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Original Article

An MRI study of sex- and age-related differences in the dimensions of the corpus callosum and brain

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ABSTRACT

The primary purposes of this study were to investigate the possible existence of sex- and age-related differences in 1) the various dimensions of the corpus callosum, and 2) its relative position within the brain. Magnetic resonance images (MRI) from 21 females and 14 males, ranging in age from 24 to 80, were reviewed. Only MRI studies without any pathologic findings were included in analysis. The following corpus callosum measurements were done: maximum longitudinal dimension (frontal to occipital pole-AB); maximum vertical dimension (upper to lower surface-CD); length of the genu (EZ/3); length of the splenium (EZ/5); and total longitudinal dimension of the corpus callosum (EZ). Callosal longitudinal dimensions were measured using the Witelson division method, and were correlated with brain dimensions in the same living humans, in order to examine for sex- and age-related differences.

To investigate age-related differences, we stratified the studied population into age subgroups (24-45, 46-65, 66-80). Statistical analysis involved Spearman correlations and Wilcoxon sign ranks tests. Across all subjects, there was minimal variability in the dimensions and relative dimensions of the corpus callosum. The longitudinal dimension of the genu (EZ/3) and total corpus callosum (EZ) were found to be larger in males, whereas the longitudinal dimension of the splenium (EZ/5) was larger in females. Females exhibited a smaller brain vertical dimension versus males. The ratios -EZ:AE and EZ:CD - were larger in females, but the dimensions EZ/3, EZ, and EZ/5 did not vary with gender. Corpus callosum dimensions were statistically less, by 3%, in those over age 45 versus those younger than 45. The corpus callosum's dimensions and position remain stable relative to surrounding brain, but some sex differences exist. Also, the brain and corpus callosum both appear to decrease in size in older individuals. ***Neuroanatomy; 2007; 6: 63–65.***

Key words [corpus callosum] [dimensions] [MRI] [gender] [age] [brain]

Introduction

Corpus callosum dimensions, morphology and sex-related differences have been of interest to scientists, because they influence the performance of callosotomies in patients with intractable epilepsy. Reports describing numerous conflicting studies have been published with respect to variations in the size of the corpus callosum relative to handedness, gender and age. Witelson [1] found that the corpus callosum was significantly larger in left-handed and ambidextrous persons. Kertesz et al [2] identified no differences in callosal size based upon handedness and gender. DeLacoste-Utamsing and Holloway [3] found the splenium to be larger in females. Hayakawa et al [4] found that callosal size decreases in both sexes, and that this reduction in size appears to transpire between the ages of 40 and 60.

The corpus callosum is the main fiber tract connecting the two cerebral hemispheres. The role of the corpus callosum in brain function still is a matter of debate. There is a topographic organization of callosal fibers, which represents the cortical regions that are connected. Fibers connecting frontal regions travel through the anterior aspect of the corpus callosum, while fibers connecting occipital cortices travel through the posterior segment. In this study, we used magnetic resonance imaging (MRI) to measure the longitudinal dimensions of the corpus callosum and its various parts. We also measured the longitudinal and vertical dimensions of the brain, in order to define the relative topographic locations of the corpus callosum within the brain, and to search for any sex- and age-related differences in dimensions or relative position.

Materials and Methods

The various dimensions of the corpus callosum and its relative position within the brain were studied in 35 humans, using brain MRI studies. For each case, a detailed reviewed was conducted to confirm the absence of any pathology. Then, using a mid-sagittal view of the cerebral hemispheres, the following global dimensions were measured: 1) from the frontal to the occipital pole (AB); 2) from the superior to the inferior surface of the brain, including the cerebellum (CD); 3) from the frontal pole to the genu (AE); and 4) from the occipital pole to the splenium (ZB). These measurements were conducted using a straight-line method of measurement (Figure 1). For measurement purposes, by means of the method proposed by Witelson, the corpus callosum (EZ) was subdivided into three regions, according to maximum straight length (Figure 2). The genu, which contains fibers connecting the prefrontal cortices, was defined as the anterior third (EZ/3). The mid-body of the corpus callosum, which contains projections from motor, somatosensory and auditory cortices, was allocated the middle third. The posterior third was subdivided into 1) the posterior fifth (splenium-EZ/5) - containing temporal, parietal and occipital visual fibers - and 2) the isthmus, a region between the mid-body and the splenium, which contains fibers connecting the superior temporal and parietal regions.

