

An MRI-Based Normative Morphometric Atlas of the Corpus Callosum and Ventricular System in a Northwestern Nigerian Population: A Descriptive Cross-sectional Study

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ABSTRACT

Background: Accurate morphometric definition of the corpus callosum (CC) and ventricular system is important for clinical neuroradiology and neuroanatomic research. Northwestern Nigeria lacks population-specific normative MRI data for adults, limiting accurate anatomical interpretation and diagnostic accuracy. **Objective:** To determine the MRI-based morphometric dimensions of the corpus callosum and ventricular system among neurologically normal adults in Northwestern Nigeria. **Methods:** A retrospective cross-sectional study of 422 MRI scans of adults (18 to 80 years) from Usmanu Danfodiyo University Teaching Hospital, Sokoto. Using sagittal T1-weighted and axial T2-weighted sequences, CC (rostrum, genu, body, and splenium) and ventricular subregions (lateral, third, and fourth ventricles; frontal and posterior horns) were identified. Measurements followed standardised protocols. Sex-stratified descriptive statistics and percentile-based reference ranges (2.5th-97.5th) were assessed. **Results:** The anteroposterior length of the CC was approximately 68.1 mm to 81.3 mm, and other sub-regions of the callosal region exhibited low dispersion, implying that there is a stable midline morphology. An increased range of variance was observed in the ventricular dimensions, with a mean lateral ventricular width of 8.01 ± 0.799 mm, a third ventricular width of 4.19 ± 0.869 mm, and a frontal horn width of 33.32 ± 0.264 mm. A normative percentile range of all the CC and ventricular measurements was established. **Conclusion:** This study presents the first comprehensive MRI-based normative morphometric atlas of the corpus callosum and ventricular system for adults in northwestern Nigeria. Such reference data promote anatomical understanding and aid accurate neuroradiological analysis in clinical practice.

Keywords: Corpus callosum, Ventricular system, Brain morphometry, Normative data, Neuroanatomy

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INTRODUCTION

The corpus callosum (CC) and ventricular system are critical structural components of the human brain whose morphometric characteristics have important applications in neuroscience, neuroradiology, and clinical neurology. The CC,

the largest white matter commissure, facilitates interhemispheric integration of sensory, motor, and cognitive functions through its anatomically distinct subregions, including the genu, body, splenium, and rostrum [1–3]. Morphometric alterations in

these regions, such as reduced genu or splenial thickness and changes in callosal length or height, have been associated with neurodevelopmental disorders, traumatic brain injury, and neurodegenerative diseases [4,5]. Similarly, measurements of the ventricular system, including lateral ventricular width, frontal and posterior horn dimensions, third ventricular width, and derived indices such as the Evans and bicaudate indices, provide valuable markers of intracranial dynamics [6]. Enlargement of these structures is widely used in the assessment of hydrocephalus, cerebral atrophy, and neuroinflammatory disorders, while more subtle changes may indicate early neurodegeneration or abnormalities in cerebrospinal fluid circulation [7,8].

Despite their clinical importance, normative morphometric reference data are derived predominantly from populations in Europe, North America, and East Asia, where large-scale MRI studies have established widely used quantitative atlases [9-11]. Because brain morphology is influenced by cranial size, genetic background, and environmental factors across the lifespan [12,13], reliance on non-representative reference values may compromise diagnostic accuracy and clinical interpretation [14]. Comparative neuroanatomical studies have demonstrated population-specific differences in callosal morphology, ventricular dimensions, and cranial proportions, indicating that structural normative values are not universally applicable [14-16]. In sub-Saharan Africa, the limited availability of advanced neuroimaging until recent years has

resulted in relatively few morphometric studies, most of which involve small sample sizes and lack comprehensive, sex-stratified normative datasets [15]. Consequently, clinicians and researchers often depend on reference values derived from non-African populations that may not adequately reflect the neuroanatomical diversity of the region.

