Received: 17.06.2014 / **Accepted:** 02.10.2014
DOI: 10.5137/1019-5149.JTN.11850-14.1

The Paracondylar Skull Base: Anatomical Variants and Their Clinical Implications

Parakondiler Kafa Tabanı: Anatomik Varyantlar ve Klinik Uygulamaları

B.V. MURLIMANJU, Ganesh Kumar CHETTIAR, Ashwin KRISHNAMURTHY, Mangala M. PAI, Vasudha V. SARALAYA, Latha V. PRABHU, Rajanigandha VADGAONKAR

Manipal University, Kasturba Medical College, Department of Anatomy, Mangalore, Manipal, Karnataka, India

Presented in: *11th European Skull Base Society Congress, which was held at Palais des Congres de Paris, Paris, FRANCE on 26th to 28th June 2014.*

Corresponding Author: B.V. MURLIMANJU / E-mail: flutesnowmm@gmail.com

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

ÖZ

AMAÇ: Parakondiler bölgenin çevresindeki vasküler yapı parakondiler ve lateral suprakondiler yaklaşımlar gibi nöroşirürjikal girişimlerde önemlidir. Çalışmanın amacı erişkin kafa tabanında parakondiler emisser foramen'in prevalansını belirlemek ve kondiler kanal ile hipoglosal kanalların morfolojisini araştırmaktır.

YÖNTEM ve GEREÇLER: Çalışma kurumumuzun anatomi laboratuvarından elde edilen 48 adet erişkin kafatasında yapılmıştır. Parakondiler bölge, foramenlerin, kanalların ve olukların varyasyonları yönünden makroskopik olarak incelenmiştir.

BULGULAR: Parakondiler emisser foramenin 16 (%33,3) adet kafatasında var olduğu gözlenmiştir. Foramen 7 (%14,6) kafatasında bilateral ve 9 (%18,7) kafatasında unilateral olarak bulunmuştur. Hipoglosal kanal 35 (%72,9) kafatsında tek, 11 (%22,9) kafatasında çift, 2 kafatasında ise 3 (%4,2) adet idi. Parakondiler çıkıntı (%2,1) ve parakondiler oluk (%2,1) birer kafatasında izlenmiştir. Posterior kondiler kanal 19 (%39,6) kafatasında patent (açık) olarak bulunmuştur.

SONUÇ: Çalışma parakondiler emisser venin sıklığının hiç de nadir olmadığını ve olguların %33.3'ünde görüldüğünü göstermiştir. Parakondiler emisser venlerin ve aksesuar damarların ortaya konması, cerrahi sırasında tehlikeli kanamaların önlenmesinde önemlidir. Parakondiler bölge çevresindeki foramenlerin morfolojik bilgisi masörler, nöroşirürjiyenler ve radyologlar açısından aydınlatıcıdır.

