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Research Article

Measuring the Posterior Fossa with Neuronavigation in Patients with Chiari Type 1 Malformation and the Relation Between the Syrinx Cavity and Posterior Fossa Volume

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Summary

Objective: To measure posterior fossa volumes in patients with type 1 chiari malformation (type 1 CM) and the normal population using neuronavigation, and to evaluate the relation between posterior fossa volume in patients with type 1 CM and the syrinx cavity.
Materials and Methods: In this study, the posterior fossa volumes of 72 patients (36M, 36F) with type 1 CM were measured using a neuronavigation device. Normal posterior fossa volumes were obtained from a healthy control group (n=70; 35M, 35F). Posterior fossa limits were marked within the axial sections, and three-dimensional images were obtained through the neuronavigation device's programme. Posterior fossa volumes were measured using planimetric three-dimensional images. Syrinx cavity measurements were performed through T1 sagittal magnetic resonance imaging, by calculating the width of the cavity's spinal cord ratio. Results were compared statistically with posterior fossa volumes.
Results: The average posterior fossa volumes of the female patients with type 1 CM and female controls were 154.83 m^3 and 168.39 cm^3, respectively. The average posterior fossa volumes of male patients with type 1 CM and male controls were 163.26 m^3 and 182.6 cm^3, respectively. A statistically significant volume difference was found between patients with type 1 CM and the controls $p<0.001$.
Conclusion: Neuronavigation devices and programs provide great benefits in spinal or cardinal anatomic and pathologic examinations of any part. It is quite advantageous to obtain three-dimensional images in morphometric analyzes such as posterior fossa volume measurement.

Key words: Type 1 Chiari, posterior fossa volume, neuronavigation

Chiari Tip 1 Malformasyonlu Hastalarda Nöronavigasyon İle Posterior Fossa Hacmi Ölçülmesi ve Sirinks kavitesi ile Posterior Fossa Hacmi Arasındaki İlişki

Özet

Amaç: Tip 1 Chiari malformasyonlu (Tip I CM) hastalar ve normal popülasyonun posterior fossa hacimlerinin nöronavigasyon kullanılarak ölçülmesi ve Tip 1 Chiari malformasyonlu hastaların posterior fossa hacmi ile sirinks kavitesi arasındaki ilişkinin değerlendirilmesi.

Gereç ve Yöntem: Bu çalışmada, 72 (36E, 36K) Tip I CM'li hastanın posterior fossa hacimleri, nöronavigasyon cihazı kullanılarak ölçüldü. Elde edilen değerler normal posterior fossa yapısına sahip 70 (35E, 35K) kişiden oluşturulan kontrol grubunun posterior fossa hacim değerleriyle karşılaştırıldı. Aksiyel kesitlerden posterior fossa sınırları işaretlenerek navigasyon cihazının programı vasıtasıyla üç boyutlu görüntüler elde edildi. Son olarak üç boyutlu görüntüler kullanılarak planimetrik yöntemle posterior fossa hacim ölçümleri yapıldı. Sirinks kavitesi ölçümü T1 sagittal MR görüntüleri üzerinden kavite genişliğinin spinal korda oranı hesaplanarak yapıldı. Sonuçlar posterior fossa hacim değerleri ile istatistiksel olarak karşılaştırıldı.

Bulgular: Tip I CM'li kadın olguların ortalama posterior fossa hacmi 154.83 cm^3 ve kontrol grubundakilerinki ise 168.39 cm^3 idi. Tip I CM'li erkek olguların ortalama posterior fossa hacmi 163.26 cm^3, kontrol grubundaki erkeklerin ortalama hacmi ise 182.6 cm^3 idi. Tip I CM'li hastalar ile kontrol grubu arasındaki hacim farkı istatistiksel olarak anlamlı bulundu.

