obtained from the Department of Clinical Anatomy at the University of Kwa-Zulu Natal. The age, ancestry and sex of the skulls were unknown. Ethical approval was obtained from the Biomedical Research Ethics Committee (BREC Number: BE362/19). Any skulls that were damaged or deformed were excluded from this study.

Methodology

Morphology

The morphology of foramen magnum, occipital condyles and hypoglossal canals were observed in the selected sample using the following classification schemes:

1. Foramen magnum

- Oval shape
- Round shape

2. Occipital condyle

- Kidney shape
- Oval shape
- Round shape

3. Hypoglossal canal

- Oddly shape
- Oval shape
- Round shape

Morphometry

In this study, each of the following morphometric parameters was measured three times by the first author in accordance with Farid and Fattah [6], using a digital Vernier Caliper set to the precision of 0.01mm:

- ✓ Length and width of the foramen magnum
- ✓ Bilateral length and width of the occipital condyles
- ✓ Bilateral length and width of the hypoglossal canal

The foramen magnum index was calculated for each skull using the formula: Foramen magnum= foramen magnum length/ foramen magnum width. If the Index is greater or equal to 1.2, then the morphology of the foramen magnum is said to be oval. However, if it is less or equal to 1.2, then the foramen magnum has an asymmetrical shape [6].

RESULTS

Morphology

Foramen magnum

The foramen magnum was predominantly oval-shaped in this study, with an incidence of 58.0%. This was followed by the round shape, with an incidence of 42.0% (Table I).

Occipital condyles

In the present study, the right occipital condyle was recorded to be oval-shaped in 76.0% of the specimens, while in 10.0% and 14.0% of specimens, it was recorded to be kidney and round-shaped, respectively (Table II). Similarly, the left occipital condyle was

also predominantly oval-shaped (64.0%), while the kidney and round-shaped occipital condyles were documented in 16.0% and 20.0%, respectively (Table II).

Hypoglossal canal

The right hypoglossal canal was observed to be oval, round and oddly shaped in 54.0%, 40.0% and 6.0% of the specimens in this study, respectively (Table III). The left hypoglossal canal was found to be oddly shaped (10.0%), oval-shaped (44.0%) and round shaped (46.0%) (Table III).

Morphometry

Foramen magnum

In this study, the mean length and width of the foramen magnum were 35.19mm and 27.77mm, respectively (Table IV). The foramen magnum index was calculated to be 1.3, which denoted that the oval-shaped foramen magnum was most prevalent (Table IV).

Occipital condyles

The mean length of the occipital condyle was 21.75mm on the right side and 21.72mm on the left side in the selected South African sample (Table V). While the mean width of the right and left occipital condyle was 12.32mm and 13.43 mm, respectively (Table V).

Hypoglossal canal

In this study, the hypoglossal canal had a mean length of 4.59mm on the right side and 5.68mm on the left side (Table V). The mean width of the hypoglossal canal was 3.79mm and 3.94mm on the right and left sides, respectively (Table V).

DISCUSSION

The surgeons must have a firm grasp of the anatomical landmarks during neuro-surgical procedures [12]. In particular, when performing transcondylar surgery and occipital condyle drilling, the craniovertebral junction is an important landmark [13]. Therefore, it is imperative to have extensive knowledge of the relationship between the foramen magnum, occipital condyles and hypoglossal canal in different population groups [12].

