



## Measurement of the Corpus Callosum Using Magnetic Resonance Imaging in the North of Iran

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### ABSTRACT

**Background:** Morphometric measurements of the corpus callosum (CC) are important to have normative values according to sex, age and race/ethnicity.

**Objectives:** This study was done to measure the size of CC and to identify its gender- and age-related differences in the North of Iran.

**Patients and Methods:** The size of CC on midsagittal section was measured in 100 (45 males, 55 females) normal subjects using magnetic resonance imaging (MRI) admitted to the Kowsar MRI center in Gorgan-Northern Iran.

Longitudinal and vertical dimensions of the CC, longitudinal and vertical lengths of the brain and the length of genu and splenium were measured. Data were analyzed by student's unpaired t test, ANOVA and regression analysis.

**Results:** The anteroposterior length and vertical dimension of the CC, the length of genu and splenium were larger in males than in females, but these differences were not significant. The anteroposterior and vertical lengths of the brain were significantly larger in males than in females ( $P < 0.05$ ). The length of CC increased with age and regression equations for predicting age were derived from the length of the CC. There was also a positive significant correlation between the anteroposterior length of the CC and the length of the brain and vertical dimension of the CC.

**Conclusions:** This study showed that various CC parameters vary with the values documented in the Caucasian, Indian and Japanese population.

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### ► Implication for health policy/practice/research/medical education:

This study indicates that the size of corpus callosum is related to gender and age which may help in finding possible changes in degenerative diseases and correcting the target zones in brain stereotactic surgery.

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## 1. Background

The corpus callosum (CC) with more than 300 million fibers is the most important anatomical and functional inter-hemispheric commissure in the human brain. The activities of the left and right cerebral hemispheres correlate via CC. Callosal fibers have a special topographic organization (1). It means that the prefrontal cortex of the right and left human cerebral hemispheres corre-

late via genu and rostrum. Besides, premotor and supplementary motor cortical areas, primary motor and primary sensory cortex of the two hemispheres link via the body of the CC; whereas, parietal, temporal and occipital fiber bundles of the two hemispheres cross the CC through the splenium.

CC has a special influence on the affective behavior, non-literal language and bilateral functional connection in both motor and sensory cortices (2, 3). Several studies have reported that the size of CC changes in bipolar disorders (4), Alzheimer disease (5), leukoaraiosis (6) and Williams syndrome (7). Indeed, some researchers have reported that the morphology of CC may change in diseases such as dyslexia (8), Tourette's syndrome (9), Down's syndrome (10), depression (11), schizophrenia (12) and HIV/AIDS (13).

Regarding differences in the size of organs in humans including CC according to race/ethnicity in various parts of the world, CC dimensions, morphology and sex-related differences have been of interest to researchers (1).

By using magnetic resonance imaging (MRI), the dimensions of CC including size, diameters, age morphology and also gender-related differences have been determined in several studies (1, 14-26).

Most of the studies on the size and shape of CC were carried out in Western countries on the Caucasian population (1, 14-18) and a few studies were performed in the East Asian (21, 23) and Indian population (19, 20, 22).

Minimal variability in the dimensions and relative dimensions of the CC in Greek people was reported by Mourgila *et al.* (1). They also found that the longitudinal dimension of the genu (EZ/3) and total CC (EZ) are larger in males.

In another study carried out by Gupta *et al.* on Indians, no sexual dimorphism was observed in most of the CC parameters. They also reported that shrinkage of the anterior half of the CC due to aging could be due to the atrophic alteration of the brain (19). One other of their findings was that the length and width of CC in Indians were less than those of the Caucasian population (22).

Takada in 2003 did not observe any difference in the regional size of CC between genders in Japanese subjects (21). On the other hand, Bermudez and Zatorre (15) found a well established difference in size, shape and position of the CC between genders.

Furthermore, Luders *et al.* (16) did not find significant sex difference in scaled data. Although few studies have been performed in different parts of the world on the size and shape of CC reporting different findings about it, there is no documented data regarding anatomical characteristics of CC in the Iranian population.