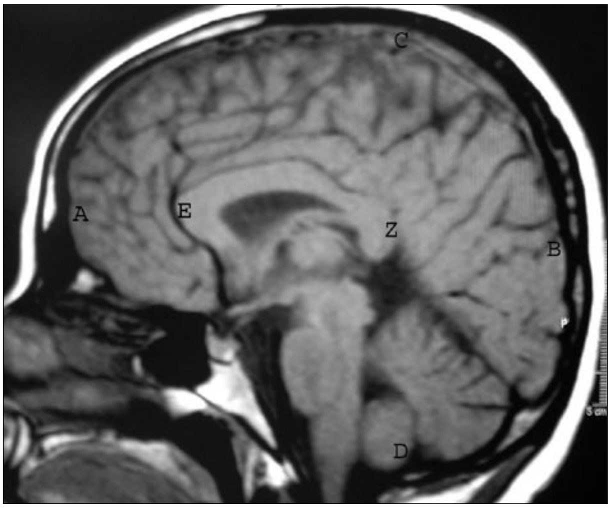

Figure 1. A brain MRI demonstrating the dimensions measured.

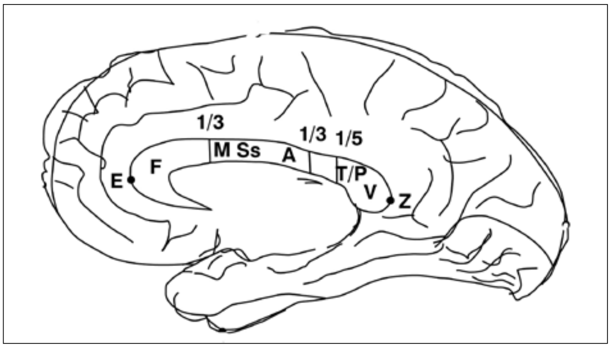

Figure 2. The Witelson dividing method for measurement of the corpus callosum longitudinal dimension.

Subjects were stratified by gender to identify sex-related differences. They also were stratified by age group (24-45, 46-65, and 66-80 years) to assess for any age-related differences in corpus callosum dimensions and relative dimensions.

Statistical analysis was conducted, using SPSS for Windows. In view of the small number of specimens (n=35), both Spearman correlation coefficients and Wilcoxon sign ranks test were conducted. The various dimensions of the corpus callosum - AB, CD, AE, ZB, EZ, EZ/3, and EZ/5 - were correlated with each other. Then, these dimensions were correlated with the global dimensions of the brain, in order to determine whether a stable topographic relationship exists between the various anatomical structures. These findings were then examined for possible sex- and age-related differences. All tests examined for differences at the $p<0.05$ level.

Results

The mean value for the longitudinal dimension of the brain (AB), orientated from the frontal to occipital pole, was 15.25±0.80 cm, while the mean value for the longitudinal dimension of the corpus callosum (EZ) was 6.91±0.51 cm, a ratio of greater than 2:1. The mean value for the longitudinal dimension of the genu (EZ/3) was 2.13±0.38 cm the splenium (EZ/5) 0.74±0.16 cm. The distance between the genu and the frontal pole (AE) had a mean value of 3.16±0.33 cm, while the distance from the splenium to the occipital pole (ZB) was 5.15±0.48 cm, a ratio of approximately 1:1.5. The mean value for the distance between the upper and lower surfaces of the brain, including the cerebellum (CD-vertical diameter), was 12.99±0.74 cm.

A positive linear correlation was evident between AB and CD (r=0.54), and between AB and AE (r=0.46), but not between AB and EZ (r=0.09). A stronger positive correlation (r=0.63) 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=0.54), AE (r=0.43), and BZ (r=0.29), but not with EZ (r=0.09) (Table 1). The ratios of EZ/AB (mean value=0.45), EZ/CD (mean value=0.53), EZ/AE (mean value=2.20), and EZ/BZ (mean value=1.35) varied a little in absolute numbers in all the studied brains.

With respect to sex-related differences, the mean values of the longitudinal dimensions and measured ratios tended to be smaller in women, but only the inter-sex difference in mean value for CD (m=13.36±0.65 cm, f=12.75±0.72 cm) was statistically significant (p=0.016) (Table 2).

In terms of age, there was a statistically-significant decrease in the longitudinal dimensions of the corpus callosum after age 45. The mean length of the corpus callosum was 7.24±0.53 cm in those subjects younger than age 45. It was 6.63±0.37 cm in those older than 45 while in those older than 65 years of age 6.92±0.47 cm (p=0.011) (Table 3). By performing multiple statistical comparisons between the age groups 45-65 and 66-80 for corpus callosum longitudinal diameter (EZ), no statistically significant difference was found.

Discussion

These data demonstrate that the longitudinal and vertical dimensions of the brain and the distance of the corpus callosum from the frontal and occipital poles have a positive linear association. However, there is no statistical relationship between the maximum dimensions of the brain with the longitudinal dimensions of the corpus callosum. This means that the various dimensions of the brain change in concert with each other, thereby maintaining brain symmetry; but they do not directly influence the position and dimensions of the corpus callosum. In other words, the corpus callosum adopts a certain position within the cerebral hemispheres, but its dimensions are not correlated with those of the brain.

