The Paracondylar Skull Base: Anatomical Variants and Their Clinical Implications

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ABSTRACT

AIM: The knowledge of the vasculature around the paracondylar region is important in neurosurgical procedures such as the paracondylar and lateral supracondylar approaches. The objectives of the present study were to determine the prevalence of paracondylar emissary foramina in the adult skull bases and to study the morphology of condylar canals and hypoglossal canals.

MATERIAL and METHODS: The present study included 48 adult human skulls that were obtained from the gross anatomy laboratory of our institution. The paracondylar region was macroscopically observed for the variant foramina, canals and grooves.

RESULTS: It was observed that the paracondylar emissary foramen was present in 16 skulls (33.3%). The foramen was found bilaterally in 7 skulls (14.6%) and unilaterally in 9 skulls (18.7%). The hypoglossal canal was single in 35 (72.9%) skulls, double in 11 skulls (22.9%), and triple in 2 skulls (4.2%). The paracondylar process (2.1%) and the paracondylar groove (2.1%) were seen in 1 skull each. The posterior condylar canal was found to be patent in 19 (39.6%) skulls.

CONCLUSION: The present study observed that, the paracondylar emissary vein is not rare in occurrence as it is observed in 33.3% of cases. The identification of the paracondylar emissary veins and accessory vessels is important to avoid dangerous bleeding during the surgery. The morphological knowledge of the foramina around the paracondylar region is enlightening to the chiropractors, neurosurgeons and radiologists.

KEYWORDS: Emissary foramen, Hypoglossal canal, Paracondylar, Skull base

INTRODUCTION

The human cranial variations have been the topic of interest to anatomists for many centuries. Non-metric cranial variants are of considerable interest to the researchers due to their geographical and racial variation (26). A few variations are due to the underlying disease and other extrinsic factors; however most of the variants result from the normal developmental process and are determined genetically (4). The vertebrate skull is the most modified part of the axial skeleton. It is a skeleton that is adapted to protect the brain, cranial nerves and the special senses. The morphological study of skull and its foramina provides information about the evolutionary history of humans (17). A few cranial variants have been studied by researchers and doctors. There are many such variations, which were observed by Carolineberry and Berry (4), on a racial basis. They performed a detailed study of non-metric...
variants of the skull, which included the double hypoglossal canal (4). Tuli et al. (23) described that the human skull may have anatomical variations like small foramina, canals and grooves that require reporting in the literature. In their study, the bony tunnels were observed just adjacent to the occipital condyles and they were named paracondylar canals (23). These paracondylar variants had not been previously reported in the medical literature. Tuli et al. (23) reported that the paracondylar canals can be a peculiar cranial morphology which is confined to the Indian people. The paracondylar canals may be normal and they are due to developmental variation. They may serve as a valuable anthropological marker (23). The paracondylar foramen was reported for the first time by Manjunath (12). This variant foramen belonged to the occipital bone in 3.4% of his specimens. Manjunath (12) reported that the paracondylar foramen was situated between the jugular fossa and the occipital condyle. He opined that the paracondylar foramen may transmit the posterior condylar emissary vein. This variation may be due to the absence of the condylar canal or its anomalous course into the foramen jugulare.

The morphological knowledge of the paracondylar region is enlightening to the neurosurgeon. It may help in minimizing dangerous bleeding during the paracondylar approach and supracondylar approach neurosurgeries. The lateral approaches have been preferred during operations on lesions of the vertebral artery and tumors that are present anterior to the medulla oblongata region. In the neurosurgical literature, the lateral approach is the term that is used to describe the transcondylar, far lateral and extreme lateral approaches (14). Due to all this clinical interest and the interesting report from the Indian population (23), the present study was conducted to study the paracondylar region in South Indian samples. The goals of the present investigation were to determine the prevalence of paracondylar emissary foramina in the adult skull bases and to study the morphology of paracondylar canals, posterior condylar canals and hypoglossal canals.

