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ORIGINAL ARTICLE

Incidence and Size of the Fossa Navicularis in Chiari Type I Malformation

Göktuğ Ülkü[1], Çağrı Elbir[1], Oğuz Kağan Demirtaş[1], Ali Erhan Kayalar[2], Mustafa Efendioğlu[3], Hadice Ucar[4], Onur Özgüral[5], Orhan Beger[6]

[1]Department of Neurosurgery, Ankara Etlik City Hospital, Ankara, Türkiye
[2]Department of Neurosurgery, Umraniye Training and Research Hospital, Istanbul, Türkiye
[3]Department of Neurosurgery, Private Clinic, Istanbul, Türkiye
[4]Department of Anatomy, Gaziantep University, Institute of Health Sciences, Gaziantep, Türkiye
[5]Department of Neurosurgery, Ankara University, Faculty of Medicine, Ankara, Türkiye
[6]Department of Anatomy, Gaziantep University, Faculty of Medicine, Gaziantep, Türkiye

Abstract

Introduction: This study aimed to compare the morphology of the fossa navicularis (FN) in patients with Chiari type I malformation (CIM) and healthy subjects.

Methods: Radiologic views of 50 CIM patients (21 men/29 women) with a mean age of 26.93±16.03 years and 50 healthy subjects (29 men/21 women) with a mean age of 33.13±21.40 years were included in this computed tomography study. The presence or absence of FN was noted, and the depth (FN-D), width (FN-W), and length (FN-L) of FN, as well as the clivus length (CL), were measured.

Results: FN was observed in 14 CIM patients (28%) and in eight controls (16%). In CIM patients, FN-L, FN-W, FN-D, and CL were measured as 3.62±1.64 mm, 4.91±1.31 mm, 2.71±1.06 mm, and 43.45±5.62 mm, respectively. In controls, FN-L, FN-W, FN-D, and CL were measured as 4.95±1.18 mm, 3.42±0.97 mm, 1.98±1.22 mm, and 48.01±3.51 mm, respectively. CIM subjects had greater FN-W ($p=0.008$) but smaller CL ($p=0.042$). FN-L ($p=0.059$) and FN-D ($p=0.070$) were similar between the groups. In CIM patients, all parameters were similar between sexes. In controls, men had greater FN-L compared to women ($p=0.029$).

Discussion and Conclusion: CIM patients had greater FN-W compared to controls. FN incidence was not affected by CIM. These findings may help clinicians better understand clivus anatomy in CIM patients.

Keywords: Chiari type I malformation; clivus; fossa navicularis.

The fossa navicularis (FN) — also referred to as the large pharyngeal fossa, fossa pharyngea, medial basal fossa, keyhole defect, and fossa navicularis magna — is a small pit situated on the lower surface of the clivus, anterior to the pharyngeal tubercle [1–6]. Clinicians may encounter FN incidentally on radiologic views, as its incidence has been reported between 3.04–27.50% [1,3,7]. Although rare, FN has clinical implications [3,8]. FN-related pathologic entities include sphenoidal sinus mucocele, Thornwaldt's cyst, Rathke pouch cyst, adenoid hypertrophy, adenoid retention cyst, and local or metastatic tumors [3]. Due to its close relationship with the nasopharynx, this small pit may facilitate the spread of infection from the pharyngeal region to the intracranial area [8]. Therefore, clinicians

Correspondence: Göktuğ Ülkü, M.D. Department of Neurosurgery, Ankara Etlik City Hospital, Ankara, Türkiye
Phone: +90 507 576 60 58 **E-mail:** dr.gulku@gmail.com
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should be well aware of FN morphology to understand its possible role in various diseases.

Chiari type I malformation (CIM) is defined as the downward herniation of the cerebellar tonsils through the foramen magnum [9]. This malformation has a prevalence of 0.24–3.6% [10]. The primary cause of this anomaly is believed to be deviations in the development of the occipital somite, which originates from the paraxial mesoderm [11]. This malformation primarily affects the bony structures of the posterior cranial base and causes approximately a ¼ reduction in its volume [11,12]. This volumetric reduction may lead to overcrowding of the hindbrain and diverse symptoms [9,11,12]. One of the bony structures most affected by CIM is the clivus [13,14]. Despite the obvious changes in clivus morphology, no study systematically focusing on clivus variations (including FN or canalis basilaris medianus) in patients with CIM has been encountered in the literature. In this regard, our main aim is to evaluate the incidence and dimensions of FN in CIM to improve current knowledge regarding the morphometric features of the cranial base.

