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Morphological Analysis of the Hypoglossal Nerve Canal in Dry Skulls from Northeastern Brazil

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ABSTRACT

Introduction: the hypoglossal nerve, XII cranial nerve, is a motor nerve for the muscles of the tongue that arises from the medulla and crosses the hypoglossal nerve canal in the occipital bone. This canal may present variations that induce changes in the path of the nerve and vascular structures related to it. This understanding is essential for choosing the best surgical techniques to avoid injuries to the components that transit through the canal.

Objectives: to analyze the morphology of the hypoglossal nerve canal in skulls from a population in northeastern Brazil.

Method: fifty dry adult human skulls (25 male and 25 female) belonging to 2 anatomy laboratories in northeastern Brazil were analyzed. The morphological analysis was performed according to the classification by Kumar *et al*.[9] regarding the presence of septa and spores. The morphometric analysis was performed with a digital caliper with a precision of 0.01mm. Student's t test was applied to assess sexual dimorphism using IBM SPSS Statistics for Windows version 21.0.

Results: twenty-three skulls were classified as type l (no changes in the canal), of which 10 are female and 13 male (46% of the sample). No type 2a and 2b skulls were found. The most prevalent variations were type 3, with 11 skulls 3a (22%) and 5 3b (10%). Five skulls corresponded to type 4 (10%) and another 5 to type 5 (a combination of spore and septum), which is a variation discovered and adapted to the classification used in this study. In the morphometric analysis, there was no difference between the analyzed parameters, except for extracranial width, in males (p=0.003).

Conclusion: a peculiar anatomy of the hypoglossal nerve canal was observed in this population from northeastern Brazil. It is essential to recognize these variations to guide professionals in their surgical interventions, avoiding injuries to the hypoglossal nerve and associated structures.

Keywords: Anatomy; Hypoglossal Canal; Cervical atlas.

Introduction

The hypoglossal nerve is the twelfth pair of cranial nerves, it originates at the medulla and emerges from the skull through the hypoglossal nerve canal, which is situated above the occipital condyles, constituting a bone passage that extends from the posterior cranial fossa to the nasopharyngeal carotid[1,2]. This nerve constitutes an important element destined to the motor innervation of the intrinsic and extrinsic muscles of the tongue. Along the hypoglossal nerve canal it is possible to find a small variable emissary vein, a venous plexus, a branch of the ascending pharyngeal artery and occasionally the persistence of a hypoglossal artery[1,3,4].

Several variations produced during embryonic development can generate bone crypts in the hypoglossal nerve canal that cause changes in the nerve path and vascular structures within it. Although few types of variations can be identified and classified in the literature, they range from formations of one or two bone spicules to complete bridges[4,5,6].

These bone variants reflect the distinct genetic, environmental, anthropological, and racial influences on the human body[5,7,8]. The hypoglossal nerve canal is within this context of morphological diversity. Therefore, it has a clear clinical importance in the different populations of the world, since these variations can have impacts on the therapeutic planning of pathological conditions such as occipital bone fractures, congenital defects, intra and extracranial neoplasms and also for the classification of embryological aspects[7, 8, 9, 10].

Therefore, the decision for surgical intervention in these pathological processes takes into account not only anatomical aspects of the hypoglossal nerve, but also anatomical variations of its canal. The knowledge of the morphological and morphometric variations of the hypoglossal nerve canal helps neurosurgeons

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in many ways, especially in more invasive surgeries at the base of the skull and head and neck, with the aim of minimizing damage to the nervous and vascular structures of this region[6, 8, 9, 10].

Hypoglossal nerve palsy, for example, can result from changes in the morphology of its canal. Injury to this nervous structure causes loss of motricity of the tongue muscles on the corresponding side, with tongue deviation ipsilateral to the lesion, dysarthria, pain, difficulty in chewing, impaired speech articulation, and inability to swallow, and can even be a medical emergency leading to airway obstruction and requiring tracheostomy[6,11].

Turning to the phylogenetic and functional aspect, there are reports that, with evolution, there was a process of expansion and increase in the diameter of the canal that, in primates, for example, because they exhibit a smaller passage than modern humans, fewer fibers would reach to the language, determining less skills in speech articulation[7,12].

Some studies even classify the variations of the hypoglossal nerve channel into different groups, ranging from a normal channel to the presence of bone bridges throughout the channel, starting from the internal to the external orifice, dividing it into two channels[6]. However, these variations and their impacts are less comprehensively described in the literature, especially in Brazilian databases.

