Original

MRI-Based Morphometric Study of the Corpus Callosum in Nigerian Adults

[1]Beryl S. Ominde, [2]Mamerhi T. Enaohwo, [3]Joyce E. Ikubor, [3]Denise O. Ogholoh, [2]Ogheneyole Jeremiah, [2]Orovwoghene F. Omoro, [2]Patrick Sunday Igbigbi

[1]Department of Biomedical Sciences, Aga Khan University, Nairobi, Kenya
. [2]Department of Human Anatomy and Cell Biology, Delta State University, Abraka, Nigeria
[3]Department of Radiology, Delta State University Teaching Hospital, Ogbara, Nigeria.

Corresponding author: Beryl S. Ominde, Department of Biomedical Sciences, Aga Khan University, 3rd Parklands Avenue, Nairobi, Kenya. berylominde@gmail.com: +254712855766
Article history: Received 17 December 2024, Reviewed 1 March 2025, Accepted for Publication 6 March 2025

Abstract

Background: Alterations in the dimensions of the corpus callosum have been linked to conditions like Alzheimer's, schizophrenia and bipolar disorder. This study was designed to investigate the normal cut-off measurements of the corpus callosum.

Methods: The cross-sectional study retrospectively assessed the corpus callosum on apparently normal brain Magnetic Resonance scans of 199 adults (91 males, 108 females) aged 20-80 years. The digital radiological storage of a Nigerian Hospital in Delta State was accessed for data collection after institutional authorization was granted. Statistical Package for Social Sciences analyzed the gathered data using the independent t-test for sex comparison and analysis of variance for age-related differences. Inter-variable association was probed using the Pearson's correlation test. Significance in the inferential statistics was deemed at $P<0.05$.

Results: Sexual dimorphism was observed in the distance of the callosum's genu and splenium from the frontal and occipital poles of the brain respectively ($p= 0.010$ and 0.007). The corpus callosum's length, height, index, and thickness of its genu and splenium exhibited significant disparities across age-groups. The length and height had a positive association with age while the thickness of the splenium had a negative correlation with age ($p<0.05$).

Conclusion: This study provides normative range morphometric values for the normal corpus callosum in adults that will aid in accurate diagnosis and follow-up of neurodegenerative and psychiatric conditions besides planning for corpus callosotomy in epileptic patients.

Keywords: Corpus Callosum, Dimensions, Brain, Morphometry

How to cite this article

Ominde BS, Enaohwo MT, Ikubor JE, Ogholoh DO, Orovwoghene OJ, Omoro F, Igbigbi PS. MRI-Based Morphometric Study of The Corpus Callosum in Nigerian Adults. The Nigerian Health Journal 2025; 25(1):357 – 364.
https://doi.org/10.71637/tnhj.v25i1.989

Introduction

The corpus callosum (CC) is a commisural white matter tract located on the floor of the longitudinal fissure of the cerebrum. [1] It is an inter-hemispheric bridge that is made up of four parts namely; the rostrum, genu, body and splenium from anterior to posterior correspondingly. [1, 2] In humans, the CC contains approximately 200-350 million nerve fibres that connect corresponding regions of the bilateral cerebral hemispheres that sub-serve a similar function. [3, 4] These aids in the integration of sensory, motor, speech and cognitive information. [1, 5]

The development of the CC begins at the 8th week of intrauterine life. At the midline exists a lamina terminalis that lies adjacent to the tela choroidea. This usually thickens and develops to the septal area primordium. Later, the midline crossing of nerve fibres commences between the 12th and 13th week of fetal life. [6] After birth, the commencement of myelination occurs at around 4 months and carry on throughout adolescence. The growth of the CC is thereafter rapid until the mid-20s and later reduces in the advanced years.[7] According to Al-Hadidi *et al.*,[8] the growth of the CC length increases until 18 years of age while Arda *et al.* [3] observed a significant decline in the CC's thickness with age. The reduction of the CC size with age has been attributed to shrinkage caused by degenerative atrophy of the brain. [9]

Several studies conducted on the CC of difference populations have reported sexual dimorphism in the shape, dimensions and area of the CC. [4, 10, 11] However, in the population evaluated by Ajare *et al.*, [2] the CC's morphometry lacked any association with sex. This highlights the controversy regarding the sexual dimorphism in the CC's dimensions and morphology. [1]