Previous research has established an association between CIM and morphometric alterations in skull base bony structures [11,12]. Numerous studies have specifically demonstrated structural deviations in the cranio-cervical junction and clivus compared with the normal population [11,14]. Therefore, the present study was designed to investigate the morphological impact of CIM on the fossa navicularis, a component of the cranial base and cranio-cervical junction [11,12,14].

Materials and Methods

Study Population

The Clinical Research Ethics Committee approved our retrospective examination (confirmation no: I10-711-23, date: 21.11.2023). All participants provided informed consent, and the study was conducted in accordance with the principles outlined in the Helsinki Declaration, ensuring ethical standards throughout the research process. Subject folders were reviewed according to the study criteria (Table 1). Patient files included the following information: cranial computed tomography (CT) and magnetic resonance imaging (MRI) views, sex, age, treatment and diagnostic procedures, hospital admission/discharge dates, and complaints. Cases without a history of meningomyelocele but exhibiting tonsillar herniation >5 mm downward from the foramen magnum were accepted as CIM. The study population was divided into two groups: CIM and controls.

CT Protocol

A 64-row multidetector scanner (Aquillion 64, Toshiba Medical Systems, Tokyo, Japan; 0.3-mm interval, 120 kV, 230 mA, 0.5-mm slice thickness, pixel size 0.46 mm, field of view 240 mm, and matrix 512×512) was used to acquire radiologic data. The raw data were processed to obtain coronal, axial, and sagittal images, which were then reformatted to acquire three-dimensional (3D) images. Study parameters were measured using the RadiAnt DICOM Viewer.

Table 1. The inclusion and exclusion criteria for the study populations.

Criteria	CIM	Controls
Inclusion criteria	Patients with CIM Patients without a history of surgical intervention around the clivus Patients with good quality CT images	Patients without malformations (syndromic or genetic) Patients without fractures, infections, tumors Patients without a history of surgical intervention around the clivus Patients without a history of medical treatment related to the clivus Patients with good quality CT images
Exclusion criteria	Patients with the other types of Chiari malformation Patients with a history of surgical intervention around the clivus Patients with low quality CT images	Patients with malformations (syndromic or genetic) Patients with fractures, infections, tumors patients with a history of surgical intervention around the clivus Patients with a history of medical treatment related to the clivus Patients with low quality CT images

CT: Computed tomography; CIM: Chiari type I malformation.

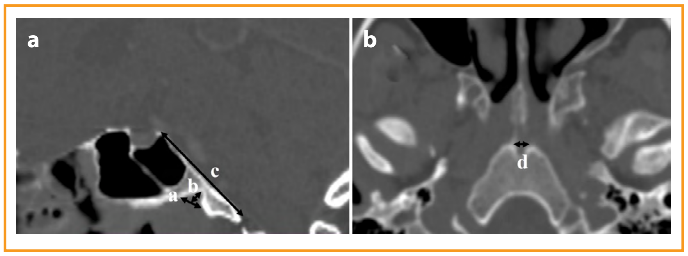

Figure 1. The measurements. **(a)** FN-L, (Length of the fossa navicularis) **(b)** FN-D, (Depth of the fossa navicularis), **(c)** CL (Length of Clivus), and **(d)** FN-W (Width of the fossa navicularis).

Table 2. Comparisons of CIM and controls

Parameters	CIM (N=14)	Controls (N=8)	p
FN-L (mm)	3.62±1.64	4.95±1.18	0.0591
FN-W (mm)	4.91±1.31	3.42±0.97	0.0081
FN-D (mm)	2.71±1.06	1.98±1.22	0.0701
CL (mm)	43.45±5.62	48.01±3.51	0.0421

N: numbers of subjects, CIM: Chiari type I malformation, FN-L: fossa navicularis lenght, FN-W: fossa navicularis width, FN- D: fossa navicularis depth, CL: clivus lenght

