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Original Article

Morphometry of corpus callosum: an anatomical study

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ABSTRACT

The purpose of this study was to measure the longitudinal and vertical diameters of corpus callosum and its parts as well as the brain; in order to define the position of corpus callosum within the brain.

In this study, 42 formalin fixed brains, which were removed from cadavers (23 males, 19 females), aged 30-40 years, were used. Brains were carefully cut in the mediosagittal plane and the medial surface of the brain hemispheres were printed on a transparent sheet of paper. On these papers, the longitudinal diameters of every anatomical part of corpus callosum and longitudinal and vertical diameters of brain hemispheres were measured.

The diameters measured were: the longitudinal (frontal to occipital pole-AB) and the vertical diameter (upper to lower surface of brain hemisphere-CD) of brain hemispheres, the distance of genu to frontal pole (AE), the distance of splenium to occipital pole (ZB), the longitudinal diameter of genu (EZ/3) and splenium (EZ/5), and the longitudinal diameter of CC (EZ). Statistical analysis followed, which was performed by using the 2-tailed Pearson correlation test. AB has a positive linear correlation with CD, AE, BZ and with EZ. EZ has a positive linear correlation with AB and with CD. The ratios EZ/AB=0.46, EZ/CD=0.85, EZ/AE=2.29 and EZ/ZB=1.42 represented stable analogies.

By applying these ratios to radiological images of patients, the neurosurgeons would perform the targeted callosal procedures in a more precise way. ***Neuroanatomy; 2006; 5: 20–23.***

Key words [callosotomy] [corpus callosum] [morphometry] [dissection] [cadaver] [intractable epilepsy]

Introduction

There is a number of studies in literature concerning the diameters, morphology, size, age and sex-related differences of corpus callosum (CC) [1-8]. This scientific interest is due in the performance of callosotomies for intractable epilepsy and in the clinical features and experimental evaluations and observations related to the shape and size of CC.

CC is the main fiber tract connecting the two cerebral hemispheres [9]. There is a topographic organization of callosal fibers, which represents the cortical regions to be connected [10]. Topographically, fibers connecting frontal regions travel through the front of CC and those connecting occipital cortices travel through the posterior part of CC. The role of CC in brain function is still a matter of debate. Agenesis of CC is a congenital abnormality with unclear etiology and pathogenesis, which results in various clinical pictures [11]. In contrast, total corpus callosotomy represents the therapy of choice for patients with intractable epilepsy.

In this study we have measured the longitudinal diameters of human CC itself and its parts, the vertical and longitudinal diameters of brain hemispheres and the distances of CC to the frontal and occipital poles, in order to define the topographic location of CC in brain hemispheres and the way these anatomical structures interact to each other.

Material and Methods

The longitudinal diameters of CC in relation to vertical and longitudinal diameters of brain hemispheres were studied in 42 (23 males and 19 females, aged 30-40 years) formalin fixed adult brains. The brains were removed during autopsies were lack of any visible pathological findings. The technique used was as follows: immediately after removal of the brains from the cranial vault, they were fixed with basilar suspension in 10% formalin solution for four weeks. Thereafter the brains were dissected and CCs were prepared in all their lengths and the midsagittal line of each CC were identified. By using this line as an anatomical landmark, we cut the brains carefully in the midsagittal plane passing from the body of CC, the hemispheric fissure, the septum, third ventricle cavity and aqueduct (Fig. 1). Then methylene blue dye was administered over the medial cut surface of brain and CC; then the outlines of medial hemispheric surface and CC were copied on a transparent sheet of paper. On these papers, the longitudinal diameters of CC, splenium and genu were measured, as well as the distances between the frontal and the occipital poles and also between the superior and the inferior surfaces of brain hemispheres (Fig. 2). For study purposes, CCs were divided with the method proposed by Witelson [11], in which CC has been arbitrarily divided into three regions according to maximal straight length: the anterior third (genu), which contains fibers connecting prefrontal cortices; the mid-third (mid-body) of the CC, which