## 2. Objectives

This study was performed to determine the longitudinal and vertical dimensions of the brain and the dimensions of various parts of CC by MRI.

## 3. Patients and Methods

This descriptive study was carried out on 100 subjects (45 male) admitted to Kowsar MRI center in Gorgan-Northern Iran from 24 July, 2006 to 16 December, 2006. Informed consent was obtained along with a clearance from the institutional ethics committee.

The subjects were referred to Kowsar MRI center for headache survey. Inclusion criteria were no neurological signs, no intracranial lesions, mass or head injury on MRI and no history of neurological disease. The subjects were divided into three age groups including less than 30 years old, 30-44 and 45 years old and more.

Brain and CC dimensions were measured on MRI unit (Siemens, symphony, 1.5 Tesla). MR images were acquired in the axial and vertical planes by using FLAIR, T1 and T2 weighted sequences. For each case, using a mid-sagittal view of the cerebral hemispheres, the following global dimensions (1, 22) were measured (*Figure 1*):

AB: Longitudinal dimension of the brain from the frontal to the occipital pole

CD: From the superior to the inferior surface of the brain, including the cerebellum

AE: From the frontal pole of the brain to the genu of CC

BZ: From the occipital pole of the brain to the splenium of CC

EZ: Length of CC from anterior most point of CC to its posterior most point. According to the maximum straight length by Witelson's method (1) EZ is subdivided into three regions:

1) The genu (EZ/3) was defined as the anterior third.

2) The mid-body of the CC was allocated the middle third.

3) The posterior third was subdivided into A) the posterior fifth (splenium-EZ/5) and B) the isthmus, a region between the mid body and the splenium.

FG considered as the width of CC in the vertical view of the brain hemispheres. The width of CC was measured at the midpoint, which was taken at the center of the CC length.

The various dimensions of the CC (AB, CD, AE, BZ, EZ, EZ/3, EZ/5 and FG) were correlated with each other. Then, these dimensions were correlated with the dimensions of the brain. These findings were then examined for possible sex- and age-related differences.

Statistical analysis was conducted using SPSS version 11.5 and ANOVA, TUKEY and *t* student tests. For all the comparisons *P* lower than 0.05 was considered as significant.

The 95% confidence interval (CI) for variables was calculated. For determining correlation of EZ as a dependent variable and AB, AE and FG as independent variables, we used multi variant linear regression.

Pearson correlation test was used to determine linear correlation between quantitative variables.

## 4. Results

The mean value for the longitudinal dimension of the

brain (AB) was  $16.12 \pm 0.081$  cm (95% CI; 15.96-16.28), while the mean value for the longitudinal dimension of the CC (EZ) was  $7.06 \pm 0.052$  cm (95% CI; 6.96-7.17), a ratio greater than 2:1.

The mean value for the longitudinal dimension of the genu (EZ/3) and the splenium (EZ/5) was  $2.35 \pm 0.017$  cm (95% CI; 2.316-2.385) and  $1.41 \pm 0.010$  cm (95% CI; 1.388-1.429), respectively.

The distance between the genu and the frontal pole (AE) had a mean value of  $3.68 \pm 0.034$  cm (95% CI; 3.616-3.751), while the distance from the splenium to the occipital pole (BZ) was  $5.580 \pm 0.052$  cm (95% CI; 5.476-5.485), an approximate ratio of 1:1.5.

The mean value for the distance between the upper and lower surfaces of the brain (CD-vertical diameter) was  $10.63 \pm 0.51$  cm.

A positive linear correlation was evident between AB and CD ( $r = 0.45$ ), AB and AE ( $r = 0.45$ ), and between AB and EZ ( $r = 0.56$ ). A stronger positive correlation ( $r = 0.71$ ) was noted between AB and BZ (the distance between the splenium and the occipital pole). CD (vertical brain diameter) exhibited a positive linear correlation with AB ( $r = 0.45$ ), but not with EZ ( $r = 0.04$ ) (Table 1).