Patients with multiple sclerosis, schizophrenia, Alzheimer's, and bipolar disorder have reduced white matter volume and this explains why the dimensions of their CC are smaller. Consequently, this reduces the efficiency of information integration. [2,9] Conditions characterized by cerebral white mater degeneration have recently demonstrated increasing prevalence in Nigeria.[12] Recognition of the CC's normal dimensions in a given population group is pertinent for neurologists, psychiatrists and radiologists for precise diagnosis of these conditions and ensure proper follow-up with better decision making.[2] Furthermore, the CC's normogram assists the neurosurgeons in the planning of corpus callosectomy in patients with intractable epilepsy. [9, 13]
Significant appreciation of the structural organization of the brain has been enhanced in the recent past due to the advancement in imaging modalities.[14] The magnetic resonance imaging (MRI) has been widely acknowledged as the best modality for evaluating the CC's size, shape, and variations. [2, 9, 10, 15] Furthermore, the MRI has been reported to be a useful tool in preoperative estimation of the extent of callosectomy and postoperative evaluation.[1] This research was thus designed to measure the CC's dimensions using apparently normal brain MRIs of adult Nigerian patients in Delta State.

Methods

Setting

This study was conducted in the imaging unit of a Teaching and Referral Hospital located within Delta State, Nigeria after obtaining ethical authorization (HREC/PAN/2023/076/0600) from the institution

Design

The study adopted the cross-sectional retrospective design.

Population

The study utilized brain MRI scans of adult (aged 20 years and above) patients who presented to the radiological unit with suspicious intracranial lesions or cerebrovascular disease.

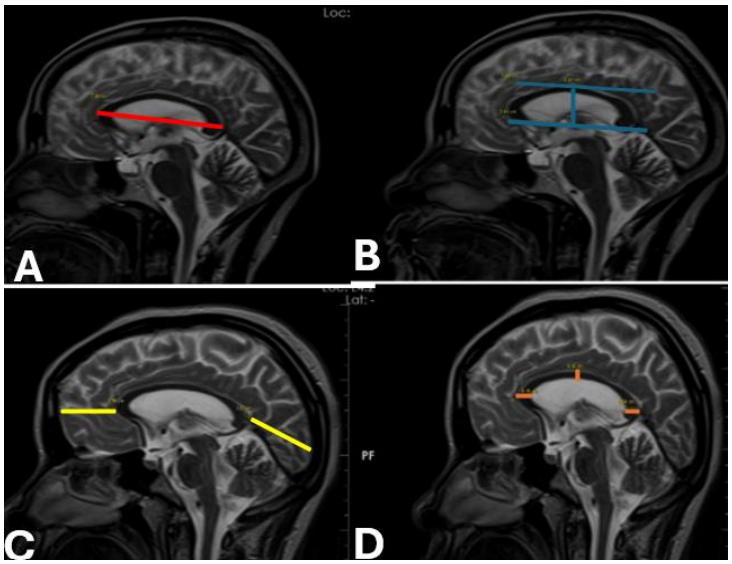
Sampling

The study conveniently sampled brain MRI scans taken between January 1st 2015 and December 31st 2020. Exempted from the study were images that demonstrated traumatic brain injury, tumors, cerebral blood clots, intracranial bleeds, raised intracranial pressure and congenital anomalies. Besides, images with motion and metal artefacts or skull asymmetry

Print ISSN: 0189-9287 Online ISSN: 2992-345X

were similarly excluded. All the brain MRIs that fit the selection standards were utilized. These included brain MRI scans of 108 females and 91 males.

The images had previously been acquired using the Toshiba Excelart Vantage scanner from Japan (1.5- Tesla MRI). This machine has a gradient system of maximum amplitude and slew rate of 30 mt/M and 130 mT/m/ms correspondingly. The images were captured with the patient lying supine and the head immobilized within a head coil. Three mm thick axial cuts were obtained from the skull base at the level of the foramen magnum to the vertex using a 0.3mm intersection gap and a matrix gap of 256x256. After obtaining various sequences, further enhancement of the image contrast was achieved by intravenous administration of Gadolinium diethylenetriamine penta-acetic acid (DTPA) (Magnevist).



Data Collection

Using a designated desktop, the T2 weighted sequences were identified and sagittal reconstructions selected for the CC morphometric assessment.

