Original Article

The anatomical perspective of human occipital condyle in relation to the hypoglossal canal, condylar canal, and jugular foramen and its surgical significance

ABSTRACT

Background: The transcondylar approach (TCA) has gained importance in recent era which enables shorter and direct route to access the lesions ventral to the brainstem. The important step in this approach is resection of the occipital condyle (OC). The detailed knowledge of bony anatomy of OC and its relation to the hypoglossal canal (HC), condylar canal (CC), and jugular foramen (JF) is very important to avoid any iatrogenic injury during craniovertebral surgeries. The aim of the present study is to conduct a morphometric and morphological study and note the variations of the OC and the structures surrounding it in North Indian population.

Materials and Methods: The study was carried out on 100 OC. Morphometric measurements of OC and the distances of HC and JF from the posterior end of OC were noted. In addition, the extent of the HC and JF in relation to OC, presence or absence of CC, shape of the OC, and its articular facet were also noted.

Results: The incidence of short OC was seen in 13% skulls. The most common shape of OC was oval or rhomboid. Even though the articular facet was convex in majority of skulls but flat (10%) and concave (1%) were also observed. The external and internal distance of HC from the posterior end of OC was13.83 mm and 10.66 mm on the right side and 15.02 mm and 11.89 mm on the left side. The OC was related in its middle 1/3 to the HC in 15% skulls and to the whole extent of JF in 3% skulls. Thirty-four percent skulls displayed the septa in the HC. The CC was present bilaterally in 38% skulls and unilaterally in 40% skulls.

Conclusion: The OC and related structures such as HC, CC, and JF are likely to have variations in respect to morphometry and morphology. This study may prove helpful to neurosurgeons operating in this field, especially during TCA where neurovascular structures emerging from these canals and foramen are more vulnerable to injury.

Key words: Condylar canal; hypoglossal canal; jugular foramen; occipital condyle; transcondylar approach.

Introduction

The lateral condylar parts of the occipital bone which flank the foramen magnum (FM) are oval or reniform in shape, and their long axis converges anteromedial so that their anterior ends are closer to the midline. The occipital condyle (OC) is a unique structure which connects cranium to the vertebral column forming craniovertebral joint (CVJ) which is specialized to provide a wider range of movement of skull on the vertebral column.[1] The stability of CVJ depends largely on the morphology and morphometric

Access this article online	
	Quick Response Code
Website: www.jcvjs.com	
DOI: 10.4103/0974-8237.193258	

Ranjana Verma, Shalini Kumar, Arpita Mahajan Rai, Iqra Mansoor, Raj D Mehra

Department of Anatomy, Hamdard Institute of Medical Sciences and Research, Jamia Hamdard, New Delhi, India

Address for correspondence: Dr. Ranjana Verma, Hamdard Institute of Medical Sciences and Research, Jamia Hamdard, New Delhi, India.
E-mail: drabhasinha@gmail.com

How to cite this article: Verma R, Kumar S, Rai AM, Mansoor I, Mehra RD. The anatomical perspective of human occipital condyle in relation to the hypoglossal canal, condylar canal, and jugular foramen and its surgical significance. J Craniovert Jun Spine 2016;7:243-9.

parameters of the OC.[2] The OC is related anterolaterally to the hypoglossal canal (HC), laterally to jugular foramen (JF), and posteriorly to the condylar canal (CC) [Figure 1]. Various neural structures emerging from these foramina are in close vicinity to OC like - IX to XII cranial nerves, C1 and C2 spinal nerves, caudal aspect of the medulla oblongata, rostral aspect of the spinal cord, inferior vermis, and tonsil of the cerebellum. In addition, vascular structures such as vertebral, cerebellar, meningeal arteries, dural venous sinuses, and internal jugular vein are also closely associated with it.[3]

The anterolateral aspect of the FM is the most complex area of the skull base and being deeply situated, it poses a clinical challenge to surgeons during craniovertebral surgeries for extra- or intra-dural tumors. Various surgical approaches such as ventral, dorsal, and transcondylar are taken into consideration for craniovertebral surgeries in an area close to the FM. Nowadays, transcondylar approach (TCA) has been used more frequently which enables shorter and more direct route to the anterior part of pontomedullary junction with minimal brainstem retraction.[4] To expose the tumors in this region, extensive dissection of paravertebral muscles, neurovascular structures is required along with the removal of bony structures such as OC and jugular tubercle.[5] The important neurovascular structures which are emerging from various foramina surrounding the OC are prone to injury during OC resection, and it may also result in craniocervical instability.[6]

