Magnetic resonance imaging mesencephalic tectum dimensions according to age and gender

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ABSTRACT

الأهداف: تحليل وتصنيف طول السقف لأشعةالمغناطيس الطبيعية وأبعاد الأكيمية طبقاً للعمر والجنس.

الطريقة: تم قياس أقطار طول السقف وأشعة الرنين المغناطيسي للقحف المحوري في أرشيف الأشعة لعدد 532 مريض (344 امرأة، 188 رجل) تتراوح اعمارهم 91–4 عام (37.36±21.49) وبدون أي اصابات لسقف الدماغ. خضع 532 مريض لأشعة الرنين المغناطيسي في القحف وذلك في وحدة الرنين المغناطيسي لمستشفى سفاس، سفاس، تركيا خلال الفترة من فبراير حتى ديسمبر 2011م.

النتائج: أظهرت الدراسة ارتباط خطي ايجابي بين أبعاد الأكيمية والعمر وارتباط سلبي بين بين أبعاد الأكيمية العلوية والسفلية والعمر القيمة الإحصائية $p<0.00$. ازداد طول السقف مع العمر كلما انخفض القطر الأمامي الخلفي للأكيمية العلوي والسفلي (M1، M2) القيمة الإحصائية $p<0.00$. كما كانت الأكيمية أكبر وأطول لدى الرجال. لم يكن هنالك أي اختلاف في الحجم بين الأكيمية العلوية في الجانب الأيمن والأيسر ولكن الأكيمية اليسرى كانت أكبر من اليمنى.

خاتمة: إضافة إلى الحقيقة أن سقف الدماغ المتوسط الطبيعي يعطي معلومات عن تطور دماغ الأشخاص وقد يكون مفيداً لاكتشاف وعلاج الامراض المشابهه.

Objective: To analyze and classify normal MRI tectum length and colliculus dimensions according to age and gender.

Methods: Tectum length and colliculus diameters were measured on the T1 midsagittal and axial cranial MR images in the radiology archive of 532 (344 women, 188 men) patients aged 37.36±21.49 (range: 4-91) years old on average, and with no disorders affecting the mesencephalic tectum. All 532 patients underwent clinical MR imaging of the cranium at the MRI Unit of Sivas Numune Hospital and Sivas Cumhuriyet University Hospital, Sivas, Turkey between February and December 2011.

Results: Although there was a positive linear correlation between tectum length and age, there was a negative correlation between the anteroposterior diameter of the colliculus superior and colliculus inferior and age ($p<0.01$). While tectum length (M3) increases with age, the anteroposterior diameter of the colliculus superior and inferior (M1 and M2) decreased ($p<0.01$). The colliculi were larger, and the tectum was longer in men. Although there was no difference in size between right and left superior colliculi, the left colliculus inferior was larger than the right one.

Conclusion: In addition to the fact that normal mesencephalic tectum dimensions provide information on the brain development of individuals, they may also be beneficial for the detection and treatment of related pathologies.

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The tectum mesencephalicus is located at the back of the aqueductus cerebri of the mesencephalon. There are 4 circular swellings named the lamina tecti (lamina quadrigemina) that are separated from one another by vertical and transverse grooves. Of these swellings the upper ones are named the colliculus superior, and the lower ones are named the colliculus inferior. The colliculus superior is the center for the seeing reflexes and the colliculus inferior is the center for the hearing reflexes.[1] The colliculus inferior plays a crucial role in mediating auditory gating processes and inhibitory neural transmission, while the colliculus superior is a key structure in a distributed network mediating saccadic eye movements and shifts of attention.[2] Disorders that affect the lamina tecti may induce changes in form by causing growth or abasement in the colliculi. While primary and metastatic tumors of the tectum, granulomatous disorders, periaqueductal gliosis, and hamartomas increase the diameter of the colliculi, progressive supranuclear palsy (PSP) may cause atrophy in the tectum.[3-8] Friedman stated that particularly the colliculus superior were atrophic in some patients with PSP.[8] According to Sherman et al,[9] though most of the primary or metastatic neoplastic disorders that affect the tectal region cause abnormal signal density in T2 weighted images, it is difficult to detect small lesions on transaxial images due to volume averaging or non-contiguous sections. Therefore, if the colliculus thickness is or more than 8 mm, an infiltrative lesion on the tectum should be suspected.[9] Knowledge of the colliculi thickness and tectum length in healthy individuals may help in the early diagnosis of infiltrative or degenerative disorders of the tectal region and make their treatment easier. However, the number of studies in the literature carried out in this field is very few, and the number of individuals involved in the research is limited. Moreover, we could not source a study in the literature concerning the changes in tectum dimensions according to gender and age. Therefore, we aimed to analyze and classify normal MRI tectum length and colliculus dimensions according to age and gender.

