Eur J Anat, 28 (5): 601-607 (2024)

Morphometric analysis of the frontal horns of the lateral ventricles using normal computed tomographic images

Beryl S. Ominde[1], Emmanuel C. Ogbolu[1], Joyce E. Ikubor[2], Orovwoghene F. Omoro[1], Patrick S. Igbigbi[1]

[1] Department of Human Anatomy and Cell Biology, Delta State University, Abraka, Nigeria

[2] Department of Radiology, Delta State University Teaching Hospital, Oghara, Nigeria

SUMMARY

The ventricular system is altered by the normal aging process and various pathological conditions such as Alzheimer's, schizophrenia, hydrocephalus, and tumors. This study aimed at establishing the normal baseline data regarding the dimensions of the frontal horns of the lateral ventricles in adults Nigerians. This retrospective observational study evaluated CT brain images stored in a Radiology unit in Delta State, Nigeria. Ethical clearance was sought from the Hospital's ethics board. Images of 202 patients, aged 18 years and above, were included. Measurements of frontal horn length and width were conducted using a standardized digital caliper approach. The data were analyzed based on gender and age groups, employing statistical methods such as t-tests and Pearson correlation. A p-value of < 0.05 in the inferential statistics was deemed statistically significant. The length of the bilateral frontal horns and distance between their tips were significantly higher in males than in females (p<0.05). The left frontal horn length was consistently larger than the right. Both lengths and widths exhibited significant variations across age groups and had a positive correlation with age (p<0.05). The study provides standard reference values for clinicians in the study center to consider during neuroimaging and diagnostic assessments. The gender-, age- and side-related findings enhance the understanding of the normal anatomical diversity, which has crucial clinical implications.

Key words: Frontal horn – Length – Width – Diameter – Surgery

INTRODUCTION

The emergence of the cerebral ventricular system can be traced back to the central lumen of the neural tube, marking the embryonic origin of a complex network of interconnected spaces (Agegnehu et al., 2021). This system comprises the lateral ventricle, a spacious region located in each cerebral hemisphere; the third ventricle, a narrow slit-like space situated between the diencephalon; and the fourth ventricle, positioned between the pons and medulla anteriorly and the cerebellum posteriorly (Annongu et al., 2017; Arun et al., 2017; Agegnehu et al., 2021). Filled with cerebrospinal fluid (CSF), the ventricular system is an essential component

Corresponding author:
Dr. Beryl S. Ominde. Department of Human Anatomy and Cell biology, Delta State University, P.M.B. 1, Abraka, Nigeria. Phone: +2347085458946. E-mail: berylominde@gmail.com

Submitted: January 11, 2024. **Accepted:** May 1, 2024

https://doi.org/10.52083/BVBF3444

of the brain, contributing to its mechanical protection, buoyancy, and metabolic support (Arun et al., 2017). The lateral ventricles, having a roughly C-shaped configuration, enfold the dorsal portions of the basal ganglia. Comprising the inferior (temporal), frontal, and occipital horns, along with a central body, each lateral ventricle plays a distinct role in the distribution and circulation of CSF (Bijaylakshmi et al., 2014; Arun et al., 2017).

As individuals age, there is a regression of thalamic nuclei, which is associated with the early demonstration of third ventricular enlargement (Blinkouskaya et al., 2021). Age-related changes are also evident in the frontal cortex, brain stem, cerebellum and diencephalon, with the left lateral ventricle exhibiting a larger size than the right (Honnegowda et al., 2017). Ventricular enlargement is a reliable indicator of age-related brain atrophy, which commences by the seventh decade and accelerates with advancing age (Moawia et al., 2015; Arun et al., 2017).

Multiple studies highlight the clinical significance of the changes in the ventricular system. Degenerative conditions such as Alzheimer's, Huntington's and Parkinson's diseases, are characterized by an increase in cerebrospinal fluid (CSF) spaces (Patnaik et al., 2016; Annongu et al., 2017; Olawande et al., 2020; Blinkouskaya et al., 2021). Additionally, psychiatric disorders like bipolar disorders, schizophrenia, and depression, as well as conditions with cognitive decline such as chronic alcoholism, dementia, malignant, and traumatic lesions, have been associated with alterations of the ventricular size (Polat et al., 2019; Agegnehu et al., 2021). The diagnosis, classification, and follow-up of hydrocephalus after ventricular shunting therapy is dependent on morphometric evaluation of the ventricular system (Annongu et al., 2017; Arun et al., 2017). For accurate localization and excision of space occupying lesions such as gliomas, the morphometry of the ventricular system is also important (Agegnehu et al., 2021). It is challenging for clinicians to establish whether the ventricular size is within the normal limits, or enlarged due to aging process or pathological changes. Moreover, subjective analysis can cause misdiagnosis (Annongu et al., 2017; Quarshie et al., 2021).