**MATERIAL and METHODS**

In the present study, 48 dry skull specimens of South Indian origin were analyzed. The skulls were obtained from the neuroanatomy laboratory of our institution. The exact age and gender of the specimens were not determined. The skulls that showed pathological changes at the cranial base were excluded from the present study. We were able to examine 96 paracondylar regions (48 right sides and 48 left sides) macroscopically for the number and location of the variant foramina around the foramen magnum region. The skull

**Figure 1:** Pictures of the skull bases showing A) bilateral paracondylar foramen (14.6%); B) unilateral paracondylar foramen (18.7%); C) double paracondylar foramen (2.1%); D) triple paracondylar foramen (2.1%).
base around the foramen magnum region was evaluated macroscopically by using a magnifying lens to observe the variant foramina. The foramina were confirmed by probing a 24 gauge needle through each of them. The double and triple hypoglossal canals and the presence of any bony septum in the hypoglossal canal were also observed macroscopically.

RESULTS
We observed in the present study that the paracondylar emissary foramen was present in 16 skulls (33.3%) of our specimens. The foramen was found bilaterally (Figure 1A) in 7 skulls (14.6%) and unilaterally (Figure 1B) in 9 skulls (18.7%). One skull each, had double (Figure 1C) (2.1%) and triple (Figure 1D) paracondylar foramina (2.1%). The morphological distribution of the frequency of the paracondylar foramen is presented in Figure 2.

The hypoglossal canal was observed to be single in 35 (72.9%) skulls, double (Figure 3A) in 11 skulls (22.9%) and triple (Figure 3B) in 2 skulls (4.2%). The morphological distribution of hypoglossal canals in the present study is presented in Table I. The prevalence of a double hypoglossal canal in the present study is compared geographically with the data available from the literature (Table II). The paracondylar process (2.1%) and paracondylar groove (Figure 4A) (2.1%) were seen in 1 skull each. The posterior condylar canal (Figure 4B) was found to be patent in 19 (39.6%) skulls. Among them, 12 (25%) were observed on the left side, 3 (6.3%) on the right side and 4 (8.3%) were found bilaterally.

DISCUSSION
The craniovertebral junction has been studied in depth in recent years, thanks to advanced imaging technologies such as magnetic resonance and computed tomography. These advanced diagnostic procedures have led to increased information and interest in craniovertebral junction surgery. The surgical procedures for the lesions of the craniovertebral junction are performed by the lateral approach (16). The craniovertebral junction is a complex region of the axial skeleton and lies between the skull base and the upper cervical vertebrae. It is accepted that knowledge of the anatomy, embryology and biomechanics of the craniovertebral junction is important in understanding the pathophysiology of this region (15) and performing surgical procedures (6).

The hypoglossal canal or anterior condylar canal is located just anterior to the occipital condyles of the skull base. The structures passing through the hypoglossal canal include the hypoglossal nerve (12th cranial nerve), a branch of the ascending pharyngeal artery that supplies the dura mater, and an emissary vein connecting the veins over the clivus with the superior bulb of internal jugular vein. It is not uncommon to observe the hypoglossal canal having a septum, either completely or incompletely with a...
The paracondylar region (5). The paracondylar process is an enlarged bony process of the cranial base, which is observed lateral to the occipital condyle and it runs downwards towards the transverse process of the first cervical vertebra. In severe cases, the paracondylar process will be fused with the transverse process of the atlas and cause restriction in the mobility of neck. The clinical symptoms in this type are due to altered position of the neck and lack of movements (18). The paracondylar process belongs to the large and heterogenic group of developmental variations of the craniovertebral junction (22). This process might have been formed from the maldevelopment of the first cervical sclerotome around the 4th week of intrauterine life (3) and it represents the vestiges of the cranial half of the first cervical sclerotome (20). The formation of this process is referred as the lower shifting, a vertebra mimicking the characteristics of its lower caudal, where the occipital vertebra separates from the occipital bone. There are only a few cases of this rare developmental variation found in the literature (1). The prevalence of this variation was reported in anthropological, radiological and cadaveric studies (24). The amount of data from the anthropology literature is high as they include smaller bony projections, which would be missed radiologically. In a paper from the X rays of 4000 patients, 5 cases (0.125%) of paracondylar processes were reported (10). In an anatomical study by Srisopark, only a slight higher frequency was reported, with 2 cases (0.29%) from 692 specimens (1). In 7 of the skulls with a paracondylar process, Anderson (1) noted that 4 had an associated bipartition of the hypoglossal canal. It is believed that the knowledge about the paracondylar process