Study Parameters

The presence or absence of FN was noted, and the depth (FN-D), width (FN-W), and length (FN-L) of FN, as well as the clivus length (CL), were measured. Descriptions of the measured parameters were as follows (Fig. 1):

- FN-L: FN's sagittal diameter (i.e., the farthest distance in the anteroposterior direction on sagittal CT views)
- FN-W: FN's transverse diameter (i.e., the farthest distance in the mediolateral direction on axial CT views)
- FN-D: FN's depth (i.e., the distance at the deepest part of FN on sagittal CT views)
- CL: Clivus length (i.e., the furthest diagonal distance between the basion and dorsum sellae on sagittal CT views)

Statistical Analysis

Correlations between FN-D, FN-W, FN-L, and CL were analyzed using the Pearson correlation coefficient test. Sex and group comparisons were carried out using the independent student's t-test. The relationship of FN incidence with the study groups was evaluated using the Chi-square test. The normality of data was assessed using the Shapiro-Wilk test. Statistical evaluations were performed using SPSS version 22.0 (IBM, Armonk, NY). A $p<0.05$ was considered significant.

Results

The CIM group consisted of 50 patients (21 men/29 women) with a mean age of 26.93±16.03 years. The control group consisted of 50 healthy subjects (29 men/21 women) with a mean age of 33.13±21.40 years. Our findings are as follows:

- In CIM, FN was observed in 14 patients (28%), while in controls, FN was found in eight subjects (16%).
- Compared with controls, CIM subjects had greater FN-W (p=0.008) but smaller CL (p=0.042). FN-L (p=0.059) and FN-D (p=0.070) were similar between the groups (Table 2).
- In CIM, all parameters were similar between sexes (p>0.05). In controls, all parameters except FN-L were similar between sexes (p>0.05). Men had greater FN-L compared with women (p=0.029) (Table 3).
- In CIM, a positive correlation was found between FN-W and FN-D (p=0.048, r=0.537). In controls, a positive correlation was found between FN-L and FN-D (p=0.045, r=0.719) (Table 4).
- The distribution of FN presence and absence according to study groups is presented in Table 5, which showed that FN incidence was not affected by CIM (p=0.227).

Table 3. Sex comparison for CIM and controls.

	CIM			Controls		
Parameters	Females (N=9)	Males (N=5)	p	Females (N=4)	Males (N=4)	p
FN-L (mm)	3.58±1.47	3.70±2.11	0.898	4.07±0.75	5.83±0.80	0.0291
FN-W (mm)	4.76±1.22	5.20±1.59	0.438	2.92±0.62	3.93±1.07	0.2001
FN-D (mm)	2.38±1.01	3.32±0.96	0.147	1.47±0.30	2.49±1.65	0.1141
CL (mm)	42.73±6.14	44.74±4.89	0.606	46.82±2.71	49.20±4.20	0.4861

N: numbers of subjects; CIM: Chiari type I malformation; FN-L: fossa navicularis lenght; FN-W: fossa navicularis width; FN- D: fossa navicularis depth; CL: clivus lenght.

Table 4. Correlations between the parameters for CIM and controls

Groups	Parameters	FN-W (mm)	FN-D (mm)	CL (mm)
CIM	FN-L (mm)	0.392	0.090	0.138
		0.166	0.759	0.637
	FN-W (mm)		0.537*	-0.240
			0.048	0.409
	FN-D (mm)			-0.262
				0.366
	Parameters	FN-W (mm)	FN-D (mm)	CL (mm)
Controls	FN-L (mm)	0.333	0.719*	-0.071
		0.420	0.045	0.867
	FN-W (mm)		0.539	0.571
			0.168	0.139
	FN-D (mm)			0.168
				0.691

CIM: Chiari type I malformation, FN-L: fossa navicularis lenght, FN-W: fossa navicularis width, FN- D: fossa navicularis depth, CL: clivus lenght.

Table 5. Distribution of FN incidence in CIM and controls.

	CIM	Control	Total	p
Presence	14 (28%)	8 (16%)	22	0.227
Absence	36 (72%)	42 (84%)	78	
Total	50	50	100	

FN: fossa navicularis; CIM: Chiari type I malformation.