Advancements in imaging technologies, particularly computerized tomography and magnetic resonance imaging (MRI), have significantly improved our understanding of the normal structural development and organization of the brain (Honnegowda et al., 2017; Sharmin et al., 2020). Computed tomography, being both safe and non-invasive, serves as a valuable tool for evaluating ventricular morphometry, and spatial characteristics of the ventricular system (Farheen and Sukre, 2017; Polat et al., 2019). It remains the most widely used, accessible, cost-effective, and rapid method for imaging the brain.

Establishing normal reference values for specific populations is imperative, providing neuroradiologists, neurosurgeons, and neurologists with essential guidance in the accurate assessment and effective management of conditions associated with alterations in ventricular size, hence improving patient outcomes (Honnegowda et al., 2017). This study aimed at determining the dimensions of the frontal horn of the lateral ventricles using CT images of a selected Nigerian population in Delta State.

MATERIALS AND METHODS

Brain CT images stored in the digital archives (Picture Archiving Communications Systems [PACS]) of a Radiology unit in Delta State, Nigeria, were assessed in this study. These images belonged to patients referred for imaging between May 1, 2015, and May 30, 2020, due to suspected intracranial space-occupying lesions, head injury, pulmonary embolism, or stroke. Institutional approval (DELSUTH/HREC/2023/058/0712) was obtained for the retrospective review of these images. A total of 202 adult patients (109 males and 93 females), aged 18 years and above, were purposively selected for this study. The imaging data were acquired using a 64-slice Toshiba Aquilon CT scanner (Japan, 2009) with the following parameters: 120kV and 300mA.

Exclusion criteria comprised CT images of patients below 18 years, images of poor quality with artifacts or evidence of patient rotation, and images displaying intracranial pathologies such as bleeds, tumors, infarcts, cerebral hydrocephalus, or raised intracranial pressure.

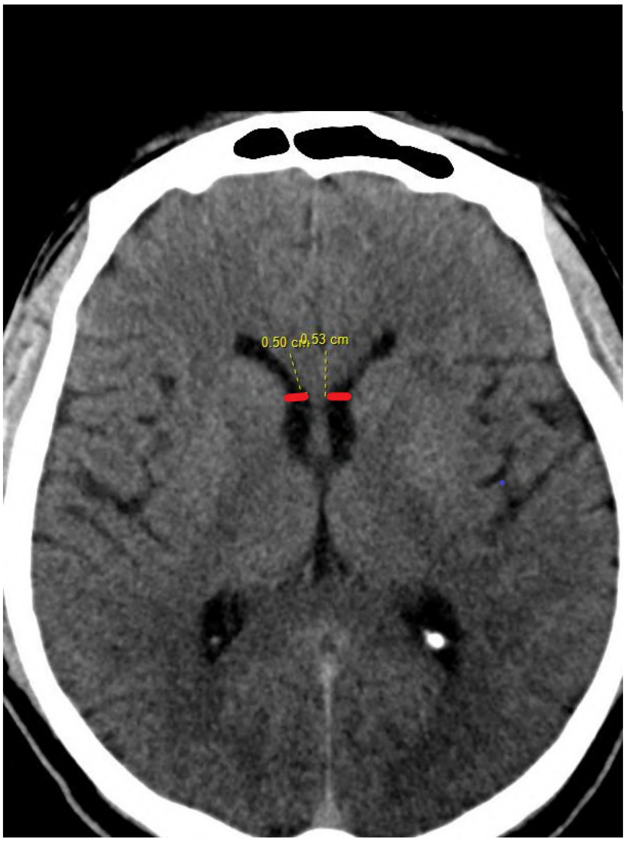

Fig. 1.- Axial CT sections of the brain showing measurement of the maximum frontal horn width.

Identification of the frontal horns of the lateral ventricles was performed on axial sections. The length and width of the frontal horn were quantified in centimeters using a digital caliper. Width was determined as the maximum transverse distance from the medial to lateral walls of each frontal horn (Fig. 1), while length was defined as the maximum distance from the interventricular foramen to the tip of the frontal horn on both sides (Fig. 2). The distance between the bilateral frontal horn tips (FHTD) was measured as the maximum distance between the right and left frontal horn tips (Singh et al., 2020) (Fig. 3).

Data analysis was conducted using the International Business Machine (IBM) Statistical Package for Social Sciences (SPSS), version 25. The data were categorized according to gender and 10-years age groups. Independent and paired sample t-tests were employed for gender and side comparisons of mean variables, respectively. Bivariate Pearson's correlation was utilized to assess the correlation of frontal horn parameters with age. One-way Analysis of Variance (ANOVA) was employed to evaluate differences in means

Fig. 2.- Axial CT sections of the brain showing the measurement of the frontal horn length.