Table I: Morphological Distribution of the Hypoglossal Canal in South Indians (n = 96)

<table>
<thead>
<tr>
<th>Hypoglossal canal morphology</th>
<th>Frequency</th>
<th>Bilateral</th>
<th>Unilateral (right side)</th>
<th>Unilateral (left side)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single hypoglossal canal</td>
<td>81 (84.4%)</td>
<td>35 (72.9%)</td>
<td>8 (16.7%)</td>
<td>3 (6.2%)</td>
</tr>
<tr>
<td>Bipartitioned hypoglossal canal</td>
<td>13 (13.5%)</td>
<td>2 (4.2%)</td>
<td>2 (4.2%)</td>
<td>7 (14.6%)</td>
</tr>
<tr>
<td>Tripartitioned hypoglossal canal</td>
<td>2 (2.1%)</td>
<td>nil</td>
<td>1 (2.1%)</td>
<td>1 (2.1%)</td>
</tr>
</tbody>
</table>

Table II: Comparison of the Prevalence of Double Hypoglossal Canal as per Berry (2)

<table>
<thead>
<tr>
<th>Population</th>
<th>Prevalence of double hypoglossal canal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigerian</td>
<td>11.60%</td>
</tr>
<tr>
<td>Palestine</td>
<td>8.30%</td>
</tr>
<tr>
<td>Burman</td>
<td>9.80%</td>
</tr>
<tr>
<td>Egyptian</td>
<td>16.60%</td>
</tr>
<tr>
<td>North American</td>
<td>24%</td>
</tr>
<tr>
<td>South American</td>
<td>27.40%</td>
</tr>
<tr>
<td>North Indian</td>
<td>17.90%</td>
</tr>
<tr>
<td>South Indian (present study)</td>
<td>22.90%</td>
</tr>
</tbody>
</table>
is important to the radiologists, surgeons and chiropractors. It is suggested that the surgical excision of this process has to be performed to resolve the symptoms (11). It is interesting to note that, the present study has observed only a single case (2.1%) of paracorndylyar process. We believe that, this process is of rare occurrence in an Indian population.

Chauhan and Sharma (5) conducted a study on the skulls of North Indian origin, in which 164 sides of the paracorndylyar region were examined. In their study, the paracorndylyar foramen was observed in 12.1% of the specimens. This variant foramen was situated between the occipital condyles and foramen jugulare. The foramina were observed on the left side in 10.9% of the cases and it was bilateral in 1.2% of the cases. The foramina were not observed along the right paracorndylyar region. Tuli et al. (23) studied 608 paracorndylyar regions from the skulls of the Indian population and the paracorndylyar foramina were observed in 59 sides (9.7%). Among them, 36 (11.8%) were bilateral and 23 (7.6%) were unilaterally patent. These paracorndylyar vascular grooves continued as paracorndylyar canals in 52 sides (15.8%). In the present study, the paracorndylyar foramen was present unilaterally in 18.7% of the cases. This percentage is higher in comparison to the 10.9% rate of Chauhan and Sharma (5) and the 7.6% rate of Tuli et al. (23). The present study observed the paracorndylyar foramina bilaterally in 14.6% of the cases, which is almost similar to Tuli et al. (23), 11.8%. The present study also observed a paracorndylyar groove in one of the skulls (2.1%).