Nigeria, with its large and ethnically diverse population, represents an important setting for the development of population-specific neuroimaging reference standards. However, existing MRI morphometric studies are largely limited by small sample sizes or focus on isolated callosal or ventricular measurements rather than comprehensive morphometric assessment [15,17]. Northwest Nigeria remains particularly underrepresented despite its large population and expanding access to advanced neuroimaging facilities. Developing region-specific normative data would provide objective reference values for clinical interpretation, improve the detection of subtle structural abnormalities, and support future neuroimaging research, including machine learning applications and cross-population comparisons [19-24]. Therefore, this study aimed to develop an MRI-based normative morphometric atlas of the corpus callosum and ventricular system in adults from Northwest Nigeria. The resulting atlas is expected to enhance context-specific neurodiagnostic decision-making and provide a valuable reference for future neuroimaging and anthropometric research in Nigeria and the wider West African region.

METHODOLOGY

Study design and setting:

This retrospective cross-sectional study utilized archived brain MRI scans acquired between 2019 and 2024 at the Department of Radiology, Usmanu Danfodiyo University Teaching Hospital (UDUTH), Sokoto, Northwestern Nigeria.

Participants

A total of 578 archived brain MRI scans were screened. Sample size was estimated using the single population proportion formula with a 95% confidence level, 5% margin of error, and an assumed prevalence of 50%, yielding a minimum sample size of 384 participants [27]. To maximize statistical power and improve the precision of normative estimates, all eligible scans meeting the

inclusion criteria were analyzed, resulting in a final sample of 422 participants [15].

Inclusion Criteria: Adults aged 18–80 years with MRI scans reported as normal and free of imaging artefacts were included.

Exclusion Criteria: Individuals younger than 18 years or older than 80 years were excluded to minimize the effects of ongoing brain maturation and advanced age-related cerebral changes. Additional exclusion criteria included intracranial lesions, traumatic brain injury, cerebrovascular disease, demyelinating or neurodegenerative disorders, congenital abnormalities of the corpus callosum or ventricular system, previous neurosurgical intervention, psychiatric or neurological illness, and a history of psychopharmacotherapy.

Overall, 156 scans were excluded: 64 with intracranial pathology, 38 with significant motion or imaging artefacts, 27 with previous trauma or neurosurgery, 19 with neurodegenerative or demyelinating disorders, and 8 with congenital structural abnormalities of the corpus callosum or the ventricular system.

Study Procedures:

i) MRI Protocol

MRI examinations were performed using a 1.5-T Siemens Avanto scanner (Erlangen, Germany) equipped with a circularly polarised head coil. Standard institutional brain MRI protocols were used, including axial T2-weighted turbo spin-echo (TR/TE 4500/118 ms, slice thickness 6 mm, interslice gap 1.5 mm, field of view 230–240 mm) and midsagittal T1-weighted spin-echo sequences (TR/TE 450/11 ms, slice thickness 5 mm, interslice gap 1.5 mm, field of view 230 mm). All images were exported in DICOM format and analyzed using RadiAnt DICOM Viewer.

ii) Morphometric Variables

Corpus Callosum Subregions

Measurements were obtained from midsagittal T1-weighted images and included the thickness of the rostrum, genu, body, and splenium, as well as corpus callosum length, maximum height, and anteroposterior cranial length (Figure 1). Anatomical landmarks were identified according to established neuroanatomical guidelines described by Allouh *et al.* [16].

Ventricular Parameters

Ventricular measurements included right and left lateral ventricular widths, frontal horn width and length, posterior horn width, total ventricular length, third ventricular width, and the anteroposterior diameter of the fourth ventricle. Measurements were obtained from axial and sagittal T2-weighted images. Evans Index and Bicaudate Index were calculated to assess global ventricular proportions (Figure 2).

iii) Measurement Procedure

All measurements were performed manually to the nearest 0.1 millimetre using the electronic calipers in RadiAnt DICOM Viewer. Each measurement was obtained twice by a trained anatomist at separate sittings, and the mean value was used for analysis. Intra-observer reliability was assessed by repeating measurements on 30 randomly selected scans after a two-week interval.

Prior to data collection, the observer underwent two weeks of training under the supervision of an experienced consultant neuroradiologist, who also reviewed measurements throughout the study to ensure accuracy and consistency.

Outcomes:

The primary outcome was the establishment of normative MRI-based morphometric values for the corpus callosum and ventricular system in adults from Northwestern Nigeria. Measured parameters included corpus callosum length and height, regional callosal thicknesses (rostrum, genu, body, and splenium), ventricular dimensions, and Evans Index.