Methods. Tectum length and colliculus diameters were measured on the MR images in the radiology archive of 532 (344 women, 188 men) patients aged 37.36±21.49 (range: 4-91) years old on average, with no disorders affecting the mesencephalic tectum such as neoplastic diseases, sarcoidosis, degenerative diseases, and so forth, and whose MRI findings were evaluated as within normal ranges. The selected individuals were examined within 4 age groups, each of which comprised at least 20 men and 20 women. The average ages of the females was 37.99±20.81 (age range: 8-91), while the average ages of males was 36.19±22.70 (age range: 4-85). All 532 patients underwent clinical MR imaging of the cranium at the MRI Unit of the Sivas Numune Hospital, and the Sivas Cumhuriyet University Hospital, Sivas, Turkey between February and December 2011. The Human Ethics Committee of Sivas Province approved the study, and all participants provided written informed consent.

The MRI was performed on a 1.5-T whole-body MR system (Magnetom Symphony, Siemens, Erlangen, Germany). Examination included T1-weighted fast spin-echo sagittal and axial constructive interference in steady state (CISS) images with effective echo time and repetition times (TE/TR) of 250/4000 ms. A field of view (FOV) of 22 cm x 22 cm, matrix of 192×256 matrix and 1.7 mm sections were used. The following distances were measured on the axial and midline sagittal T1-weighted MR images for dimensions of the mesencephalic tectum (**Figures 1 and 2 A & B**).

Sagittal T1-weighted images. Anteroposterior dimensions of the colliculi and length of the tectum were measured on the sagittal T1-weighted images according to Sherman et al[9] (**Figure 1**).

Thickness of the superior colliculus (M1). The maximum cross-sectional diameter in the anteroposterior plane of the superior colliculus on the midline sagittal section. The measurement was made from the posterior margin of the superior colliculus to the posterior margin of the cerebral aqueduct.

Thickness of the inferior colliculus (M2). The maximum cross-sectional diameter in the anteroposterior

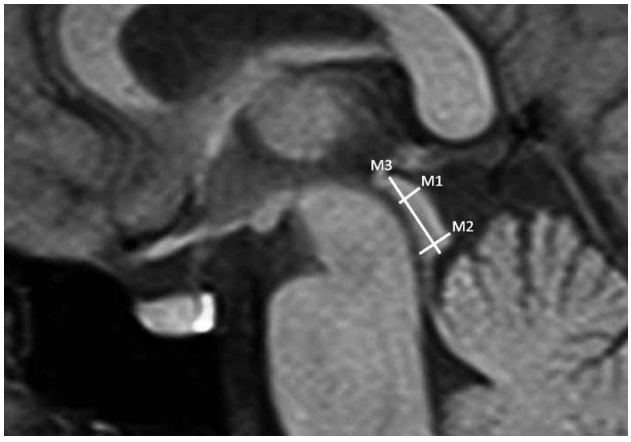

Figure 1 - Anteroposterior dimensions of the colliculi and length of the tectum were measured on the sagittal T1-weighted images. M1: Thickness of the superior colliculus, M2: Thickness of the inferior colliculus, M3: Length of the tectum.

