

Morphometry of Corpus Callosum Related with Gender and Age: Magnetic Resonance Imaging Study

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ABSTRACT

Objective: The corpus callosum (CC) is an important structure of connecting the two cerebral hemispheres. The purpose of this study was to examine the morphometry of the CC of normal cases and its relationship with gender and age.

Methodology: Morphometric measurements of the corpus callosum were made on MR imaging in the mid-sagittal plane in 42 male and 48 female total 90 healthy subjects, age range was 6-17 year-old. Age of the cases were divided into three group as 6-9, 10-13 and 14-17 year-old. The length was measured by drawing a straight line at greatest antero-posterior diameter of CC, a perpendicular at its midline, anterior, posterior and medium segments of CC were measured. In addition as a result of these morphometric measurements index of corpus callosum (CCI) was calculated for every cases. Statistical analysis was performed by One-Way ANOVA- Tukey test, Independent Sample t test, Kruskal-Wallis test and Mann - Whitney U test.

Results: Without considering sex between the age group, antero-posterior, anterior, posterior and medium segments diameters of CC was found statistically significance ($p < 0.05$) while analysis of CCI values was not found significant ($p > 0.05$).

Conclusions: These datas can be used as morphometric guide, for evaluation of the CC specially in years 6-17 age group.

KEY WORDS: Corpus Callosum, Morphometry, Magnetic Resonance Imaging.

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INTRODUCTION

The Corpus callosum (CC) is the main structure that occupies between two cerebral hemisphere and provide the connection between cortical and sub-cortical neurons.¹⁻⁴ It includes approximately 200 million myelinated fibers. The functions of the CC can generally be thought of as integrating the activities of the left and right cerebral hemispheres.⁵ The sexual dimorphism of the CC started with the original report de Lacoste-Utamsing and Holloway.⁶ The size and shape of the adult CC may show variety according to gender and age.⁷ Several studies have indicated that CC development continues to progress throughout adolescence.^{8,9} Despite decades of research, there is still no agreement over the presence of gender-based morphologic differences in the human CC.⁵

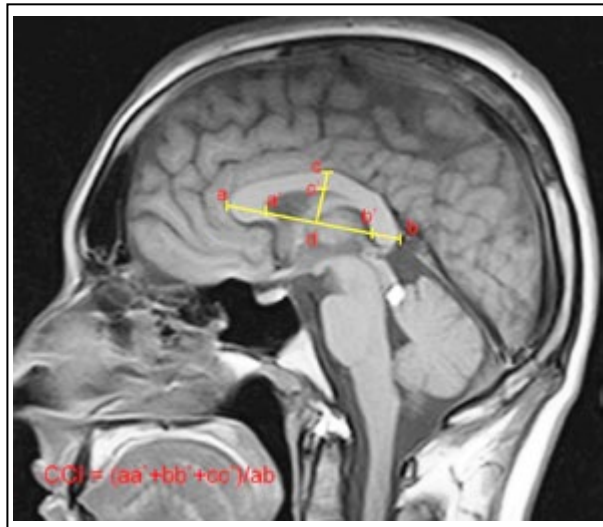


Fig.1: Determination of corpus callosum index, using a midsagittal slice on a T1W brain MRI. Anterior (aa'), posterior (bb') and medium (cc') segments of CC were measured and normalized to its greatest anteroposterior diameter (ab).

In this study, CC diameters were measured according to age and gender that can show variability, in normal cases ages between 6-17 year-old. In addition CC index was calculated for each case using measured parameters, and obtained index also evaluated relationship between the each group.

METHODOLOGY

This study carried on Magnetic Resonance Imaging (MRI) appearance belong to 42 male, 48 female, total of 90 children cases retrospectively after ethical approval. Evaluated MRI belonged to 6-17 year-old cases obtained from Cumhuriyet University, Department of Radiology, (dated between 1 march and 30 April of 2007-2008). Our study included normal subject's MRI appearances who had no serious history of pathological diagnose and no cerebral dephormity that could affect our measurements.

Table-I: Comparison of the CC measurements according to age group.

