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Spinal and cranial morphometric features of chiari malformation patients undergoing decompression surgery

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Abstract

Chiari malformation (CM) is characterized by herniation of the cerebellar tonsil(s) and/or medulla oblongata into the spinal canal, resulting in various morphometric abnormalities. The current study aimed to evaluate the magnetic resonance imaging (MRI) findings and morphometric features of the craniocervical region in patients who underwent surgery for CM. Demographic and radiological data were collected from 59 patients who underwent surgery for CM and a control group of 58 randomly selected nonsurgical patients. For between-group comparisons, Continuous variables were described as the mean (±SD) or median (IQR) and categorical variables as frequency (%). The mean age of the control group participants was 33.38 years. The mean age of patients in the CM group at the time of surgery was 33.83 years. The diameter of the foramen magnum, the maximum anteroposterior diameter of the C1 vertebra, the maximum diameter of the spinal canal at the C2 vertebra, and the atlantodental interval were all positively correlated with the total cerebellar tonsil length [r=0.54, 0.37, 0.42, 0.71]. Comparisons of total cerebellar tonsil length with other morphological and clinical variables, including contact between the brainstem and clivus, basilar invagination, preoperative hydrocephalus, remnant cartilage between the odontoid and C2 corpus, and associated craniovertebral junction anomalies, revealed no other significant correlations. CM is associated with many structural anomalies in the brain. However, there is relatively little detail in the existing literature on the morphometric parameters associated with the malformation. The findings of this study provide insights for future research and contribute to knowledge of the morphometric features of CMs in general and CMs in patients requiring surgical management in particular.

Keywords: Chiari malformation, craniovertebral, measurements, morphometric, posterior fossa

Introduction

Chiari malformation (CM) is characterized by the posterior fossa anomalies and displacement of neural structures, particularly into the spinal canal. CM is classified into types based on the degree of herniation. The main types are type I and type II [1]. Type I displays herniation of the cerebellar tonsils, while type II includes herniation of the fourth ventricle and the medulla oblongata as well as the posterior cerebellum [2]. The condition is usually congenital and tends to manifest in adulthood. It is often associated with syringomyelia and other bone abnormalities at the base of the skull, such as basilar invagination [3-5]. When CM manifests, there is a migration of posterior fossa structures, primarily the cerebellar tonsils, through the foramen magnum to the spinal canal. CM patients may suffer from hydrocephalus, syringomyelia, and other anomalies.

Research has identified CM as a primarily neurological disease involving the posterior cranial fossa and the hindbrain [6]. However, there is some uncertainty about this as more recent evidence has shown that the chronic tonsillar herniation observed in CM can be caused by congestion within the posterior cranial fossa when it is small and low due to a poorly developed occipital bone [1,7].

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The morphometric anomalies associated with CM include a small posterior cranial fossa, a shortened clivus, and tonsillar herniation [8]. These malformations generally co-occur with other bony anomalies of the skull base and cervical spine, such as occipital and suboccipital dysplasia [9].

In this study, we performed morphometric analyses of the cranial and spinal structures in patients who underwent surgery for CM. Variables were measured using the magnetic resonance imaging (MRI) scans of patients in our sample. We aimed to define and distinguish the specific morphometric features of CM patients requiring surgery.

Material and Methods

In the present study, patients who underwent surgery for CM were compared with healthy individuals. The project was approved by our institutional review board (IRB: 20/17). The MRI data of patients who underwent decompression surgery for CM at our institution between 2012 and 2019 were reviewed. Informed consent from each and every patient was obtained before the procedures. Those with other posterior fossa diseases such as cerebral mass lesions or ischemia and those who had previously undergone cranial or spinal surgeries were excluded. A total of 59 CM patients were included in the study. A control group of 58 patients who had undergone cranial and spinal MRI during the period studied was randomly selected from the medical records. After determination of the study parameters, the main authors independently evaluated the MR images of all 117 patients included in the study.

