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ORIGINAL ARTICLE

Anatomical variations of clivus: a descriptive anatomical study

Bhavana Murjani[1] · Rohini Bhosale[1] · Easwaran Ramaswami[1] · Sonali Kadam[1] · Amit Ramchandani[1]

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Abstract

Purpose The clivus is a part of the sphenoid bone. It may show some anatomical variations such as fossa navicularis magna (FNM), canalis basilaris medianus (CBM) and craniopharyngeal canal (CPC). These variations have been associated with conditions like meningitis and tumors of skull base. Inadequate information about these structures may pose a risk of inaccurate diagnosis resulting in unwarranted interventional procedures. Hence, the knowledge about the prevalence of these variations is important. Thus, the objective of this study was to determine the prevalence of fossa navicularis magna, craniopharyngeal canal and canalis basilaris medianus and its types utilizing cone-beam computed tomography (CBCT) images.

Methods Retrospectively, a total of 350 CBCT scans were evaluated for the presence of FNM, CBM, its types and CPC. The analysis was done by two observers independently. Cohen's kappa statistics was used to determine the interobserver agreement.

Results FNM was noted in 19.4% cases, CBM in 9.7% cases, whereas CPC was not identified in any case. Type 5 was the most common type of CBM. There was no significant difference ($p > 0.05$) between genders and age groups for the prevalence and a highly significant ($p < 0.01$) substantial agreement between observers for the prevalence of FNM and highly significant ($p < 0.01$) moderate agreement for the prevalence of CBM and its types was obtained.

Conclusion FNM, CBM, CPC, albeit rare anatomical variations of clivus, knowledge of these structures is important for radiologists, anatomists and surgeons to avoid misdiagnosis and provide awareness to the individual of a higher possibility of meningitis or tumors of the skull base.

Keywords Canalis basilaris medianus · Craniopharyngeal canal · Fossa navicularis magna · Skull base

Introduction

The clivus is one of the central structures of the posterior skull base (also known as Blumenbach's clivus after German physiologist and anthropologist Johann Friedrich). The word clivus is derived from Latin; meaning slope or hill [17]. It is formed by the occipital bone and sphenoid bone fusing at the spheno-occipital synchondrosis and is a wedge-shaped structure extending from the anterior margin of foramen magnum till the dorsum sella.

The notochord is a developmental patterning structure around which the vertebral column develops. It generally disappears on development except in the nucleus pulposus which lies in the center of the intervertebral fibrocartilages. The notochord emerges from the vertebral axis and extends towards the base of the skull. At the base of the skull, it emerges towards the ventral surface and enters the pharyngeal area following which it re-enters the clivus at the basisphenoid to end below the dorsum sella [10]. With development, ossification takes place and the notochord atrophies and disappears. However, at times, complete ossification might not take place and remnants of notochord might persist resulting in morphological variations of the clivus.

Fossa navicularis magna (FNM), also known as pharyngeal fossa or pharyngeal foveola, is a notch-like defect noted in the occipital part of clivus on the inferior aspect in the midline [10, 16]. First described by Testut in 1921 and also has been referred to as a type of canalis basilaris medianus [16]. It has been hypothesized that this structure was a result of remnant notochord or could have been due to the expansion of emissary vein [5]. The knowledge about this structure prevents misdiagnosis as a pathology

✉ Bhavana Murjani
bhavana.murjani91@gmail.com

[1] Department of Oral Medicine and Radiology, Government Dental College and Hospital, Mumbai, Maharashtra, India

as well as it has been shown to play a role in assisting the spread of infection resulting in meningitis [16].

Canalis basilaris medianus (CBM) is a canular defect in the occipital part of clivus and it has been known to bring about a path for the spread of infection from the nasopharynx to the base of skull [5]. Six forms of canalis basilaris medianus has been noted; three complete forms namely—type 1: bifurcating type, type 2: inferior type, type 3: superior type and three incomplete forms namely—type 4: inferior recess, type 5: superior recess, type 6: channel [5]. The complete forms will have two open ends while the incomplete ones will have one open end and one blind end. The previous basivertebral veins, which originate from the upper vertebral region and integrate into the skull base may be found in the basilar canalis, which tend to increase the risk of haemorrhage during any surgical procedures of this region [4].