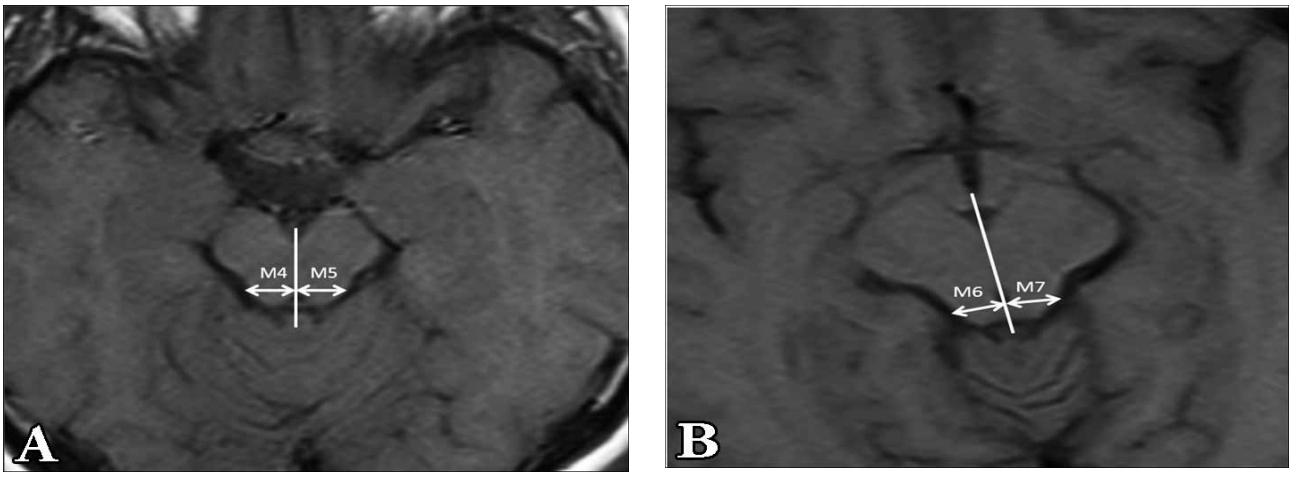

Figure 2 - The following distances were measured on the axial T1-weighted MR images for diameter of right and left colliculus. **A**) M4: Thickness of the right inferior colliculus, M5: Thickness of the left inferior colliculus **B**) M6: Thickness of the right superior colliculus, M7: Thickness of the left superior colliculus.

plane of the inferior colliculus on the midline sagittal section. The measurement was made from the posterior margin of the inferior colliculus to the posterior margin of the cerebral aqueduct.

Length of the tectum (M3). Direct distance from the superior margin of the superior colliculus to the inferior margin of the inferior colliculus.

Axial T1-weighted images. The following distances were measured on the axial T1-weighted MR images for the diameter of the right and left colliculus[10] (**Figures 2 A & B**).

Thickness of the right inferior colliculus (M4). The direct distance from the midline of the tectum to the outer margin of the right inferior colliculus on the axial section through the floor of the third ventricle at the level of the mamillary bodies.

Thickness of the left inferior colliculus (M5). The direct distance from the midline of the tectum to the outer margin of the left inferior colliculus on the axial section through the floor of the third ventricle at the level of the mamillary bodies.

Thickness of the right superior colliculus (M6). The direct distance from the midline of the tectum to the outer margin of the right superior colliculus on axial section through the third ventricle at the level of the beginning of the aqueduct of the midbrain.

Thickness of the left superior colliculus (M7). The direct distance from the midline of the tectum to the outer margin of the left superior colliculus on axial section through the third ventricle at the level of the beginning of the aqueduct of the midbrain.

Using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA) version 16.0, T-test, Mann-Whitney U, Kruskal Wallis variance analysis and Pearson correlation coefficient were used for the statistical assessment. Results with a *p*-value less than 0.05 were accepted as significant.