The TCA for craniovertebral surgeries requires special attention regarding detailed information about the morphology and morphometry of the OC and the structures surrounding it. Even though there are studies on the morphometry of OC, there is a paucity of literature on its relationship to the different foramina and canals. In the present study, we revisited the morphology and morphometry of the OC and its relation with HC, CC, and JF, especially giving more attention to any variations which may affect the surgical route to be taken while performing surgeries in this region.

Figure 1: Foramina present in relation to occipital condyle: red-hypoglossal canal, black-jugular foramen, blue-condylar canal

Materials and Methods

The study was performed on 100 OC of fifty adult human dry skulls of unknown age and sex obtained from the department of anatomy, Hamdard Institute of Medical Sciences and Research, New Delhi and MAMC, New Delhi. Morphometric and morphological study of OC and nearby canals and foramina were done on these skulls [Figures 2 and 3].

I. Morphometric study was done on the following parameters:
   - Length of OC
   - Width of OC
   - Thickness of OC
   - Anterior intercondylar distance
   - Posterior intercondylar distance
   - Distance of posterior end of OC from external opening of HC
   - Distance of posterior end of OC from internal opening of HC (if two internal openings are present, then posterior opening, i.e., closer to posterior end of OC was considered)
   - Distance of posterior end of OC from posterior most end of JF.

II. Morphological study was done on the following parameters:

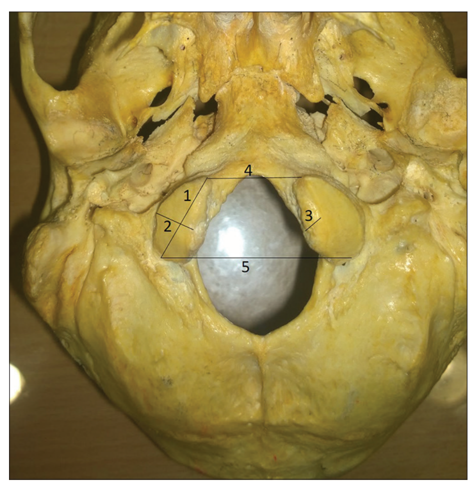

Figure 2: Morphometric measurements of occipital condyle: 1-length of occipital condyle, 2-width of occipital condyle, 3-thickness of occipital condyle, 4-anterior intercondylar distance, 5-posterior intercondylar distance

1. Shape of OC
2. Shape of facet of OC
3. Types of OC on the basis of length
4. Extent of HC in relation to OC
5. Extent of JF in relation to OC
6. Presence or absence of CC.

All distances were measured using a vernier sliding caliper, accurate to 0.01 mm. Statistical analysis was performed using IBM SPSS Statistics for Windows Version 20.0 (Armonk, NY: IBM Corp.). Descriptive statistics such as range, mean, and standard deviation were evaluated for all the parameters collected from the skull. For all the analyses, $P < 0.05$ was accepted as statistically significant, $P < 0.01$ was accepted as highly significant.

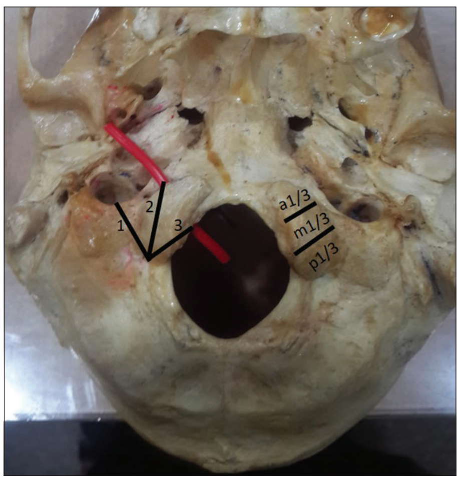

Figure 3: Morphometric measurements around hypoglossal canal and jugular foramen: (Left side) 1-distance of posterior end of occipital condyle from the posterior margin of jugular foramen, 2-distance of posterior end of occipital condyle from external opening of hypoglossal canal, 3-distance of posterior end of occipital condyle from the internal opening of hypoglossal canal. (Right side) a1/3-anterior one-third of occipital condyle, m1/3-middle one-third of occipital condyle, p1/3-posterior one-third of occipital condyle