Variables

First, the patient's sex and age were noted and thereafter, a digital linear rule in the Picture Archiving and Communication system (PACS) was employed to obtain the CC and brain measurements. The study adopted the measurement protocol described by Sehgal *et al.* [9] The CC's maximum length (Lmax) was defined from the anterior edge of genu to the splenium's tip posteriorly (Figure 1A). The maximum height (Hmax) was the vertical distance between two parallel horizontal lines; one drawn at the top of the CC while the other extending from the inferior ends of the rostrum to the splenium (Figure 1B). The tip of the genu was noted and measured from the frontal pole (DfFP) while that of the splenium was measured from the occipital (DfOP) pole (Figure 1C). Additionally, CC's genu, body and splenium at the site of maximum white matter intensity were identified and the thickness measured (Figure 1D). The extreme points on the frontal and occipital poles formed the landmarks for obtaining the brain length. The CC index (CCI) was calculated by dividing the sum thickness of the CC's individual parts by the maximum CC length, (Tg +Tb +Ts)/Lmax Where Tg, Tb and Ts is the thickness of the genu, body and splenium correspondingly.[9]

Data Analysis

The recorded data was analyzed using Statistical Package for the Social Sciences for Windows version 27.0 (SPSS Inc. Chicago, IL, USA). Descriptive statistics were tabulated and compared sex-wise using the independent t-test and age-wise employing the analysis of variance. The association between all quantitative variables was ascertained by the Pearson's correlation test. These inferential statistics were significant at <5% probability value.

Figure 1. T2- weighted mid-sagittal brain MRI scan showing how the CC was measured A. Maximum length B. Height C. Distance of genu from frontal pole and splenium from occipital pole D. Thickness of the genu, body and splenium of CC (Original).

Results

The 199 images utilized in this research belonged to 91 (45.7%) males and 108 (54.3%) females within 20-80 years and having an average age of 46.77±15.62 years. A greater frequency of patients was revealed in the 31-40 years age-group (48, 24.1%) while the least represented age-group was the 71-80 years (18, 9.0%) (Table 1).

Print ISSN: 0189-9287 Online ISSN: 2992-345X

Table 1. Age and gender composition of the study population (Original)

Age Groups (years)	Males – N (%)	Females- N (%)	Total Population N (%)
20-30	16(17.6)	16(14.8)	32(16.1)
31-40	15(16.5)	33(30.6)	48(24.1)
41-50	19(20.9)	23(21.3)	42(21.1)
51-60	12(13.2)	17(15.7)	29(14.6)
61-70	19(20.9)	11(10.2)	30(15.1)
71-80	10(11.0)	8(7.4)	18(9.0)
Total	91(100.0)	108(100.0)	199(100.0)

The mean values of the CC and cerebral hemisphere are depicted in Table 2. The mean Lmax to brain length ratio was 0.48. Sexual differences in the mean DfFP, DfOP and brain length ($p<0.05$) were demonstrated with males having greater dimensions than females (Table 2).

Table 2. Descriptive statistics of the CC and related Brain morphometry (Original)

Variables	Total Population			Males	Females	P-value
	Minimum	Maximum	Mean ±Std Deviation	Mean ±Std Deviation	Mean ±Std Deviation	
Lmax (cm)	6.28	9.54	7.74±0.51	7.82± 0.53	7.68 ± 0.48	0.052
Hmax (cm)	1.66	3.70	2.42±0.35	2.44± 0.38	2.40 ± 0.33	0.449
DfFP (cm)	2.81	4.93	3.68±0.32	3.74 ± 0.34	3.63 ± 0.30	0.010*
DfOP (cm)	1.34	6.89	5.42±0.67	5.56 ± 0.61	5.31 ± 0.69	0.007*
Tg (cm)	0.44	1.83	1.01±0.21	1.04 ± 0.23	0.99 ± 0.19	0.083
Tb (cm)	0.25	0.98	0.54±0.12	0.55 ± 0.13	0.54 ± 0.11	0.396
Ts (cm)	0.11	1.77	1.07±0.20	1.07 ± 0.21	1.14 ± 0.69	0.964
Brain Length (cm)	14.61	18.62	16.30±0.75	16.55 ± 0.71	16.09 ± 0.72	0.001*
CCI	0.18	0.50	0.34±0.05	0.34±0.05	0.34±0.05	0.790

Lmax = Maximum length of corpus callosum, Hmax = Maximum height of corpus callosum, DfFP= Distance of genu from frontal pole, DfOP = Distance of splenium from occipital pole, Tg= Thickness of the genu, Tb= Thickness of the body, Ts= Thickness of the splenium, CCI-corpus callosum index

Comparison across age-groups revealed increasing Lmax from the youngest (20-30 years) to the oldest (61-70 years) age category. Additionally, significant disparities in the means measurements across age-groups were observed on only the Lmax, Hmax, Tg, Ts and CCI (Table 3).

