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Rare anatomical variation of the hypoglossal canal: morphology, morphometry, and clinical-surgical implications

Variação anatômica rara do canal do hipoglosso: morfologia, morfometria e implicações clínico-cirúrgicas

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Abstract

The hypoglossal nerve canal is a bony structure present above the occipital condyle that gives passage to important structures, such as the hypoglossal nerve, the meningeal branch of the ascending pharyngeal artery, and the emissary vein of the basilar plexus. As this structure may undergo variations, it is of particular interest to researchers, especially due to its clinical, radiological, and surgical implications. This study aimed to report a rare anatomical variation of the hypoglossal canal, describe the morphological and morphometric aspects and topographical relationships with the occipital condyle, and discuss the main clinical-surgical implications of this structure.

Keywords: Anatomy; Hypoglossal nerve; Neurosurgery; Measurement equipment; Anatomy variation.

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Resumo

O canal do nervo hipoglosso é uma estrutura óssea presente acima do côndilo occipital e dá passagem a importantes estruturas, tais como o nervo hipoglosso, o ramo meníngeo da artéria faríngea ascendente e a veia emissária do plexo basilar. Essa estrutura pode sofrer variações sendo um campo de estudo de particular interesse dos pesquisadores, especialmente devido às suas implicações clínicas, radiológicas e cirúrgicas. O presente estudo visou relatar uma variação anatômica rara do canal do nervo hipoglosso e descrever os aspectos morfológicos, morfométricos e sua relação topográfica com o côndilo occipital, além de discorrer sobre as principais implicações clínicas e cirúrgicas dessa estrutura.

Palavras chaves: Anatomia; Nervo hipoglosso; Neurocirurgia; Equipamentos de medição; Variação anatômica.

INTRODUCTION

The hypoglossal nerve canal (HC) is a bony structure located above the occipital condyle at its antero-posterior junction. This canal gives passage to vital structures, including the hypoglossal nerve responsible for innervating the intrinsic and extrinsic muscles of the tongue, the meningeal branch of the ascending pharyngeal artery, and the emissary vein that connects the basilar venous plexus to the internal jugular vein[1,2].

This structure may exhibit variations, such as when the HC is divided by a bony spur and results in a double HC. Other variations related to ancestry and biological sex have also been reported in the literature. Studies aimed at understanding these variations have been of particular interest to researchers, mainly due to their clinical, radiological, and surgical implications[1,3].

Several lesions have the potential to affect the HC, including tumors, abscesses, hematomas, aneurysms, arteriovenous malformations, cysts, and traumatic injuries. These conditions may impair the structures near the HC and lead to speech, swallowing, and chewing alterations. In the case of tumors in this region, the decision about the surgical intervention relies on its size, histological type, and anatomical variations of the HC. Thus, early identification of these lesions and a thorough understanding of anatomy and its variations are imperative for preventing neurological complications[1,2,4].

The present study aims to report an anatomical variation of the HC not documented in the literature, describe its morphological and morphometric aspects, explore topographical relationships with the occipital condyle, and address the primary clinical-surgical implications associated with this structure.

CASE REPORT

The current study was conducted at the Laboratory of Forensic Anthropology and Osteology of a higher education institution. The rare anatomical variation of the left HC was identified in a skull (Figure 1A) during a routine process of washing and drying the skeletons of the collection for subsequent storage.

Morphologically, the bilateral presence of the HC was observed. The HC traversed superiorly and positioned slightly on the anterior, lateral, and superior portion of the occipital condyle. The internal and external foramina delineated the HC, while an accessory foramen on the superior wall of the left HC connected the HC and the left jugular fossa (Figure 1B).