ANAHTAR SÖZCÜKLER: Emisser foramen, Hipoglossal kanal, Parakondiler, Kafa tabanı

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

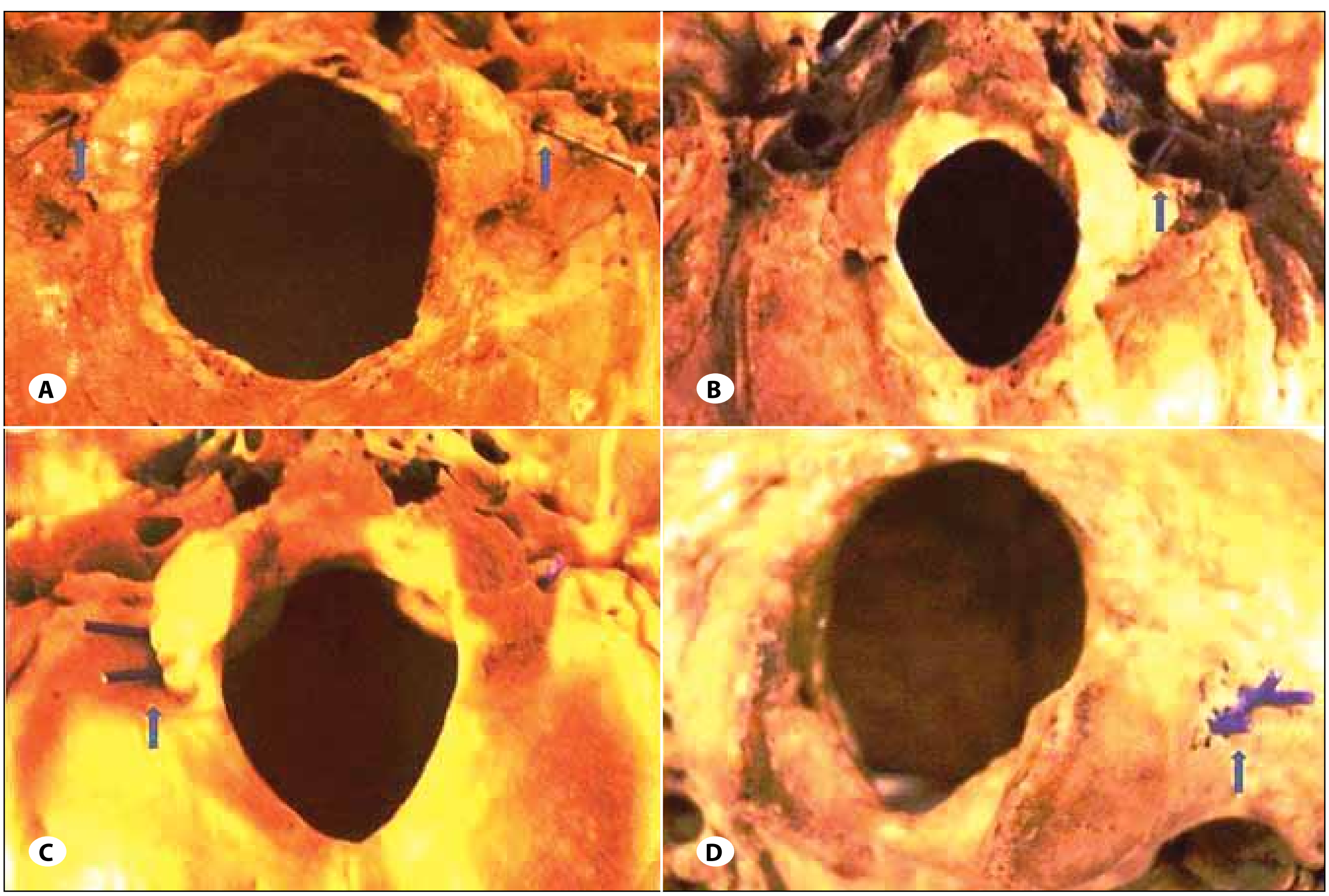

Figure 1: Pictures of the skull bases showing **A)** bilateral paracondylar foramen (14.6%); **B)** unilateral paracondylar foramen (18.7%); **C)** double paracondylar foramen (2.1%); **D)** triple paracondylar foramen (2.1%).