Multi variant linear regression showed that there is a significant correlation between EZ (as the dependent variable of the model) and AB and AE ( $P < 0.0001$ ) (Table 2). The results have also shown that FG had no significant correlation with EZ in the mentioned multivariate linear regression model.

Regarding sex-related differences, the mean of the longitudinal dimensions and measured ratios tended to be smaller in women, and the inter-sex difference in mean value for AB (male; =  $16.46 \pm 0.11$  cm, female; =  $15.83 \pm 0.10$  cm;  $P < 0.001$ ), AE (male; =  $3.77 \pm 0.05$  cm, female; =  $3.60 \pm 0.04$  cm,  $P < 0.012$ ), BZ (male; =  $5.81 \pm 0.08$  cm, female; =  $5.40 \pm 0.06$  cm,  $P < 0.001$ ) and CD (male; =  $10.82 \pm 0.08$  cm, female; =  $10.47 \pm 0.06$  cm,  $P < 0.01$ ) was statistically significant (Table 3).

Regarding age, there was a statistically-significant increase in the longitudinal dimensions of the CC. The mean length of the CC was  $7.25 \pm 0.08$  cm in those subjects who were 45 years old and more. It was  $7.19 \pm 0.06$  cm in those who were 30-44 years old while in those younger than 30 years it was  $6.82 \pm 0.10$  cm ( $P = 0.001$ ) (Table 4). ANOVA and Tukey tests showed that mean of EZ was significantly increased in 30-44 and  $\geq 45$  age groups compared to  $< 30$  age group and the mean of FG was significantly increased in 30-44 age group compared to  $< 30$  age and  $\geq 45$  age groups (Figure 2 and 3 and Table 4).

### 5. Discussion

According to our findings there is no significant sexual dimorphism in human CC dimensions in the North of Iran, although the dimensions of CC in males was higher than females. Besides, there was a positive correlation between CC and brain longitudinal diameters.

In recent years, several studies on MRI scans have been carried out to determine the diameters, morphology and sex-related differences of CC in various parts of the world (1, 14-26).

In a study by Takeda *et al.* (2003) using MRI on the Japanese showed that the length and height of CC was  $69.7 \pm 4.15$  and  $25.9 \pm 2.90$  mm, respectively in males and  $69.4 \pm 4.33$  and  $25.8 \pm 2.80$  mm, respectively in females. He concluded that there is no difference in callosal measures between the two genders (21).

Bermudez and Zatorre in a study on 137 young normal volunteers reported that male subjects show significantly larger absolute total areas as the anterior third and posterior midbody of CC. However, the total area of the anterior midbody and splenium in females were bigger than males. Moreover, a strong difference in size, shape and position of CC among genders were found (15).

In Suganthy *et al.*'s study in India which was performed on 100 subjects using MRI, the length of CC in males was

**Table 1.** Spearman's Rho Correlation Coefficient Between the Corpus Callosum Diameters (n=100)

Morphometric Index	AE	BZ	CD	FG	EZ <sup>a</sup>
AB <sup>a</sup> , cm	0.449 <sup>b</sup>	0.713 <sup>b</sup>	0.448 <sup>b</sup>	0.122	0.560 <sup>b</sup>
AE <sup>a</sup> , cm	-	0.314 <sup>b</sup>	0.428 <sup>b</sup>	-0.160	-0.252
BZ <sup>a</sup> , cm	-	-	0.403 <sup>b</sup>	0.081	0.034
CD <sup>a</sup> , cm	-	-	-	0.235 <sup>c</sup>	0.041
FG <sup>a</sup> , cm	-	-	-	-	0.236 <sup>c</sup>

<sup>a</sup> AB, Longitudinal dimension of the brain from the frontal to the occipital pole; AE, From the frontal pole of the brain to the genu of CC; BZ, From the occipital pole of the brain to the splenium of CC; CD, From the superior to the inferior surface of the brain, including the cerebellum; EZ, Length of CC from anterior most point of CC to its posterior most point; FG, Considered as the width of CC in the vertical view of the brain hemispheres.