Results

Morphometric study

The results obtained from metric parameters are presented in Table 1. The mean length, width, and thickness of OCs were found 23.22 ± 2.3, 12.93 ± 1.7, and 11.22 ± 1.4 mm on the right side and 22.76 ± 2.6, 13.37 ± 1.9, and 8.98 ± 1.3 mm on the left side, respectively. The respective external and internal distance of HC from posterior end of OC was13.83 ± 2.9 mm and 10.66 ± 2.7 mm on the right side and 15.02 ± 1.9 mm and 11.89 ± 2.9 mm on the left side. The distance of JF from the posterior end of OC was15.73 ± 3 mm on the right side and 16.77 ± 2.9 mm on the left side, respectively. P value was highly significant ($P < 0.05$) for distance of external and internal opening of HC and posterior most point of JF from posterior end of OC. The anterior intercondylar distance was 21.22 ± 3.4 mm, and posterior intercondylar distance was 40.46 ± 4.1 mm.

Morphological study

The results of the morphologic study are shown in Table 2. The OC was divided into different categories according to its shape. The most common shape of the OC was oval (53%). The other shapes found were rhomboid (15%), quadrangular (7%), and reniform (6%). Circular, S-shape, comma shape, and irregular shapes were less frequently observed [Figure 4]. The shape of the facet of OC was convex in majority of the skulls but flat (10%) and concave facets (1%) were also noted [Figure 5]. OC was classified according to its length. The condyle of 2–2.4 cm was considered as moderate, the condyle shorter than 2 cm was considered as short and condyle longer than 2.4 cm was considered as long OC.[6] In the present study, short OC was observed in 10% and moderate length in 72% on the right side. On the left side,

Table 1: Morphometric measurements

(a) Occipital condyle and related foramina and canal

Parameters	Total (n=50)				P
	Right		Left		
	Range (mm)	Mean±SD (mm)	Range (mm)	Mean±SD (mm)	
Length of OC	19-29.2	23.22±2.3	16.4-28.8	22.76±2.6	0.89
Width of OC	9.2-17.8	12.93±1.7	9.5-19.1	13.37±1.9	0.11
Thickness of OC	7.4-11.6	11.22±1.4	6.3-11.4	8.98±1.3	0.268
Distance of posterior end of OC from external opening of HC	6.3-19.4	13.83±2.9	11.3-19.7	15.02±1.9	0.006*
Distance of posterior end of OC from internal opening of HC	5.3-19.1	10.66±2.7	7.5-20.1	11.89±2.9	0.010*
Distance of posterior end of OC from postboundary of JF	10-23.3	15.73±3	9-23.3	16.77±2.9	0.001*

(b) Intercondylar distance

Parameters	Range (mm)	Mean±SD (mm)
Anterior intercondylar distance	11.5-31.1	21.22±3.4
Posterior intercondylar distance	32.8-50.1	40.46±4.1

*Significant P<0.05. OC - Occipital condyle, HC - Hypoglossal canal, JF - Jugular foramen, SD - Standard deviation

Table 2: Morphologic features

(a) Shape of occipital condyle			
Shape of OC	**Right (n=50)**	**Left (n=50)**	**Total (n=100)**
Circular	Nil	2	2
Oval	27	26	53
Rhomboid	8	7	15
Quadrangular	3	4	7
Reniform	4	2	6
Triangular	2	3	5
Irregular	2	2	4
S shape	2	1	3
Pentagonal	1	2	3
Comma	1	1	2

(b) Shape of the facet of occipital condyle			
Shape of facet of OC	**Right (n=50)**	**Left (n=50)**	**Total (n=100)**
Concave	1	NIL	1
Flat	4	6	10
Convex+	28	24	52
Convex++	16	19	35
Convex+++	1	1	2

Thickness of OC at its highest point of convexity– (convex+ - 6-8 mm, convex++ - 8-10 mm and convex+++ - >10 mm). OC - Occipital condyle