Craniopharyngeal canal (CPC) is a defect resulting in communication between the sella turcica and nasopharynx. It extends from the floor of the sella turcica till the roof of the pharynx [5]. It is said to result from the persistence of the embryological stalk of Rathke's pouch, which forms by the sixth week and by the seventh week, gets obliterated by the growing sphenoid cartilage [12]. Craniopharyngeal canal has been found to be associated with nasopharyngeal masses, risk of herniation of pituitary gland, etc. [5]. Abele et al. proposed a classification for the craniopharyngeal canal which might assist in the identification of midline lesions [1].

Cone beam computed tomography (CBCT) is a three-dimensional imaging modality that provides accurate information and representation of the hard tissues of the craniofacial region. Since its introduction in dentistry, it has become an integral part of the field and an important utility in multiple procedures of the craniofacial region. With a hard tissue resolution comparable to computed tomography (CT) and the introduction of larger field of view in CBCT, hard tissue variations such as mentioned above can be easily studied using CBCT imaging with an additional of benefit of reduced radiation exposure as compared to CT.

Thus, this study aimed to determine the prevalence of FNM, CPC and CBM and its types using CBCT among a part of Indian population.

Materials and methods

This was a retrospective study. Ethical approval was obtained from the institutional ethical committee for this study. Four hundred scans from the archives were viewed and among them 350 were selected and included in this study, according to the inclusion and exclusion criteria as mentioned below. In this study, 350 CBCT scans of patients were collected from the department archives, which had been taken for various other reasons like implant assessment, impacted teeth assessment, temporomandibular disorders, etc. CBCT images were obtained on Planmeca Promax 3D (Helsinki, Finland) and Romexis viewer was utilized for analyzing the scans. CBCT images that had a good diagnostic quality and sufficient imaging area were included in the study. Patients with a history of trauma or surgery in the midline skull base were excluded. Also, scans with inadequate imaging area and blurred or distorted scans were excluded.

FNM (Fig. 1) was identified in sagittal, axial and coronal sections. It was seen as a deep notch like defect on the inferior aspect of clivus. CPC and CBM were best identified on the sagittal section. CBM (Fig. 2) was evaluated for in the basiocciput region as a proper corticated canal and based on its morphology, was identified into the six different types. CPC (Fig. 3) was evaluated as a canal connecting the sella turcica and nasopharynx. The analysis was done on a 0.4 mm slice thickness of the scan. Two observers were included in the study to avoid observer bias and both evaluated and interpreted the images independently. Data obtained was compiled on an MS Office Excel Sheet (v 2013, Microsoft Redmond Campus, Redmond,