Secondary outcomes included assessment of morphometric variation according to age, sex, and ethnicity, and evaluation of correlations between corpus callosum and ventricular measurements.

Operational Definitions:

Corpus callosum length was defined as the linear distance between the most anterior point of the genu and the most posterior point of the splenium on the midsagittal MRI. Corpus callosum height was defined as the maximum perpendicular distance between its superior and inferior borders. Regional callosal widths represented the maximum thickness of the rostrum, genu, body, and splenium. Evans Index was calculated as the ratio of the maximum frontal horn width to the maximum internal cranial diameter on the same axial image.

Statistical analysis:

Data were analyzed using R version 4.2.3. Continuous variables were summarized using means, standard deviations, standard errors, and reference percentiles (2.5th–97.5th). Normality was assessed using the Shapiro–Wilk test. Variables with non-normal distributions were analyzed using non-parametric methods, with sex differences compared using the Mann–Whitney U test. Statistical significance was set at $p < 0.05$. Comparisons with published studies were made descriptively using reported summary statistics and reference ranges.

Ethics:

Ethical approval was obtained from the UDUTH Health Research Ethics Committee (Approval No. UDUTH/HREC/2025/1545/VI).

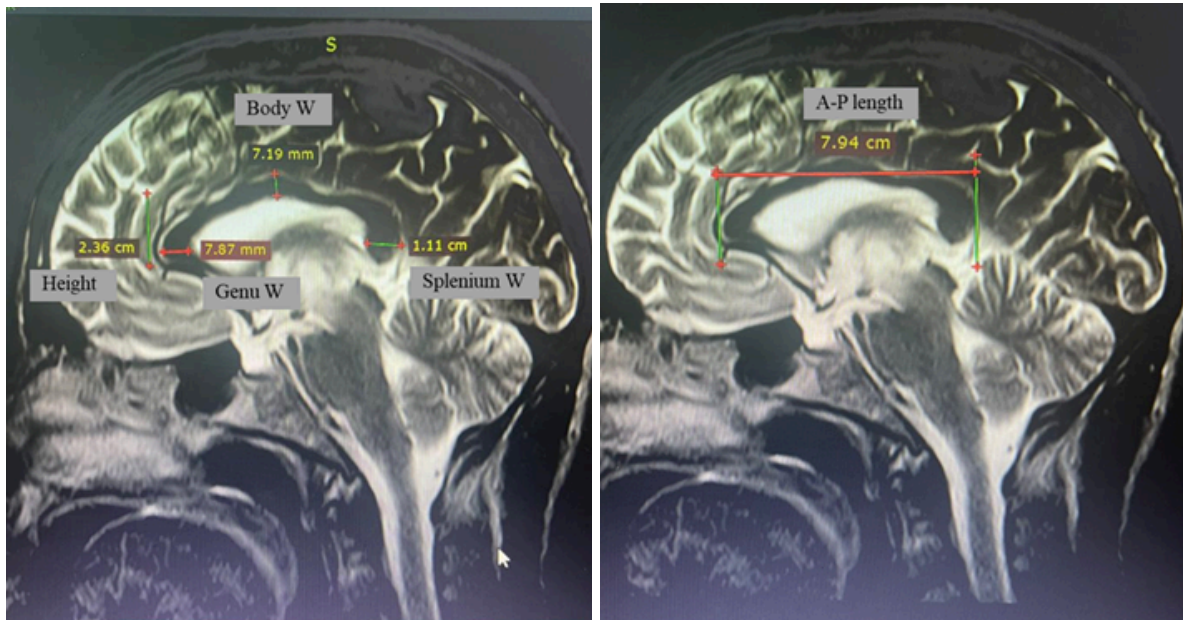


Figure 1: Midsagittal T1-weighted MRI demonstrating morphometric measurements of the corpus callosum, including height, genu width, body width, splenium width, and anteroposterior (A–P) length in a 54-year-old male participant.

RESULTS

Baseline Characteristics

The study involved a total of 422 individual images. Their age ranged from 18 to 80 years, with a mean age of 51.26 ± 22.16 years. There was a male predominance in the study population, with males constituting 66.6% ($n = 281$) and females making up 33.4% ($n = 141$). The Hausa ethnic group made up the bulk of the study population (58.5%, $n = 247$), followed by Fulani (15.9%, $n = 67$), Yoruba (10.4%, $n = 44$), Other ethnic groupings (10.0%, $n = 42$), and Igbo (5.2%, $n = 22$).