(c) Classification of occipital condyle according to its length			
Type	**Right (n=50)**	**Left (n=50)**	**Total (n=100)**
Short	5	8	13
Moderate	36	26	62
Long	9	16	25

Short OC - <20 mm length, moderate OC - 20-24 mm, long OC - >24 mm).[6] OC - Occipital condyle

(d) Extent of hypoglossal canal in relation to occipital condyle			
	Right (n=50)	**Left (n=50)**	**Total (n=100)**
Extent of HC			
Anterior 1/3	45	40	85
Middle 1/3	5	10	15
Posterior 1/3	Nil	Nil	Nil
Septate HC	24	10	34

HC - Hypoglossal canal

(e) Condylar canal		
Condylar canal	**n=50**	**Percentage**
Present bilaterally	19	38
Absent bilaterally	11	22
Present (left side)	12	24
Present (right side)	7	14
Double anterior opening	1	External opening lateral to hypoglossal canal Internal opening in jugular foramen

(f) Extent of jugular foramen in relation to occipital condyle			
Extent of jugular foramen	**Right (n=50)**	**Left (n=50)**	**Total (n=100)**
Anterior 1/3	3	4	7
Anterior 2/3	45	45	90
Whole extent	2	1	3

16% were of short length, and 52% were of moderate length. In rest of the skulls, the OC was long. The HC was related to anterior 1/3 of OC in 85% cases and in middle 1/3 of OC in 15% cases. Septa in the HC were present in 34% skulls. The CC was bilaterally present in 38% skulls and bilaterally absent in 22% skulls. In rest of the cases, it was present unilaterally either on the right side or on the left side. In one of the skulls, the right CC instead of opening into posterior cranial fossa was bifurcating into two canals where the medial one was opening externally lateral to HC, and the lateral one was opening into the posterior boundary of JF [Figure 6]. The JF was related to anterior 2/3 of OC in 90% cases, anterior 1/3 of OC in 7% cases, and to the whole extent in 3%.

Discussion

The most frequently reported lesions in the craniovertebral region are extra- and intra-dural tumors, vertebral artery lesions, rheumatoid diseases, and malformations of the craniocervical junction.[7-9] Surgical management of these lesions is a big challenge to neurosurgeons to decrease morbidity and mortality of the patients. Many surgical approaches and their several modifications have been developed to approach these lesions safely and effectively. Irrespective of the approach, the main goal is the dissection and early extracranial exposure of the vertebral artery, lateral suboccipital craniotomy, and removal of the OC. The degree of resection of the OC depends on the pathology, exact location, and variations of morphometry and morphology of OC and related foramina in this region.[10-14] Recently, TCA has gained importance as it minimizes the brain retraction at the cost of maximum bone removal. In these procedures, vital neurovascular structures near OC may be compromised during drilling and excessive resection may also lead to craniovertebral instability. The knowledge of the morphology, morphometry of OC, and nearby foramina along with its variations can improve the surgical outcome.[10,15,16]

Occipital condyle

The condylar drilling is an important step in the TCA, and the important question is how much of OC can be removed without damaging nearby structures and causing craniocervical instability. Hence, the knowledge of the length, width and thickness of the OC, shape of the condyle, and its articular facet will help the surgeons to decide the extent of bone that can be removed.

In case of the shorter OC, removal of its >2/3 part can lead to craniocervical instability.[10] In our study, short OC was found in 13% skulls and long OC in 25% skulls. In comparison to the present study, previous investigators observed short