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

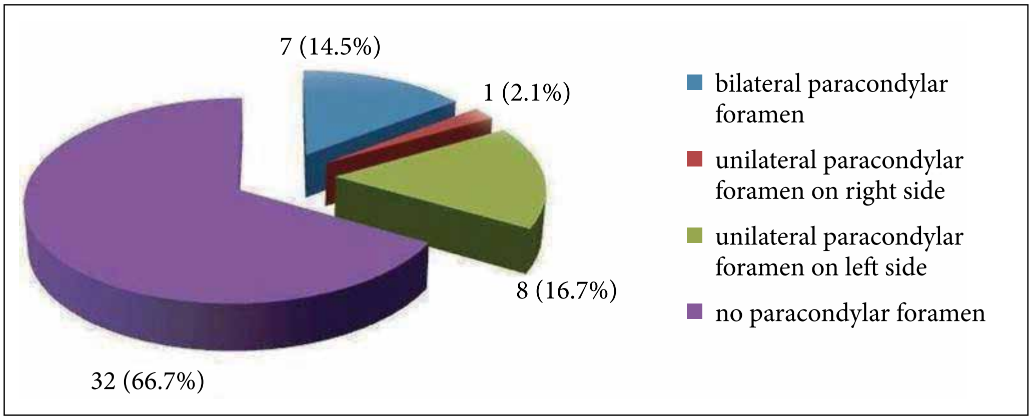

Figure 2: Morphological distribution of the frequency of paracondylar foramen in the present study (n = 96).

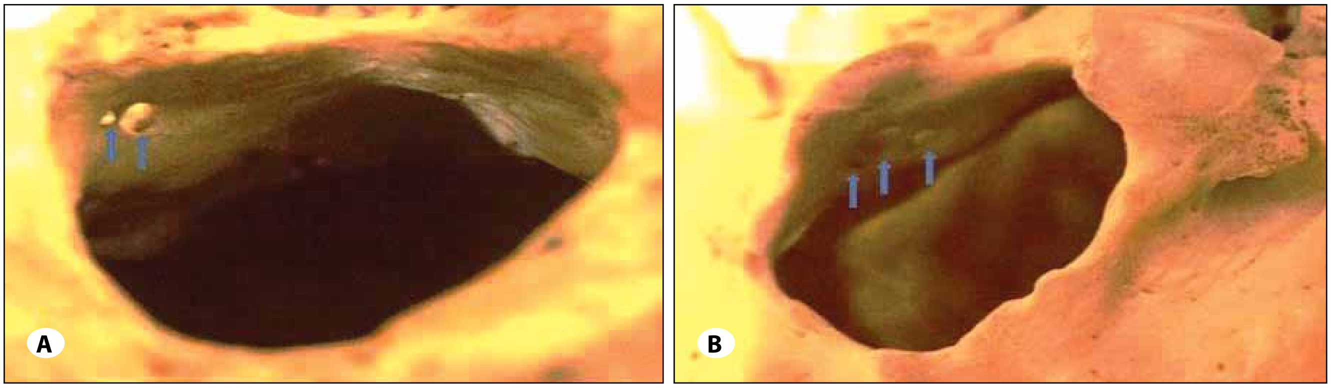

Figure 3: Pictures of the skull bases of the present study showing **A)** double hypoglossal canal (22.9%); **B)** triple hypoglossal canal (4.2%).