Results. The length of the tectum (M3) and thickness of the inferior colliculus (M2) were statistically higher in males compared with females on the midline sagittal section ($p<0.01$). At the same time, both right superior colliculus (M6) and left superior colliculus (M7) were thicker in males compared with females on the T1 weighted axial images ($p<0.01$) (**Table 1**).

The colliculus superior thickness on midsagittal sections was lower in women and men aged or over 61 than in individuals in other groups ($p<0.05$). The colliculus inferior thickness on midsagittal sections was lower in men and women over 41 than in individuals in group I and II ($p<0.05$). The tectum length was statistically higher in individuals aged 41 or over ($p<0.05$). Right and left colliculus inferior thicknesses measured on axial sections were higher both in men and women in the third group ($p<0.05$). Right and left colliculus superior thicknesses were also higher in the third group than the other groups. However, only the difference between the first and the third group was statistically meaningful (**Table 2**).

While the tectum length (M3) increased with age, the anteroposterior (M1 versus M2) diameter of the colliculus superior and inferior decreased ($p<0.01$). Although there was a positive linear correlation

Table 1 - Comparison of average tectum length and colliculus dimensions according to gender.

Variable	Female (n=344)		Male (n=188)		Total (n=532)		Test (t-test)	*P*-value
	Mean±SD (mm)	Range (mm)	Mean±SD (mm)	Range (mm)	Mean±SD (mm)	Range (mm)		
M1	3.89±0.62	2.20-6.10	3.97±0.63	2.40-5.60	3.92±0.62	2.20-6.10	1.513	0.131
M2	4.74±0.53	3.00-6.30	4.88±0.53	3.10-6.30	4.79±0.54	3.00-6.30	2.931	0.004*
M3	13.42±0.99	10.70-16.00	13.84±1.00	10.30-16.00	13.57±1.01	10.30-16.00	4.601	0.000*
M4	8.48±0.72	6.60-10.80	8.58±0.75	6.80-10.70	8.51±0.73	6.60-10.80	1.502	0.134
M5	8.64±0.73	6.40-10.60	8.75±0.76	6.50-10.50	8.68±0.74	6.40-10.60	1.686	0.092
M6	7.54±0.66	5.50-9.20	7.75±0.71	6.00-9.70	7.62±0.68	5.50-9.20	3.483	0.001*
M7	7.52±0.72	5.30-9.50	7.78±0.73	5.80-9.50	7.61±0.73	5.30-9.50	3.919	0.000*

M1 - thickness of the superior colliculus, M2 - thickness of the inferior colliculus, M3 - length of the tectum, M4 - thickness of the right inferior colliculus, M5 - thickness of the left inferior colliculus, M6 - thickness of the right superior colliculus, M7 - thickness of the left superior colliculus, *correlation is significant at the 0.05 level

Table 2 - Tectum length and colliculus dimensions according to age groups in females and males.

Variable	Group I (n=125) (0-20 age)		Group II (n=219) (21-40 age)		Group III (n=70) (41-60 age)		Group IV (n=118) (61-91 age)	
	Female (n=68)	Male (n=57)	Female (n=153)	Male (n=66)	Female (n=48)	Male (n=22)	Female (n=75)	Male (n=43)
M1	4.15±0.55	4.13±0.60	4.00±0.58	4.13±0.56	3.81±0.53	3.96±0.65	3.46±0.59	3.52±0.54
M2	4.93±0.51	4.91±0.55	4.78±0.54	5.06±0.44	4.60±0.48	4.76±0.58	4.56±0.51	4.63±0.51
M3	13.20±0.93	13.55±1.08	13.36±1.03	13.95±0.91	13.56±0.99	14.28±1.15	13.65±0.91	13.82±0.86
M4	8.43±0.65	8.40±0.70	8.46±0.72	8.52±0.78	8.78±0.76	9.00±0.79	8.36±0.71	8.69±0.69
M5	8.53±0.65	8.55±0.75	8.64±0.73	8.78±0.77	8.90±0.74	9.16±0.77	8.57±0.79	8.77±0.69
M6	7.48±0.62	7.50±0.69	7.52±0.72	7.83±0.69	7.70±0.49	8.12±0.79	7.52±0.64	7.79±0.64
M7	7.45±0.69	7.60±0.73	7.51±0.77	7.81±0.75	7.76±0.70	7.96±0.77	7.44±0.61	7.86±0.65