Table 3. Differences in measured variables across several age clusters (Original)

Morphometric parameters	Age-groups (years) 20-30	31-40	41-50	51-60	61-70	71-80	P
Lmax (cm)	7.50±0.44	7.59±0.41	7.71±0.55	7.92±0.45	8.10±0.37	7.76±0.68	0.001*
Hmax (cm)	2.29±0.24	2.36±0.30	2.47±0.46	2.36±0.33	2.53±0.32	2.55±0.35	0.024*
DfFP (cm)	3.82±0.26	3.65±0.31	3.67±0.32	3.64±0.28	3.64±0.35	3.68±0.46	0.191
DfOP (cm)	5.47±0.59	5.50±0.52	5.47±0.75	5.39±0.61	5.43±0.60	5.06±1.03	0.272

Print ISSN: 0189-9287 Online ISSN: 2992-345X

Tg (cm)	1.01±0.14	1.06±0.21	1.00±0.22	1.02±0.19	1.03±0.23	0.86±0.24	0.034*
Tb (cm)	0.55±0.10	0.55±0.12	0.55±0.13	0.53±0.11	0.57±0.12	0.49±0.12	0.292
Ts (cm)	1.06±0.17	1.14±0.18	1.09±0.23	1.07±0.18	1.06±0.15	0.90±0.25	0.002*
Brain Length (cm)	16.10±0.72	16.14±0.73	16.48±0.73	16.36±0.84	16.53±0.74	16.21±0.64	0.072
CCI	0.35±0.04	0.36±0.05	0.34±0.05	0.33±0.05	0.33±0.05	0.29±0.06	0.002*

Lmax = Maximum length of corpus callosum, Hmax = Maximum height of corpus callosum, DfFP= Distance of genu from frontal pole, DfOP = Distance of splenium from occipital pole, Tg= Thickness of the genu, Tb= Thickness of the body, Ts= Thickness of the splenium, *p considered significant at <0.05

The Lmax, Hmax and brain length exhibited a weak positive association with age, however, statistical significance was only detected in the Lmax and Hmax ($0<r<0.5$, $p<0.05$). On the contrary, age exhibited a weak negative association with Ts and CCI ($p<0.05$) (Table 4).

The Lmax correlated positively with Hmax, Tb, Tg, Ts and brain length while the DfFP associated negatively with the CCI. Hmax demonstrated a positive relationship with Tb, and brain length however, its relationship with DfOP was a weak negative one. The DfFP and DfOP showed a weak positive association with the brain length and a weak negative relationship with Tb. The DfFP had a weak negative association with Tg, Tb, Ts and CCI. The Tg and Tb showed a weak positive correlation with the Ts. The CCI also had a strong positive relationship with Tg, Tb and Ts. All these correlations were statistically significant ($p<0.05$) (Table 4).

Table 4. Association between the metric parameters evaluated (Original)

Variables		Hmax	DfFP	DfOP	Tg	Tb	Ts	Brain Length	CCI	Age
Lmax	r	0.421*	-0.158*	-0.138	0.223*	0.217*	0.195*	0.435*	-0.143*	0.313
	P value	0.001	0.026	0.053	0.002	0.002	0.006	0.001	0.044	0.001*
Hmax	r		-0.126	-0.187*	0.088	0.314*	0.035	0.152*	-0.031	0.202
	P value		0.077	0.008	0.218	0.001	0.623	0.032	0.663	0.004*
DfFP	r			0.054	-0.156*	-0.176*	-0.174*	0.343*	-0.149*	-0.132
	P value			0.446	0.028	0.013	0.014	0.001	0.035	0.064
DfOP	r				-0.130	-0.219*	0.003	0.469*	-0.062	-0.123
	P value				0.066	0.002	0.971	0.001	0.381	0.084
Tg	r					0.108	0.443*	0.072	0.772*	-0.127
	P value					0.127	0.001	0.310	0.001	0.073
Tb	r						0.476*	-0.042	0.693*	-0.064
	P value						0.001	0.559	0.001	0.369
Ts	r							0.066	0.753*	-0.174
	P value							0.352	0.001	0.014*
Brain Length	r								-0.123	0.134
	P value								0.084	0.059
CCI										-0.298
										0.001*