	6-9 (n=30) $\bar{X} \pm S$	10-13 (n=30) $\bar{X} \pm S$	14-17 (n=30) $\bar{X} \pm S$	Result
ab	61.26 $\pm$ 6.04	63.50 $\pm$ 5.09	66.26 $\pm$ 4.97	F= 6.47 *p= 0.002
aa'	11.20 $\pm$ 1.60	11.76 $\pm$ 1.86	11.73 $\pm$ 1.55	F= 1.07 p= 0.347
bb'	9.96 $\pm$ 2.05	10.66 $\pm$ 2.33	11.56 $\pm$ 2.35	F= 3.79 *p= 0.026
cc'	5.86 $\pm$ 1.222	6.46 $\pm$ 1.19	6.76 $\pm$ 1.33	F= 4.02 *p= 0.021
cd	16.10 $\pm$ 2.46	17.03 $\pm$ 2.87	18.23 $\pm$ 2.89	F= 4.52 *p= 0.013
CCI	0.44 $\pm$ 0.04	0.45 $\pm$ 0.05	0.45 $\pm$ 0.04	F= 0.84 p= 0.432

Considering the gender subjects were grouped as 6-9, 10-13 and 14-17 year old, 2001 modal 1, 5 Tesla (Exelart, Toshiba, Tokyo, Japan) of MRI was used for radiological examination besides using standardt cranial band. Measurements were calculated on midsagittal and T1 sections of MRI as described by Figueira by et al.¹⁰

Corpus callosum index (CCI) was obtained on a conventional best midsagittal T1W image, using a simple orthogonal semi-automated system, by drawing a straight line at greatest anteroposterior diameter of CC and a perpendicular at its midline, owing to points a, b and c (Fig.1). Anterior (aa'), posterior (bb'), medium (cc') segments and cd length of CC were measured and normalized to its greatest anteroposterior diameter (ab), CCI was found for each cases, one by one, from the calculated measurements by (aa' + bb' + cc') / ab = CCI Formula. Obtained data transferred to SPSS (ver: 13.0) programme. Statistical analysis was performed by One-Way ANOVA- Turkey test, Independent Sample t test, Kruskal-Wallis test and

Table-II: Comparison of the CC measurements according to age group and gender.

	6-9			10-13			14-17		
	Male $\bar{X} \pm S$	Female $\bar{X} \pm S$	Result	Male $\bar{X} \pm S$	Female $\bar{X} \pm S$	Result	Male $\bar{X} \pm S$	Female $\bar{X} \pm S$	Result
Ab	61.13 $\pm$ 7.95	61.40 $\pm$ 3.52	p=0.868	64.42 $\pm$ 3.39	62.68 $\pm$ 5.89	p=0.285	65.38 $\pm$ 5.96	66.94 $\pm$ 4.13	p=0.424
aa'	11.20 $\pm$ 2.00	11.20 $\pm$ 1.14	p=0.798	11.85 $\pm$ 2.03	11.68 $\pm$ 1.77	p=0.768	11.61 $\pm$ 1.75	11.82 $\pm$ 1.42	p=0.654
bb'	9.80 $\pm$ 2.59	10.13 $\pm$ 1.40	p=0.950	10.35 $\pm$ 1.78	10.93 $\pm$ 2.76	p=0.865	11.23 $\pm$ 2.58	11.82 $\pm$ 2.21	p=0.308
cc'	5.73 $\pm$ 1.53	6.00 $\pm$ 0.84	p=0.560	6.42 $\pm$ 1.01	6.50 $\pm$ 1.36	p=0.763	6.38 $\pm$ 1.55	7.05 $\pm$ 1.08	p=0.289
Cd	16.33 $\pm$ 2.66	15.86 $\pm$ 2.32	p=0.645	17.42 $\pm$ 3.00	16.68 $\pm$ 2.79	p=0.485	19.15 $\pm$ 2.96	17.52 $\pm$ 2.71	p=0.233
CCI	0.43 $\pm$ 0.05	0.44 $\pm$ 0.04	p=0.633	0.44 $\pm$ 0.05	0.46 $\pm$ 0.05	p=0.183	0.44 $\pm$ 0.04	0.45 $\pm$ 0.03	p=0.391

Table-III: Comparison of the CC measurements according to gender.