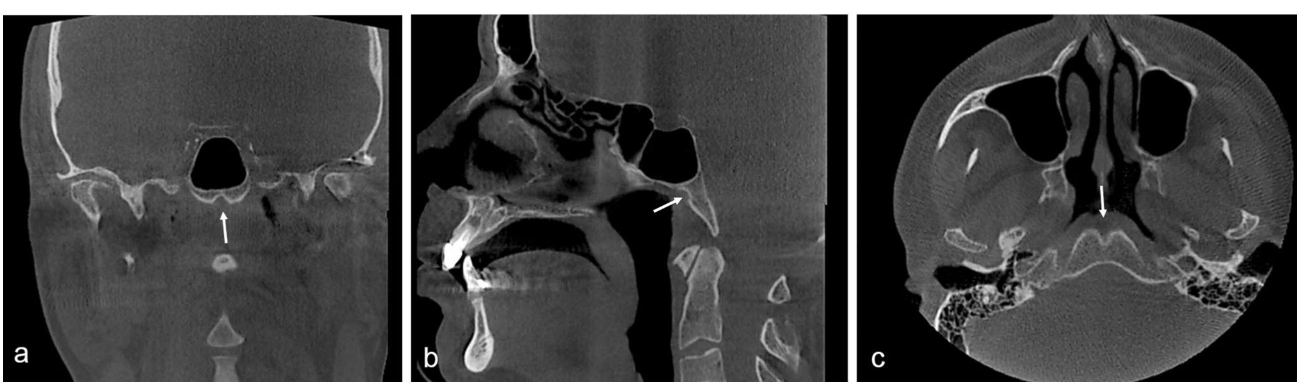
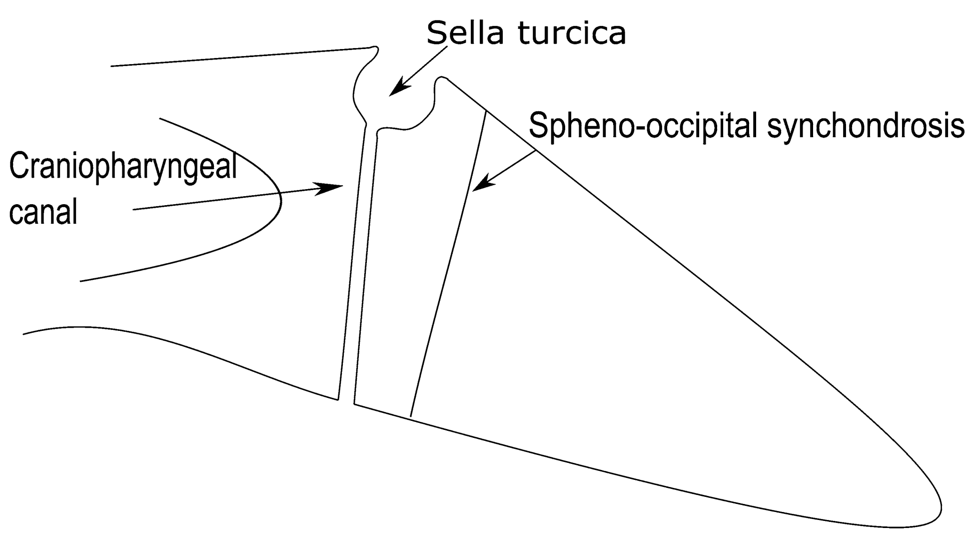


Fig. 1 Fossa navicularis magna as seen in the coronal (**a**), sagittal (**b**) and axial (**c**) sections of CBCT

Fig. 2 Types of canalis basilaris medianus: Inferior type (**a**), superior type (**b**), inferior recess (**c**), superior recess (**d**) and channel (**e**) in CBCT on sagittal sections

Fig. 3 Diagrammatic representation of craniopharyngeal canal



Washington, United States) and was subjected to statistical analysis using Statistical package for social sciences (SPSS v 21.0, IBM). Along with descriptive statistics, a comparison of frequencies of categories of variables with groups (age and gender) was done using the chi-square test and the degree of agreement between two examiners was checked using the Kappa coefficient. The statistically significant difference was kept at $p < 0.05$, statistically highly significant difference at $p < 0.01$ and no significant difference at $p > 0.05$.

Results

Three hundred and fifty scans of patients with the age range of 10–83 years (mean age: 32.02 ± 15.944) were included, out of which, 138 (39.4%) were females and 212 (60.6%) were males. FNM was found in 68 (19.4%) patients, out of which 45 were males and 23 were females. CBM was found in 34 (9.7%) patients, out of which 22 were males and 12 were females. There was no significant difference found between different age groups and gender for the prevalence of both ($p > 0.05$) (Tables 1 and 2).

The total number of CBM was 39 in the 34 patients demonstrating the presence, as some of the cases had two different types of CBM present in one (Table 3). The most common type of CBM was type 5, whereas the least common was type 1. The majority of CBM identified were of incomplete variety. The prevalence of complete variety of CBM was less in the study population.