Sonuç: Nöronavigasyon cihazları ve kullanılan programlar spinal veya kranial herhangi bir bölgenin anatomik ve patolojik incelemelerinde, büyük kolaylıklar sağlamaktadır. Posterior fossa hacim ölçümü gibi morfometrik analizlerde üç boyutlu görüntü elde edilebilmesi oldukça avantajlıdır.

Anahtar Kelimeler: Chiari tip 1, posterior fossa hacmi, nöronavigasyon

INTRODUCTION

Chiari malformations(CM) are structural defects in the base of the skull and cerebellum. Although the exact cause of Chiari malformation is unknown, it is thought that a problem during fetal development may cause the abnormal brain formation. CM first was defined by Cleland in 1883, but in 1891, it was classified and published by Hans von Chiari (1). Morphometric analysis of the posterior cranial fossa is important for the neuroradiologic evaluation. The small posterior fossa is considered as responsible for tonsillar herniation in patients with CM. Many different techniques have been used for posterior fossa volume (PFV) measurements in the literature. Posterior fossa and cerebellum volume ratios were analyzed in research on patients with CM and it was found that these values were lower than in healthy individuals. In the literature, planimetric methods with two-dimensional stereologic methods and three-dimensional computer-aided programmes have been used for posterior fossa and cerebellum volume values analysis. In the present study, the magnetic resonance imaging (MRI) and PFV values, which were measured using a neuronavigation device, of 72 patients with type 1 CM were compared with a control group that had normal posterior fossa structures. The differences between the two groups were evaluated statistically. In addition, we evaluated the relation of the posterior fossa volume of patients with type 1 CM with the syrinx cavity.

MATERIAL AND METHODS

The present study included 72 patients with type 1 CM who attended the Erciyes University, Medical Faculty, Department of Neurosurgery, with no pathologic symptoms or coexistent intracraniasyringomyelia. The control group comprised 70 patients who attended the hospital for any reason and underwent cranial/cervical MRI, and whose images

were normal. Patients in the pediatric age group were not included in the study. In the morphometric analysis, axial and sagittal MRI images were used. MRI was performed using a 1.5 Tesla (Philips MR Systems Intera Release 12.6.1.4.2012). The images were transferred to a radiologic imaging system (Infinitt Pacs 2002-2014 INFINITT Healthcare Co. Ltd.). Posterior fossa boundaries were determined as the front of the basion and dorsumsella, and behind the opisthion and occipital protuberance, and its height was from the tentorium to the foramen (2) (Image 1). The images were then transferred to a neuronavigation device. The boundaries of the posterior fossa were marked through axial cavities using a neuronavigation programme (Brainlab-IPlan RT Planning Software-Smartbrush), three-dimensional images were obtained, and posterior fossa volumes were measured (Image 2). Ratios of the syrinx cavity to the spinal cord were analyzed using a T1 nominal sagittal MR section imaging system (3) (Image 3).

Statistical Analysis

Normality of group distributions was checked using parametric tests (Kolmogrov-Smirnov), and Shapiro-Wilks test for non-parametric data. Continuous data are given as averages. For the analysis between the groups, parametric tests and the independent T-test were used. Pearson's test was used to assess correlations. Statistical significance was accepted as $p<0.05$.

FINDINGS

The type 1 CM patient group consisted of 72 patients (36 males and 36 females), and the control group comprised 70 volunteers (35 males and 35 females) who had normal posterior fossa structures. The posterior fossa volume values of the males and females in the control and patients groups were calculated and evaluated by considering the differences of genders. The demographic data of these groups are shown in Table 1. The average ages of male and female patients with type 1 CM were calculated as 38.6 years 39.9 years, respectively. The average ages of the males and females in the control group were 40.8 years and 38.3 years, respectively. There was no statistical difference found between the groups regarding age ($p>0.05$).