<sup>b</sup>  $P < 0.05$

<sup>c</sup>  $P < 0.01$

**Table 2.** Multivariate Linear Regression Between EZ and AB, AE and FG

Model	Unstandardized Coefficients		Standardized Coefficients	T value	P value
	B	Standard-Error	Beta		
Constant	1.766	0.667	-	2.647	0.009
AB <sup>a</sup> , cm	0.536	0.045	0.835	11.780	< 0.0001
AE <sup>a</sup> , cm	-0.943	0.108	-0.622	-8.717	< 0.0001
FG <sup>a</sup> , cm	0.237	0.439	0.035	0.539	0.591

<sup>a</sup> AB, Longitudinal dimension of the brain from the frontal to the occipital pole; AE, From the frontal pole of the brain to the genu of CC; FG, Considered as the width of CC in the vertical view of the brain hemispheres.

**Table 3.** Dimensions of Corpus Callosum in the Iranian Population According to Gender

Morphometric Index	Female, Mean $\pm$ SEM <sup>d</sup>	Male, Mean $\pm$ SEM <sup>d</sup>	T value	P value
AB <sup>a</sup>	15.83 $\pm$ 0.10	16.46 $\pm$ 0.11	4.21	< 0.0001
EZ <sup>a</sup>	7.03 $\pm$ 0.07	7.10 $\pm$ 0.07	0.62	0.535
AE <sup>a</sup>	3.60 $\pm$ 0.04	3.77 $\pm$ 0.05	2.57	0.012
BZ <sup>a</sup>	5.40 $\pm$ 0.06	5.81 $\pm$ 0.08	4.07	< 0.0001
EZ/3 <sup>b</sup>	2.34 $\pm$ 0.02	2.36 $\pm$ 0.02	0.64	0.523
EZ/5 <sup>c</sup>	1.40 $\pm$ 0.01	1.41 $\pm$ 0.01	0.61	0.540
CD <sup>a</sup>	10.47 $\pm$ 0.06	10.82 $\pm$ 0.08	3.60	0.001
FG <sup>a</sup>	0.54 $\pm$ 0.01	0.56 $\pm$ 0.01	1.55	0.123

<sup>a</sup> These are explained in the (first footnote) of Table 1.

<sup>b</sup> EZ/3, Longitudinal dimension of the genu

<sup>c</sup> EZ/5, The posterior fifth

<sup>d</sup> Abbreviation: SEM, standard error of mean

**Table 4.** Dimensions of Corpus Callosum in the Iranian Population According to Age

Morphometric Index	Age, y, Mean $\pm$ SEM <sup>b</sup>			F value	P value
	< 30	30-44	$\geq$ 45		
AB <sup>a</sup>	16.13 $\pm$ 0.14	16.05 $\pm$ 0.13	16.18 $\pm$ 0.13	0.2	0.795
EZ <sup>a</sup>	6.82 $\pm$ 0.10	7.19 $\pm$ 0.06	7.25 $\pm$ 0.08	8.1	0.001
AE <sup>a</sup>	3.88 $\pm$ 0.05	3.59 $\pm$ 0.05	3.51 $\pm$ 0.06	13.7	< 0.0001
BZ <sup>a</sup>	5.65 $\pm$ 0.09	5.51 $\pm$ 0.10	5.61 $\pm$ 0.09	0.7	0.512
EZ/3 <sup>a</sup>	2.27 $\pm$ 0.03	2.39 $\pm$ 0.02	2.41 $\pm$ 0.03	8.3	< 0.0001
EZ/5 <sup>a</sup>	1.36 $\pm$ 0.02	1.43 $\pm$ 0.01	1.45 $\pm$ 0.02	8.1	0.001
CD <sup>a</sup>	10.82 $\pm$ 0.08	10.64 $\pm$ 0.07	10.33 $\pm$ 0.09	8.3	< 0.0001
FG <sup>a</sup>	0.53 $\pm$ 0.01	0.58 $\pm$ 0.01	0.53 $\pm$ 0.01	4.2	0.018

<sup>a</sup> These are explained in the (first footnote) of Table 3.