Table 1 Gender distribution of fossa navicularis magna and canalis basilaris medianus

Variant	Present/absent	Gender		Total	Chi-square value	*p* value
		F	M			
Fossa navicularis magna	Absent	115	167	282		
	Present	23	45	68	1.110	0.292*
Canalis basilaris medianus	Absent	126	190	316		
	Present	12	22	34	0.270	0.604*
	Total	138	212	350		

*Statistically no significant difference ($p > 0.05$)

Table 2 Age distribution of fossa navicularis magna and canalis basilaris medianus

Age groups (year)	Fossa navicularis magna			Canalis basilaris medianus		
	Absent	Present	Total	Absent	Present	Total
10–20	73	25	98	86	12	98
21–30	89	24	113	99	14	113
31–40	38	8	46	44	2	46
41–50	27	7	34	31	3	34
51–60	34	3	37	35	2	37
61–70	18	0	18	17	1	18
≥71	3	1	4	4	0	4
Total	282	68	350	316	34	350
Chi-square value	10.152			4.747		
p value	0.118*			0.577*		

*Statistically no significant difference ($p > 0.05$)

Table 3 Age and gender distribution of types of canalis basilaris medianus

Gender	Type 1		Type 2		Type 3		Type 4		Type 5		Type 6	
	M	F	M	F	M	F	M	F	M	F	M	F
Age groups (year)												
10–20	0	0	1	0	0	1	4	1	4	2	1	1
21–30	0	0	2	1	1	0	1	3	3	4	1	0
31–40	0	0	0	1	0	0	1	0	0	0	0	0
41–50	0	0	0	0	0	0	2	0	1	0	0	0
51–60	0	0	0	0	0	0	1	0	1	0	0	0
61–70	0	0	0	0	0	0	0	1	0	0	0	0
≥71	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	3	2	1	1	9	5	9	6	2	1
	0		5		2		14		15		3	
	39											

Not a single case of CPC was identified in all the 350 cases included in this study.

Kappa coefficient was used to study the interobserver agreement and it was obtained as $k = 0.63$ for the prevalence of FNM indicating that there was substantial agreement between the observers which was highly significant ($p < 0.01$). The kappa value for the prevalence of CBM was obtained as $k = 0.47$ indicating there was moderate agreement between the observers which was also highly significant ($p < 0.01$). There was a statistically highly significant ($p < 0.01$) moderate agreement ($k = 0.43$) between the observers for the occurrence of types of CBM.

Discussion

The posterior base of the skull is encroached infrequently with multiple pathologies such as Tornwald's cyst, metastatic tumors, ecchordosis physaliphora, notochordal cell tumor, Rathke's pouch cyst, adenoid retention cyst, etc. [5]. The skull base is not easily accessible for clinical examination and thus imaging plays an important role for identification of the lesions. Hence, the knowledge about any morphological variations should be well known, to differentiate it from the pathological lesions and vice-versa. The clivus is a part of the base of the skull and in this study, three morphological variations of the clivus were studied.

The present study evaluated the prevalence of the anatomical variations of clivus and found a prevalence of 19.4% for FNM, 9.7% for CBM and 0% for CPC.

Multiple case reports have attributed FNM as a path for the spread of infection to the base of the skull. Prabhu et al. in 2009 reported a case of clival osteomyelitis due to spread of infection from FNM [16], Segal et al. reported a case of intracranial infection which had possibly spread due to FNM [20], Alalade et al. reported a pediatric case of recurrent meningitis due to FNM [3].

CT, CBCT and dry skulls were used in the past for the analysis of FNM. Cankal et al. in 2004 studied 492 dry skulls and 525 CT images of patients and found the prevalence of FNM as 5.3% and 3.0%, respectively. He stated that the prevalence was higher in the anatomic analysis as compared to radiologic analysis, because in the CT images, it was difficult to identify < 2 mm depth FNM [6]. Ray et al. studied 202 dry skulls and found the prevalence of FNM to be 1.49% [18]. The prevalence of FNM in this study was obtained as 19.4% which was higher as compared to study done Cankal et al. and Ray et al. which could be attributed to the use of different modalities.

