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The radiological anatomy of clivus for surgical approaches

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Abstract

Objectives: Clivus is the central part of the skull base that extends from the anterior part of the foramen magnum to the posterior clinoid process. Clivus has close relationships with crucial neurovascular structures. The purpose of the study was to evaluate the anatomical relationships at the clival region on computed tomography (CT) images for to provide data to conduct best pathways and safe zones for clival surgeries.

Methods: Brain and cervical CT images of 103 patients (48 female, 55 male; mean age: 63) were examined retrospectively. The length of the clivus at the sagittal plane, the width of the inferior and middle parts of the clivus at the midsagittal plane, and the distance between the internal carotid arteries at the sagittal plane in axial sections were measured.

Results: The mean length of the clivus at the sagittal plane was 38.40±5.82 mm. The mean width of the inferior and middle parts of the clivus at the midsagittal plane was 6.67±1.45 mm and 10.32±1.66 mm, respectively. In axial sections, the mean distance between the internal carotid arteries was 22.10±03.42 mm in the sagittal plane.

Conclusion: Knowing the dimensions of the clivus and the distance between the internal carotid arteries at the sagittal plane is important for a safe and successful clival surgery.

Keywords: clivus; computed tomography; skull base

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Introduction

The clivus, which was first named by Johannes Blumenbach, is the central part of the skull base that extends from the anterior part of the foramen magnum to the posterior clinoid process.[1–3] It divides the posterior fossa from the nasopharynx and is made up of the posterior region of the body of the sphenoid bone and the basilar segment of the occipital bone.[4] The fusion of these bony parts starts in the second month of intrauterine life and completes at the age of 16–20 years.[5]

Clivus can be divided into three parts as upper (sellar clivus), middle (sphenoidal clivus), and lower (nasopharyngeal) thirds. The upper and the middle thirds of the clivus are formed by the sphenoid bone, and the lower third is formed by the occipital bone.[6]

Clivus is a complex skull base region which has close relationships with crucial neurovascular structures such as the brainstem, sellar region, and internal carotid arteries.[3] In 1992, Samii and Knosp have written a book that reviewed the approaches to the clivus and the name of the book was "Approaches to the clivus: approaches to no man's land." Many different approaches to the clival region were defined in the last three decades and particularly with the technological advances in endoscopic surgery, the transnasal transsphenoidal endoscopic approach to the clivus maintains a good exposure for the tumors of this region.[3]

Because of the restrictions of the clival region and its complicated relationships, detailed anatomical knowledge plays a critical role in avoiding injury to these vital structures. In this study, the computed tomography (CT) anatomy of the region was analyzed for to provide data to conduct best pathways and safe zones for clival surgeries.

Materials and Methods

Brain and cervical CT images of the 103 patients (48 females and 55 males) were retrospectively analyzed between January 1, 2022 and December 31, 2022. The mean age of the patients was 63 (range: 1–92) years. The images were randomly selected from Radiology Unit of the Private Medikar Hospital. The CT images were taken with a CT device (General Electric VCT 128 Slice Scanner, Milwaukee, Wisconsin, USA) that had a collimation of 1.25 mm, tube tension of 140 kV, and tube current of 240 mAs (with dosage modulation).

The length of the clivus in the sagittal plane, the width of the inferior and middle parts of the clivus at the midsagittal plane, the distance between the internal carotid arteries at the sagittal plane in axial sections were measured (**Figure 1**). The wide angle between the line extending across the anterior cranial fossa to the tip of the dorsum sella, and the line drawn along the posterior margin of the clivus was determined as basal angle and measured on sagittal images (**Figure 2**).

The Shapiro–Wilk test was used to determine whether continuous variables had a normal distribution or not. The variables were represented as mean and standard deviation if they did not conform to the normal distribution and as median, minimum, and maximum values if they did not conform to the normal distribution. Mann–Whitney U test was employed to compare continuous variables between age and gender groups. Analyses were conducted using SPSS (Version 26.0, IBM Corp., Armonk, NY, USA). The significance level was set at 5%.