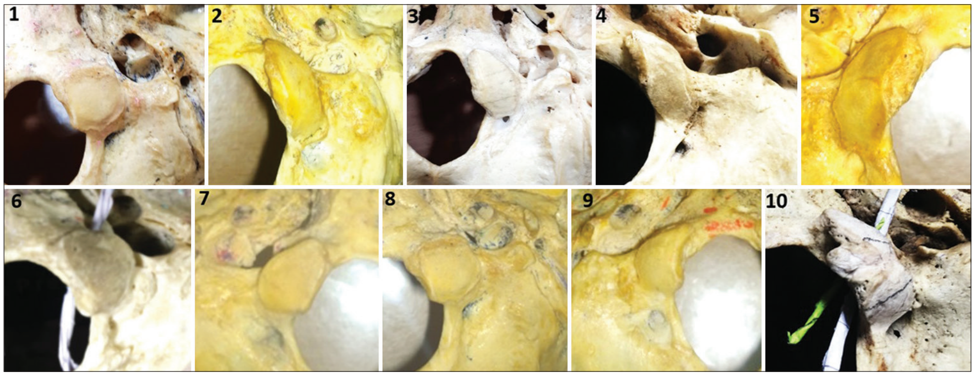

Figure 4: Shape of the occipital condyle: 1-circular, 2-oval, 3-rhomboid, 4-S shape, 5-reniform, 6-triangular, 7-quadrangular, 8-pentagonal, 9-comma shape, 10-irregular

OC in 9.2%, 8.6%, 7%, and in 5% of skulls, respectively.[6,7,10,17] Hence, it can be presumed that North Indians are more likely to have craniocervical instability due to more incidence of short OC.

The shape of OC is also important during condylectomy as kidney-like triangle and deformed types require more extensive condylectomy to reach ventral lesions.[17] The nail insertion is more easy in oval type because large surface area is available for the fixation, while it is difficult in triangle, ring-like, and two-portioned type of OC.[15] In our study, the most common shape of OC was oval (53% skulls) and high-risk types (triangle, reniform, and irregular) were observed in 15% skulls. Similar to our study, Ozer *et al*.[15] and Naderi *et al*.,[16] both examined Greek population and found that oval type was the most common (59.67 and 50%, respectively). In contrast to our findings, Natsis *et al*.[7] found that oval type was present only in 8.6% on the right and 6.5% on the left side. Kalthur *et al*.[6] also noted that oval type was the most common shape but having lesser frequency than North Indians (25%). These findings suggest that North Indians and Greeks, having more incidence of oval type of OC, may be at lesser risk for atlanto-occipital instability during condylectomy surgeries and is easier to approach ventral lesions.

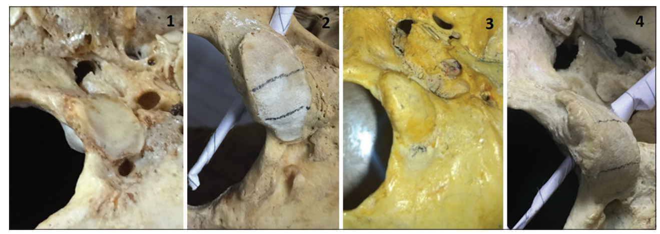

Figure 5: Shape of the facet of occipital condyle: 1-concave, 2-flat, 3-convex+, 4-convex+++

The shape of an articular facet of OC is reported in textbooks as convex.[1] In the present study, concave and flat facets were observed in 1%, and 10% of skulls, respectively, which may be the cause of decreased thickness of OC. In such situations, HC may be exposed easily during condylar drilling leading to damage of neurovascular structures passing through it.

Hypoglossal canal

The HC passes from posteromedial to anterolateral direction and is surrounded inferiorly by OC. This relationship is important while performing condylectomy during TCA as there may be chances of damage to neurovascular structures present in the canal. In the present study, the mean distance of the external orifice of HC from the posterior end of the OC is 13.8 mm on the right side and 15.0 mm on the left side. The mean distance of the internal orifice of HC from the posterior end of the OC is 10.7 mm on the right side and 11.9 mm on the left side. These distances are important as it gives an indication about the amount of OC that can be resected without damaging the structures present in the HC. Similar to our study, Muthukumar *et al*.[17] and Kizilkanat[18] reported that the distance from the intracranial end of the

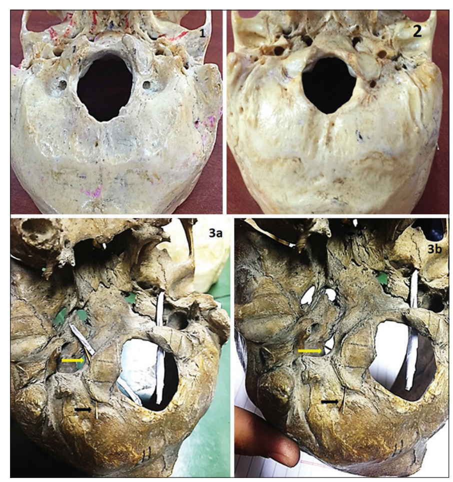

Figure 6: Condylar canal: 1-bilaterally present, 2-unilaterally present, 3a-condylar canal (black arrow) opening anteriorly lateral to hypoglossal canal (yellow arrow), 3b-condylar canal (black arrow) opening anteriorly in the posterior boundary of jugular foramen (yellow arrow)