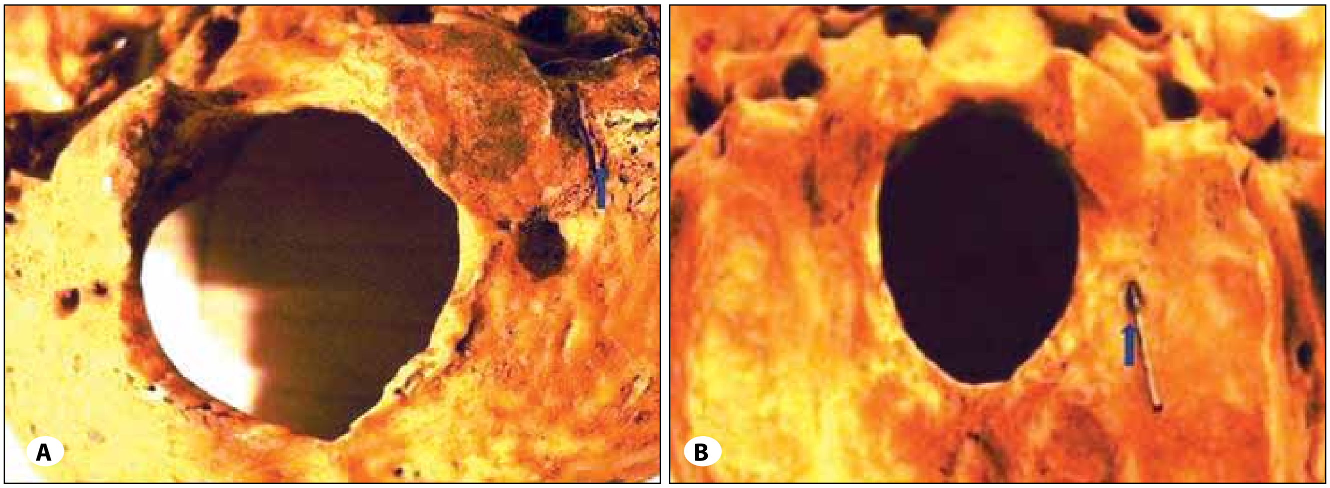

Figure 4: Pictures of the skull bases of the present study showing **A)** paracondylar groove (2.1%); **B)** patent posterior condylar canal (39.6%).

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

Hypoglossal canal morphology	Frequency	Bilateral	Unilateral (right side)	Unilateral (left side)
Single hypoglossal canal	81 (84.4%)	35 (72.9%)	8 (16.7%)	3 (6.2%)
Bipartitioned hypoglossal canal	13 (13.5%)	2 (4.2%)	2 (4.2%)	7 (14.6%)
Tripartitioned hypoglossal canal	2 (2.1%)	nil	1 (2.1%)	1 (2.1%)

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

Population	Prevalence of double hypoglossal canal
Nigerian	11.60%
Palestine	8.30%
Burman	9.80%
Egyptian	16.60%
North American	24%
South American	27.40%
North Indian	17.90%
South Indian (present study)	22.90%

tiny bony spicule. The condylar fossa is located posterior to the occipital condyles and it provides space for the superior articular facet of the first cervical vertebra (21). The condylar fossa may exhibit a foramen, which is named the posterior condylar foramen. The posterior condylar foramen may be patent and transmit the emissary posterior condylar vein. The emissary posterior condylar vein is a bridging vein between the sigmoid venous sinus and the sub occipital venous plexus (21). The posterior condylar vein opens either into the bulb of internal jugular vein or to the emissary vein which is present in the hypoglossal canal anteriorly and the vertebral venous plexus which is found in the condylar fossa posteriorly (14). It was reported that many more variant foramina and grooves that merit documentation in the literature may be present in 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 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 paracondylar 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 paracondylar region were examined. In their study, the paracondylar 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 paracondylar region. Tuli et al. (23) studied 608 paracondylar regions from the skulls of the Indian population and the paracondylar foramina were observed in 59 sides (9.7%). Among them, 36 (11.8%) were bilateral and 23 (7.6%) were unilaterally present. These paracondylar vascular grooves continued as paracondylar canals in 52 sides (15.8%). In the present study, the paracondylar 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 paracondylar 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 paracondylar 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 paracondylar foramina also lead to the same location at the posterior cranial fossa. This suggests that the variant foramina in the paracondylar 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 paracondylar foramen was observed and the posterior condylar canal was absent. Chauhan and Sharma (5) opined that these paracondylar 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 paracondylar 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