Ersan [9] studied 723 CBCT scans of patients belonging to the Turkish population and obtained a prevalence of 6.6% for FNM. Bayrak et al. analyzed 1059 CBCT scans of the Turkish population for the prevalence of FNM and found it to be 7.6% [5]. Compared to these studies, the prevalence obtained was higher in this study which could be attributed to a smaller sample size in this study and the difference in the population under study.

Kaplan et al. [11] analysed 195 CBCT scans of orthodontic subpopulation and found the prevalence of FNM as 17.4%. This was comparable to the present study.

CBM was first identified by Gruber in 1880 and he classified it into three different types: superior, inferior and bifurcates. Later on, other types were added to include six morphologies of CBM [7]. Initially, it was not considered to be of any clinical importance, however, in 1981, Martinez et al. reported a case of an infant boy who suffered from recurrent meningitis. Polytomograms revealed a rounded defect in the clivus communicating with the subarachnoid space appearance similar to the inferior type of CBM. Surgically, a cyst-like structure was removed which was given as a meningocele. The recurrent episodes of meningitis stopped once the defect was restored [14].

Morabito et al. reported a case of an inferior type of CBM in a 1-month-old female child which was associated with rhino-oropharyngeal enterogenous cyst, detected and evaluated by CT and magnetic resonance imaging (MRI) [15]. Khairy et al. reported a case of cerebrospinal leak occurring through CBM of a 22-year-old male with a complaint of frontal headache and running nose [13]. A case of recurrent meningitis was reported by Schick et al. with two skull base malformations, one of which was a CBM acting as a path for the spread of infection [19]. Syed et al. in 2016 was the first to report two cases with CBM as an incidental finding on CBCT imaging of the patients [21].

Bayrak et al. performed a study on 1059 CBCT scans and found a prevalence of 2.5% for CBM in the Turkish population [5]. Kaplan et al. studied various skull base foramina using cone beam computed tomography and concluded a prevalence of 4.3% for CBM [2]. In this study, the prevalence of CBM was obtained as 9.7% which was higher in comparison to both of the above studies.

CPC, occurring due to incomplete closure of Rathke's pouch, was classified into three major types by Abele et al. in 2014. They studied retrospectively MRI, CT and clinical data of 29 patients with CPC and separated them in three major types: type 1—incidental canals (anteroposterior average diameter 0.8 mm); type 2—canals with ectopic adenohypophysis (average diameter 3.9 mm) and type 3 (average diameter 9 mm) which was subdivided into three types namely type 3A—canals containing cephaloceles, type 3B—canals containing tumors, type 3C—canals containing both [1].

Ekinci et al. reported a case of a CPC in a 16-year-old female with hyperprolactemia and hypothalamic hamartoma. The pituitary gland was inferiorly displaced in the canal and there was an extension of a part of the gland in the nasopharynx. Hypothalamus was associated with a hamartoma and it was suggested that the traction of the pituitary stalk has resulted in hyperprolactemia [8]. Vinayagamani et al. [22] reported a case of a craniopharyngeal canal along with a cephalocele and lipoma in a 13-year-old male.

Bayrak et al. [5] performed a study on 1059 CBCT scans and found a prevalence of 0.3% for the craniopharyngeal canal in the Turkish population. In this study, however, not a single case of craniopharyngeal canal was observed.

The difference in the prevalence obtained for the anatomical variants in this study as compared to the previous ones could be due to the small sample size of the study as well as differences between the populations under study indicating that the provenance of the population influenced the prevalence.

Conclusion

FNM, CBM and CPC are rare anatomical variations of clivus. As the skull base lesions are not easily accessible for examination, imaging is an important tool for the evaluation of these lesions. With the advent of the increased field of view for CBCT and increasing use of it for treatment procedures in dentistry, a maxillofacial radiologist stands at higher possibility of coming across these structures and the knowledge about these anatomical variants is needed to avoid the misinterpretation with pathological conditions, thus avert any unnecessary procedures.

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Data availability CBCT data was obtained from department archives.

Code availability Not applicable.

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflicts of interest.

Ethics approval Approval obtained from the institutional ethical committee.

Consent to participate Written informed consent was taken from all the patients before the scan was taken.

Consent for publication All authors have given their consent for publication.

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