	Male n=42 $\bar{X} \pm S$	Female n= 48 $\bar{X} \pm S$	Result
Ab	63.54 $\pm$ 6.36	63.79 $\pm$ 5.14	t= 0.20 p= 0.841
aa'	11.54 $\pm$ 1.91	11.58 $\pm$ 1.47	t= 0.09 p= 0.922
bb'	10.42 $\pm$ 2.36	11.00 $\pm$ 2.27	t= 1.16 p= 0.247
cc'	6.16 $\pm$ 1.39	6.54 $\pm$ 1.18	t= 1.37 p= 0.171
Cd	17.57 $\pm$ 3.03	16.72 $\pm$ 2.66	t= 1.40 p= 0.165
CCI	0.44 $\pm$ 0.04	0.45 $\pm$ 0.04	t= 1.58 p= 0.116

Mann - Whitney U test. Data expressed in tables as arithmetical mean ($\bar{X}$) $\pm$ standart deviation (S), based on 0.05.

RESULTS

Data of ab, aa', bb', cc', cd and CCI values that belong to 90 subjects is showed in Table-I without considering the gender.

According to age group without considering the gender, in comparison between parameters of ab, bb', cc' and cd and age, differences between age group results was found to be statistically significant ($p < 0.05$). While there was a difference in ab, bb', cc' and cd parameters between the age group of 6-9 and 14-17, there was no difference between other ages. Similarly among the age group, aa' and CCI values did not show difference. Data of the ab, aa', bb', cc', cd and CCI, according to age group and gender had been given in Table-II.

In 6-9, 10-13 and 14-17 age group that belong to male and female, values of ab, aa', bb', cc', cd, CCI does not show important significance ($P > 0.05$). Values belong to male and female without considering the age group are given in Table-III.

In comparison of all male and female without separation of age group it did not find any difference. Data belonging to male according to age group is given in Table-IV and to female in Table-V.

In male cases only cd measurement showed difference between the 6-9 and 14-17 age group.

In comparison of ab, bb', cc' parameters of female, and age group, differences between the group was found important ($p < 0.05$). Age group that compared with ab, bb', cc' parameters whereas there

Table-IV: Comparison of the CC measurements belong to male cases according to age group.

	6-9 (n=15) $\bar{X} \pm S$	10-13 (n=14) $\bar{X} \pm S$	14-17 (n=13) $\bar{X} \pm S$	Result
Ab	61.13 $\pm$ 7.95	64.42 $\pm$ 3.39	65.38 $\pm$ 5.96	KW= 2.41 p= 0.298
aa'	11.20 $\pm$ 2.00	11.85 $\pm$ 2.03	11.61 $\pm$ 1.75	KW= 0.58 p= 0.748
bb'	9.80 $\pm$ 2.59	10.35 $\pm$ 1.78	11.23 $\pm$ 2.58	KW= 1.33 p= 0.512
cc'	5.73 $\pm$ 1.53	6.42 $\pm$ 1.01	6.38 $\pm$ 1.55	KW= 2.41 p= 0.289
Cd	16.33 $\pm$ 2.66	17.42 $\pm$ 3.00	19.15 $\pm$ 2.96	KW= 6.39 *p= 0.041
CCI	0.43 $\pm$ 0.05	0.44 $\pm$ 0.05	0.44 $\pm$ 0.04	KW=0.291 p= 0.865

was a difference in 6-9 / 14-17 age and 10-13 / 14-17 age group but 6-9 / 10-13 age group did not show difference. In female cases also could not found difference between the age group and parameters of ab, cd and CCI.

DISCUSSION

The development of the CC has been described to begin at approximately 8 to 10 weeks of gestation.^{11,12} Number of colossal fibers are fixed at birth, however, structural changes at corpus collosium continues due to myelination of fibers during postnatal development, redirection, pruning and myelination.¹³ The complete formation of CC continues to enlarge throughout infancy, childhood, and young adulthood.¹⁴ Schaefer et al stated that growing of CC continues till the 15 year age and during this period it could be reflections of increasing the myelinisation of CC.¹⁵ On the other

Table-V: Comparison of the CC measurements belong to female cases according to age group.