Lmax = Maximum length of corpus callosum, Hmax = Maximum height of corpus callosum, DfFP= Distance of genu from frontal pole, DfOP = Distance of splenium from occipital pole, Tg= Thickness of the genu, Tb= Thickness of the body, Ts= Thickness of the splenium,
r- Pearson's correlation coefficient, *Correlation is significant at the 0.05 level (2-tailed)

Print ISSN: 0189-9287 Online ISSN: 2992-345X

Discussion

The CC's length was less than the findings by Habibi *et al.*[10] and exceeded the length reported by Mastery *et al.*,[16] Choudhury *et al.*,[4] Khasawneh *et al.,* [15] and Ajare *et al.*[2] Mastery *et al.*[16] and Ajare *et al.*[2] documented greater CC's height than the observations in the index study. The tip of the genu was farther from the frontal pole compared to results by Choudhury *et al.*[4] and Ajare *et al.*[2] The edges of the splenium and genu were closer to the occipital and frontal poles in relation to the outcomes by Mastery *et al.*[16] The Ts, Tg, and Tb were greater than the thickness reported by Choudhury *et al.*[4] and Habibi *et al.*[10] but less than Ajare *et al.* [2] The brain lengths were longer than reports of Mastery *et al.*[16] and Choudhury *et al.*[4] (Table 7). The mean CCI (0.34) corresponded with Sehgal *et al.*[9] but contrasted with Mohammed *et al.*[18] who recorded a higher value.

Dissimilarities in the geographical background, genetics, race, age, sample size, measuring methods, measuring equipment and type of specimen could be a reason for the population diversity in CC's morphometry.[8, 10, 14] This study utilized a digital rule to determine the CC's dimensions on MRI scans while Choudhury *et al.*[4] and Poleneni *et al.*[5] employed a vernier caliper to take measurements on fixed brain specimens.

The knowledge of the normal CC dimensions makes it easy to detect any brain alterations in conditions such as schizophrenia and bipolar disorder.[5] Khasawneh *et al.*[15] found a significant decrease in the CC's size in Alzheimer's patients compared to the control group. Clinical recognition of the CC's dimensions facilitates a more precise callosotomy and minimizes the neuropsychological complications that may arise after the procedure.[9] Knowledge of the expanse of the CC's splenium and genu from the occipital and frontal poles respectively is surgically important. Techniques involving the CC's manipulations become increasingly challenging beyond a depth of >5cm (either anterior or posteriorly).[17]

The ratio Lmax/Brain length in this study was 0.48 which may be considered normal reference value for the CC length, being approximately half (50%) of the brain length. Clinically, any deviation from this may potentially indicate structural or functional neurological abnormalities. More recent developments encompass MRI guided stereotactic laser ablation of particular callosal tissues, hence requiring accurate location of the CC. [5] Our findings can aid in accurately locating the CC and its parts during callosotomy hence minimizing the postoperative neuropsychological complications.[5]

Consistent with literature, the Lmax and Hmax lacked significant sex variations. [2, 4, 9, 11,15] Conversely, Mastery *et al.*[16] documented significantly larger Lmax and Hmax among males while Pasricha *et al.*[1] observed sexual dimorphism of the Lmax only. Congruent with Pasricha *et al.*[1], the DfFP and DfOP exhibited significant sex variances, with larger values in males. Sehgal *et al.*[9] revealed significantly bigger DfFP in males. Correspondingly, Choudhury *et al.*[4], Sehgal *et al.*[9] and Tuncer [11] reported no sex-wise variances in the Tg, Tb, Ts and CCI. However, according to Mohammed *et al.*[18], these parameters were significantly greater among female subjects than males. Sexual dimorphism of the brain length corresponded with some past literature. [1,4]

Ethnicity and race are responsible for variable manifestation of the CC's sexual dimorphism seen in diverse populations.[18] Testosterone advances the white mater architecture in boys.[10]. Additionally, gender variation exists in the extent of lateralization in visuospatial function specifically in the splenium.[8] The lack of gender variances in the CC's morphometry in some studies could be due to individual differences and dissimilar sample size or gender composition.[1,19]

