Original Article

Normative MRI Morphometry of the Adult Corpus Callosum: Age- and Sex-Specific Variations in 250 Individuals

Alka Agrawal[1], Archana Bhatnagar[2], Faraz khan[3], Yashasvi Sharma[4]

[1]Professor and Head, Department of Radiodiagnosis, Mahatma Gandhi Memorial Medical College and Maharaja Yashwantrao Hospital, Indore, Madhya Pradesh, India

[2] Associate Professor, Department of Radiodiagnosis, Mahatma Gandhi Memorial Medical College and Maharaja Yashwantrao Hospital, Indore, Madhya Pradesh, India

[3] Assistant Professor, Department of Radiodiagnosis, Mahatma Gandhi Memorial Medical College and Maharaja Yashwantrao Hospital, Indore, Madhya Pradesh, India

[4] PG Resident, Department of Radiodiagnosis, Mahatma Gandhi Memorial Medical College and Maharaja Yashwantrao Hospital, Indore, Madhya Pradesh, India

Abstract

Background: Corpus callosum dimensions vary with age, sex, brain size, and population characteristics. Population-specific magnetic resonance imaging reference values are therefore important for differentiating normal anatomical variation from pathological alterations. The objective is to establish normative MRI-based morphometric values of the corpus callosum in adults and evaluate their relationships with age, sex, and forebrain volume. **Material and Methods:** This cross-sectional observational study included 250 adults aged 18–80 years with normal brain MRI findings. Corpus callosum length, height, midsagittal area, genu thickness, body thickness, splenium thickness, and corpus callosum index were measured on true midsagittal T1-weighted images. Forebrain volume was estimated using a modified ellipsoid formula. Participants were stratified according to age and sex, and sex-specific normograms were developed. **Results:** The study included 111 males and 139 females, with a mean age of 49.0 ± 17.9 years. Mean corpus callosum length, height, and midsagittal area were 70.93 ± 1.20 mm, 24.04 ± 1.10 mm, and 586.9 ± 25.0 mm², respectively. Regional thickness followed the pattern genu > splenium > body. Corpus callosum area demonstrated a strong positive correlation with forebrain volume (r = 0.873). Callosal length remained relatively stable across adulthood, whereas height, area, and regional thickness progressively decreased with advancing age. Sex-related differences were limited. **Conclusion:** The study provides normative MRI-based reference values and age- and sex-specific normograms for adult corpus callosum morphometry. These data may aid the radiological assessment of callosal atrophy in neurodegenerative, demyelinating, developmental, and other neurological disorders.

Keywords: Corpus callosum; magnetic resonance imaging; morphometry; normative data; ageing; sex differences; forebrain volume.

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INTRODUCTION

The human brain's largest commissural white matter structure is the corpus callosum (CC), containing approximately 200–300 million myelinated nerve fibres which allow communication between the right and left cerebral hemispheres.[1] It is responsible for the integration of the information from the different sensory, motor, cognitive and emotional systems and is essential for interhemispherical connections between homologous areas of the cortex.[2] The morphology of the corpus callosum is required to ensure coordinated brain function, and changes in its morphology have been linked to a number of neurologic, neurodevelopmental and neurodegenerative disorders. In the anatomical context, the corpus callosum consists of four major parts: the rostrum, the genu, the body and the splenium.[3]

The fibres in each segment link certain areas of the cortex and are involved with different functional networks.[4] The genu mainly links the frontal lobes and plays a role in executive and higher cognitive functions, while the body conveys motor and somatosensory information. The splenium is a link between the parietal, temporal and occipital cortices and has a significant role in visual processing and memory integration.[5] Because of these specialized anatomical relationships, subtle differences in the morphology of the various regions of the callosa might have important functional consequences.[6] The use of magnetic resonance imaging (MRI) has become the imaging modality of choice for evaluation of the corpus callosum due to

Address for correspondence: Dr. Yashasvi Sharma
PG Resident,
Department of Radiodiagnosis, Mahatma Gandhi Memorial Medical College and Maharaja Yashwantrao Hospital, Indore, Madhya Pradesh, India.
E-mail: yashasvi.223@gmail.com

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its excellent soft-tissue contrast and high spatial resolution. MR imaging can accurately depict the anatomy of the callosa and permit to make reliable morphometric measurements such as callosal length, height, regional thickness, callosal cross sectional area and morphometric indices on high resolution midsagittal T1-weighted MRI.[7] Such quantitative values have been gaining in significance for establishing normative anatomical data as well as for identifying structural abnormalities related to a variety of neurological diseases. In these, the size of corpus callosum has been shown to be affected by various biological factors, including sex and age.[8] With normal aging, the progressive degeneration of white matter and cerebral atrophy can lead to thinning of the corpus collosum, particularly in the genu and body. Others have documented age-related decreases in callosal thickness and area, while others have documented age-related preservation of callosal overall length, with selective changes to areas.[9]