HC to the posterior margin of the OC was 12 mm. On the other hand, Wen *et al*.,[4] Kalthur *et al*.,[6] and Fetouh and Awadalla[19] reported that the distance was 8.4 mm, 7.5 mm, and 4–7 mm, respectively.

The procedure is more complicated when the HC is septate. In the present study, we observed septum in 34% skulls having more frequency on the left side. In concurrence to the present study, Muthukumar *et al*.[17] and Natsis *et al*.[7] observed septa in 30% and 25.5% skulls, respectively. In another study, septate HC was seen only in 6% of the dry skulls whether unilateral or bilateral.[20] In another study, the prevalence of septa in the HC was higher on the right side (65.8%).[21] In majority of skulls, the HC was located in the anterior 1/3, only in the 15% of skulls, it is located in relation to the middle one-third of the OC where the chances of injury to the hypoglossal nerve are more during condylectomy if half of the OC has to be removed. Therefore, the preoperative radiological examination is essential to determine the location of the HC and the existence of a septum to avoid the hypoglossal nerve injury.

Condylar canal

Ginsberg[22] in their study, identified CC unilaterally in 50% of the cases and bilaterally in 30%. In another study, CC was absent unilaterally in 27% cases and bilaterally in 17% cases.[10] Thompson *et al*.[23] visualized the condylar foramen by preoperative imaging and found that CC was present unilaterally in 50% of the cases and bilaterally in 31% of the cases. In the present study, CC was present unilaterally in 40% skulls and bilaterally in 38% skulls. In one skull, we observed a rare finding on the right side. CC instead of opening into posterior cranial fossa bifurcated into two canals where the medial one was opening externally lateral to the HC, and lateral one was opening into the posterior boundary of the JF.

The CC transmits emissary veins which connect vertebral venous plexus to the sigmoid sinus. During surgical procedures in this region, emissary veins passing through CC can be damaged accidently if present. In cases of achondroplasia and complex cranial synostosis, there may be an obstruction at the JF level leading to decreased sigmoid-jugular venous flow and consequently increased venous flow in the posterior condylar vein. Failure to appreciate this fact can lead to fatal complications during surgery.[22]

Jugular foramen

In the present study, the distance of JF from the posterior end of the OC was found to be 15.73 mm on the right side and 16.77 mm on the left side. The JF was related to the whole extent of OC in 3% skulls. These measurements are important during TCA as the various neurovascular structures emerging from the JF may be at risk during craniovertebral surgeries.[24]

Conclusion

Results of our study and literature reviewed here on the morphologic and morphometric parameters of OC, HC, CC, and JF compel us to point to the essentiality of preoperative assessment of radiological examination and CT imaging of each patient planned for TCA for craniovertebral surgeries.

Acknowledgment

The author is extremely thankful to Dr. Neelam Vasudeva, Head, Department of Anatomy, MAMC, New Delhi, for permitting us to do a study on skulls available in the Department of Anatomy, MAMC, New Delhi.

Financial support and sponsorship

Human skulls were obtained from HIMSR, Jamia Hamdard and MAMC, New Delhi, India.

Conflicts of interest

There are no conflicts of interest.