The demographic and radiological imaging data recorded for each patient comprised age, sex and several measurements were selected based on the ease-of-recognition of the structures. Measurements were taken and other relevant morphological and clinical variables were recorded; a. the distance between the pontomedullary junction and the foramen magnum (describe the length of the medulla in the cranial cavity), b. the diameter of the foramen magnum, c. the maximum height and diameter of the fourth ventricle (to identify compression and elongation of the ventricular system, which can alter the dynamics of the cerebrospinal fluid, in turn, altering the clinical presentation), d. the maximum anteroposterior (AP) diameter of the C1 vertebra (mm), e. the maximum diameter of the spinal canal at the C2 level, f. the thickness of the ligamentous complex behind the odontoid process (This was based on observed hypertrophy of these ligaments, possible due to occiput-C1–2 instability), g. the presence of remnant cartilage between the odontoid and C2 corpus (which was based on our observations in clinical practice), and h. the angles between the tentorium and occiput and between the clivus and occiput (to provide information about the shallowness of the fossa, which could differ in surgical cases) (Figure 1).

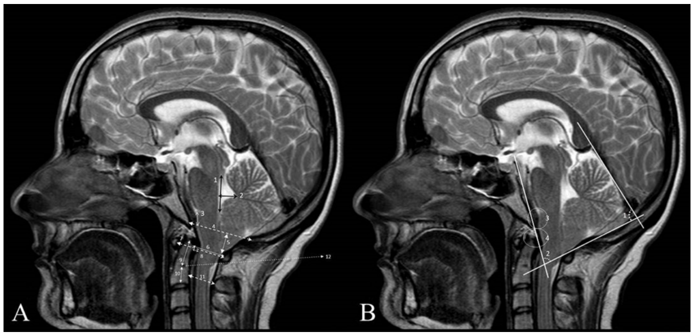

Figure 1. A) 1. Maximum height of the fourth ventricle; 2. Maximum diameter of the fourth ventricle; 3. Distance between the pontomedullary junction and the foramen magnum (mm) (calculated using a line drawn parallel to the medulla and a line connecting the anterior and posterior edges of the foramen magnum); 4. Diameter of the foramen magnum; 5. Vertical length and level (e.g., C1 level) of tonsillar herniation; 6. Posterior atlantodental interval (from odontoid to C1 posterior arch); 7. Maximum anteroposterior (AP) diameter of the C1 vertebra; 8. Thickness of the ligamentous complex behind the odontoid process; 9. Height of the odontoid process; 10. Height of the C2 corpus; 11. Maximum spinal canal diameter of the C2 vertebra; 12. Presence of remnant cartilage between the odontoid and the C2 corpus. **B)** 1. Angle between the tentorium and occiput; 2. Angle between the clivus and occiput; 3. Contact between the brainstem and clivus (contact +/−); 4. Basilar invagination (invagination +/−)

Statistical analysis

Normally distributed continuous variables were described as the mean (±standard deviation [SD]) and skewed continuous variables as the median (interquartile range [IQR]). Categorical variables were given as frequency (percentage). The Shapiro–Wilk test was used to assess the normality of the data. Pearson's chi-square tests were used to determine the relationships between categorical variables (with Fisher's exact test where required). Mann–Whitney U-tests and Kruskal–Wallis tests were used to compare differences between skewed data. Post hoc analyses were performed using Bonferroni correction. Wilcoxon signed-ranks tests were used for comparisons between the preoperative and postoperative thickness of the PLL behind the dens. Spearman's and Pearson's tests were used to identify correlations between variables. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 23.0 (IBM Corp., Armonk, NY, USA). A two-sided p-value of <0.05 was considered statistically significant.

Results

Participants

A total of 117 patients were included in the study, 59 who underwent surgery for CM at our institution (mean age, 33.8 [±13.1] years) and 58 randomly selected control patients who underwent MRI at our institution during the study period, (mean age, 36.3 [±14.2] years).

Demographic and clinical data and radiologic images of all participants were gathered from the medical records (Table 1). In both groups, the ratio of males to females was 1:2.