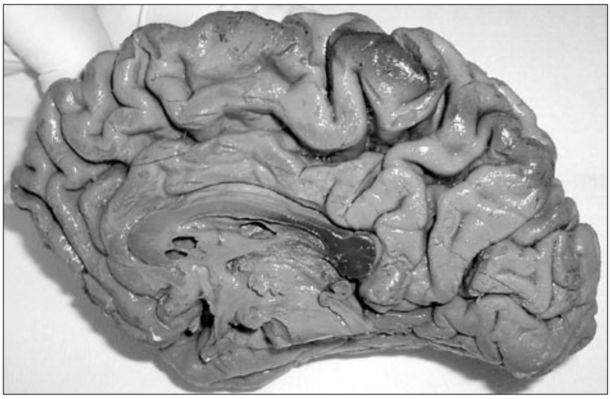

Figure 1. Midsagittal view of corpus callosum (CC) in a cadaveric brain.

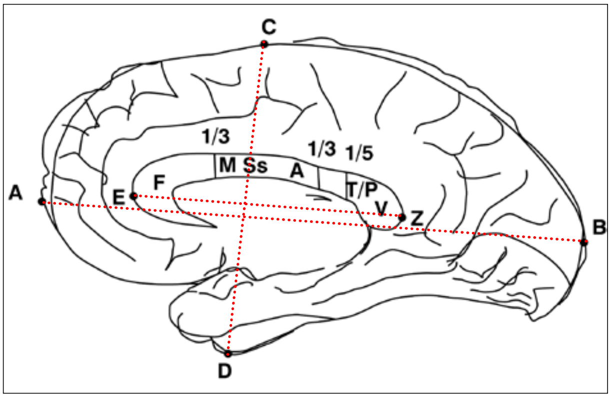

Figure 2. Diagram of the CC, indicating its different regions *(**F**:frontal; **M**: motor; **SS**: somatosensory; **A**: auditory; **T/P**: parietotemporal, **V**: visual).*

contains projections from motor, somatosensory and auditory cortices; and the posterior third, which is divided into the posterior fifth (splenium), that contains temporal, parietal and occipital visual fibers, and the isthmus, a region between the mid body and the splenium, which is believed to contain fibers connecting superior temporal and parietal regions. By using the commercially available statistical program SPSS for MS Windows a statistical analysis of the data (Table 1) was carried out to examine whether any eventual correlation was present between the longitudinal diameters of CC with the longitudinal and vertical diameters of brain hemispheres.

In view of the small number of specimens (n=42), we evaluated the correlation coefficient of the variables-parameters according to Spearman as well as the statistical trial known as "paired t-test" (Wilcoxon sign ranks test). A statistically significant difference was considered to be present when the p value was less than 0.05 in all tests. The correlated statistical parameters were five: AB, CD, AE, ZB, and EZ (EZ/3 or EZ/5). The correlation between the diameters of different anatomical parts of CC as well as the correlation between the longitudinal diameters of CC with the vertical and horizontal diameters of brain hemispheres were analyzed in order to find any stable topographical relationship between these anatomical structures.

Table 1. Diameters of corpus callosum (cm).