The fact that the values of EZ/AB and EZ/CD had a little variation between the subjects studied suggests further that there is symmetry in the distances between every part of the corpus callosum and every part of the brain. Although there is no statistical correlation between corpus callosum and brain dimensions, we could observe from the measurements that there was a symmetry between corpus callosum and brain size, with stable proportions, in every studied individual, a finding which agrees with the conclusions of Estruch et al [5], that corpus callosum size is proportionate to the size of the brain.

Table 1. Correlation-coefficient between the diameters measured-Spearman's rho (n=35).

	CD	AE	BZ	EZ
AB	0.536**	0.464**	0.630**	0.090
CD		0.430*	0.291	0.094
AE			0.176	-0.233
BZ				-0.344*

*** Correlation is significant at the 0.01 level (2-tailed)*
** Correlation is significant at the 0.05 level (2-tailed)*

From the findings of our study, we conclude that brain size does not itself determine the size of the corpus callosum, but that the size of both may be influenced by a common growth mechanism, as shown by the existence of stable dimensional ratios. These findings agree with the findings of Bishop and Wahlsten [6], who further proposed that brain size and weight both are the sum of many components, whether they be viewed as anatomical regions or histological elements. However, that there is a statistical correlation says nothing about the reasons behind the correlation.

Our study indicates that there is no cause and effect relationship, but nonetheless there is some common developmental relationship between the corpus callosum and the brain, a finding that agrees with that of Kawamura et al [7], who, in a series of 23 patients, found that all callosal anomalies were accompanied by hemispheric ones. Although EZ, CD and AE are smaller in females, the ratios EZ/CD and EZ/AE are larger in females, in absolute numbers and not in a statistically significant way, a finding that may reflect another brain-volume arrangement in females.

There appears a statistically-significant reduction in corpus callosum size after the age of 45, a finding that agrees, in part, with the writings of Driesen and Raz [8], who concluded, based upon a meta-analysis of 26 studies, that corpus callosum area does decrease slightly with age. Decreasing callosal size in older patients should be expected, because of the generalized atrophy of cortical neurons that occurs with advancing age. Atrophy not only causes a decrease in the amount of gray matter, but also a loss of white matter. This age-related decrease in neuronal size, number of myelinated fibers, and amount of myelination likely is responsible for the age-related decrease in size of the corpus callosum [2].

Table 2. Group statistics – sex differences.

	Male (n=14) Mean (cm)	Female (n=21) Mean (cm)	p
AB	15.44 (±0.82)	15.14 (±0.80)	0.293
CD	13.36 (±0.65)	12.75 (±0.72)	0.016
EZ	7.02 (±0.58)	6.84 (±0.46)	0.305
EZ/3	2.15 (±0.40)	2.12 (±0.38)	0.819
EZ/5	0.72 (±0.19)	0.75 (±0.15)	0.594
AE	3.25 (±0.32)	3.10 (±0.33)	0.208
BZ	5.16 (±0.40)	5.15 (±0.55)	0.945
EZ/AB	0.45 (±0.04)	0.45 (±0.04)	0.874
EZ/CD	0.53 (±0.05)	0.54 (±0.46)	0.509
EZ/AE	2.18 (±0.28)	2.23 (±0.30)	0.624
EZ/BZ	1.37 (±0.15)	1.35 (±0.20)	0.742

Table 3. Group statistics – age differences.

	Ages 24-45 (n=11)	Ages 46-65 (n=13)	Ages 66-80 (n=11)	p
AB	15.12 (±0.66)	15.46 (±0.96)	15.15 (±0.77)	0.527
CD	12.84 (±0.70)	12.88 (±0.74)	13.28 (±0.78)	0.307
EZ	7.24 (±0.53)	6.63 (±0.37)	6.92 (±0.47)	0.011
EZ/3	2.23 (±0.51)	2.02 (±0.31)	2.16 (±0.30)	0.363
EZ/5	0.79 (±0.14)	0.73 (±0.21)	0.70 (±0.12)	0.432
AE	3.07 (±0.36)	3.16 (±0.28)	3.25 (±0.36)	0.449
BZ	4.97 (±0.36)	5.44 (±0.55)	5.01 (±0.40)	0.027
EZ/AB	0.48 (±0.03)	0.43 (±0.03)	0.46 (±0.04)	0.006
EZ/CD	0.56 (±0.03)	0.52 (±0.04)	0.52 (±0.05)	0.026
EZ/AE	2.38 (±0.26)	2.11 (±0.22)	2.16 (±0.32)	0.056
EZ/BZ	1.46 (±0.17)	1.23 (±0.15)	1.39 (±0.15)	0.003

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