PFV measurements were made separately for the men and women in the patient and control groups (Table 2). The average PFV of the female patients and controls was 154.31 cm^3 and 168.39 cm^3, respectively. The average PFV of the male patients and controls was 162.68 cm^3 and 182.6 cm^3, respectively. The posterior fossa volumes of patients with type 1 CM were lower than those of the control group and this difference was statistically significant. (Table 2)

For patients with syringomyelia and chiari malformation, no statistically significant relation was found between the syrinx cavity width and posterior fossa volumes. (Table 3)

Table 1. Demographic Data of Patients with Type 1 CM and Controls

	Sex	n	Mean	Standard deviation	P value
Control	Female	35	40.8	9.3	>0.05
group	Male	35	38.3	12.1	>0.05
Patient	Female	36	39.9	11.9	>0.05
group	Male	36	38,6	9.3	>0.05

Table 2. Posterior Fossa Volumes Evaluation Table

	Sex	n	Mean	Standard deviation	P value
CM Patient Group	Female	36	154.31	16.09	<0.001
	Male	36	162.68	12.73	<0.001
Control Group	Female	35	168.39	9.27	<0.001
(Normal)	Male	35	182.60	13.82	<0.001

Table 3: Evaluation of the Relation Between Posterior Fossa Volume and Syringomyelia Cavity

		PFV	Syringomyelia
Posterior	Pearson Correlation	1	0.224
Fossa	Sig. (2-tailed)		0.059
Volume	N	72	72
Syringomyelia	Pearson Correlation	0.224	1
	Sig. (2-tailed)	0.059	
	N	72	72

Table 4: Comparison of Posterior Fossa Volume Measurements (cm^3)

	n	CMI	n	Normal	Method
Bagci et al.(14)	5	162.1	3	196.0	planimetry
Kanodia G et al.(15)			100	E-162.8	stereology
				B-148.9	
Milhorat et al.(8)	388	165.8	80	190.1	stereology
Nishikawa et al.(17)	30	156.0	50	174.2	stereology
Our study	113	E-162.6	70	E-182.6	planimetry
		B-154.8		B-168.3	

RESULTS

Stereologic methods are more successful among the given resources for measuring volumes. However, considering the measurement values, there are no significant differences with planimetry method results. In addition, the devices and programmes used in planimetry methods are used for calculating values and clinical and surgical applications. Nevertheless, more comprehensive research is required to compare planimetry and stereologic methods.

Figure 1: *The posterior fossa was anatomically bordered by the basion, opisthion, clivus, tentorium cerebelli, occipital protuberens, and foramen magnum.*

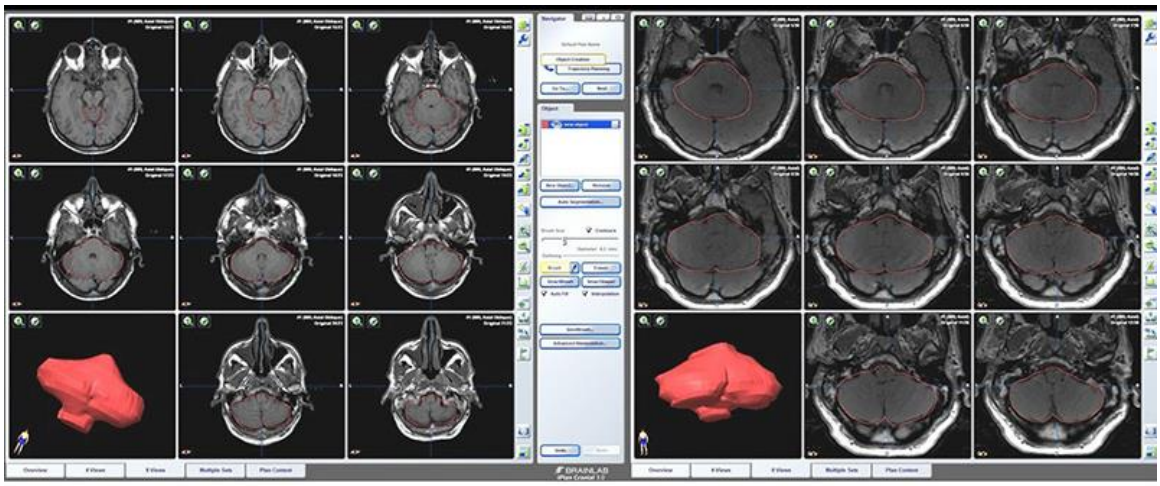

Figure 2: *The measurement and outline of the posterior fossa volume using neuronavigation*