<sup>b</sup> Abbreviation: SEM, standard error of mean

**Figure 1.** Brain MRI demonstrating the measured dimensions.

A, Frontal pole of the brain; B, Occipital pole of the brain; E, Genu of the corpus callosum; Z, Splenium of the corpus callosum

significantly higher than females (72.6  $\pm$  5.2 mm in male, 70.6  $\pm$  4.0 mm in female). Suganthy also reported that only the length of CC increased with the increase of age (20).

In a study by Gupta *et al.* on the Indian population in 2009, their MRI showed that the length and width of CC was 7.57 cm and 3.27 cm, respectively in men and 7.1 cm and 2.59 cm, respectively in women and the splenial width values were 1.15 cm in men and 1.17 cm in women. Furthermore, Gupta reported that the length and widths of CC in the Indian population were greater than the Japanese, but lower than the Caucasian population (22).

Mourgela *et al.* (1) in Greece reported that despite the positive linear correlation between the distance of the frontal and occipital poles of the brain to CC and brain dimensions, no significant linear correlation between

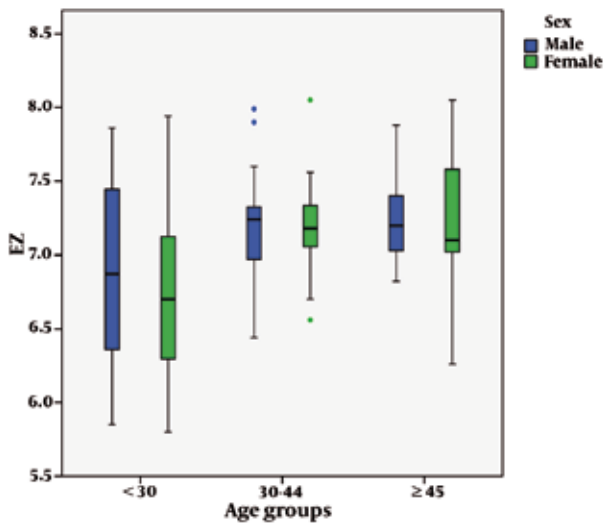
the longitudinal dimensions of the brain and CC was observed.

In this study, there was no significant difference detected in CC diameters such as EZ, EZ/3, EZ/5, FG between genders. Our results were similar to the findings of Takeda's study in Japan (21) and Tuncer's study in Turkey (25).

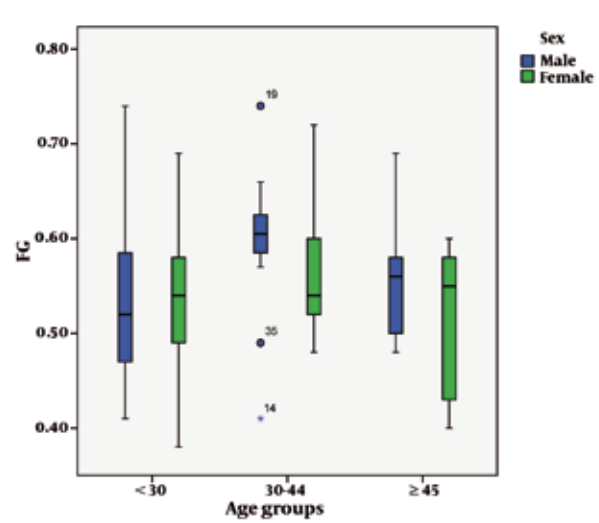
Suganthy *et al.* (2003) and Mourgela *et al.* (2007) reported that only longitudinal dimension of CC is higher in males (1, 20). In our study, longitudinal dimensions of CC were higher than other studies such as Mourgela in Greece (1), Takeda in Japan (21) and similar to Indians (20). In addition, the width of CC was similar to other studies (1, 21). According to our findings, EZ, EZ/3, EZ/5 and FG were related to age groups. Takeda *et al.*'s study has shown that the longitudinal diameter of CC increased with age, but the width of the rostrum and splenium and body decreased (21). Suganthy *et al.* also reported that the length of CC increased with age but the other dimensions had no changes (20).