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Table 1. Comparison of characteristics between control and patient groups

	Control (n=58)	Patients (n=59)	p
Age at the time of surgery (years)	36.38±14.22	33.83±13.11	0.315
Gender			
Female	40 (69)	40 (67.8)	0.892
Male	18 (31)	19 (32.2)	
Distance from pontomedullary junction to F. Magnum (mm)	16.07±4.27	10.64±4.33	**<0.001**
Diameter of F. magnum (mm)	37.95±5.85	38.91±5.48	0.419
Maximum length of the whole tonsils (mm)	0 (-3.6-0)	9.25 (6.3-16.5)	**<0.001**
Maximum height of fourth ventricle	18.99±3.22	20.89±5.97	0.094
Maximum diameter of fourth ventricle	10.54±1.73	10.04±1.82	0.199
Maximum anterioposterior (AP) diameter of C1 (mm)	31.73±2.43	30.9±3	0.132
Maximum spinal canal diameter at C2 level (mm)	16.57±1.74	17.36±2.74	0.093
Maximum height of odontoid process (mm)	20.76±2.5	19±3.31	**0.002**
Thickness of the ligamentous complex behind the odontoid process (mm)	3.7 (3-4.6)	3.9 (3-5)	0.659
Presence of remnant cartilage between odontoid and C2 corpus (n=104)			
Yes	27 (46.6)	32 (69.6)	**0.019**
No	31 (53.4)	14 (30.4)	
Degree of angle between tentorium and occiput	92.71±9.32	90.29±8.13	0.194
Degree of angle between clivus and occiput	75.36±8.34	81.7±6.94	**<0.001**
Atlantodental interval (mm)	14.39±2.05	14.93±3	0.329

Data are presented as mean±SD, median (IQR) or n (%). Independent t-test, Mann-Whitney U test, Pearson chi-square test

Clinical features

In our retrospective analysis, the clinical presentation of the 59 patients was diverse and included a range of neurological symptoms.

Headache and Neck pain observed among the CM patients in our cohort. Occipital headaches were documented in 75% of the patients. Neck pain was also reported by 52% of the surgical patients preoperatively. Sensory and Motor findings were relatively less common findings in our patients. About 48% of the patients experienced sensory disturbances such as numbness or tingling sensations in the extremities. Motor findings are lesser being observed in 30% of the cases, similarly, corrdination and balance complaints were reported in 35%. In decreasing frequencies, the following was also observed; dysphagia (difficulty in swallowing) in 22%, any alterations in speech patterns (hoarseness) in 18%.

Postoperatively, mainly occipital headaches and sensory disturbances were improved. On the follow-up, 60% of the patients reported significant relief from the headache and 45% were satisfactory for their improved coordination. In the surgical cohort, 15 % of the patients reported persistence of their findings.

Radiological evaluation

Our comparison of the morphometric analyses of the CM and control groups found that the mean distance between the pontomedullary junction and the foramen magnum was significantly less in the CM group than in the control group (16.07 [±4.27] vs 10.64 [±4.33] mm). The mean total cerebellar tonsil length was significantly higher in the CM group (12.05 [±6.7] mm) than in the control group (1.8 [±4.48] mm) (Table 2). The maximum height of the odontoid process was significantly less in the CM group (19 [±3.31] vs 20.76 [±2.5] mm). There was a significantly higher incidence of remnant cartilage in the CM than in the control group (69.6% vs 46.4%). The average angle between the clivus and occiput was significantly higher in the CM group than in the control group (81.7 [±6.94]° vs 75.36 [±8.34]°). There was no significant difference between the CM and the control group in the diameter of the foramen magnum, the maximum height or diameter of the fourth ventricle, or the maximum spinal canal diameter at the C1 or C2 levels. The thickness of the ligamentous complex behind the odontoid process was similar between the groups (Table 3).