References

1. Standring S. Head and neck: Overview and surface anatomy. In: Gleeson M, Tunstall R, editors. Gray's Anatomy. The Anatomical Basis of Clinical Practice. 40th ed. Edinburg: Churchill and Livingston; 2008. p. 415-6.
2. Vishteh AG, Crawford NR, Melton MS, Spetzler RF, Sonntag VK, Dickman CA. Stability of the craniovertebral junction after unilateral occipital condyle resection: A biomechanical study. J Neurosurg 1999;90 1 Suppl: 91-8.
3. Boulton MR, Cusimano MD. Foramen magnum meningiomas: Concepts, classifications, and nuances. Neurosurg Focus 2003;14:e10.
4. Wen HT, Rhoton AL Jr., Katsuta T, de Oliveira E. Microsurgical anatomy of the transcondylar, supracondylar, and paracondylar extensions of the far-lateral approach. J Neurosurg 1997;87:555-85.
5. Avci E, Dagtekin A, Ozturk AH, Kara E, Ozturk NC, Uluc K, *et al.* Anatomical variations of the foramen magnum, occipital condyle and jugular tubercle. Turk Neurosurg 2011;21:181-90.
6. Kalthur SG, Padmashali S, Gupta C, Dsouza AS. Anatomic study of the occipital condyle and its surgical implications in transcondylar approach. J Craniovertebr Junction Spine 2014;5:71-7.
7. Natsis K, Piagkou M, Skotsimara G, Piagkos G, Skandalakis P. A morphometric anatomical and comparative study of the foramen magnum region in a Greek population. Surg Radiol Anat 2013;35:925-34.
8. Babu RP, Sekhar LN, Wright DC. Extreme lateral transcondylar approach: Technical improvements and lessons learned. J Neurosurg 1994;81:49-59.
9. Cross J, Coles A. Suppliers of advanced neuro embolisation coils. ACNR 2002;2:16-7.
10. Barut N, Kale A, Turan Suslu H, Ozturk A, Bozbuga M, Sahinoglu K. Evaluation of the bony landmarks in transcondylar approach. Br J Neurosurg 2009;23:276-81.
11. Goel A, Desai K, Muzumdar D. Surgery on anterior foramen magnum

meningiomas using a conventional posterior suboccipital approach: A report on an experience with 17 cases. Neurosurgery 2001;49:102-6.
12. Mintelis A, Sameshima T, Bulsara KR, Gray L, Friedman AH, Fukushima T. Jugular tubercle: Morphometric analysis and surgical significance. J Neurosurg 2006;105:753-7.
13. Mori K, Nakao Y, Yamamoto T, Maeda M. Intradural jugular tuberclectomy in a case of inadequate extradural removal. Surg Neurol 2005;64:347-50.
14. Spektor S, Anderson GJ, McMenomey SO, Horgan MA, Kellogg JX, Delashaw JB Jr. Quantitative description of the far-lateral transcondylar transtubercular approach to the foramen magnum and clivus. J Neurosurg 2000;92:824-31.
15. Ozer MA, Celik S, Govsa F, Ulusoy MO. Anatomical determination of a safe entry point for occipital condyle screw using three-dimensional landmarks. Eur Spine J 2011;20:1510-7.
16. Naderi S, Korman E, Citak G, Güvençer M, Arman C, Senoglu M, *et al.* Morphometric analysis of human occipital condyle. Clin Neurol Neurosurg 2005;107:191-9.
17. Muthukumar N, Swaminathan R, Venkatesh G, Bhanumathy SP. A morphometric analysis of the foramen magnum region as it relates to the transcondylar approach. Acta Neurochir (Wien) 2005;147:889-95.
18. Kizilkanat E. Morphometry of the hypoglossal canal, occipial condyle and foramen magnum. Neurosurg Q 2006;16:121-5.
19. Fetouh FA, Awadalla AM. Morphometric Analysis of the Occipital Condyle and its Surgical Implications in Transcondylar Approach. The Pan Arab Neurosurgery Society. Available from: http://www.panarabjn.org/wp-content/uploads/2013/03. [About 15 p.].
20. Rhoton AL Jr. The foramen magnum. Neurosurgery 2000;47 3 Suppl:S155-93.
21. Pereira GA, Lopes PT, Santos AM, Duarte RD, Piva L, Pozzobon A. Morphometric analysis related to the transcondylar approach in dry skulls and computed tomography. Int J Morphol 2012;30:399-404.
22. Ginsberg LE. The posterior condylar canal. AJNR Am J Neuroradiol 1994;15:969-72.
23. Thompson DN, Hayward RD, Harkness WJ, Bingham RM, Jones BM. Lessons from a case of kleeblattschädel. Case report. J Neurosurg 1995;82:1071-4.
24. Ishwarkumar S, Naidoo N, Lazarus L, Pillay P, Satyapal KS. An osteometric evaluation of the jugular foramen. Int J Morphol 2015;33:251-4.