The results of this research may be relevant to health professionals in general, neurosurgeons and neurologists, since the data collected here will serve to choose the best surgical techniques to be used in order to avoid injuries to the components that transit through the hypoglossal nerve canal[6,8,9,10,13]. Therefore, the present study aims to analyze the morphology of the hypoglossal nerve canal in dry skulls from a population in northeastern Brazil.

Methods

The study was carried out in anatomy laboratories in the states of Ceará and Paraíba, both located in northeastern Brazil, after institutional approval. This study complies with Brazilian Federal Law 8501 (November 30, 1992).

Fifty dry adult human skulls were analyzed (25 male and 25 female). Skulls in good condition were selected and those that showed damage to their structure, with signs of degradation or with infantile conformation that made analysis impossible were excluded.

The data were recorded in forms and the photos were used to identify the specimens. Skull sexing was based on morphological characteristics[14]. Morphometric measurements of the extracranial and intracranial length and width of the hypoglossal nerve canal (HC) were performed with the aid of a digital caliper (DIGIMESS®, Instrumentos de Preciso Ltda., São Paulo, Brazil) of 0.01 mm accuracy).

The morphological variability of HC in relation to the presence of spores, incomplete and complete septa was analyzed according to the classification suggested by Kumar *et al.*[9] (Table 1). Type 1 of this classification refers to HC that does not show any evidence of bone spurs or septum; Type 2 refers to HC with spurs; Type 3 has incomplete septa dividing a portion of the HC into two parts; and Type 4 is HC with complete septa dividing it completely into two parts.

Student's t test was applied to assess the existence of significant differences between the genders on each side and between the sides of each skull. Statistical analysis was performed using IBM SPSS Statistics for Windows version 21.0. The value of $p<0.05$ was considered significant in the study.

Table 1. Classification of morphological variations in the HC into different types (KUMAR *et al.*, 2017[9]).

Type	Characteristics		Abbreviation
Type 1	No evidence of bony spur or septum		Type 1 HC
Type 2	Spur in HC	Spur present near external opening of HC	Type 2a HC
		Spur present near internal opening of HC	Type 2b HC
		Spur present in the middle part of HC	Type 2c HC
Type 3	Incomplete septa dividing a portion of HC into two parts	Septa present near external opening dividing it into double external opening	Type 3a HC
		Septa present near internal opening dividing it into double internal opening	Type 3b HC
		Septa present in the middle part dividing a portion of HC into two	Type 3c HC
Type 4	Complete septa dividing whole HC into two parts		Type 4 HC

Results

Fifty dried skulls were included in the analysis, 25 (50%) male and 25 (50%) female. The morphometric analysis showed that only the extracranial width of the hypoglossal nerve canal (HCW) was greater in male skulls than in females (p = 0.003). No differences between genders or antimeres were observed in the other measurements (Table 2).

Table 2. Mean (mm) ± SD values of hypoglossal canal measurements in both sexes. N=50.

	MALE				FEMALE			
	Right side		Left side		Right side		Left side	
Parameters	Min- Max	Mean (SD)	Min- Max	Mean (SD)	Min- Max	Mean (SD)	Min- Max	Mean (SD)
HCH	0.22 - 0.62	0.38±0.11	0.22 - 0.67	0.40± 0.14	0.22 - 0.63	0.39±0.13	0.21 - 0.55	0.36±0.11
HCW	0.16 - 0.44	0.27±0.07	0.16 - 0.62	0.33±0.11	0.22 - 0.37	0.29±0.05	0.22 - 0.32	0.24±0.02

HCH: Hypoglossal canal height; HCW: Hypoglossal canal width; N: number of skulls analyzed; Min: minimum; Max: Maximum; SD: standard deviation

In the qualitative analysis (Table 3), the presence of anatomical variations in the canal of 27 skulls was observed, accounting for 54% of the total sample, being 12 female skulls and 15 male (24% and 30%, respectively). Thus, the remaining 23 are classified as type 1 HC by Kumar *et al.*[9] as skulls without evidence of septa or bone spores, which adds up to 46% of the total sample, being 13 female and 10 male (26% and 20% of the skulls). evaluated, respectively).

Among the variations, there was a greater number of HC located on the left side (15 skulls), constituting 30% of the total number of skulls analyzed. Right side variations were present in 12 skulls, making up 24% of the total. Regarding the variations on the left side, there was a prevalence in male skulls (8 skulls, 16%). Changes on the right side were also higher in males (7 skulls, 14%).

The type 4 HC variation was found in 4 male (2 on the left and 2 on the right) and 2 female (1 on the right and 1 on the left) skulls. (Figure 1 and Table 3). The type 3a HC variation was found in 3 male and 2 female skulls on the right side. On the other hand, on the left, it was present in 3 male skulls and 3 female skulls (Figure 2 and Table 3). The Type 3b HC variation was observed in 2 skulls on the right side: 1 male and 1 female. On the left side, they were found in 1 male and 2 female skulls (Figure 3 and Table 3).