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Table 2. Correlation between whole tonsil length and the other parameters

	Maximum length of the tonsils (mm)	
Variables	**r**	**p**
Distance from pontomedullary junction to F. Magnum (mm)	-0.335	0.056
Diameter of F. magnum (mm)	0.537	**0.001**
Maximum AP diameter of syrinx cavity (mm)	0.274	0.343
Maxi um height of fourth ventricle	0.176	0.360
Maximum diameter of fourth ventricle	0.162	0.402
Maximum anterioposterior (AP) diameter of C1 (mm)	0.376	**0.031**
Maximum spinal canal diameter at C2 level (mm)	0.442	**0.009**
Maximum height of odontoid process (mm)	0.090	0.614
Thickness of PLL behind dens (mm)	0.175	0.322
Degree of angle between tentorium and occiput	0.245	0.177
Degree of angle between clivus and occiput	-0.033	0.856
Posterior Atlantodental interval (mm)	0.712	**<0.001**

Spearman correlation test

Table 3. Correlation between distance from pontomedullary junction to F. Magnum (mm) and the other parameters

	Distance from pontomedullary junction to F. Magnum (mm)	
Variables	**r**	**P**
Diameter of F. magnum (mm)	-0.522	**0.001**
Maximum AP diameter of syrinx cavity (mm)	-0.196	0.451
Maxi um height of fourth ventricle	-0.213	0.227
Maximum diameter of fourth ventricle	-0.024	0.894
Maximum anterioposterior (AP) diameter of C1 (mm)	-0.165	0.330
Maximum spinal canal diameter at C2 level (mm)	-0.357	**0.028**
Maximum height of odontoid process (mm)	0.083	0.622
Thickness of PLL behind dens (mm)	-0.086	0.609
Degree of angle between tentorium and occiput	-0.088	0.606
Degree of angle between clivus and occiput	0.115	0.497
Posterior Atlantodental interval (mm)	-0.461	**0.005**

Pearson correlation test, Spearman correlation test.

We also compared the morphometric analyses of patients with and without syrinxes. We found most variables to be similar between these two groups; however, the maximum AP diameter of the C1 vertebra, was significantly less in those with syrinxes (p=0.022). A subgroup analysis of those with syrinxes based on the level of the syrinx found no significant differences in morphology.

In the CM group, the preoperative median thickness of the ligamentous complex behind the odontoid process was 3.9 (IQR: 3–5) mm, and the postoperative median thickness was 3.75 (3–4.9) mm; this was not a significant difference. However, we found a significant difference in thickness in the ligamentous complex behind the dens in a subgroup analysis of CM patients comparing surgical techniques. The two methods used were dural opening and expansion and dural longitudinal cuts.

The diameter of the foramen magnum (Figure 2A), the maximum AP diameter of the C1 vertebra, the maximum spinal canal diameter at the C2 level, and the posterior atlantodental interval (PADI) were all positively correlated with the total cerebellar tonsil length [r=0.54, 0.37, 0.42, 0.71, respectively] (Table 4). No significant correlations were found between total cerebellar tonsil length and the other clinical and morphological variables, including contact between the brainstem and clivus, basilar invagination, preoperative hydrocephalus, remnant cartilage between the odontoid and C2 corpus, and associated craniovertebral junction anomalies. Significant negative correlations were found between the distance between the pontomedullary junction and the foramen magnum (Figure 2B) was found to be negatively correlated with the diameter of the foramen magnum (Figure 2C), the maximum spinal canal diameter at the C2 level, and the PADI (r=−0.52, −0.36, −0.46, respectively) (Table 5).

Table 4. Correlation between PADI (posterior atlantodental interval) and the other parameters

	Atlantodental interval (mm)	
Variables	**r**	**p**
Distance from pontomedullary junction to F. Magnum (mm)	-0.461	**0.005**
Diameter of F. magnum (mm)	0.772	**<0.001**
Thickness of the ligamentous complex behind the odontoid process (mm)	0.063	0.710

*Pearson correlation test, Spearman correlation test

Table 5. Comparison of characteristics of patients according to Level of tonsillar herniation