In this study, the CC dimensions increased in the 45- to 60-years age group. The finding is in contrast with other studies (1, 20, 21). This difference may be due to the low number of 60-year-old subjects and age groups in our study.

A positive linear correlation was obvious between EZ and AB and between EZ and FG but not between EZ and



**Figure 2.** The graph shows dimensions of EZ of the corpus callosum according to gender and age groups.



**Figure 3.** The graph shows dimensions of FG of the corpus callosum according to gender and age groups.

CD. These findings are not similar to Mourgela's study (1).

In our study, multivariate linear regression showed that AB had a strong positive correlation with EZ. Indeed, the longitudinal and vertical dimensions of the brain and the distance of the CC from the frontal and occipital poles had a positive linear correlation. However, there is a statistical relationship between the dimensions of the brain with the longitudinal dimensions of the CC. Thus, the various dimensions of the brain change correlatively with each other. So to preserve the symmetry of the human brain, the size and dimensions of CC can vary.

Regarding the correlation between the brain and CC dimensions in our study, we concluded that there is symmetry between the brain and the size of CC. This conclusion is similar to Estruch *et al.* (26) and Mourgela *et al.*'s study (1).

The differences on quantitative data of CC in various areas of the world which were seen in different studies may be due to racial/ethnic factors (21, 22). Therefore, further studies should be performed in order to estimate differences among various ethnicity/races and to establish the normal standard data in each population. There were limitations for our study; namely the low sample size and the low number of older than 60-year-old samples.

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## References

- Mourgela S, Anagnostopoulou S, Sakellaropoulos A, Gouliamos A. An MRI study of sex-and age-related differences in the dimensions of the corpus callosum and brain. *Neuroanatomy*. 2007;**6**(1):63-5.
- Paul LK, Van Lancker-Sidtis D, Schieffer B, Dietrich R, Brown WS. Communicative deficits in agenesis of the corpus callosum: nonlateral language and affective prosody. *Brain Lang*. 2003;**85**(2):313-24.
- Quigley M, Cordes D, Turski P, Moritz C, Haughton V, Seth R, et al. Role of the corpus callosum in functional connectivity. *AJNR Am J Neuroradiol*. 2003;**24**(2):208-12.
- Yasar AS, Monkul ES, Sassi RB, Axelson D, Brambilla P, Nicoletti MA, et al. MRI study of corpus callosum in children and adolescents with bipolar disorder. *Psychiatry Res*. 2006;**146**(1):83-5.
- Teipel SJ, Bayer W, Alexander GE, Zebuhr Y, Teichberg D, Kulic L, et al. Progression of corpus callosum atrophy in Alzheimer disease. *Arch Neurol*. 2002;**59**(2):243-8.
- Yamauchi H, Fukuyama H, Shio H. Corpus callosum atrophy in patients with leukoaraiosis may indicate global cognitive impairment. *Stroke*. 2000;**31**(7):1515-20.
- Tomaiuolo F, Di Paola M, Caravale B, Vicari S, Petrides M, Caltagirone C. Morphology and morphometry of the corpus callosum in Williams syndrome: a T1-weighted MRI study. *Neuroreport*. 2002;**13**(17):2281-4.
- von Plessen K, Lundervold A, Duta N, Heiervang E, Klauschen F, Smievoll AI, et al. Less developed corpus callosum in dyslexic subjects—a structural MRI study. *Neuropsychologia*. 2002;**40**(7):1035-44.
- Plessen KJ, Wentzel-Larsen T, Hugdahl K, Feineigle P, Klein J, Staib LH, et al. Altered interhemispheric connectivity in individuals with Tourette's disorder. *Am J Psychiatry*. 2004;**161**(11):2028-37.
- Teipel SJ, Schapiro MB, Alexander GE, Krasuski JS, Horwitz B, Hoehne C, et al. Relation of corpus callosum and hippocampal size to age in nondemented adults with Down's syndrome. *Am J Psychiatry*. 2003;**160**(10):1870-8.
- Lacerda AL, Brambilla P, Sassi RB, Nicoletti MA, Mallinger AG, Frank E, et al. Anatomical MRI study of corpus callosum in unipolar depression. *J Psychiatr Res*. 2005;**39**(4):347-54.