Foramen magnum

In this study, the mean length and width of the foramen magnum were recorded to be 35.19mm and 27.77mm, respectively. Similarly, Farid and Faataah [6] reported that the foramen magnum had a mean length of 35.00mm, and a mean width of 29.40mm in the Egyptian population. However, Muthukumar et al. [9] documented that the length and width of the foramen magnum in the Indian population was 34.60mm and 29.00mm, respectively. In addition, Ulcay et al. [14] reported an observed mean length and width of 35.81mm and 28.14mm in the Turkish population. When observing the morphology of the foramen magnum, the oval shape was most frequently observed in this study, which correlated with the study conducted by Ulcay et al. [14]. However, in the Indian and Turkish population groups, the foramen magnum was predominantly rounded in shape. Furthermore, in this study, the foramen magnum index was calculated to be 1.3, which indicated that the foramen magnum was oval-shaped (>1.2), which correlated with the findings of Muthukumar et al. [9]. In contrast, Farid and Fataah [6] found that the asymmetrically shaped foramen magnum (<1.2) was most prevalent in 60% of their sample, followed by the oval shape (>1.2) with a 40% prevalence.

Occipital condyles

The right and left occipital condyles had a mean length of 21.75mm and 21.72mm, and a mean width of 12.32mm and 13.43mm, respectively. In comparison to the present study, Farid and Fataah [6] reported a slightly larger mean length and width of the occipital condyles in the Egyptian population, i.e., a mean length of 22.90mm and 23.20mm and a width of 14.80mm and 15.00mm on the right and left sides, respectively. Furthermore, Muthukumar et al. [9] found that the mean length and width of the occipital condyles were 23.60mm and 14.70mm, respectively. This indicates that population-specific differences may exist. In this study, the occipital condyles were predominantly oval-shaped, however, Bayat et al. [8] documented that the kidney-shaped occipital condyles were most prevalent in the Iranian population.

Hypoglossal canal

In this study, the right and left hypoglossal canals had mean length of 4.59mm and 5.68mm, respectively. While the mean width of the hypoglossal canals is 3.79mm on the right side and 3.94mm on the left side in this study. However, Muthukumar et al. [9] documented that the mean length of the hypoglossal canal was 12.60mm in the Indian population group. Kizilkanat [10] reported that the hypoglossal canal had a mean length of 9.90mm in their

study. In addition, the right hypoglossal canal was most frequently oval-shaped, while the left was predominantly round in this study.

Limitations of the study

The limitation of this study was that the demographic data of the specimens was not accessible to the authors, hence further studies should investigate, if any differences exists among the different age groups and sexes in South Africa.

CONCLUSIONS

The findings of this study may contribute to the existing body of anatomical knowledge and may assist in reducing the risk of injury and mortalities during trans-condylar approach procedures.

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Conflict of interest: None declared

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Table I: Morphology of foramen magnum

Shape	Frequency	Percentage (%)
Oval	29	58.0
Round	21	42.0
Total	50	100.0

Table II: Morphology of occipital condyles

Shape	Right		Left	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Kidney	5	10.0	8	16.0
Oval	38	76.0	32	64.0
Round	7	14.0	10	20.0
Total	50	100.0	50	100.0

Table III: Morphology of hypoglossal canal

Shape	Right		Left	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Oddly	3	6.0	5	10.0
Oval shape	27	54.0	22	44.0
Round Shape	20	40.0	23	46.0
Total	50	100.0	50	100.0

Sample size (n)	Mean Length		Mean Width		<i>FM index:</i> <i>FM mean length/FM mean width</i>
	Length ± Standard derivation	Standard Error	Width ± Standard derivation	Standard Error	
50	35.19±3.37mm	0.78	27.77±3.84mm	0.71	1.3

Table IV: Morphometry of foramen magnum in the South African sample (in mm)

Table V: Morphometry of occipital condyles and hypoglossal canals in the South African sample (in mm)

Parameters	Sample size (n)	Occipital condyle				Hypoglossal canal			
		Right	Standard Error	Left	Standard Error	Right	Standard Error	Left	Standard Error
Mean Length	100	21.75±2.97 mm	0.55	21.72±3.17 mm	0.57	4.59±1.41 mm	0.20	5.68±1.61 mm	0.24
Mean Width	100	12.32±2.02 mm	0.34	13.43±2.05 mm	0.36	3.79±1.21 mm	0.18	3.94±1.98 mm	0.28