1. Anderson T: Paracondylar process-manifestation of an occipital vertebra. Int J Osteoarchaeol 6:195-201, 1996
2. Berry AC: Factors affecting the incidence of non-metrical skeletal variants. J Anat 120:519-535, 1975
3. Black MacLaughlin S, Scheuer L: Occipitalization of the atlas with reference to its embryological development. Int J Osteoarchaeol 6:189-194, 1996
4. Carolineberry A, Berry RJ: Epigenetic variation in the human cranium. J Anat 101:361-379, 1967
5. Chauhan K, Sharma A: Osteotic variations in paracondylar region of adult human skulls-incidence and clinical significance. Int J Anat Res 1:158-160, 2013
6. Das S, Suri R, Kapur V: Unusual occipital condyles of the skull: An osteological study with clinical implications. Sao Paulo Med J 124:278-279, 2006
7. Ginsberg LE: The posterior condylar canal. AJNR Am J Neuroradiol 15:969-972, 1994
8. Hollinshead WH, Rosse C: Textbook of Anatomy. 4th ed, New York: Harper and Row, 1985: 871
9. Lillie RD: Variations of the canalis hypoglossi. Anat Rec 13:131–144, 1917
10. Lombardi G: The occipital vertebra. Am J Roentgenol Radium Ther Nucl Med 86:260-269, 1961
11. Mangal A, Choudhry R, Tuli A, Singh P, Kaur Narula M, Khera V: Imaging and morphology of the paracondylar process in a dry adult human skull: A case report. Surg Radiol Anat 26:334-337, 2004
12. Manjunath KY: Paracondylar foramen--a new anomalous aperture of the occipital bone. Ind J Med Sci 52:317-319, 1998
13. Marca FL, Zubay G, Morrison T, Karahalios D: Cadaveric study for placement of occipital condyle screws: Technique and effects on surrounding anatomic structures. J Neurosurg Spine 9:347-353, 2008
14. Matsushima T, Natori Y, Katsuta T, Ikezaki K, Fukui M, Rhoton AL: Microsurgical anatomy for lateral approaches to the foramen magnum with special reference to transcondylar fossa (supracondylar transjugular tubercle) approach. Skull Base Surg 8:119-125, 1998
15. Menezes AH: Craniovertebral junction anomalies: Diagnosis and management. Semin Pediatr Neurol 4:209-223, 1997
16. Naderi S, Korman E, Citak G, Guvencer M, Arman C, Senoglu M, Tetik S, Arda MN: Morphometric analysis of human occipital condyle. Clin Neurol Neurosurg 107:191-199, 2005
17. Nikumbh RD, Nikumbh DB, Karambelkar RR, Shewale AD: Morphological study of hypoglossal canal and its anatomical variation. Int J Health Sci Res 3:54-58, 2013
18. Nolet PS, Friedman L, Brubaker D: Paracondylar process: A rare cause of craniovertebral fusion – a case report. J Can Chiropr Assoc 43:229-235, 1999
19. Setty SNRS, Katikireddi RS: Study of duplicated hypoglossal canal in South Indian human skulls-original article. Int J Cur Res Rev 5:103-105, 2013
20. Shapiro R, Robinson F: Anomalies of the craniovertebral border. AJR Am J Roentgenol 127:281–287, 1976
21. Standring S: Gray's Anatomy, Anatomical Basis of Clinical Practice. 40th ed, London: Churchill Livingstone, 2008: 415
22. Stathis G, Economopoulos N, Mavraganis D, Kelekis N, Alexopoulou E: Paracondylar process, a rare normal variant: The value of MRI in the diagnosis. Surg Radiol Anat 34:281-284, 2012
23. Tuli A, Mangal A, Dixit SG, Choudhry R, Sanghwan S: Incidence, morphology and clinical relevance of bony canals and vascular grooves in the paracondylar region of adult human skulls. J Clin Neurosci 15:689-692, 2008
24. Williams JA: An enlarged paracondylar process and associated anomalies in a plains woodland burial. Plains Anthropologist 27:323–326, 1982
25. Wysocki J, Kobryń H, Bubrowski M, Kwiatkowski J, Reymond J, Skarzyńska B: The morphology of the hypoglossal canal and its size in relation to skull capacity in man and other mammal species. Folia Morphol (Warsz) 63:11-17, 2004
26. Zaidi SHH, Gupta R, Usman N: A study of hypoglossal canal in north Indian crania. J Anat Soc India 60:224-226, 2011