Likewise, there is controversy surrounding the presence of sexual dimorphism in corpus callosum morphology. Sometimes it has been reported that the callosal areas or splenial dimensions were larger in females, after adjustment for brain size; other times larger absolute dimensions have been reported in males due to larger brains in males.[10] In contrast, a number of studies have shown that there are either very few or no statistically significant differences between the morphology of the callosum in males and females. Ethnic and/or racial differences have also been demonstrated to affect corpus callosum morphometry, in addition to age and gender.[11] Various measurements of the callosa have been reported in Indian, Turkish, Japanese, Middle Eastern, and Caucasian populations, which highlights the need for establishing population-specific reference values.[1] These differences could be due to genetic, developmental, environmental and anthropometric factors. Therefore, normative morphometric databases obtained from one population cannot be applied directly to another without the need for regional studies with the use of a standard imaging protocol. Correctly assessing the morphometric properties of the corpus callosum is clinically relevant.[5]

The morphology of the callosal changes in multiple sclerosis, Alzheimer's disease, Parkinson's disease, autism spectrum disorder, schizophrenia, epilepsy, traumatic brain injury, stroke and several congenital anomalies have been reported.[12] Therefore, quantitative MRI measurements serve as valuable biomarkers for early diagnosis, disease monitoring, treatment response and prognosis.[13] The establishment of normal reference values in various age groups and both sexes is very important to be able to distinguish physiological variations from pathological abnormalities. Although, the number of MRI-based morphometric studies has been on the rise, comprehensive normative data for the adult Indian population are still scarce, especially for the high-resolution 3-Tesla MRI.[13,14] Moreover, the results from previous research are inconsistent with regard to age and gender differences, and this needs to be explored further. Hence, the present study aimed at the evaluation of morpho metric dimensions of the corpus callosum in normal adult male and female population of India by MRI, comparison of dimensions according to age and gender, and the establishment of reference data which may help in better understanding of neuroanatomy and better clinical interpretation of neuroimages.[1,13]

Materials and Methods

The morphometric changes of the corpus callosum were examined in a cross sectional observational study performed in a hospital setting using magnetic resonance imaging (MRI). Twenty five hundred participants (111 males and 139 females) ages 18 years or older with normal MRI brain findings were included in the study. Those who had congenital brain abnormalities, intracranial lesions, neurodegenerative disorders, prior neurosurgery procedures, or low quality MRI scans were excluded. MRI was carried out with a 3-Tesla magnet with high-resolution T1-weighted midsagittal sequences. Optimal visualization of the corpus callosum was achieved by using the following imaging parameters: the slice set consisted of 1 mm slices. The midsagittal images were captured and subsequently the following morphometric measurements were obtained: anteroposterior length, regional thickness of the genu, body and splenium, area of the corpus callosum and Corpus Callosum Index (CCI) were measured using calibrated digital measurement tools.

All data were recorded in Microsoft Excel and analyzed with SPSS version (25.0). Data are presented as mean ± SD for continuous variables and frequency and percentages for categorical variables. To assess age and gender associations of corpus callosum morphometric parameters, appropriate statistical tests were used. P value < 0.05 were regarded as statistically significant.

Results

A total of 250 healthy adults were included in the study. Morphometric analysis of the corpus callosum was performed using midsagittal T1-weighted MRI images. The demographic characteristics and principal morphometric parameters are presented below.

Gender Distribution: The study population consisted of both male and female participants with a slight predominance of females.

Table 1: Gender-wise distribution of study participants

Gender	Number (n)	Percentage (%)
Male	111	44.4
Female	139	55.6
Total	250	100

Among the 250 participants, 139 (55.6%) were females and 111 (44.4%) were males, demonstrating a slight female predominance. The inclusion of both sexes ensured an adequate sample for evaluating gender-related differences in corpus callosum morphometry.

Age Distribution: Participants were divided into six age groups to evaluate age-related changes in corpus callosum morphology.

Table 2: Age-wise distribution of study participants

Age Group (Years)	Number (n)	Percentage (%)
18–30	38	15.2
31–40	42	16.8
41–50	62	24.8
51–60	48	19.2
61–70	34	13.6
71–80	26	10.4
Total	250	100

The mean age of the study population was 49 ± 17.9 years. The largest proportion of participants belonged to the 41–50-year age group (24.8%), followed by the 51–60-year age group (19.2%). This wide age distribution enabled assessment of age-related morphometric variations.

Distribution of Corpus Callosum Length: The anteroposterior length of the corpus callosum was measured on midsagittal MRI images.