Chauhan and Sharma (5) observed a patent posterior condylar canal in 9.7% of the cases; 6% were observed on the left side and 3.6% of the cases had the foramen bilaterally. No right-sided patent posterior condylar canal was observed. In the present study, the posterior condylar canal was found patent in 39.6% of the skulls. Among them, 25% were on the left side, 6.3% were on the right side and 8.3% were found bilaterally. This prevalence is higher than that reported in the Chauhan and Sharma (5) study. According to Hollinshead and Rosse (8), the posterior condylar canal reaches the posterior cranial fossa at the sigmoid sinus groove, which is located posterior and lateral to the foramen jugulare. It was reported that the paracorndylyar foramina also lead to the same location at the posterior cranial fossa. This suggests that the variant foramina in the paracorndylyar skull base are an accessory route of drainage of the veins of the cranial cavity to the veins outside. In some of the skulls of the present study, only the paracorndylyar foramen was observed and the posterior condylar canal was absent. Chauhan and Sharma (5) opined that these paracorndylyar foramina may be variants in the topography of the posterior condylar canal or a variant course of the emissary posterior condylar vein. This type of case was reported for the first time by Manjunath (12). The observations of the present study agree with the previous reports that the paracorndylyar foramina are variations in the topography of the posterior condylar canal or a variant course of the emissary posterior condylar vein.

It has been reported that the prevalence rate of duplication of hypoglossal canal ranges between 12.2% and 22.5%. In a study by Wysocki et al. (25), the percentage of cases of unilateral/bilateral division of the hypoglossal canal as a whole amounted to 43.5%. They observed that the right-sided unilateral double hypoglossal canal was found in 21% of the cases and a left-sided occurrence was observed in 22.5% of the cases. Lillie (9) reported that the hypoglossal canal is divided into 3 or 4 compartments on rare occasions. The anatomical basis of the division of the hypoglossal canal is that the hypoglossal nerve, which originates from 2-3 rootlets, would initially run individually and merge later near its exit from the anterior condylar (hypoglossal) canal, the external foramen of it is almost always single. However, on few occasions, the hypoglossal canal will have a small spicule of bone and it is partitioned (9, 25). Nikumbh et al. (17) observed the double hypoglossal canal unilaterally and bilaterally in 25% and 3% of their cases respectively. Chauhan and Sharma (5) observed the double hypoglossal canal in 4.8% of their specimens. The present study observed the double hypoglossal canal in 22.9% of the cases. The frequency of a double hypoglossal canal observed in the present study was compared with the data available globally (2) and this comparison of data from the literature is presented in Table II. Another interesting observation was that triple hypoglossal canals were present in 4.2% of the cases of the present study.

The hypoglossal nerve exits the anterolateral sulcus of medulla oblongata with multiple roots and runs posterolateral to the vertebral artery as two bundles. These two bundles pierce the dura mater separately at two locations, opposite the hypoglossal canal in the anterior part of the occipital condyles. After passing through the hypoglossal canal, the bundles join together and appear as a single nerve bundle. The hypoglossal nerve begins with several rootlets, which eventually join to form the two bundles. A failure of merging of the two nerve bundles would result in the formation of a double hypoglossal canal. This is the developmental basis of the duplication of the hypoglossal canal. The function of the hypoglossal nerve is to supply all the muscles of the tongue except the palatoglossus. It has been reported that the presence of a duplicated hypoglossal canal in the human population may result in minor degrees of alterations in the movements of the tongue. On some occasions, the hypoglossal nerve may get trapped in the occipital bone during the ossification process (19). It is known that the morphology of the hypoglossal canal is enlightening to the neurosurgeon, as micro neurosurgery is becoming popular these days. The knowledge is important in the management of posterior cranial fossa tumors such as hypoglossal nerve schwannoma and also in the sleep apnea syndrome (17).

Sound anatomical knowledge and adequate preoperative planning will minimize the risk of damage to the neurovascular structures around the foramen magnum (13). The variant foramina and the emissary veins around the foramen magnum may cause misinterpretation clinically. They may confuse the radiologists (7) and neurosurgeons by
mimicking enlarged lymph nodes and pathological lesions. We believe that the present study has provided additional information on the variant foramina around the paracondylar region. The present study observed that the paracondylar emissary foramen is prevalent in 33.3% of cases and we opine that the paracondylar foramen is not rare in occurrence. The accessory hypoglossal canals were observed in 27.1% of the cases. The recognition of the paracondylar emissary veins and accessory structures is critical to avoid potentially catastrophic bleeding while surgery. The morphological knowledge of the foramina and structures around the paracondylar region is of importance to the neurosurgeons, radiologists and chiropractors. We believe that the details of the present study may help the neurosurgeons in the surgical procedures around the craniovertebral junction.

REFERENCES