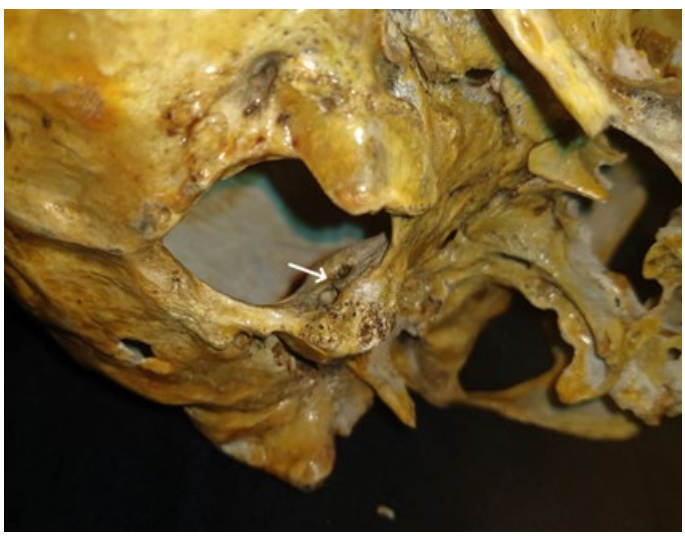

Figure 1. Right inferolateral view of skull. Type 4 HC variation on the left side (arrow), according to the classification by Kumar *et al.* (2017)[9].

Table 3. Hypoglossal nerve canal's type percentage in both sexes (Adapted from Kumar *et al.*, 2017[9]). N=50

Types of HC	Male skulls		Female skulls		TOTAL
	Right	Left	Right	Left	
Type I	10		13		23 (46%)
Type 2	0	0	0	0	0%
Type 3a	3	3	2	3	11 (22%)
Type 3b	1	1	1	2	5 (10%)
Type 4	2	2	1	1	6 (12%)
Type 5*	1	2	1	1	5 (10%)
Total	25		25		50 (100%)

*Type 5 designates a new finding: combination of septum and spur in the same canal.

Figure 2. Right inferolateral view of skull. Type 3a HC variation (septa present near external opening dividing it into double external opening) on the right side (arrow), according to the classification by Kumar *et al.* (2017)[9].

Figure 3. Right inferolateral view of skull. Type 3b HC variation (septa present near the internal opening dividing it into a double external opening) on the left side (arrow), according to the classification by Kumar *et al.* (2017)[9].

Furthermore, not fitting the types proposed by Kumar *et al.*[9], a new anatomical variation (suggested as type 5 HC in the present study) was found (Figure 4 and Table 3) in a total of 5 skulls: the combination of spores with septation in the hypoglossal nerve canal. This was observed in 2 skulls on the right (4% of the total sample), one female and one male and 3 on the left (6% of the total sample), composed of one female and 2 males.

Não foram encontradas nenhuma variação dentro da classificação do Tipo 2 (presença de esporos isolados). Nesta classificação, há presença de esporos próximos à abertura extracraniana do canal (Tipo 2a), esporo próximo à abertura intracraniana (tipo 2b) e esporo na parte média do canal do nervo hipoglosso (tipo 2c). Houve apenas a prevalência de esporos em combinação com septos ósseos em 10% dos crânios, como descrito anteriormente, a qual não consta na classificação de Kumar *et al.*[9], representado pela figura 4. Os dados morfológicos sobre as variações encontradas no presente estudo estão resumidos na Tabela 3.

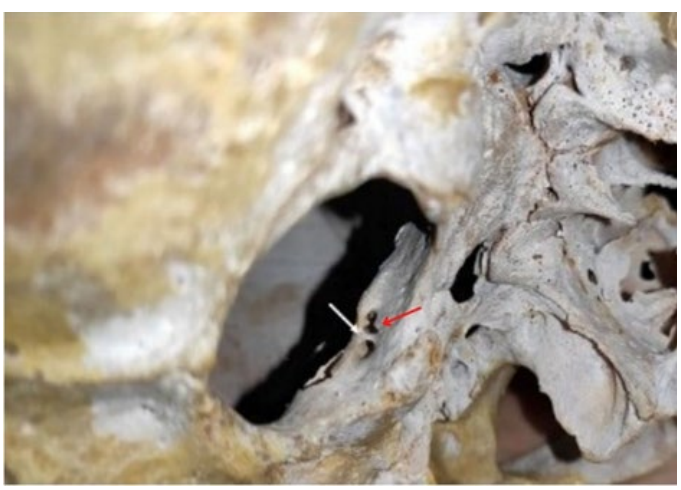

Figure 4. Right inferolateral view of skull. Type 5 HC variation. This is a combination of spores (red arrow) with septation (white arrow) in the hypoglossal nerve canal on the left side, according to the classification by Kumar *et al.* (2017)[9].