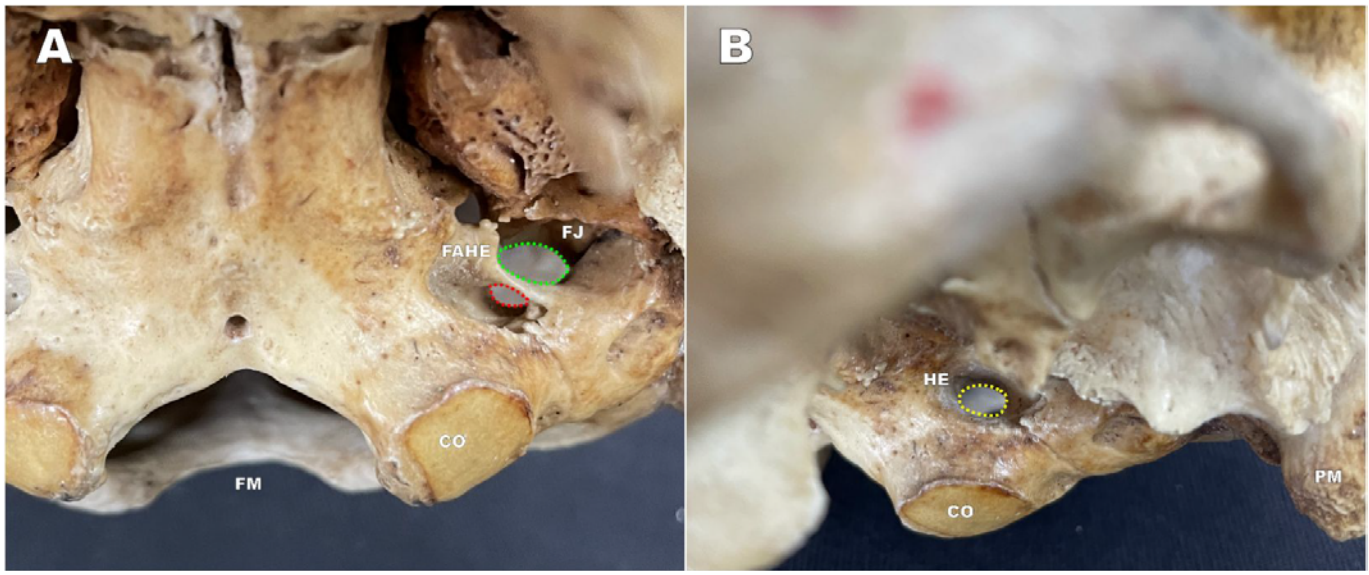

Figure 1. A: Antero-inferior view of the left extracranial hypoglossal canal, showing the accessory foramen communicating with the jugular foramen. **B:** Antero-lateral view of the left extracranial hypoglossal canal. Foramen magnum (FM); occipital condyle (CO); accessory foramen of the extracranial hypoglossal canal (AEHC); jugular foramen (FJ); and mastoid process (PM).

Regarding morphometry, the metric parameters for the intra- and extracranial HC were measured using a *Castroviejo* compass and a digital caliper.

The metric parameters for the intracranial hypoglossal canal (HI) were obtained as follows (Figure 2A): (1) vertical diameter of 0.35 mm on the right and 0.50 mm on the left; (2) transverse diameter of 0.75 mm on the right and 0.60 mm on the left; (3) distance between HI and occipital condyle of 11.00 mm on the right and 10.0 mm on the left; (4) distance from HI to the jugular foramen of 7.50 mm on the right and 6.00 mm on the left; (5) distance between HI and the jugular tubercle of 10.00 mm on the right and 10.50 mm on the left; (6) distance from HI to the basion of 15.50 mm on the right and 14.50 mm on the left; (7) distance from HI to the opistium of 3.50

mm on the right and 3.50 mm on the left; and (8) depth of the HC (i.e., from the intracranial to the extracranial HC) of 1.15 mm on the right and 1.20 mm on the left.

The metric parameters for the extracranial hypoglossal canal (HE) were also measured (Figure 2B): (1) vertical diameter of 0.45 mm on the right and 0.60 mm on the left; (2) transverse diameter of 1.05 mm on the right and 0.50 mm on the left; (3) distance between the HE and the occipital condyle of 0.5 mm on the right and 0.60 mm on the left; (4) distance from the HE to the jugular foramen of 0.30 mm on the right and 0.20 mm on the left; (5) distance from the HE to the basium of 1.90 mm on the right and 1.70 mm on the left; and (6) distance from the HE to the opistium of 4.50 mm on the right and 5.00 mm on the left.

Furthermore, the position of the HC in relation to the occipital condyle was measured. The maximal antero-posterior axis of this condyle can be divided into three equivalent parts: “a”, “b”, and “c” for the anterior, middle, and posterior third, respectively. In the present case, both HC were classified as type “a” because they were located in the anterior third (Figure 2C).