Corpus Callosal Parameters

The corpus callosum measurements showed relatively narrow dispersion around their mean values across all parameters. The anterior–posterior diameter, height, body width,

genu, splenium, and rostrum demonstrated stable central tendencies with defined minimum and maximum ranges (Table 1). Percentile distributions (2.5th - 97.5th) for corpus callosum parameters are presented in Table 2, defining the lower, central, and upper ranges within the study population.

Ventricular Parameters

For the ventricular system, the right and left lateral ventricles, third ventricle, frontal horn indices, Evans Index, and bifrontal measures displayed measurable variation across the sample, with median values centred within the expected adult morphometric ranges (Table 3). Percentile distributions (2.5th–97.5th) for ventricular parameters are presented in Table 4, defining the lower, central, and upper ranges within the study population.

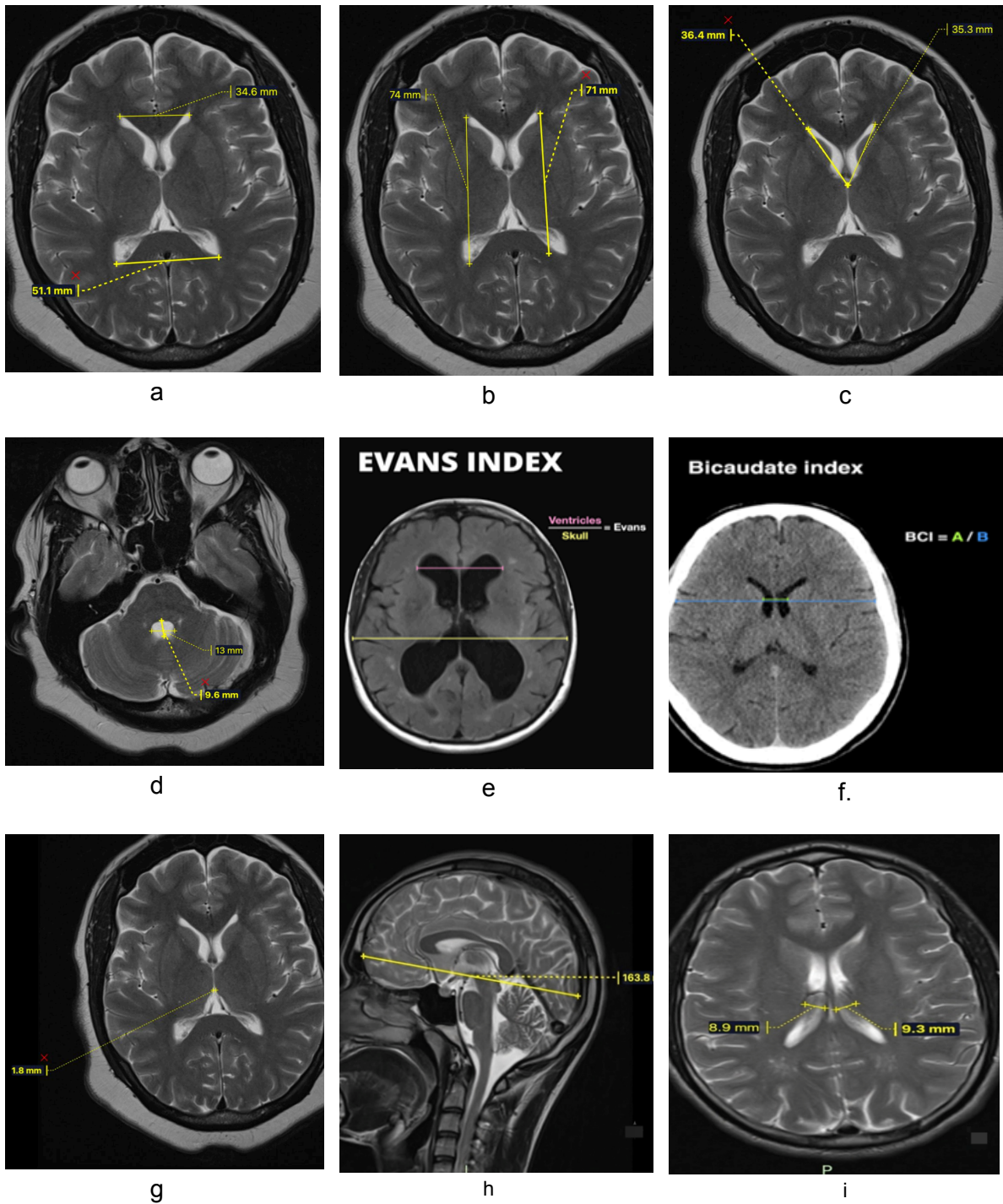


Figure 2: Corpus callosum and ventricular system MRI-based morphometric measures of normal adult subjects. **(a)** Showing measurement of the anterior horn width (AHW) and the posterior horn width (PHW) of the corpus callosum. **(b)** Measurement of the frontal horn length (FHL) is defined as the distance from the tip of the frontal horn to the interventricular foramen (of Monro). **(c)** Measurement of the right and left lateral ventricular lengths. **(d)** Measurement of the fourth ventricle width and anteroposterior diameter. **(e)** Determination of the Evans Index, calculated as the ratio of the maximum width of the frontal horns of the lateral ventricles to the maximal internal diameter of the skull at the same axial level. **(f)** Determination of the bicaudate index (BCI), measured as the ratio of the width of the frontal horns at the level of the caudate nuclei to the corresponding transverse diameter of the brain. **(g)** Measurement of the third ventricle width. **(h)** Measurement of the fronto-occipital length. **(i)** Measurement of the right and left ventricle widths.

Table 1. Descriptive Statistics for Corpus Callosum Parameters (n = 422)

| | Mean | Std. Deviation | Min | Max |
|---------------|-------|----------------|------|-------|
| A-P (cm) | 7.808 | .327 | 5.21 | 9.10 |
| Height (cm) | 2.456 | .995 | 1.90 | 22.42 |
| Body (mm) | 7.203 | .236 | 6.57 | 8.87 |
| Genu (mm) | 7.778 | .283 | 5.13 | 9.00 |
| Splenium (cm) | 1.099 | .079 | .75 | 1.87 |
| Rostrum (mm) | 3.785 | .720 | 5.21 | 9.10 |

Table 2: Percentile-Based Reference Ranges for CC (2.5th–97.5th Percentile)

| Variable | SEX | Percentiles | | | | | | |
|---------------|--------|-------------|------|------|------|------|------|------|
| | | 2.5 | 5 | 25 | 50 | 75 | 95 | 97.5 |
| A-P (cm) | Male | 6.81 | 6.97 | 7.82 | 7.88 | 7.92 | 8.02 | 8.10 |
| | Female | 6.83 | 7.01 | 7.80 | 7.85 | 7.92 | 8.01 | 8.13 |
| Height (cm) | Male | 2.14 | 2.26 | 2.33 | 2.37 | 2.41 | 2.86 | 3.05 |
| | Female | 2.17 | 2.30 | 2.34 | 2.37 | 2.41 | 2.71 | 2.96 |
| Body (mm) | Male | 6.89 | 6.98 | 7.12 | 7.17 | 7.19 | 7.87 | 8.01 |
| | Female | 6.85 | 6.98 | 7.14 | 7.18 | 7.20 | 7.78 | 7.99 |
| Genu (mm) | Male | 6.98 | 7.15 | 7.77 | 7.83 | 7.88 | 7.98 | 8.09 |
| | Female | 7.16 | 7.22 | 7.79 | 7.84 | 7.89 | 8.01 | 8.34 |
| Splenium (cm) | Male | .87 | .97 | 1.09 | 1.11 | 1.12 | 1.17 | 1.20 |
| | Female | .97 | .99 | 1.09 | 1.11 | 1.13 | 1.17 | 1.17 |
| Rostru (mm) | Male | 2.90 | 3.02 | 3.10 | 3.80 | 4.08 | 5.04 | 5.29 |
| | Female | 2.43 | 3.00 | 3.08 | 3.80 | 4.15 | 5.03 | 5.07 |