M1 - thickness of the superior colliculus, M2 - thickness of the inferior colliculus, M3 - length of the tectum, M4 - thickness of the right inferior colliculus, M5 - thickness of the left inferior colliculus, M6 - thickness of the right superior colliculus, M7 - thickness of the left superior colliculus

between the tectum length and age, there was a negative correlation between the anteroposterior diameter of the colliculus superior and colliculus inferior and age (p<0.01). In midsagittal sections, there was a positive linear correlation between tectum length and the diameters of the colliculus superior and colliculus inferior (p<0.01). The tectum length indicated a positive correlation in all the lengths except for the axial diameter of the left colliculus superior (p<0.05). The anteroposterior diameter of the colliculus superior and inferior on sagittal sections had no correlation with the diameter of the right colliculus superior and inferior in axial sections (p>0.05). There was a statistically meaningful positive linear correlation between all the parameters except for the axial diameters of the left colliculus superior and inferior and the anteroposterior diameter of the colliculus superior and tectum length (p<0.05) (**Table 3**).

The right and left colliculus dimensions were more or less the same on axial sections, the left colliculus inferior was greater in both men and women. These differences between right and left colliculus inferiors were also statistically meaningful (p<0.05) (**Table 4**).

Discussion. Neoplastic or degenerative disorders of the mesencephalic tectum may lead to enlargements or reductions without causing a change in signal density. Therefore, it is clinically important to have knowledge of the exact variations of the mesencephalic tectum during assessment of the cranial MR.[9] Some infiltrating brain

stem gliomas do not lead to a change in the blood-brain barrier. However, they lead to diffuse enlargement in the brain stem.[6,11] Brain stem gliomas may be isodense with the brain parenchyma or may have either lower or higher density.[11] As particularly small infiltrative lesions do not lead to a change in signal density, noticing them is only possible through the detection of variations in tectum anatomy.[9] Sherman et al[9] stated that the colliculus superior diameter in midsagittal sections ranged between 1-6 mm, and the average diameter was 4.5±1.1 mm. In our study, we recorded an average colliculus superior diameter in midsagittal sections of 3.89±0.62 mm (2.20-6.10) in women, and 3.97±0.63 mm (2.40-5.60) in men. The colliculus inferior was larger, and it had an average diameter of 4.74±0.53 mm (3.00-6.30) in women, and 4.88±0.53 mm (3.10-6.30) in men (p=0.004) (**Table 1**). Sherman et al[9] reported an average colliculus inferior diameter of 5.0±1.0 mm (3.0-7.1), and tectum length of 13.4±1.8 mm (9.8-17.0) in both genders. We found an average tectum length of 13.57±1.1 mm (10.30-16.00), which is similar to Sherman et al's findings.[9] While this distance was 13.84±1.00 mm (10.30-16.00 mm) on average in men, it was 13.42±0.99 mm (10.70-16.00) in women (p=0.000) (**Table 1**).

Bentson and Keesey[12] measured the colliculus diameters on lateral pneumoencephalographic CT images. They stated that the colliculus diameters ranged between 3-6 mm, and the average diameter was 5 mm. Sherman et al[9] claimed that colliculus diameters did not exceed 7 mm in the normal group, which did not have any mesencephalic region pathology, but an infiltrative lesion may be found in individuals who had a colliculus thickness of 8 mm or over.