	Between F.magnum and C1 (n=19)	C1 (n=9)	C1-2 (n=5)	C2 and below (n=9)	p
Distance from pontomedullary junction to F. Magnum (mm)	**11 (9.6-13.3)[a]**	**8.3 (5.5-17.7)[a,b]**	**9 (7.6-9.33)[a,b]**	**6 (5-11.2)[b]**	**0.045**
Diameter of F. magnum (mm)	37 (34.8-39)	37.3 (33.55-41.15)	38.8 (37.9-40.9)	42.8 (40-45)	0.068
Maximum AP diameter of syrinx cavity (mm)	6 (2.7-7.9)	8.45 (4.8-8.95)	35.5 (35.5-35.5)	11 (11-11)	0.155
Presence of brain stem and clivus contact					
Yes	1 (5.3)	1 (12.5)	0 (0)	0 (0)	
No	18 (94.7)	7 (87.5)	5 (100)	7 (100)	
Maximum height of fourth ventricle	18.5 (17-26.4)	21.25 (17.7-23.1)	20.9 (19.7-23.6)	24.65 (19.1-29)	0.599
Maximum diameter of fourth ventricle	10 (9.8-11)	9.65 (8.9-10.2)	12.35 (10.01-12.95)	10 (8.5-11.2)	0.369
Presence of bazilar invagination					
Yes	1 (5.3)	1 (12.5)	0 (0)	0 (0)	
No	18 (94.7)	7 (87.5)	5 (100)	8 (100)	
Associated craniovertebral junction anomaly					
Yes	2 (10.5)	2 (25)	0 (0)	2 (22.2)	
No	17 (89.5)	6 (75)	5 (100)	7 (77.8)	
Presence of hydrocephalus before surgery					
Yes	0 (0)	0 (0)	1 (25)	0 (0)	
No	19 (100)	9 (100)	3 (75)	9 (100)	
Maximum anterioposterior (AP) diameter of C1 (mm)	31 (29-32)	29.25 (24.9-33.65)	33.8 (32.6-35)	32 (31.4-32.4)	0.096
Maximum spinal canal diameter at C2 level (mm)	**16.3 (15-18.1)[a]**	**16 (14.4-17.6)[a]**	**19.5 (18.1-22)[a,b]**	**19.7 (18-22.4)[b]**	**0.030**
Maximum height of odontoid process (mm)	19 (17.6-20.2)	17.5 (15.2-20.4)	21.2 (17-25.5)	18.55 (16.7-19.95)	0.605
Thickness of the ligamentous complex behind the odontoid process (mm)	4 (2.9-5)	3.4 (3.05-3.95)	4.5 (4.35-5)	3.5 (3-4.9)	0.596
Presence of remnant cartilage between odontoid and C2 corpus					
Yes	11 (61.1)	6 (75)	4 (80)	5 (62.5)	
No	7 (38.9)	2 (25)	1 (20)	3 (37.5)	
Degree of angle between tentorium and occiput	88.2 (85.7-96.2)	85.65 (83.1-89.9)	93.2 (92.6-95.3)	93.4 (90.3-104)	0.078
Degree of angle between clivus and occiput	80.7 (78.3-84.4)	86.2 (82.5-89.9)	86.2 (78.3-87.5)	78.9 (71.8-91.2)	0.309
Posterior Atlantodental interval in mm	**13.6 (12-15)[a]**	**14 (11.7-15.3)[a]**	**18 (16.1-18.6)[b]**	**18.95 (18.8-20)[b]**	**<0.001**

Data are presented as median (IQR) or n (%), Kruskal-Wallis test. Fisher's Exact test, same letters in a row denote the lack of statistically significant difference

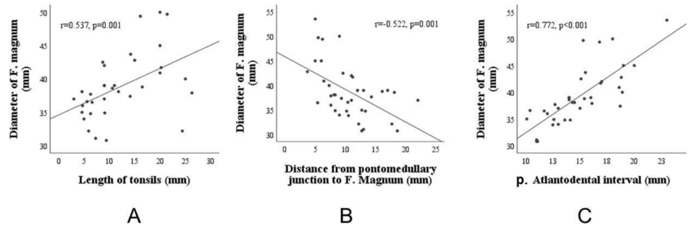

Figure 2. A) Correlation between total cerebellar tonsil length and foramen magnum diameter; **B)** Correlation between the pontomedullary junction to foramen magnum distance (mm) (calculated using a line drawn parallel to the medulla and a line connecting the anterior and posterior edges of the foramen magnum) and the foramen magnum diameter; **C)** Correlations between the posterior atlantodental interval (PADI) and the foramen magnum diameter

The distance between the pontomedullary junction and the foramen magnum differed significantly between CM patients with and without basilar invagination (18.15 [17.7–18.6] vs 9.9 [7.45–12.7] mm). There was a negative correlation between the PADI and the distance between the pontomedullary junction and the foramen magnum, and a strong positive correlation between the PADI and the diameter of the foramen magnum (Table 5).