Discussion

Recent publications focusing on skull base morphology in CIM suggest that, presumably due to a mesodermal defect, CIM substantially affects the bony components of the entire cranial base [14,15]. For instance, subjects with CIM have been shown to possess a smaller sella volume and area, a greater angle of the optic canal in the axial plane, a shorter and wide-angled anterior clinoid process, a longer optic strut, a longer anterior fossa, and a more pneumatized posterior clinoid process compared with healthy controls [14–18]. Some studies have investigated morphometric features of the cranium in an effort to determine additional signs specific to CIM [14].

In the present study, we observed that CIM subjects (43.45±5.62 mm) had a smaller CL (p=0.042) compared with controls (48.01±3.51 mm). Nwotchouang et al. [14] reported a smaller CL in CIM (43.6±3.9 mm) compared to controls (47.3±3.1 mm) (p<0.001). Similarly, Milhorat et al. [13] found reduced CL in this malformation (CIM: 36.6±4.2 mm; control: 40.4±5.1 mm). Our results are consistent with the findings in the literature. Nwotchouang et al. [14] also noted that CIM subjects had significantly smaller clivus thickness, surface area, volume, width, and height compared with controls. Shah and Goel [19] described clival dysgenesis in an 11-year-old boy with CIM, emphasizing that this anomaly should not be confused with FN, since the lateral parts of FN are ossified.

Therefore, we believe that novel studies focusing on FN morphology in patients with different malformations such

Table 6. Data related to FN in the literature

Study	Samples	Methods	Numbers	Incidence of FN	FN-L (mm)	FN-D (mm)	FN-W (mm)
Magat [6]	Patients	CBCT	168	46 (27.50%)	8.55±3.19	2.22±0.98	5.37±2.06
Bayrak et al. [1]	Patients	CBCT	649	59 (9.08%)	7.15±1.80	2.76±1.09	5.23±1.57
	CT	410	23 (5.60%)	4.12±0.52	4.17±0.54	4.08±0.47	
Ersan [28]	Patients	CBCT	723	48 (6.60%)	5.80±2.20	2.20±1.00	4.70±1.40
Aktan-İkiz et al. [30]	Dry skull	Dry skull	95	6 (6.30%)	6.50±1.73	1.58± 0.84	4.66±1.43
Cankal et al. [3]	Patients	CT	525	16 (3.04%)	-	-	-
	Dry skull	Dry skull	492	26 (5.28%)	-	-	-
	All	All	1017	42 (8.32%)	5.12 (1.79-9.33)	2.24 (1.10-4.11)	2.85 (1.50-3.90)
Adanır et al. [7]	Patients	CBCT	900	122 (13.55%)	4.04±1.71	1.79±0.68	4.28±1.34
Serindere et al. [29]	Patients	CT	500	27 (5.40%)	3.77±2.15	4.96±2.73	3.48±1.11
Akbulut et al. [27]	Patients	CBCT	500	130 (26%)	4.65±1.93	1.87±0.66	4.47±1.61
This study	CIM	CT	50	14 (28%)	3.62±1.64	2.71±1.06	4.91±1.31
	Controls	CT	50	8 (16%)	4.95±1.18	1.98±1.22	3.42±0.97

CIM: Chiari type I malformation, FN-L: fossa navicularis lenght, FN-W: fossa navicularis width, FN- D: fossa navicularis depth, CT: computed tomography, CBCT: cone beam computed tomography.

as CIM are necessary to determine whether the anatomical properties of FN are altered in CIM compared with healthy individuals.

In the literature, FN formation is explained by two different theories: first, the fossa is considered to be the remnant of an emissary vein's opening, and second, the remnant of the notochord canal [1,8,10]. In utero, the notochord moves downward and connects with the primitive pharynx endoderm before reaching the precordial plate. At this stage, Seessel's pocket is formed by the spread of the pharyngeal mucosa toward the brain. During the notochord's ascension, central adhesions may develop between the endoderm and notochord, causing part of the pharyngeal mucosa to be carried along with the notochord toward the developing cranial base. Thus, a diverticulum (also known as Tornwaldt's bursa or pharyngeal bursa) covered by pharyngeal mucosa is seen in the midline. Obstruction of the opening of this diverticulum for any reason may result in a Tornwaldt's cyst [3,20,21]. This pathology is usually asymptomatic, but infection or enlargement may cause eustachian tube dysfunction, neck stiffness, headache, halitosis, postnasal drip, or nasal obstruction [20,22,23]. The pharyngeal bursa and tubercle lie posterior to FN.[3] Therefore, certain clinicians suggest that there may be a connection between clivus anomalies or variations (including FN) and Tornwaldt's cyst [3,8,24,25].