The Lmax, Hmax, Tg and Ts varied significantly across the age-groups, concurring with Ajare *et al.*[2] Parallel with Mohammed *et al.,*[18] the CCI increased significantly with age and then reduced in the older age groups. According to Pasricha *et al.,*[1] the Lmax, brain length and Ts significantly varied with age. We observed a reduction in the Tg and Ts in the older age groups (above 50 years) perhaps because of the overall age-related brain atrophy especially in the splenium and genu which contain most fibers of the CC connecting the bilateral occipital and frontal lobes respectively.[2] Al-Hadidi *et al.*[8] similarly discovered differences based on age in the CC's splenium and genu and ascribed it to differential axonal myelination. Ominde *et al.*[14] accredits the age-group variations to dissimilarities in gender composition and sample size of each age categories.

Consistent with Pasricha *et al.,*[1] age exhibited positive association with Lmax and Hmax. Age-related brain atrophy causes lateral ventricular enlargement with subsequent arching and elongation the CC, increasing

Print ISSN: 0189-9287 Online ISSN: 2992-345X

the Lmax.[1] Brain atrophy begins by the seventh decade and advances with age due to natural structural changes that alter the brain volume.[14] Consistent with Pasricha *et al.*[1] age depicted a negative correlation with Ts although this relationship was weaker in our study. All CC's metrics evaluated by Habibi *et al.*[10] demonstrated a positive association with age. Correspondingly, the significant relationship between CCI and age reported by Mohammed et al.[18] was a weak negative one. Environmental factors, ethnicity, prematurity, mother's alcohol intake in the prenatal period, and protein-poor diet are contributory factors in the early development and subsequent growth of the CC which may explain the variances in its morphometry.[20] Understanding the CC variations across the age-groups would distinguish normal age-related changes from alterations due to diseased conditions, aiding in more precise neuroimaging diagnosis and better planning for neurosurgery for subjects in the various age groups.[14]

The Lmax, Hmax, DfFP and DfOP depicted a positive relationship with the brain length, however, the strength was weak, contradicting with Patra *et al.*[13] who documented a strong association. This infers that a stable relation exists between the brain length and CC's dimensions. The CC's placement within the cerebral hemisphere may be estimated intraoperatively based on the brain length and CC's size.[13] This clarity of the CC's location is highly important in callosotomy surgeries for management of intractable epilepsy.[8,13]

Limitations of study

The images were conveniently selected from one radiological unit; hence, the findings may not be generalized to the entire Nigerian population. Important history of the patients such as psychiatric illnesses could not be obtained owing to the retrospective design of the study.

Strength of the study

This study utilizes MRI images which provides more soft tissue contrast options, that gives a more detailed representation of brain architecture.

Suggestions for Further Research

For a greater sample composition, brain MRI scans from multiple hospitals in the country can be utilized. Furthermore, the total and regional CC's volume and area may be determined using advanced technology. Additionally, the CC's morphometry in neurodegenerative and psychiatric conditions can be evaluated.

Conclusion

This study provides the normal CC morphometry range in adults that will aid in accurate diagnosis and follow-up of neurodegenerative and psychiatric conditions besides planning for corpus callosotomy in epileptic patients.

Declarations

Conflict of interest: None

Acknowledgements: Immense gratitude to the resident doctors in the imaging department who supported us throughout the period of data acquisition.

Ethics approval and consent to participate: We received ethical approval from the hospital's research and ethics committee (HREC/PAN/2023/076/0600)

Funding: This research did not receive any funding

References

1. Pasricha N, Sthapak E, Thapar A, Bhatnagar R. Morphometric Analysis of Age and Gender-related Variations of Corpus Callosum by using Magnetic Resonance Imaging: A Cross-sectional Study. JCDR. 2023;17(6):15-20.
2. Ajare EC, Campbell FC, Mgbe EK, Efekemo AO, Onuh AC, Nnamani AO, Okwunodulu O, Ohaegbulam SC. MRI-based morphometric analysis of corpus callosum dimensions of adults in Southeast Nigeria. LJM. 2023;18(1):2188649.
3. Arda KN, Akay S. The relationship between corpus callosum morphometric measurements and age/gender characteristics: a comprehensive MR imaging study. JCIS. 2019; 9:33.
4. Choudhury PR, Choudhury P, Baruah P. Morphometric Assessment of Human Corpus Callosum on Cadaveric Brain Specimens. J Evol Med Dent Sci. 2020;9(7):388-393.
5. Poleneni SR, Jakka LD, Chandrupatla M, Vinodini L, Ariyanachi K. Morphometry of Corpus Callosum in South Indian Population. Ann Neurosci. 2021;28(3-4):150-155.
6. Al-Hashim AH, Blaser S, Raybaud C, MacGregor D. Corpus callosum abnormalities: neuroradiological and clinical correlations. DMCN. 2016;58(5):475–484.