Cartilage was found in the dens of the axial bone in some CM patients. There was no difference in the mean maximum height of the odontoid process between patients with and without cartilage in the axial bone dens (18.53 [±3.43] vs 20.01 [±3.01] mm; p=0.173)

Positive correlations were found between the diameter of the foramen magnum and both the maximum AP diameter of C1 and the maximum spinal canal diameter at C2.

The extent of tonsillar descent was significantly correlated with the distance between the pontomedullary junction and the foramen magnum, the spinal canal diameter at C2, and the PADI (Table 5).

Discussion

The purpose of this study was to gain insights into the differences between patients with Chiari malformation (CM) requiring surgical treatment and control group. The researchers also wanted to explore the relationships between CM morphometric abnormalities and various factors, such as the presence and level of syrinxes, the thickness of the ligamentous complex behind the odontoid process, the descending cerebellar tonsil length, the distance between the pontomedullary junction and the foramen magnum, and the PADI. Morphometric analysis can help detect relationships between neural and structural abnormalities, such as thicker bands around the foramen magnum in the epidural region and strong arachnoid bands around the cerebellar tonsils, and identify surgical candidates.

The study found a positive correlation between the distances from the pontomedullary junction to the foramen magnum. Additionally, the maximum height of the odontoid process was significantly lower in the CM group than in the control group, while the mean tonsil length, the proportion of the remnant cartilage, and the clivus and occiput angles were significantly higher in the CM group. However, this finding conflicted with a previous study that found the clivus and occiput angles to be lower in their CM group [10]. This discrepancy may be due to different reference points for measurement. The degree of angle between the clivus and occiput was significantly higher in the CM group than in the control group in this study. This finding is also contrast to another study that found lower clivus canal angles in CM patients than in controls [11].

The diameter of the foramen magnum, the maximum AP diameter of the C1 vertebra, the maximum spinal canal at the C2 level, and the PADI correlated positively with the length of the cerebellar tonsil; whereas the distance between the pontomedullary junction and the foramen magnum and several other parameters such as the diameter of the foramen magnum and the maximum spinal canal diameter at the C2 level, the PADI revealed a significant negative correlation. There was a significant difference in the distance between the pontomedullary junctions to the foramen magnum in case of basilar invagination. Although extensive research has been carried out on bone anatomy in CM, few studies have measured the pontomedullary distance, the height and width of the fourth ventricle, or the posterior ligamentous complex behind the odontoid process [10,11]. These measurements are relatively easy to obtain and may provide a straightforward means of identifying surgical candidates. Although there were no significant differences between the CM and control groups in the dimensions of the fourth ventricle, the pontomedullary distance to the foramen magnum was significantly smaller in the CM patients than in the control patients (p<0.001) (Table 3).

Several reports have shown that patients with CM have smaller posterior fossa; however, the variables associated with cervical syrinxes have received less attention [12-14]. We found only one significant difference between the CM and control groups with respect to the presence of syrinxes, which was in the maximum internal diameter of the C1, which was less in those with syrinx formation.

Our study is also consistent with that of Dufton et al., who found a positive correlation between cerebellar tonsil length and the diameter of the foramen magnum [8]. It is interesting to note that the majority of earlier studies have measured the descending length of the tonsils herniating the foramen magnum. However, the current study measured the total cerebellar tonsil length. Additionally, in contrast to the existing literature, we found that the level of tonsillar herniation was greatest between the foramen magnum and the C1 vertebra [15].