Case	AB	CD	AE	BZ	EZ	EZ/3	EZ/5
1	15.0	9.1	3.2	4.9	7.6	2.53	1.52
2	15.3	9.4	3.0	4.7	7.4	2.46	1.48
3	15.6	9.3	3.3	5.1	7.8	2.60	1.56
4	18.2	9.1	3.8	6.4	8.1	2.70	1.62
5	18.0	9.0	3.5	6.3	8.0	2.60	1.60
6	18.4	9.5	4.0	6.8	8.4	2.80	1.68
7	16.8	9.1	3.5	6.4	7.1	2.36	1.42
8	16.5	8.9	3.3	6.2	6.8	2.26	1.36
9	17.1	9.5	3.8	6.7	7.5	2.50	1.50
10	17.1	9.4	3.4	5.6	8.0	2.66	1.60
11	17.5	9.7	3.6	5.8	8.2	2.73	1.64
12	17.8	9.9	3.8	6.0	8.5	2.83	1.70
13	15.1	7.6	3.3	4.8	6.8	2.26	1.36
14	14.8	7.3	3.0	4.5	6.5	2.16	1.30
15	15.5	7.9	3.6	5.1	7.1	2.36	1.42
16	14.2	7.5	3.1	4.1	7.0	2.33	1.40
17	14.0	7.3	2.8	3.9	6.8	2.26	1.36
18	14.8	7.8	3.5	4.6	7.3	2.43	1.46
19	16.0	7.9	3.5	5.6	6.6	2.20	1.32
20	15.8	7.7	3.3	5.3	6.3	2.10	1.26
21	16.5	8.3	3.8	6.0	7.0	2.33	1.40
22	15.3	8.4	2.9	4.7	7.8	2.60	1.56
23	15.0	8.2	2.6	4.4	7.5	2.50	1.50
24	15.8	8.8	3.3	5.2	8.2	2.73	1.64
25	15.5	7.9	3.1	4.7	7.8	2.60	1.56
26	15.0	7.7	2.8	4.5	7.5	2.50	1.50
27	15.9	8.3	3.5	4.9	8.1	2.70	1.62
28	15.7	9.6	3.7	4.8	7.0	2.33	1.40
29	15.0	9.3	3.4	4.6	6.8	2.26	1.36
30	16.0	10.0	4.0	5.1	7.2	2.40	1.44
31	15.2	9.6	2.9	5.2	7.1	2.36	1.42
32	14.8	9.3	2.7	5.1	6.8	2.26	1.36
33	15.3	10.0	3.1	5.5	7.3	2.43	1.46
34	16.2	8.5	3.8	4.9	7.6	2.53	1.52
35	16.0	8.3	3.6	4.7	7.3	2.43	1.46
36	16.5	8.7	4.1	5.3	8.0	2.66	1.60
37	16.1	8.7	3.4	5.7	7.0	2.33	1.40
38	15.8	8.3	3.2	5.5	6.8	2.26	1.36
39	16.5	8.8	3.7	5.9	7.4	2.46	1.48
40	15.0	8.4	2.2	5.0	7.8	2.60	1.56
41	14.8	8.2	2.3	5.1	7.5	2.50	1.50
42	15.3	8.8	2.4	5.4	8.3	2.76	1.66

Results

The mean value for the longitudinal diameter of the brain (AB), defined as the distance from the frontal to occipital pole was 15.87 cm, whilst the mean value of the longitudinal diameter of the CC (EZ) was 7.41 cm, with an analogy 2/1. The mean value of the distance between the upper to the lower surface of the brain hemisphere (CD-vertical diameter) covered a length of 8.69 cm. The mean value for the longitudinal diameter of the genu (EZ/3) was 2.46 cm and that of the splenium was (EZ/5) 1.48 cm.

The distance between the genu to the frontal pole (AE) had a mean value of 3.35 cm, whilst the distance of the splenium to occipital pole (ZB) 5.26 cm, actually with an analogy 1/1.5.

Statistical analysis followed, which showed the existence of a positive linear correlation between AB and all the other parameters CD, AE, BZ, EZ; but stronger was the positive correlation with BZ (distance between splenium and occipital pole). CD (vertical brain diameter) had a positive linear association with the four other measured parameters, the stronger with BZ. EZ had a positive linear relation with AB and CD and no relation with AE, BZ (Table 2).

The ratios EZ/AB=0.47 (p=0.736) and EZ/CD=0.86 (p=0.857) represented stable, statistically significant proportions, which was present in all the brain specimens studied.

With regression analysis, we looked over for any correlation between the longitudinal diameters of CC (EZ) with both the longitudinal (AB) and vertical (CD) diameters of brain hemispheres and found a strong, statistically significant relation between the longitudinal diameter of CC (EZ) and longitudinal diameter of the brain (AB), however no association with the vertical diameter of brain hemispheres (CD) was present (Table 3).

Discussion

In all brains we examined, all the measurements were within certain limits; and the ratios between the diameters of CC and those of brain hemispheres were stable. This means that CC had a stable position in brain hemispheres, which was retained in every brains studied.