On the other hand, FN may be a route for the spread of infection from the pharyngeal region to the intracranial area [3,8]. For example, Segal et al. [26] presented a 12-year-old girl with bacterial meningitis and stated that the patent FN caused the spread of infection from the pharynx to the intracranial region. Prabhu et al. [10] reported a 5-year-old girl with clival osteomyelitis and a retropharyngeal abscess situated in FN. Thus, clinicians recommend examining the presence of FN in cases of clival osteomyelitis, meningitis, or skull-base infection [7,26].

In this study, a significant increase in the width of the fossa navicularis (FN-W) was observed in patients with Chiari type 1 malformation (CIM). Embryological anomalies affecting the development of the skull base, particularly involving the posterior cranial fossa and the clivus, have been well documented in CIM, highlighting disruptions in normal ossification processes and cranio-cervical morphogenesis [13,14]. There are two primary embryological theories explaining FN formation: one proposing that the FN represents a remnant of the notochordal canal, and another suggesting that it originates from persistent openings associated with emissary veins during embryological development. The mesodermal defects inherent to CIM might disrupt normal ossification and developmental dynamics of the skull base, potentially leading to altered dimensions or exaggerated anatomical variations, such as the enlarged FN observed in our CIM cohort. However, due to the cross-sectional and retrospective design of our study, the findings do not conclusively determine whether these observed differences in FN morphology are a direct consequence of CIM or whether both conditions stem from a common embryological anomaly. To definitively establish a causal relationship between FN characteristics and CIM, future prospective longitudinal studies, as well as experimental embryological investigations, are warranted [1,8,10,13,14].

FN was observed in 14 patients (28%) with CIM, whereas FN was found in eight subjects (16%) in controls. The distribution of FN presence and absence according to study groups showed that its incidence was not affected by CIM (p=0.227). Our incidence rates for both groups were compatible with previous studies (Table 6) [1,3,6,7,27–30]. In those studies, FN incidence was reported between 3.04–27.50%.

In CIM, FN-L, FN-W, and FN-D were measured as 3.62±1.64 mm, 4.91±1.31 mm, and 2.71±1.06 mm, respectively. In controls, FN-L, FN-W, and FN-D were measured as 4.95±1.18 mm, 3.42±0.97 mm, and 1.98±1.22 mm, respectively. CIM subjects had greater FN-W (p=0.008), while FN-L (p=0.059) and FN-D (p=0.070) were similar between the groups. Our mean values for both groups were consistent with previous studies (Table 6) [1,3,6,7,27–29]. In those reports, the average range was presented as 3.77–8.88 mm for FN-L, 1.58–4.96 mm for FN-D, and 3.48–5.37 mm for FN-W.

In CIM, all parameters were similar between sexes. In controls, men had greater FN-L compared with women (p=0.029). Similarly, Bayrak et al. [1] observed greater FN-L in men (7.86±1.88 mm) compared with women (6.76±1.65 mm). FN incidence and size have been reported within a wide range in the literature, probably due to differences in study methods (radiologic vs direct anatomic examinations), demographic features (race, sex, etc.), and sample selections (patients vs dry skulls) [1,3,6,28]. For example, FN incidence determined on CT or cone-beam CT images may be lower than that detected on dry skulls, since it can sometimes be difficult to identify FNs with a depth <2 mm radiologically [3]. Ersan [28] observed a higher incidence in males (29 subjects) compared with females (19 subjects) (p<0.05).

Conclusion

CIM subjects had greater FN-W (p=0.008) but smaller CL (p=0.042). FN incidence was not affected by CIM (p=0.227). Our results may help clinicians better understand clivus anatomy in CIM patients.

Ethics Committee Approval: The study was approved by Ankara University Ethics Committee (No: I10-711-23, Date: 21.11.2023).

Conflict of Interest: The authors declare that there is no conflict of interest.

Informed Consent: Approval from the Institutional Review Board was obtained and in keeping with the policies for a retrospective review, informed consent was not required.

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