Discussion

The hypoglossal nerve is the twelfth pair of cranial nerves, which is destined to innervate the musculature of the tongue. Often, some benign diseases such as intra and extracranial tumors, hypoglossal nerve schwannomas, posterior fossa meningiomas, and jugulotympanic paragangliomas can seriously affect it. Therefore, it is of fundamental importance to study the anatomy of the reference area for more precise and effective surgical interventions in these alterations. It is not only a matter of evaluating the size and type of tumor, but also the anatomy variations of the hypoglossal nerve canal (HC)[4, 10].

According to Katsuta *et al.*[4], the presence of septa and bone spores in this canal can divide it, which could cause compression of some vascular structures that pass through it, such as the venous plexus. One of the possible explanations for a canal divided into two compartments would be that the hypoglossal nerve, during embryonic development, when involved in its fibrous sheath, forms two or more nerve bundles. The duplication of hypoglossal channels is still something studied, but it is considered to be a possible cause of defects in the regulation of the HOX gene[15].

In this study, 50 dried human skulls from northeastern Brazil were evaluated for the morphology and morphometry of the 100 hypoglossal nerve channels. That is, in our sample there was no absence of CH on both sides, as in important works[5, 8, 9] in this topic. These studies have also analyzed a similar number of skulls between 50 and 60 skulls. However, in these studies, none demonstrated the specification of sexing among the findings.

Observing the skulls of an Indian population[9], it was observed a prevalence of anatomical variations in the left side canal and mainly of type 3 (26%), similar to the sample of this work. On the other hand, in another Brazilian study[6], it can be seen that the presence of variations in the canal occurs, primarily, on the right side, as in a study carried out in the United States[2]. However, the variation that was most present on the left side in the Brazilian study was the formation of two bone bridges in the inner part of the canal, which divided it into three holes, a characteristic not found in the present study.

Skull sexing was only performed in a study[16], similarly to this study. Furthermore, Kumar *et al.*[9] state that one of the limitations of the study was that it did not identify the sex of the evaluated skulls, as this may be directly linked to the morphological characteristics of the variations in each sample.

The etiology of the disorders that affect the hypoglossal nerve has a multifactorial origin, requiring the application of imaging studies to observe the clinical and surgical aspects. Thus,

magnetic resonance imaging is the most used imaging test to visualize the nerve, and computed tomography is very useful for observing the skull base nerve canal and its variations. Imaging techniques can also be applied in the study of variations in morphology and morphometry of the hypoglossal nerve canal[3,10].

Direct injury or section of the hypoglossal nerve during surgical exploration of the region where the hypoglossal nerve canal is located is rare, and the pathophysiology of the dysfunction is edema resulting from trauma secondary to nerve retraction and dissection[17]. The lesion can also occur in the control of bleeding in the small vessels around the nerve[17,18,19]. Therefore, it is necessary to have a detailed knowledge of the bone anatomy of the region, the neurovascular components, their respective paths, as well as their variations, avoiding possible structural impairments. in the various surgical interventions.

Conclusion

It can be observed that there was a higher prevalence of variations in the hypoglossal nerve canal at both sides and genders in the population studied. In addition, a new variation not described in the literature on the anatomy of the hypoglossal nerve canal was evidenced. This highlights the importance of recognizing their morphological variations in the guidance of health professionals regarding surgical interventions, especially in this population in northeastern Brazil, avoiding possible injuries to the nerve and associated structures.

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Mini Curriculum and Author's Contribution

1. Daniel Dantas da Silva: discussion of the results and writing of the manuscript.

2. Maria Francisca da Conceição Maciel Targino: discussion of the results and writing of the manuscript.

3. Marcílio Ferreira de Paiva Filho: discussion of the results and writing of the manuscript.

4. André Luiz Pinto Fabrício Ribeiro: discussion of the results and writing of the manuscript.

5. Letícia Leite Cavalcante: discussion of the results and writing of the manuscript.

6. Rodrigo Freitas Monte Bispo: discussion of the results and writing of the manuscript.

7. Jalles Dantas de Lucena: discussion of the results and writing of the manuscript, conception and design of the study.

8. André de Sá Braga Oliveira: discussion of the results and writing of the manuscript, conception and design of the study.

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