It has been stated by different researchers that the tectum is enlarged particularly in primary and metastatic

Table 3 - The correlation between age and tectum length and colliculus dimensions and their relations with each other.

Variable	M1	M2	M3	M4	M5	M6	M7
Age							
r	-0.379**	-0.262**	0.139**	0.082	0.076	0.077	0.056
p-value	0.000	0.000	0.001	0.059	0.078	0.076	0.199
M1							
r	1	0.575**	0.111*	0.031	-0.010	0.019	0.021
p-value		0.000	0.010	0.469	0.818	0.657	0.624
M2							
r	0.575**	1	0.104*	0.058	0.094*	0.077	0.125**
p-value	0.000		0.016	0.185	0.030	0.077	0.004
M3							
r	0.111*	0.104*	1	0.197**	0.200**	0.140**	0.074
p-value	0.010	0.016		0.000	0.000	0.001	0.088
M4							
r	0.031	0.058	0.197**	1	0.647**	0.477**	0.361**
p-value	0.469	0.185	0.000		0.000	0.000	0.000
M5							
r	-0.010	0.094*	0.200**	0.647**	1	0.444**	0.503**
p-value	0.818	0.030	0.000	0.000		0.000	0.000
M6							
r	0.019	0.077	0.140**	0.477**	0.444**	1	0.706**
p-value	0.657	0.077	0.001	0.000	0.000		0.000
M7							
r	0.021	0.125**	0.074	0.361**	0.503**	0.706**	1
p-value	0.624	0.004	0.088	0.000	0.000	0.000	

**correlation is significant at the 0.01 level (2-tailed),
*correlation is significant at the 0.05 level (2-tailed)
M1 - thickness of the superior colliculus, M2 - thickness of the inferior colliculus, M3 - length of the tectum, M4 - thickness of the right inferior colliculus, M5 - thickness of the left inferior colliculus, M6 - thickness of the right superior colliculus, M7 - thickness of the left superior colliculus

Table 4 - Comparison of the right and left colliculus dimensions according to gender.

Gender	Right inferior colliculus	Left inferior colliculus	t	*p*-value	Right superior colliculus	Left superior colliculus	t	*p*-value
Female (n=344)	8.48±0.72	8.64±0.73	2.887	0.004	7.54±0.66	7.52±0.72	0.390	0.697
Male (n=188)	8.58±0.75	8.75±0.76	2.405	0.017	7.75±0.71	7.78±0.73	0.299	0.765

tumors of the tectum, granulomatous disorders, hamartomas, and periaqueductal gliosis.[3-6] Some studies state that tectal beaking or tectal elongation, which is defined as an increase in length, accompany various malformations.[13-16] Adeloye[16] stated that mesencephalic spurs (beaking deformity of the tectum) can accompany type II Arnold-Chiari malformation in varying degrees. When the mesencephalic spur is overt, it has been observed that the myelomeningocele is also extensive. Callen et al[13] stated that tectal elongation increased in proportion to the degree of the posterior fossa abnormalities in babies with Chiari II malformations. Furthermore, they emphasized that the detection of tectal beaking in prenatal sonography may be the supratentorial indicator of the presence and degree of a Chiari II malformation. Tubbs et al[14] indicated that there is a positive correlation between tectal beaking and nystagmus in patients with a Chiari II malformation. Particularly, nystagmus degree was also high in patients with type III tectal beaking in which the tectum length was considerably increased.[14] Moreover, it was reported by Anik et al[15] that tectal beaking observed in a 5 month-old girl accompanied tectocerebellar dysraphism, which is a very rarely observed abnormality. Therefore, it is of vital importance that the hindbrain is analyzed very carefully in cases with an increase in tectum length or widening in the colliculi to diagnose the aforementioned disorders.

Bolgov[17] stated that the colliculus superior forms earlier, but the superior and inferior colliculus have equal dimensions at the third year of life. He also added that the tectum dimensions vary in all age groups. Agreeing with Bolgov, we also found notable differences in tectum length and colliculus diameters among the different age groups (**Tables 2 & 3**).