Previous morphometric studies that have described the characteristics of CM in the brain and spine have primarily focused on abnormalities in the size of the posterior cranial fossa in CM patients [15,16]. In the current study, we also evaluated variables associated with the presence and level of syrinxes in surgical CM patients but little difference was found between the

CM and control groups except in the maximum AP diameter at the C1 level, which was smaller in those with syrinxes. Additionally, we found a negative correlation between the diameter of the foramen magnum and its distance from the pontomedullary junction. This result has not previously been reported. Both CM and basilar invagination are common malformations of the adult craniovertebral junction and are often co morbid [17].

We found that the distance between the pontomedullary junction and the foramen magnum was correlated with the diameter of the foramen magnum, the spinal canal diameter at C2, and the PADI. The mechanisms that underpin these findings are not fully understood and further research is needed to elucidate our results (Table 5). Our measurement of the pontomedullary distance has not previously been described in the literature. Instead, of measuring the direct (right angle) distance from the pontomedullary junction to the foramen magnum, our measurement calculated the distance using a line originating from the pontomedullary junction and traveling parallel to the brainstem down to the foramen magnum. This is also important as, besides being an easily recognizable structure on MR images, it allows for CM categorization as type I or II, based not only on the cerebellar tonsils but also on the descent of the brainstem through the foramen magnum. This is not always easy to discriminate in imaging studies so this measurement will make a positive contribution to future studies by providing numeric values for surgical cases.

Comparisons involving the thickness of the PLL behind the dens revealed similar results between groups. However, a subgroup analysis that compared those in the CM group who underwent dural opening and expansion to those who received simple dural cuts found a significant difference in the mean thickness of the ligamentous complex. This is a novel, previously unreported finding.

The development of CM is associated with many structural anomalies in the brain; yet, there has been little research detailing the morphometric characteristics of cerebellar structures in patients surgically treated for CM. There are other studies focused on morphometric features of posterior fossa structures. However, unique features of our manuscript are that some of our measurements did not perform before and there is no study to compare these measurements. Second, this manuscript incorporates cranial and spinal features. Thirdly, to best of our knowledge, this study is the first to compare measurements of surgical cases with normal population. Although our study provides valuable insights into this process, there are several limitations that should be considered when interpreting our findings. Firstly, the sample size of our study was relatively small, which may limit the generalizability of our findings. A larger sample size may have allowed us to identify more subtle differences in the morphometric features of patients benefiting from decompression surgery. Secondly, our study was retrospective in nature, which means that we were unable to control for various confounding variables that may have influenced our results. Despite for conscious choice not to focus on pre-surgical decision making, there may be important factors that they may have contributed to decision making process for decompression surgery, such as patient preferences, comorbidities and socioeconomic factors, the severity and duration of symptoms prior to surgery, as well as regional and genetic difference between populations, the patient load and experience of the surgical team in treatment of these patients. Thirdly, we compared surgically treated Chiari patients with a normal control group. While this comparison allowed us to identify objective and reproducible similarities, it may not be entirely appropriate to use this comparison as a benchmark for determining which patients are likely to benefit from surgery. Future studies may need to take these factors into account when assessing the utility of morphometric features in identifying surgical candidates.

Conclusion

The study aimed to explore the differences between patients with Chiari malformation requiring surgical treatment and a control group. These study findings highlighted the importance of morphometric analysis in detecting relationships between neural and structural abnormalities, such as the thicker bands around the foramen magnum and strong arachnoid bands around the cerebellar tonsils and identifying surgical candidates.

The study also found several significant differences between the CM and control groups, including a positive correlation between the distance from the pontomedullary junction to the foramen magnum, smaller maximum height of the odontoid process, and significantly higher mean cerebellar tonsil length, proportion of the remnant cartilage and clivus-occiput angles in CM group. However, some findings conflicted with previous studies, indicating the need for further research in the field. Overall, the study provides valuable insights into the morphometric differences and relationships associated with Chiari malformation and can aid in the development of effective diagnostic and treatment strategies.

Conflict of Interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

The authors declare that they have received no financial support for the study.

Ethical Approval

This study was approved by our institutional review board (IRB: 20/17) and conducted in accordance with its ethical guidelines and with the tenets of the 2013 revision of the Declaration of Helsinki.

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