Results

The mean length of the clivus at the sagittal plane was 38.40±5.82 (range: 13–52) mm. The mean width of the inferior part of the clivus at the midsagittal plane was 6.67±1.45 (range: 3–50) mm. The mean width of the middle part of the clivus at the midsagittal plane was 10.32±1.66 (range: 6–14) mm. The mean distance between the internal carotid arteries at the sagittal plane in axial sections was 22.10±3.42 (range: 10–28) mm. The mean basal angle was 118.08º±9.38º (range: 100–150º).

The patients were divided into two age groups being ≥18 years and <18 years. The mean distance between the internal carotid artery below the petrous apex and the width of the middle and inferior portions of the clivus, as well as the length of the clivus in the sagittal plane were all higher in the patients elder than 18 years ($p<0.001$, $p<0.001$, $p=0.006$ and $p=0.002$, respectively). However, there was no difference between the age groups based on the basal angle ($p=0.945$). The length of clivus at the sagittal plane was found to be higher in males when compared with females ($p=0.014$), while the other measurements did not differ according to gender ($p>0.05$) (**Table 1**) (**Figures 3–6**).

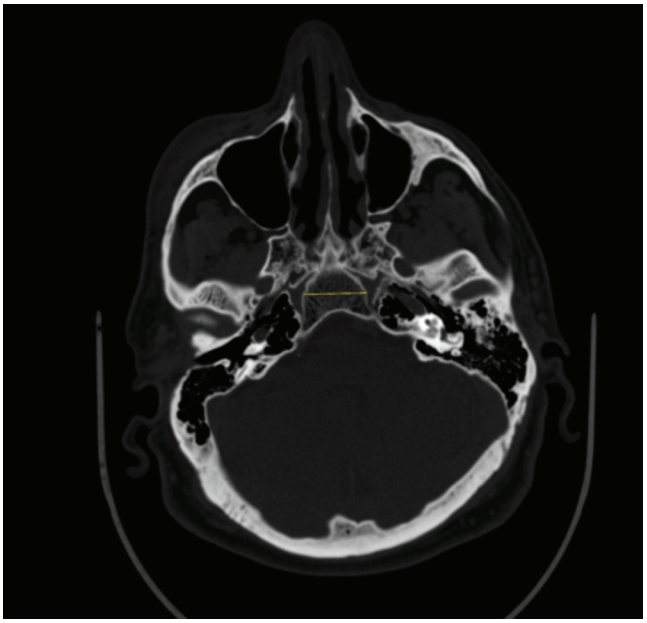

Figure 1. The distance between the internal carotid arteries (yellow line) below the petrous apex in axial views.

Discussion

There are several congenital or acquired pathologies of the clivus, such as developmental anomalies, non-neoplastic and neoplastic lesions, inflammatory processes, and trau-

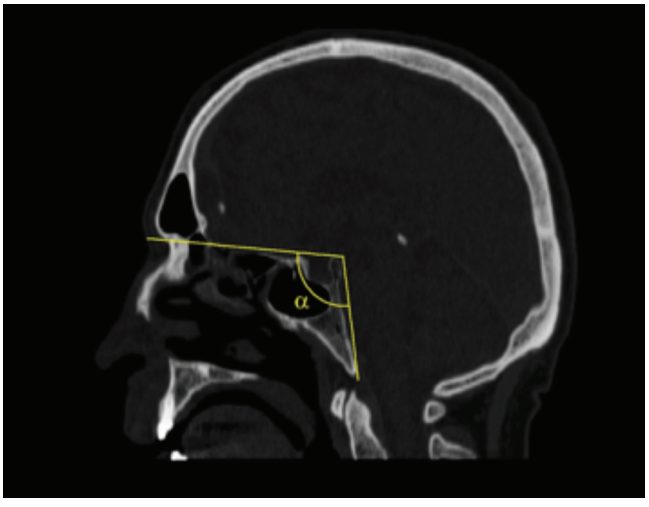

Figure 2. The measurement of the basal angle (α).