Table 3. Descriptive Statistics for Ventricular Parameters (n = 422)

| | Mean (mm) | Std. Deviation | Min | Max |
|-------------------------------|-----------|----------------|-------|-------|
| Right lateral ventricle width | 8.011 | .799 | 5.00 | 10.80 |
| Left lateral ventricle width | 8.014 | .799 | 5.00 | 10.80 |
| Third ventricle width | 4.193 | .869 | 2.78 | 7.10 |
| Fourth Ventricle width | 9.839 | .685 | 1.10 | 13.03 |
| Fourth Ventricle A-P | 13.35 | .095 | .09 | 2.10 |
| Posterior Horn Width | 48.12 | .422 | 2.93 | 9.81 |
| Front Horn Width | 33.32 | .264 | 2.08 | 5.35 |
| Frontal Horn length | 31.39 | .175 | 2.10 | 4.80 |
| Bicaudate Index | .156 | .556 | .00 | 11.00 |
| Evans Index | .264 | .038 | .11 | .45 |
| Fronto-Occipital length | 171.32 | .450 | 13.87 | 19.03 |

Table 4: Percentile-Based Reference Ranges for Ventricular Parameters in millimeters (2.5th – 97.5th Percentile)

| Ventricles | Sex | Percentiles | | | | | | |
|-------------------------|--------|-------------|-------|-------|-------|-------|-------|-------|
| | | 2.5 | 5 | 25 | 50 | 75 | 95 | 97.5 |
| Right lateral ventricle | Male | 6.30 | 6.75 | 7.81 | 7.90 | 8.12 | 9.87 | 10.12 |
| | Female | 6.80 | 6.90 | 7.81 | 7.89 | 8.10 | 9.00 | 9.76 |
| Left lateral ventricle | Male | 6.30 | 6.75 | 7.81 | 7.90 | 8.11 | 9.87 | 10.11 |
| | Female | 6.80 | 6.90 | 7.82 | 7.90 | 8.10 | 9.00 | 9.76 |
| Third ventricle | Male | 2.89 | 2.90 | 3.50 | 4.20 | 4.91 | 5.30 | 5.79 |
| | Female | 2.80 | 2.90 | 3.40 | 4.20 | 4.97 | 5.40 | 5.89 |
| Fourth Ventricle width | Male | 7.91 | 9.00 | 9.80 | 9.90 | 9.98 | 10.31 | 10.89 |
| | Female | 8.00 | 8.78 | 9.83 | 9.90 | 10.08 | 10.89 | 11.10 |
| Fourth Ventricle A-P | Male | 12.5 | 12.8 | 13.1 | 13.4 | 13.6 | 14.0 | 14.5 |
| | Female | 11.3 | 12.7 | 13.1 | 13.4 | 13.7 | 14.0 | 14.2 |
| Posterior Horn Width | Male | 38.2 | 39.7 | 48.0 | 48.7 | 49.1 | 50.7 | 51.3 |
| | Female | 37.1 | 40.3 | 47.8 | 48.6 | 49.3 | 52.4 | 59.0 |
| Frontal Horn Width | Male | 29.0 | 30.2 | 32.8 | 33.2 | 33.6 | 35.4 | 39.2 |
| | Female | 29.1 | 29.6 | 32.6 | 33.2 | 33.9 | 38.1 | 39.0 |
| Frontal Horn length | Male | 29.0 | 29.5 | 30.9 | 31.1 | 31.3 | 33.4 | 35.0 |
| | Female | 28.5 | 29.0 | 31.0 | 31.2 | 31.4 | 36.6 | 38.5 |
| Bicaudate Index | Male | .06 | .070 | .10 | .110 | .13 | .160 | .18 |
| | Female | .070 | .080 | .10 | .120 | .13 | .170 | .99 |
| Evans Index | Male | .190 | .210 | .24 | .260 | .28 | .319 | .32 |
| | Female | .186 | .210 | .24 | .260 | .30 | .349 | .37 |
| Fronto-occipital length | Male | 165.7 | 168.0 | 170.2 | 170.5 | 170.9 | 180.1 | 180.9 |
| | Female | 159.6 | 165.0 | 170.2 | 170.5 | 171.0 | 180.1 | 180.7 |

