# The size of corpus callosum normalized by the intracranial or brain parenchymal volume exhibits a significant difference between male and female brains

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## Introduction

Recently it has been recognized that the architecture of male and female brains differs quite a bit [1]. Corpus callosum is one of the foci of such arguments. It was reported that adult females have larger corpus callosum and more bulbous splenium [2], but there were a report which failed to replicate this difference [3]. Despite decades of research, there is still no agreement over the presence of sex-based morphologic differences in the human corpus callosum. In this study, mid-sagittal plane of corpus callosum was extracted from $T_1$-whighted 3D image with 1mm$^3$ spatial resolution and with high contrast between brain tissues at 4.7T. The purpose of this study was to measure the size of the corpus callosum in normal adult male and female volunteers, and to identify sex- and age-related differences in it.

## Materials and Methods

All the measurements were performed on a MRI system (Varian,Palo Alto) equipped with a 4.7Tesla/92cm magnet. 3D Modified DEFT (MDEFT) images of the brain were obtained in 33 male (Age: 21-65) and 36 female (Age: 23-55) volunteers with the optimized parameters for 4.7T [4]. We made segmented probability images of gray matter (GM), white matter (WM), and CSF from the 3D MDEFT image with the previously reported procedure [5]. Tissue volume was calculated by summing the products of a pixel volume and a probability in each pixel. To align the mid-sagittal plane in the sagittal slice, the probability image of WM was rotated along y and z axes, and resliced using MEDx software. From this probability image the mid-sagittal cross-section of corpus callosum was manually extracted. The cross-sectional area of corpus callosum was calulated by summing the products of a pixel area and a probability in each pixel. To avoid individual differences in the size of brain and age-dependent changes we normalized the area by the sum of GM,WM and CSF (intracranial volume) or that of GM and WM (volume of the brain parenchyma) in each subject.

## Results and Discussions

Figure 1 shows a mid-sagittal plane of corpus callosum extracted from a WM probability image obtained in a healthy volunteer subject. Table 1 compares the absolute and normalized area of corpus callosum between male and female along with the absolute and normalized volumes of GM and WM. Both the absolute and normalized size of corpus callosum showed any particular age-dependences in either male or female (Fig.2). Average area of corpus callosum in healthy subjects were 550±100mm$^2$ in male (n=33), and 538±67mm$^2$ in female (n=36). Student t-test gives no significant difference. On the other hand, either normalized area of corpus callosum showed a significant difference ($p<0.05$) between male and female. This is in contrast to the observation that the absolute volume of GM exhibited significant sex-difference ($p<0.0001$), whereas it disappeared after the volume was normalized by an intracranial or parencymal volume. WM was very similar to GM except that the normalized volume by the intracranial volume showed a significant sex-difference. Since dispersion in the data (SD/mean in Table1) was reduced in all the items probably due to the compensation in individual size differences or age-dependent changes in the brain, we should perform the comparison after the normalization. From these results we concluded that the absolute cross sectional area between male and female is similar, whereas the normalized area by intracranial or parencymal sizes exhibits sex-difference.

Figure 1. A mid-sagittal plane of corpus callosum

Table 1 Mean±SD in the size of corpus callosum, GM, and WM in male and female brain.

| | | absolute value | normalized I | nourmalized II |
|---|---|---|---|---|
| corpus callosum (area:mm$^2$) | male | 550±100 | (0.39±0.07)×10$^{-3}$* | (0.46±0.08)×10$^{-3}$* |
| | female | 538±67 | (0.43±0.05)×10$^{-3}$ | (0.50±0.06)×10$^{-3}$ |
| GM (volume:mm$^3$) | male | (699±71)×10$^3$*** | 0.50±0.02 | 0.58±0.02 |
| | female | (624±42)×10$^3$ | 0.50±0.02 | 0.57±0.02 |
| WM (volume:mm$^3$) | male | (502±65)×10$^3$** | 0.36±0.02* | 0.42±0.02 |
| | female | (465±46)×10$^3$ | 0.37±0.02 | 0.43±0.02 |

normalized I : normalized with an intracranial volume
normalized II : normalized with a volume of the brain parenchyma
(Student-t test coefficient *p<0.05 **p<0.01 ***p<0.001)

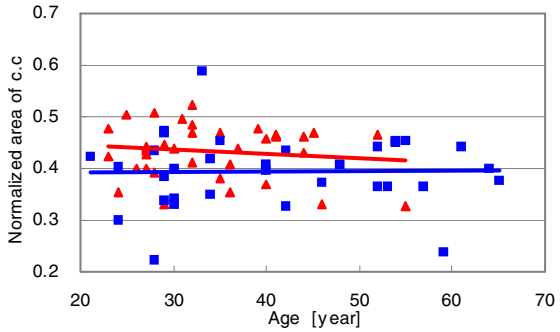


Figure 2. Age-dependence in the area of corpus callosum normalized by an intracranial volume in male and female brains.
■ and blue line: male ▲ and red line: female

## References

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