12. Narr KL, Cannon TD, Woods RP, Thompson PM, Kim S, Asuncion D, et al. Genetic contributions to altered callosal morphology in schizophrenia. *J Neurosci*. 2002;**22**(9):3720-9.
13. Thompson PM, Dutton RA, Hayashi KM, Lu A, Lee SE, Lee JY, et al. 3D mapping of ventricular and corpus callosum abnormalities in HIV/AIDS. *Neuroimage*. 2006;**31**(1):12-23.
14. Peterson BS, Feineigle PA, Staib LH, Gore JC. Automated measurement of latent morphological features in the human corpus callosum. *Hum Brain Mapp*. 2001;**12**(4):232-45.
15. Bermudez P, Zatorre RJ. Sexual dimorphism in the corpus callosum: methodological considerations in MRI morphometry. *Neuroimage*. 2001;**13**(6 Pt 1):1121-30.
16. Luders E, Narr KL, Zaidel E, Thompson PM, Toga AW. Gender effects on callosal thickness in scaled and unscaled space. *Neuroreport*. 2006;**17**(11):1103-6.
17. Sullivan EV, Pfefferbaum A, Adalsteinsson E, Swan GE, Carmelli D. Differential rates of regional brain change in callosal and ventricular size: a 4-year longitudinal MRI study of elderly men. *Cereb Cortex*. 2002;**12**(4):438-45.
18. Luders E, Rex DE, Narr KL, Woods RP, Jancke L, Thompson PM, et al. Relationships between sulcal asymmetries and corpus callosum size: gender and handedness effects. *Cereb Cortex*. 2003;**13**(10):1084-93.
19. Gupta T, Singh B, Kapoor K, Gupta M, Kochhar S. Age and sex related variations in corpus callosal morphology. *Nepal Med Coll J*. 2008;**10**(4):215-21.
20. Suganthy J, Raghuram L, Antonisamy B, Vettivel S, Madhavi C, Koshi R. Gender- and age-related differences in the morphology of the corpus callosum. *Clin Anat*. 2003;**16**(5):396-403.
21. Takeda S, Hirashima Y, Ikeda H, Yamamoto H, Sugino M, Endo S. Determination of indices of the corpus callosum associated with normal aging in Japanese individuals. *Neuroradiology*. 2003;**45**(8):513-8.
22. Gupta T, Singh B, Kapoor K, Gupta M, Kochhar S. Normative data of corpus callosal morphology in a North-West Indian population- an autopsy and MRI study. *JNMA J Nepal Med Assoc*. 2009;**48**(173):46-51.
23. Okamoto K, Ito J, Tokiguchi S. [The MR findings on the corpus callosum of normal young volunteers]. *Nihon Igaku Hoshasen Gakkai Zasshi*. 1990;**50**(8):954-63.
24. Sullivan EV, Rosenbloom MJ, Desmond JE, Pfefferbaum A. Sex differences in corpus callosum size: relationship to age and intracranial size. *Neurobiol Aging*. 2001;**22**(4):603-11.
25. Tuncer MC, Hatipoglu ES, Ozates M. Sexual dimorphism and handedness in the human corpus callosum based on magnetic resonance imaging. *Surg Radiol Anat*. 2005;**27**(3):254-9.
26. Estruch R, Nicolas JM, Salameo M, Aragon C, Sacanella E, Fernandez-Sola J, et al. Atrophy of the corpus callosum in chronic alcoholism. *J Neurol Sci*. 1997;**146**(2):145-51.