DISCUSSION

The current study presents a detailed MRI-based norming data on the morphology of the corpus callosum and ventricles in an adult population in northwest Nigeria. The dimensions of the corpus callosum found in the current Nigerian group are in the international range, and, simultaneously, exhibit local peculiarities that support the necessity of local normative atlases. The average length of the anteroposterior corpus callosum in the present study (7.81 cm) agrees with the values published in various populations. Similar mean lengths in about 7.35-7.37 cm are described in western groups [1], and smaller mean lengths (between 6.85 and 7.07 cm) have been reported in studies of Indian, Japanese, Chinese, and Middle Eastern Arab populations [9,11,15,25]. The slight increase in the mean length identified in the current study indicates that there is a slight difference in the population that could be due to differences in cranial size, genetic ancestry, or neurodevelopmental patterning.

Equally, the height of the corpus callosum in the present sample (2.46 cm) is comparable with the values found in Asian and Middle Eastern populations, where the mean values are found within a similar range [11]. This overlap of geographically separate groups implies that vertical callosal development is perhaps more evolutionary than longitudinal expansion that

seems to be more adaptive to the variation among populations. Proportional measurements of the body, genu, and splenium in this study also reinforce this interpretation, exhibiting proportional relationships that are broadly similar to international values, even in absolute sizes, of which there are small differences.

In addition to callosal morphology, there was increased dispersion of ventricular parameters in the present cohort, a pattern that is expected considering the established age, sex, cranial shape, and inter-individual neurodevelopmental heterogeneity over ventricular size. Mean lateral ventricular widths were clustered around 8.01 - 8.02 mm, and the third ventricle size was around 4.19 mm. Frontal horn sizes and indices were also close to values of adult populations, but slight changes in central tendency were noted in comparison with non-African reference data [6]. These results emphasize that the variability in the population of ventricular morphology, rather than midline commissural structures, may be observed in neurologically normal adults.

The presence of percentile-related reference values makes this dataset more clinically applicable. The 2.5th to 97.5th percentile scales represent anticipated anatomic extremes in a healthy population, and give a practical method of differentiating physiological variety and potential

pathology [26]. These percentile levels can be especially useful in the diagnosis of conditions related to ventricular enlargement or callosal thinning, whereby the use of individual mean values could conceal clinically significant deviation [8]. Notably, such reference limits are derived based on the local population, which minimizes the chances of misclassification that may occur when external normative standards are used without discrimination.

Clinically, the findings present a strong baseline for neuroradiologists when interpreting the adult brain

CONCLUSION

This study reveals a detailed, population-specific, normative atlas on the corpus callosum and ventricular shape of the adult northwestern Nigerian population. The study determines the anticipated anatomical ranges by determining mean values, sex-stratified differences, and percentile-based reference intervals, which can be used by radiologists and neuroscientists operating within this population as a solid diagnostic standard. The results indicate that, although the overall CC dimension is comparable in terms of global dimensions, some indicators of population-specificities exist in the ventricular parameters, which underlines the need to use region-specific datasets to make precise anatomical conclusions. Clinically, these normative values enhance the precision of neuroradiological assessments by distinguishing physiological variability from pathological deviations, thereby supporting early detection of conditions such as hydrocephalus, neurodegeneration, or traumatic ventricular changes.

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MRIs in northwestern Nigeria. Reference intervals, particularly the 2.5th–97.5th percentiles, allow for the identification of deviations suggestive of pathological conditions such as hydrocephalus, neurodegeneration, or post-traumatic ventricular enlargement. Reliance on Western-based reference ranges can falsely label normal anatomical variation as pathological, hence the utility of population-specific datasets in clinical practice and research, such as neurodevelopmental and volumetric research [18].

Conflicts of interest: The authors declare no conflicts of interest

Consent for publication: We (all authors) approved the final version submitted for publication and took responsibility for the statements made in the published article.

Author contributions: All authors made contribution to this work. Z. Usman and F.K Umar performed the measurements and contributed to data analysis and interpretation. Z. Usman, S.O Elijah, and S.B Danborno contributed substantially to the study conception, design, data acquisition, analysis and interpretation. Z. Usman and F.K Umar drafted the manuscript, while S.O Elijah and S.B Danborno revised the manuscript.

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