While the midsagittal diameter of the colliculus superior was low in individuals aged 61 and over, the anteroposterior diameter of the colliculus inferior began to decrease after the age 41. However, the axial diameters of the colliculus superior and inferior were maximum in individuals aged 41-60 (**Table 2**). Though there was a positive linear correlation between tectum length and age, there was a negative correlation between the anteroposterior diameter of colliculus superior and colliculus inferior and age ($p<0.01$). The tectum length was higher in individuals aged 41 and over, which was statistically meaningful ($p<0.05$). According to our findings, while tectum length (M3) increased with age, the anteroposterior diameter of the colliculus superior and inferior (M1 versus M2) decreased ($p<0.01$, **Table 3**). Bolgov did not find any correlation between either gender or the right and left hemispheres of the tectum in terms of colliculus size. Contrary to Bolgov's findings, we found that both the colliculus superior and colliculus inferior were greater in men. There was a statistically meaningful difference between men and women in terms of the colliculus inferior on midsagittal sections, and both right and left colliculus superior diameters on axial sections ($p<0.01$, **Table 1**). While the right and left colliculus dimensions were more or less the same on axial sections, the left colliculus inferior was greater in both men and women. These differences between right and left colliculus inferiors were also statistically meaningful ($p<0.05$, **Table 4**).

Sherman et al[9] did not report any mesencephalic disorder in individuals whose colliculus levels were under average. Therefore, they concluded that decreases in tectal thickness had no clinical significance.[9] However, it has been stated by some researchers that the colliculi was thinner in patients with PSP due to atrophy, and particularly, the diameter of the colliculus superior was decreased.[7,8,18] Masucci et al[18] emphasized that collicular plates becoming thinner in PSP due to atrophy was more overt in the colliculus superior, and this was one of the locations where pathology in PSP was mostly observed.[18] Oba et al[19] measured the midbrain areas of patients with PSP through midsagittal MRI and reported that the average midbrain area (56.0 mm^2) of patients with PSP was significantly lower than of the controls (117.7 mm^2). Warmuth-Metz et al[20] measured the anteroposterior midbrain diameters of 16 patients with PSP on axial T2-weighted MRI. They found that the average midbrain diameter (mean, 13.4 mm) of patients with PSP was significantly ($p<0.001$) lower than the controls (mean, 18.2 mm).[20] Similarly, Kang et al[2] found a significantly smaller right colliculus inferior in patients with schizophrenia. The measured average right colliculus inferior volume (mean, 113.18 mm^3) of patients with schizophrenia was significantly ($p<0.05$) lower than of controls (mean, 123.60 mm^3).

We acknowledge several limitations in our study. The tectum dimensions were not measured in different patient groups; for example, PSP, schizophrenia, neoplastic diseases and so forth. In addition, we did not study the mesencephalic tectum volume. In future, we recommend the MRI volumetric assessment of both the colliculus superior and colliculus inferior.

In conclusion, MRI is an appropriate and reliable method for the quantitative measurement of the degree of atrophy and hypertrophy of the colliculi. The tectum lengths and colliculus diameters measured on cranial MR images may be beneficial for the early diagnosis of pathologies related to the tectal region. We found a positive correlation between tectum length and age,

however, there was a negative correlation between the midsagittal diameters of the colliculus superior and inferior and age. While tectum length increases with age, anteroposterior diameters of the colliculi decrease. The tectum length and colliculi are bigger in men. While the left colliculus inferior is bigger, the diameter of the colliculus superior is almost the same on the right and left side. The data we obtained from a large population may be beneficial for the early diagnosis and treatment of the infiltrative lesions of the tectum, which do not cause any particular signal change. The complications that can be caused by these disorders can then be prevented.