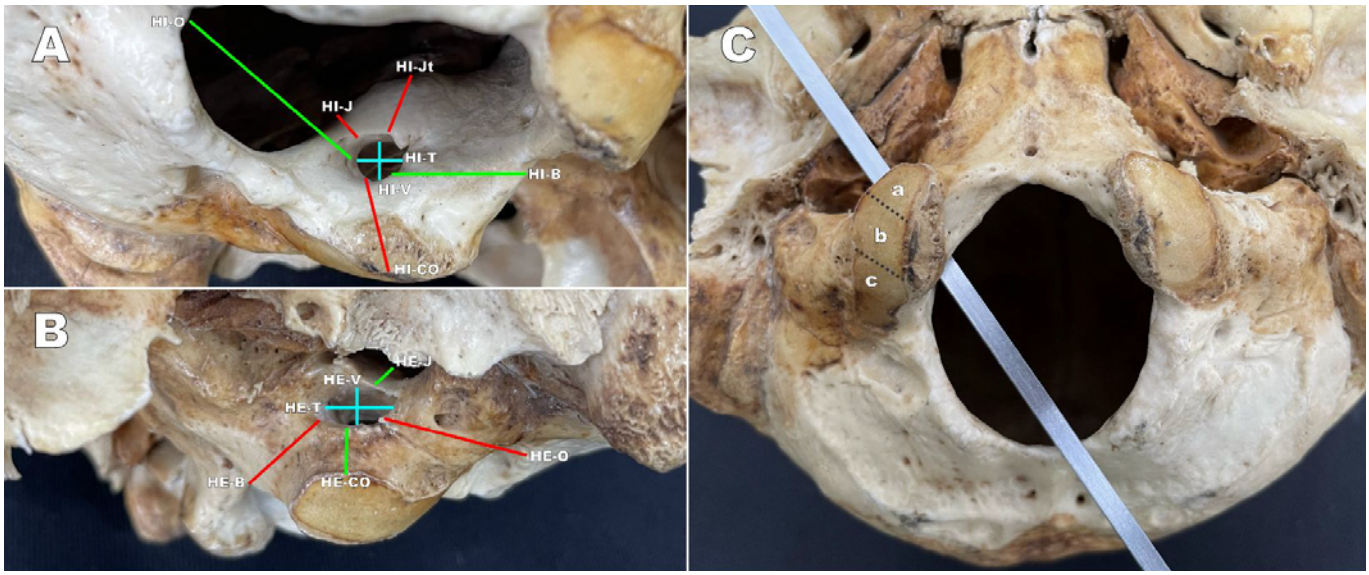

Figure 2. Postero-lateral view **(A)**, antero-lateral view **(B)**, and inferior view **(C)** of the skull base. **A:** Metric parameters obtained for the intracranial hypoglossal canal; **B:** Metric parameters obtained for the extracranial hypoglossal canal; and **C:** Location of the hypoglossal canal in relation to the occipital condyle. HI: intracranial hypoglossal canal; HI-V: vertical diameter of the HI; HI-T: transverse diameter of the HI; HI-OC: distance between HI and occipital condyle; HI-J: distance from HI to the jugular foramen; HI-Jt: distance between HI and the jugular tubercle; HI-B: distance from HI to the basion; HI-O: distance from HI to the basion; HE: extracranial hypoglossal canal; HE-V: vertical diameter of the HE; HE-T: transverse diameter of the HE; HE-OC: distance between HE and occipital condyle; HE-J: distance from HE to the jugular foramen; HE-B: distance from HE to the basion; HE-O: distance from HE to the basion; a, b, c represented the anterior, middle, and posterior third of the antero-posterior axis of the HC.

Another aspect evaluated was the non-morphometric parameter related to shape, which can be classified as round or oval. In this study, the HC exhibited a round shape. Conversely, this structure could not be categorized according to Hauser and De Stefano (type I to V)[3] since literature lacked studies about this specific variation.

Furthermore, the HC was photographed using a camera positioned 30 cm high and perpendicular to the anatomical specimen. The bone head was positioned on a flat surface, parallel to the ground, with the antero-inferior surface facing upwards. A ruler with a millimeter scale (ABFO ruler No 2, Crime Scene, Phoenix, Arizona, USA) was positioned next to the anatomical specimen to standardize the position of the lens (i.e., parallel to the anatomical accident). Consequently, the area of the foramen on the superior wall of the left HC was measured using the ImageJ software (National Institutes of Health, USA). For this, the software was calibrated by drawing a one-millimeter line on the ABFO ruler placed beside the HC. Subsequently, a cursor outlined the entire foramen to analyze the morphometry. The area of the accessory foramen was 0.55 mm².

DISCUSSION

Foramina are openings in the bone structure that allow the passage of nerves and blood vessels. Morphological alterations of the HC are relatively common and may vary in size, shape, and number of foramina or channels communicating with the main canal[5].

The anatomical variations of the HC are important for neurosurgeons and neuroradiologists due to the risks involved in surgical procedures at the skull base. This region is also associated with primary neoplasms, such as hypoglossal nerve schwannomas, vascular anomalies encompassing emissary vein dilation, and persistence of the primitive hypoglossal artery. Furthermore, although uncommon, deviations of the nerve trajectory may directly influence the likelihood of nerve injury during surgical procedures. Embryological modifications may generate bony crypts, resulting in variations in the trajectory of nerves or vascular elements or both associated with the HC and the condylar canal.