The longitudinal and vertical diameters of the brain had a positive linear association between each other, as did the distances of CC from the frontal and occipital pole, which means that augmentation of one diameter was associated with the augmentation of the other in a parallel manner, so that the symmetrical size of the brain was retained. Astonishing is the finding that the longitudinal diameter of the brain had the strongest correlation with the distance between the splenium to the occipital pole, which may present the importance of the visual cortices fiber distribution. The distance of the genu from the frontal pole had a positive linear correlation with the distance of splenium from the occipital pole, but both diameters had no relation with the longitudinal diameter of CC. These findings suggest that there is a symmetry between all the diameters of brain hemispheres; although these distances play a role in the maintenance of the symmetrical size of brain, they do not influence the position of CC. While analyzing the relationship between CC and longitudinal and vertical diameters of the brain simultaneously, we have found that only the longitudinal diameter of the brain had a statistically significant correlation with the longitudinal diameter of CC, while the vertical diameter of brain did not.

Table 2. Correlation-coefficient between the diameters measured-Spearman's rho (n=35).

	CD	AE	BZ	EZ
AB	0.475**	0.769**	0.819**	0.402**
CD		0.336*	0.513**	0.371*
AE			0.499**	0.184
BZ				0.256

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

Table 3. Correlation between CC and both diameters of the brain.

Model	Unstandardized coefficients		Standardized coefficients	t	p
	B	Std. Error	Beta		
Constant	2.774	1.192		2.327	0.025
AB (cm)	0.214	0.084	0.403	2.559	0.014
CD (cm)	0.144	0.115	0.196	1.244	0.221

Dependent variable: EZ (cm)

Anatomically, this finding means that the longitudinal diameter of brain interacts for the horizontal site of CC, whilst the vertical diameter is less important. Further the ratios EZ/AB = 0.47 and EZ/CD = 0.86 were found to be stable analogies in every individual that were studied. All these findings suggest that there is a quotation, a symmetry and stable proportions in every studied brain. These should be taken into account as stable anatomical data before performing some neurosurgical procedures [12] so as undesired intervention dependent clinical outcomes could be avoided [9].

There is a positive correlation between the size of brain and respective size of CC, a finding which is consistent with the findings of the study of Estruch et al [13]; in which they studied CC atrophy among alcoholic patients with severe cortical damage, and imposed that the size of CC depends on the size of the brain. From the clinical point of view, all these findings suggest that CC can be found in a certain place in brain hemispheres, depending on the size itself and that of the brain, a fact that is very important in callosotomy procedures for intractable epilepsy cases [14, 15].

The extent of callosal resection has long been an issue of controversy, and several authors have analyzed the surgical outcomes of their series from this perspective.

In cases of frontal localization of the cortical epileptogenic focus, patients benefit from anterior callosotomy [16, 17]. It has been hypothesized that the neuropsychological sequel may be less pronounced if some of the CC, particularly the splenium is preserved [16, 17]. Furthermore, scientists recently focused on the performance of more targeted callosal interventions like stereotactic coagulation in the genu of the CC in aggressive patients [18].

By knowing the analogies and quotes of our study and by applying them on MRI images, it could be easier to define anterior CC and perform anterior callosotomy. When intended to preserve the splenium; the knowledge and application of these analogies and quotes are even more necessary.

These anatomical relationships should be taken into account in every instance of callosotomies for some types of generalized epileptic attacks.

These neurosurgical needs described from the above mentioned studies together with the quotes measured in our study could help to perform targeted callosal interventions (surgical, stereotactic) even more precisely, as a first choice therapy, prior to total callosotomy. We believe that not only the diameters but also the shape of CC itself and of its regions must be studied before performing the callosotomies for intractable epilepsy and that could be the issue of further scientific research.

Conclusion

The anatomical parts of CC have a stable proportion to each other; and the position of CC within the brain is stable, mostly in its horizontal position. Brain retains its symmetry but does not influence the size and position of CC. Stable proportions, ratios and resulting analogies, when applied on MRI images, could facilitate the planning of callosal interventions for intractable epilepsy or other targeted neurosurgical procedures.

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