Figure 3: *The measurement technique of the syrinx cavity ratio from the largest part*

DISCUSSION

Type 1 CM is characterized by herniated cerebellar tonsils from the foramen magnum to the spinal canal, and the lower parts of the tonsils can migrate with atlas and axis levels (4). This malformation is usually seen in adults and adolescents. It is considered that type 1 CM formation is multifactorial, despite this, in many cases it is a result of a congenitally underdeveloped posterior fossa. Morphometric analysis of PF is important for neuroradiologic evaluation of Chiari malformation. Sahuguilla et al. argued that a small PF was responsible for the width of type 1 CM for various reasons. Surgical decompression should be peformed for the foramen magnum and to expand the PF with suboccipital craniectomy (5). The small PF theory was first defined by Marin-Padilla in 1981. In their study, a high dose of vitamin A was given to pregnant rats to cause mesodermal deficiency and it was seen that a secondary small PF occured in the occipital bone in this developmental disorder (6). Schady et al. determined small PFs in the measurements of patients with CM, which supported this theory (7). Likewise, Milhorat et al. showed that patients with CM has larger PFs than healthy people (8). In our study, we found that the PFV was smaller patients with CM than in the healthy population, which supports data in the literature. Another subject of debate regarding volumetric analysis is measurement techniques. In the literature, two-dimensional stereologic methods and three-dimensional computer- aided programs for planimetry methods have been discussed. There ample research supporting both methods (9-12). Both methods have advantages and disadvantages when they are compared. As a result, there are no significant differences between these methods in PFV analysis (Table 4). Mazokanis et al. assessed the intracranial volume and computed tomography of 16 people aged between 56-81 years using stereologic and planimetry methods. In their study, intracranial volume measured using the stereologic method was 1323±180.7 cm^3, which was not different to measurements made with the planimetry method (1329±168.5 cm^3) (13). In the literature, problems related with high cost of planimetry methods and requirement of specialists have frequently highlighted. In our study, measurements made with the planimetry method were found similar to the literature. The cost of the neuronavigation and computer programmes that we used was high, but as, stereologic methods show no deviation from true values statistically. Moreover,in addition to measuring volume, these programmes have many benefits for clinical applications, for instance, it is also used for navigation and stereotactic planning.

In many studies, PFV of patients with CM was lower than normal (Table 4). However, in many articles, no differences have been observed between the sexes. In the present study, males and females were analyzed separately, and our data are consistent with the literature (14,17).

Accompanying CM, in the etiology syringomyelia, there is a cerebellar disorder of circulation in the posterior fossa and in addition to this, the cerebellar

tonsil's piston effect expands the cavity. Cranio-vertebral decompression (CVD) and dural grafts on the cisterna magna are widely used in the treatment of syringomyelia. However this method was reported as insufficient for CM with a wide syrinx cavity (9,18).

In this research, correlation measurements between syrinx cavity width and posterior fossa volumes have been made for the first time in the literature. we know that the syrinx cavity could not be cured in some patients, although the mega-cisterna magna was created with duraplasty. We find that there is no correlation between width of syrinx cavity and posterior fossa volume Our findings explain that duraplasty or creating mega cisterna magna may be insufficient in some patients who have CM with a wide syrinx cavity. So, we must search new surgery methods or treatments for CM with a wide syrinx cavity.

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