The presence of the blind foramen (i.e., partial or complete closure of the HC) is one of the most frequent variations. Bifurcations of the HC into two branches can also be found in this region[6].

Hauser and De Stefano were pioneers in classifying the anatomical variations of the HC by introducing a more detailed approach regarding the presence of bony crypts in the canal. The classification comprising five types has served as reference for other researchers in the field[3].

Limited information was found regarding the anatomical variations of the HC and its relationship with the occipital condyle. Additionally, no studies involving the Brazilian population or the presence of an accessory foramen communicating the jugular foramen to the HC were observed. Similar variations, such as triple canals, were only described in studies involving *Macaca mulata*

monkeys from the *Cercopithecidae* family[7].

From a clinical perspective, pathological conditions involving the HC include tumors (schwannomas and meningiomas), cysts (dermoid cysts), arteriovenous malformations, aneurysms, hematomas, and abscesses. These lesions may result in functional disturbances of the hypoglossal nerve, possibly due to their close associations and speech, swallowing, and chewing alterations[2]. Other conditions include extra- and intradural tumors, which are frequent at the skull base near the foramen magnum. These conditions are challenging for surgeons due to their deep location[1].

Several surgical approaches are employed according to the condition, demanding an in-depth understanding of the HC morphometry. These include the extreme lateral approach to vertebral artery aneurysms, meningiomas, and chondrosarcoma; the combined lateral approach to clivus tumors and the combined approach to jugular glomus tumors; the postero-lateral approach to the foramen magnum, transcondylar, supracondylar, and paracondylar for the lower clivus, craniovertebral junction, HC, and mastoid foramen, respectively; the lateral, dorsolateral, and suboccipital approaches to the lower clivus and craniovertebral junction; and the lateral approach to the petroclival region[3].

From a surgical perspective, the transcondylar approach is the most viable since it is a shorter and more direct route to the anterior part of the pontomedullary junction, with minimal retraction of the brainstem. The critical aspect of this surgery involves the drilling through the posterior part of the occipital condyle, threatening the HC[1]. Moreover, caution must be taken in cases of atlanto-occipital dislocation, in which occipital-cervical arthrodesis becomes necessary. In these surgical approaches, the hypoglossal nerve may be at risk; therefore, anatomical knowledge of the HC is crucial during drilling of the occipital condyle, jugular tubercle, and lateral mass of C1[3].

In this context, knowledge about the morphology and morphometry of the HC is needed to understand the lesions and choose and plan appropriate surgical approaches. HC variations must also be considered when interpreting imaging studies and during surgery to preserve the hypoglossal nerve function and prevent complications. Neurosurgeons should be aware of the morphological variations of the HC and its relationships with the occipital condyle.

In this study, an accessory foramen was observed connecting the HC to the left jugular fossa. Describing variations is essential since they may be associated with changes in the trajectory of nearby neurovascular structures. Therefore, we reinforce the importance of in-depth knowledge regarding the morphometry of the skull base, mainly the type and location of the extra- and intracranial foramina of the HC, to reduce morbidity and mortality in craniovertebral surgeries. This knowledge is also crucial for avoiding damaging the hypoglossal nerve and surrounding cranial nerves and preserving large vessels in various craniovertebral surgeries.

Our study had a limitation due to the lack of epidemiological data on the studied structures

of the skull. This lack of information may have also limited the analysis of some morphological and morphometric characteristics of the HC, especially regarding biological sex, age, and ethnicity.

Given the scarcity of literature regarding the morphology and morphometry of the HC, especially in the Brazilian population, and considering the relevance of this topic in surgery and imaging, we suggest future studies including the Brazilian population and considering variables such as age, biological sex, ethnicity, and height.

The morphological and morphometric characteristics of the HC may vary according to population, geography, and ethnicity. Consequently, further investigations are needed to improve understanding of the anatomical structure and its variations in the Brazilian population.

COMPETING INTERESTS

None.

AUTHOR CONTRIBUTIONS

FAP: Conceptualization, Data Curation, Investigation, Methodology, Project Administration, Resources, Supervision, and Writing – Original Draft Preparation, Writing – Review & Editing; **LFMSA:** Writing – Original Draft Preparation and Supervision & Writing – Review & Editing; **IFGG:** Writing – Original Draft Preparation and Supervision & Writing – Review & Editing; **PHLL:** Supervision & Writing – Review & Editing; **TJMBSV:** Writing – Original Draft Preparation and Supervision & Writing – Review & Editing; **AWPX:** Supervision & Writing – Review & Editing; and **RCFC:** Resources and Supervision & Writing – Review & Editing. All authors approved the final version submitted.

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