	6-9 (n=15) $\bar{X} \pm S$	10-13 (n=16) $\bar{X} \pm S$	14-17 (n=17) $\bar{X} \pm S$	Result
Ab	61.40 $\pm$ 3.52	62.68 $\pm$ 5.89	66.94 $\pm$ 4.13	KW=12.88 *p= 0.002
aa'	11.20 $\pm$ 1.14	11.68 $\pm$ 1.77	11.82 $\pm$ 1.42	KW=1.72 p= 0.422
bb'	10.13 $\pm$ 1.40	10.93 $\pm$ 2.76	11.82 $\pm$ 2.21	KW=1.33 *p= 0.028
cc'	6.00 $\pm$ 0.84	6.50 $\pm$ 1.36	7.05 $\pm$ 1.08	KW=2.48 *p= 0.029
Cd	15.86 $\pm$ 2.32	16.68 $\pm$ 2.79	17.52 $\pm$ 2.71	KW= 6.39 p= 0.191
CCI	0.44 $\pm$ 0.04	0.46 $\pm$ 0.05	0.45 $\pm$ 0.03	KW= .291 p= 0.263

hand Simon et al claimed growing of CC continues until the 18th year-old.¹⁶ Pujol et al have measured CC area in 90 people by two years and within 14 people aged 11-19 years in their first scanning found out CC area as $535 \pm 93 \text{ mm}^2$ and $591 \pm 106 \text{ mm}^2$ (24.7 ± 5.0) in second scanning.⁸

In our study without considering the gender, according to age group we observed enlargement of CC continued and excluding the aa' other parameters showed statistical significant between the 6-9 age and 14-17 age group ($p < 0.05$).

aa' parameter showing the genu width is observed similar in three age groups. Genu region is linked with the prefrontal cortex which is responsible for higher cognitive functions.¹⁷ Prefrontal cortex, however, is one of the most recently completed structures.¹⁸ Therefore, the lack of difference in genu region among age groups may reflect the development of prefrontal cortex. A similar view by Luders et al is given who stated that growth at back is more dominant to growth in front, moreover, front growth may start in late adolescent period when frontal lobe is actively developed.¹³ Keshavan et al, examining 109 healthy people age ranking 7-32 and differently from our study has reported that between children and adolescent and again between adolescent and young adults, the genu region is significantly increasing.¹⁷ However, in this study, the distribution of age groups is children as: 7-12, adolescents as: 13-20, young adults as: 21-32. obviously doesn't match with the age group in our study. Additionally, in the same study, observed signal intensity has decreased from childhood to young adult age, but this decrease has been reported significant only between children and young adults.¹⁷ Giedd et al, in their study has reported that within CC, especially posterior regions are increasing at age 5-18.¹⁹

The sexual dimorphism of the human corpus callosum (CC) is currently controversial, possibly because of difficulties in morphometric analysis.²⁰ The controversies may be due to differences in sex, age, or race of subjects under study or differences in the method of measurement. In the studies, there are groups stating that there are differences between male and female in respect to CC morphometry,^{7,21} as well as the groups stating no difference.^{5,22,23} Holloway found that splenial portion of the corpus callosum was larger and more bulbous in females than in males.⁶ Ferrario et al have reported that effects are meaningful considering the age increase, while no meaning in respect to genders.²⁴ Ozdemir et al in their study, have reported that there is not a significant

difference due to gender on general shape of the corpus callosum.²⁵

In this study comparison of gender parameters both without separating age group and by separating age group all used parameters in both two conditions, there was no statistical difference between the male and female cases. However, it was found statistically significant in ab, bb' and cc' parameters between the 6-9 and 14-17 age group in female cases, in male cases showed statistical significant only in cd parameter between the same age group.

Figueira et al, in their controlled study with normal group have shown that corpus callosum index (CCI) can be used in long term observation of patients with multiple sclerosis.¹⁰ With this fact, in order to evaluate CC as a whole, in our study, we used Figueira et al formulated CCI in their study. In all three age groups, CCI results were similar, and no difference is observed due to gender. There are so many reasons which may affect CC morphology; such as, demyelinating diseases, congenital anomalies, cerebral infarct.²⁶ In such cases, for evaluation, besides the quantitative methods of area, length, width, we believe usage of a reliability proven index will be useful.

As a result, we observed that CC except from genu regions is being developed significantly from childhood to adult ages and in this growth, the gender does not make difference. We concluded that in studies subjected to CC in respect to pathological differences, it will be useful to consider the same age group data.

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Authors Contribution:

Mehmet Ilkay Kosar, conceived the idea, did examination of the images and manuscript writing.
Vedat Sabanciogullari, did manuscript writing and editing.
Fatma Hayat Erdil, did statistical analysis.
Mehmet Cimen, did review and gave final approval of manuscript.
Mehmet Atalar, Keziban Karacan did data collection and examination of the images.