Print ISSN: 0189-9287 Online ISSN: 2992-345X

7. Tanaka-Arakawa MM, Matsui M, Tanaka C, Uematsu A, Uda S, Miura K, Sakai T, Noguchi K. Developmental changes in the corpus callosum from infancy to early adulthood: a structural magnetic resonance imaging study. PLoS One. 2015;10(3):e0118760.
8. Al-Hadidi MT, Kalbouneh HM, Ramzy A, Al Sharei A, Badran DH, Shatarat A, Tarawneh ES, Mahafza WS, Al-Hadidi FA, Hadidy AM. Gender and age-related differences in the morphometry of corpus callosum: MRI study. Eur J Anat. 2021;25(1):15-24
9. Sehgal G, Kumar A, Kumar G, Aggarwal N. Gender-related differences in the morphometry of the corpus callosum: MRI study. Asian J Med Sci. 2023;14(9):1-6.
10. Habibi HA, Gül OB, Caliskan E, Öztürk M. Morphometric Analysis of Corpus Callosum with ID Magnetic Resonance Imaging in Children; Correlation with Age and Gender. J Behcet Uz Child Hosp. 2021;11(3):277-285.
11. Tuncer I. Morphometric Evaluation of the Human Corpus Callosum using Magnetic Resonance Imaging: Sex Difference and Relationship to Age and Intracranial Size. JASI. 2023;72(2):114-121.
12. Jidong DE, Husain MI, Ike TJ, Husain N, Taru MY, Nnaemeka NC, Francis C, Jack DB, Mwankon SB, Xue S, Pwajok JY. Bipolar disorders in Nigeria: a mixed-methods study of patients, family caregivers, clinicians, and the community members perspectives. Int J Bipolar Disord. 2023;11(1):1-9.
13. Patra A, Singla R, Chaudhary P, Malhotra V. Morphometric analysis of the corpus callosum using cadaveric brain: an anatomical study. Asian J Neurosurg. 2020;15(2):322-327.
14. Ominde BS, Ogbolu EC, Ikubor JE, Omoro OF, Igbigbi PS. Morphometric analysis of the frontal horns of the lateral ventricles using normal computed tomographic images. Eur J Anat. 2024;28(5):615-621.
15. Khasawneh RR, Abu-El-Rub E, Alzu'bi A, Abdelhady GT, Al-Soudi HS. Corpus callosum anatomical changes in Alzheimer patients and the effect of acetylcholinesterase inhibitors on corpus callosum morphometry. PLoS One. 2022;17(7):e0269082.
16. Mastery Farahani R, Aliaghaei A, Abdolmaleki A, Abbaszadeh HA, Shaerzadeh F, Norozian M, Moayeri A. Sexual Dimorphism and Age-Related Variations of Corpus Callosum Using Magnetic Resonance Imaging. Anat Sci J. 2017;14(1):19-26.
17. Smyth MD, Vellimana AK, Asano E, Sood S. Corpus callosotomy—Open and endoscopic surgical techniques. Epilepsia. 2017; 58:73-79.
18. Mohammed A, Ibrahim A, Mohammed ME, Ayad CE. A Quantitative MRI Study of the Normative Corpus Callosum in Sudanese. IOSR-JDMS. 2017;16(7):77-86.
19. Abdolmaleki A, Mastery FR, Ghoreishi SK, Shaerzadeh F, Aliaghaei A, Mirjavadi SH, Abbaszadeh H. Magnetic resonance imaging-based morphometric assessment of sexual dimorphism of corpus callosum. Anat Sci J. 2016;13(2):117-124
20. Tepper R, Leibovitz Z, Garel C, Sukenik-Halevy R. A New Method for Evaluating Short Fetal Corpus Callosum. Prenat Diagn. 2019;39(13):1283-90.

Print ISSN: 0189-9287 Online ISSN: 2992-345X