Table 1
Statistically significant differences in the cerebellar volumes and cortical thickness between the depressed and control groups and the percentage differences.

	Age		Gender	
	≤18 years (n=11)	>18 years (n=92)	Female (n=48)	Male (n=55)
The width of the middle part of the clivus (mm)	8 (6–12)	11 (7–14)	10.50 (7–14)	10(6–13)
	p<0.001		p=0.623	
The width of the inferior part of the clivus (mm)	5 (3–7)	7 (4–10)	7 (4–9)	6 (3–10)
	p<0.001		p=0.236	
Length of the clivus in the sagittal plane (mm)	27 (13–45)	39.50 (31–52)	38 (25–48)	40 (13–52)
	p=0.006		p=0.014	
The distance between the internal carotid arteries below the petrous apex (mm)	16 (10–26)	22 (14–28)	22 (14–26)	22 (10–28)
	p=0.002		p=0.141	
The basal angle	117 (111–137)	118 (100–150)	115 (100–150)	118 (103–149)
	p=0.945		p=0.326	

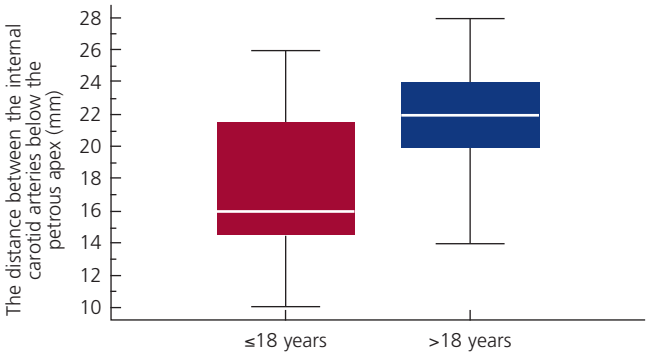

Figure 3. Distance between the internal carotid arteries below the petrous apex.

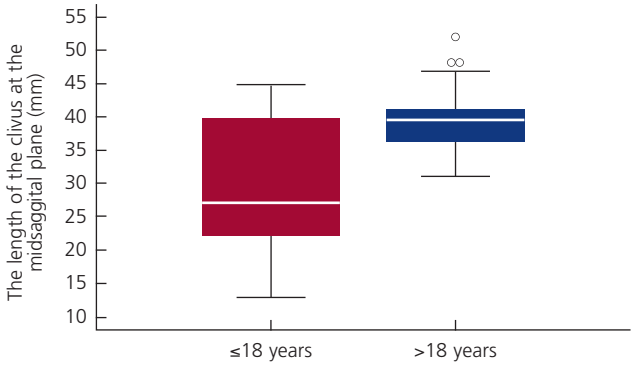

Figure 4. The length of the clivus at the midsaggital plane.

matic lesions.[2–7] Surgical approaches directed for these pathologies of the clivus include subtemporal approach, suboccipital approach, oropharyngeal approach, and endonasal–endoscopic approach.[1,3,8] Traditional transcranial approaches requires excessive brain retraction which may lead to complications such as brain edema, infarction, and hematoma.[1] With the developments in endoscopy, endonasal–endoscopic approaches for the pathologies of the clivus became a good alternative to transcranial methods as it does not require any brain retraction. Endonasal–

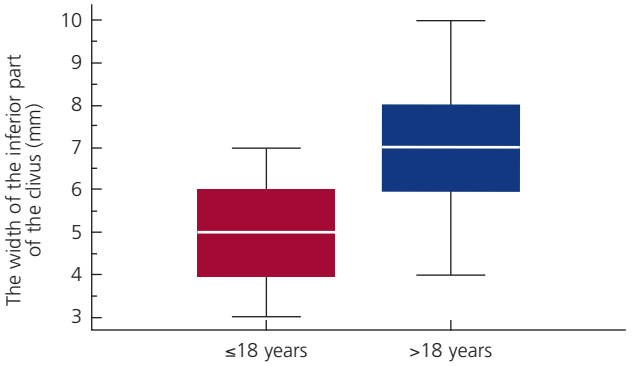

Figure 5. The width of the inferior part of the clivus.