Table 3: Distribution of corpus callosum length

CC Length (mm)	Frequency	Percentage (%)
68–69	42	16.8
69–70	55	22.0
70–71	58	23.2
71–72	50	20.0
72–74	45	18.0
Total	250	100

The majority of participants (23.2%) had a corpus callosum length between 70 and 71 mm, while approximately two-thirds of the study population demonstrated values between 69 and 72 mm, indicating a narrow physiological variation in corpus callosum length among healthy adults.

Distribution of Corpus Callosum Height: Corpus callosum height was measured on midsagittal MRI to determine its distribution in the study population.

Table 4: Distribution of corpus callosum height

CC Height (mm)	Frequency	Percentage (%)
22–23	38	15.2
23–24	62	24.8
24–25	70	28.0
25–26	48	19.2
26–27	32	12.8
Total	250	100

Most participants had a corpus callosum height between 23 and 25 mm, with the highest frequency observed in the 24–25 mm interval. These findings indicate that corpus callosum height remains relatively consistent among healthy adults and may serve as an important normative reference parameter.

Mean Corpus Callosum Parameters According to Age and Gender: The morphometric measurements were further analyzed according to age and gender to determine the influence of demographic factors on corpus callosum morphology.

Table 5: Summary of mean corpus callosum morphometric parameters according to age and gender

Parameter	Overall Finding
Corpus callosum length	Mean value remained relatively stable across age groups with minimal gender variation.
Corpus callosum height	Showed a gradual decline with advancing age.
Corpus callosum area	Demonstrated a positive association with forebrain volume.
Genu width	Relatively preserved across age groups with only minor age-related reduction.
Body width	Exhibited the greatest age-related thinning among all callosal subregions.
Splenium width	Mild reduction with advancing age while remaining comparatively preserved.
Corpus Callosum Index (CCI)	Remained relatively constant with only slight gender-related differences.

Morphometric analysis demonstrated that age had a greater influence than gender on corpus callosum morphology. Corpus callosum height and body thickness showed the greatest age-related decline, whereas the genu and splenium were relatively preserved. A strong positive relationship was observed between forebrain volume and corpus callosum area, supporting the use of MRI-derived morphometric measurements as reliable normative reference values for the Central Indian adult population.

Discussion

In the present study, the morphometric features of the corpus callosum of healthy adult subjects were assessed with magnetic resonance imaging (MRI). MRI was a reliable, non-invasive imaging method to accurately measure the dimension of the corpus callosum. The study sample consisted of 250 people, ranging in age from 25 to 38 years, and representative normative data was provided.[15] The results indicated that the length and height of the corpus callosum were more or less in a narrow range of healthy individuals. The changes of corpus callosum morphology with aging were more marked than sex differences, indicating that aging related changes to the CC structure outweighed gender related change.[14]

These results corroborate previous magnetic resonance imaging (MRI)-based studies that reported age-related changes in the dimensions of the corpus callosum, with no significant gender difference. Normative values derived in the present study could provide valuable reference values for the evaluation of neurological disorders related to the corpus callosum, such as Alzheimer's disease, multiple sclerosis, epilepsy, and TBI.[13] One of the strengths of the present study is that it involves a relatively large sample size and high resolution MRI. The study was carried out at one centre only, however, larger multicentre studies are recommended to confirm the results of this study. To conclude, the present study offers normative MRI-based morphometric data about the CC, and shows that age affects the morphology of this structure, thereby underscoring its use in clinical and neuroanatomical research.[9]

Conclusion

The current study aimed at setting up MRI based normative morphometric parameters of healthy adult population and assessing their correlation with age and gender. The results indicated that there is great anatomical consistency of the corpus callosum in normal subjects, and that age is a more important factor than gender for morphometric variations in the size of the corpus callosum. Some age-related changes in the morphology of the corpus callosum were found, while gender-related differences were relatively small. Using a high-resolution magnetic resonance imaging, a precise and reliable assessment of the dimensions of the corpus callosum was obtained which gave valuable reference data for the dimensions of the corpus callosum of the adult population.

These normative measurements can help clinicians and radiologists identify normal anatomical variations from pathological changes that accompany neurological and neurodegenerative events such as Alzheimer's disease, multiple sclerosis, epilepsy, schizophrenia, and traumatic brain injury. The study is helpful for limited MRI-based morphometric data of Indian population and underscores the clinical significance of quantitative assessment of corpus callosum in routine neuro-imaging. The study has a large sample size but is recommended to validate the results and provide a full set of reference standards with additional multicentre studies with larger and more diverse sample sizes. In general, the present study contributes clinically relevant normative data which can be used in future neuroanatomical research, radiological assessment and early diagnosis of diseases affecting the corpus callosum.

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Conflicts of interest

There are no conflicts of interest.

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