References

1. Carpenter MB. Core text of neuroanatomy. 2nd ed. Baltimore (MD): Williams & Wilkins; 1978. p. 141-163.
2. Kang DH, Kwon KW, Gu BM, Choi JS, Jang JH, Kwon JS. Structural abnormalities of the right inferior colliculus in schizophrenia. ***Psychiatry Res*** 2008; 164: 160-165.
3. Konno H, Yamamoto T, Iwasaki Y, Iinuma K, Takahashi Y. A case of quadrigeminal hamartoma. ***Acta Neuropathol*** 1985; 68: 155-159.
4. Ho KL. Tumors of the cerebral aqueduct. ***Cancer*** 1982; 49: 154-162.
5. Moffie D, Ongerboer de Visser BW, Stefanko SZ. Parinaud's syndrome. ***J Neurol Sci*** 1983; 58: 175-183.
6. Sanford RA, Bebin J, Smith RW. Pencil gliomas of the aqueduct of Sylvius. Report of two cases. ***J Neurosurg*** 1982; 57: 690-696.
7. Venmans A, Nijssen PC, Sluzewski M, van Rooij WJ. Progressive supranuclear palsy. ***JBR-BTR*** 2009; 92: 182-183.
8. Friedman DP. Extrapineal abnormalities of the tectal region: MR imaging findings. ***AJR Am J Roentgenol*** 1992; 159: 859-866.
9. Sherman JL, Citrin CM, Barkovich AJ, Bowen BJ. MR imaging of the mesencephalic tectum: normal and pathologic variations. ***AJNR Am J Neuroradiol*** 1987; 8: 59-64.
10. DeArmond SJ, Fusco MM, Dewey MM. Structure of the human brain A Photographic Atlas. 2nd ed. New York (NY): Oxford University Press; 1976. p. 26-29.
11. Bilaniuk LT, Zimmerman RA, Littman P, Gallo E, Rorke LB, Bruce DA, et al. Computed tomography of brain stem gliomas in children. ***Radiology*** 1980; 134: 89-95.
12. Bentson JR, Keesey JC. Pneumoencephalography of progressive supranuclear palsy. ***Radiology*** 1974; 113: 89-94.
13. Callen AL, Stengel JW, Filly RA. Supratentorial abnormalities in the Chiari II malformation, II: tectal morphologic changes. ***J Ultrasound Med*** 2009; 28: 29-35.
14. Tubbs RS, Soleau S, Custis J, Wellons JC, Blount JP, Oakes WJ. Degree of tectal beaking correlates to the presence of nystagmus in children with Chiari II malformation. ***Childs Nerv Syst*** 2004; 20: 459-461.
15. Anik I, Koc K, Anik Y, Yildiz DK, Ceylan S. Tectocerebellar dysraphism with vermian encephalocele. ***J Child Neurol*** 2010; 25: 1411-1414.
16. Adeloye A. Mesencephalic spur (beaking deformity of the tectum) in Arnold-Chiari malformation. ***J Neurosurg*** 1976; 45: 315-320.
17. Bolgov IuA. [Linear dimensions of the lamina of the tectum mesencephali during human ontogenesis]. ***Arkh Anat Gistol Embriol*** 1976; 71: 53-58.
18. Masucci EF, Borts FT, Perl SM, Wener L, Schwankhaus J, Kurtzke JF, et al. MR vs CT in progressive supranuclear palsy. ***Comput Med Imaging Graph*** 1995; 19: 361-368.
19. Oba H, Yagishita A, Terada H, Barkovich AJ, Kutomi K, Yamauchi T, et al. New and reliable MRI diagnosis for progressive supranuclear palsy. ***Neurology*** 2005; 64: 2050-2055.
20. Warmuth-Metz M, Naumann M, Csoti I, Solymosi L. Measurement of the midbrain diameter on routine magnetic resonance imaging: a simple and accurate method of differentiating between Parkinson disease and progressive supranuclear palsy. ***Arch Neurol*** 2001; 58: 1076-1079.

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