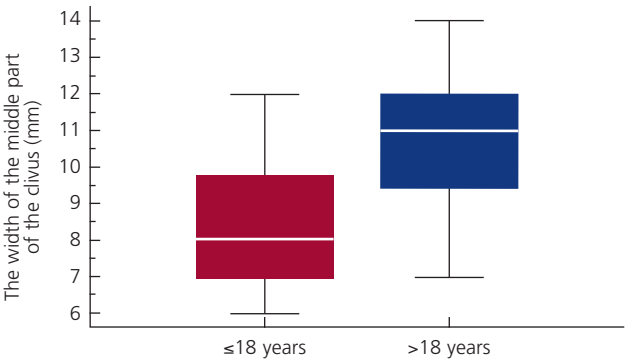

Figure 6. The width of the middle part of the clivus.

endoscopic approaches maintain the visualization of the deeper structures, a multi-perspective observation, and also a good exposure to the extradural parts of the lesions.[1,3] In this study, some essential morphometric measurements of the clivus were performed to be used during endoscopic surgery of the clivus.

The anatomical relationships of the clival region must be known in details to provide a safe and effective endonasal–endoscopic approach. Cheng et al.[3] emphasized the importance of the close relation of the clivus to the optic nerves, the internal carotid arteries, and the sub-petrosal sinuses during transclival surgeries. The cavernous part of the ICA is in close relation to the clivus. It is particularly important to know the mean distance between the internal carotid arteries during transclival surgery to prevent its vascular injury. The results of our study showed that the mean distance between the internal carotid arteries under the level of the petrous apex is 22.10±3.42 mm. The internal carotid arteries inferior to the petrous apex are separated by a distance that is more than twice the distance between the internal carotid arteries superior to the petrous apex, making it an important anatomical landmark.[3] Therefore, there is less restriction for the approaches inferior to the petrous apex, and this area is also appropriate for endoscopic surgery.[3]

According to Wang et al.,[9] the full length of the clivus is 30.6–51.2 mm, with an average length of 41.7±2.9 mm. In our study, it was 38.40±5.82 mm and also the length of clivus at the sagittal plane was shown to be higher in males and in the patient group older than 18 years.

In our study, the mean width of the middle and inferior parts of the clivus was revealed as 10.32±1.66 and 6.67±1.45 respectively. Because of the shape of the clivus, the thickness of the inferior and middle parts of the clivus varies. Knowing these dimensions are particularly important for selection of suitable equipment during the approaches directed to the brain stem.

We suggest that knowing the basal angle is also important for endoscopic approaches. According to Koenigsberg et al.[10] the basal angle was 105°–127° for adults and 104°–124° for children with the modified MR imaging technique. In our study, the mean basal angle was found as 118.08°±9.38°. The basal angle was used to be measured using plain radiographs, but with increasing use of MRI and CT, the measurements can now be done with greater accuracy and simplicity.[10]

The major limitation of this study was the number of images included to the study. We suggest conducting further studies done in larger population and in more age groups.

Conclusion

Clivus surgery has some potential risks such as neurovascular injuries including cranial nerves, internal carotid artery and injury to meninges, or directly injury to the brain. A detailed preoperative evaluation of the patient is necessary to avoid such complications. In particular, reconstructed CT images in addition to enhanced MR images should be examined carefully before surgery. The usage of technologically developed endoscopic techniques maintains good surgical outcomes when compared with traditional transcranial approaches for clival surgery, and the significance of anatomical knowledge still plays a major role in successful and safe surgery.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

TMG: data collection, data analysis; manuscript writing/editing; OFU: data collection, data analysis; manuscript writing/editing; GK: project development, data analysis, manuscript writing/editing.

Ethics Approval

Approval for this study was received from the Ethics Committee of Karabük University Faculty of Medicine (Number: E-77192459-050.99-209417).

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