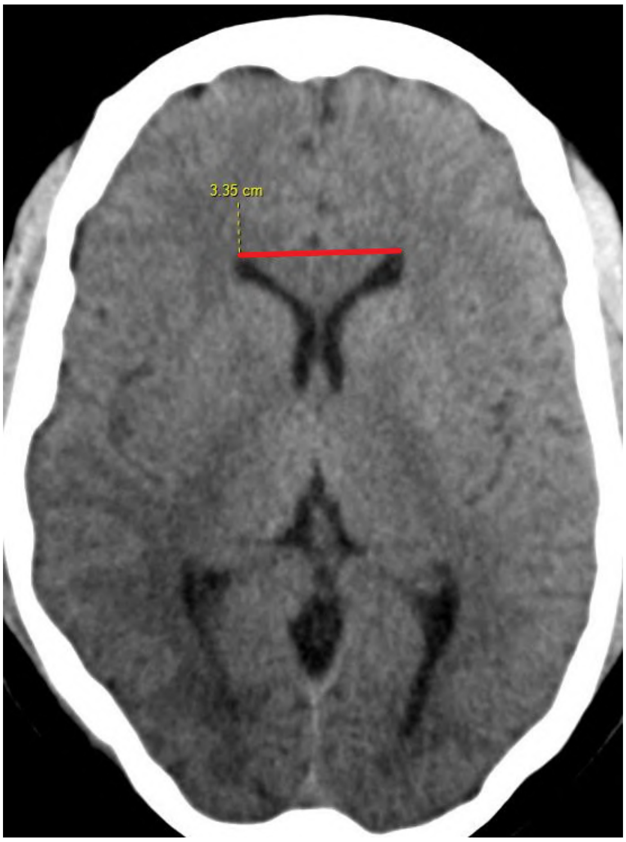

Fig. 3.- Axial brain CT scans showing the maximum distance between the tip of frontal horns.

within various age groups. All tests of significance were two-tailed, and a significance level of P ≤ 0.05 was deemed statistically significant. Data were summarized using means and standard deviations, and the results were presented in tables.

RESULTS

This investigation examined the dimensions of the frontal horn of the lateral ventricles by analyzing CT brain images of 202 adult patients, with a larger proportion of males (109, 54.0%) than of females (93, 46%). The age range of the participants was 18 to 65 years, with a mean age of 44.42 ± 13.27 years. The mean length and width of the right and left frontal horns, as well as the mean FHTD, are presented in Table 1. Additionally, the maximum and minimum values for each dimension are also included in Table 1.

Table 1. Descriptive statistics of the studied parameters.

Parameter	Minimum	Maximum	Mean ± S.D.
Age (Years)	18.00	65.00	44.42±13.27
LL (cm)	1.73	3.86	2.71±0.41
RL (cm)	1.79	3.67	2.63±0.40
LW (cm)	0.14	2.59	0.64±0.28
RW (cm)	0.19	1.78	0.61±0.25
FHTD (cm)	1.95	3.73	2.93±0.31

LL = left length, RL = right length, LW = left width, RW = right width, FHTD = frontal horn tip diameter

All the dimensions demonstrated larger measurements in males compared to females. The gender differences in the length of bilateral frontal horns and the FHTD exhibited statistical significance ($p<0.05$), whereas the width of both right and left frontal horns did not show any significant association with gender ($p>0.05$) (Table 2). Further investigation revealed a significant asymmetry in the length of frontal horns between the left and right sides (p=0.001). Conversely, no significant side differences were observed in the width of the frontal horns (p=0.068) (Table 3).

Analysis across different age groups revealed significant variations in the frontal horn length and width bilaterally ($p <0.05$). However, no significant age differences were detected in the FHTD (p= 0.451) (Table 4). The investigation into the correlation between frontal horn dimensions and age revealed a significant weak positive correlation bilaterally in terms of length (r=0.245, 0.157; $p<0.05$) and width (r=0.249,0.388; $p<0.05$) of the frontal horn. Conversely, the FHTD displayed a weak positive correlation (r=0.059) with age that did not reach statistical significance (p=0.401) (Table 5). A comparative summary of frontal horn dimensions across various study populations is presented in Table 6.

Table 2. Gender differences in the frontal horn parameters.

Parameter	Mean ± S.D (cm)		P value
	Male	**Female**	
LL	2.82 ± 0.42	2.58 ± 0.35	0.001*
RL	2.71 ± 0.41	2.54 ± 0.36	0.002*
LW	0.67 ± 0.32	0.59 ± 0.23	0.052
RW	0.62 ± 0.27	0.60 ± 0.22	0.432
FHTD	3.01 ± 0.33	2.84 ± 0.28	0.001*

LL- left frontal horn length, RL- right frontal horn length, LW- left frontal horn width, RW-right frontal horn width, FHTD- distance between the frontal horn tips, *p considered significant at <0.05

Table 3. Side differences of the frontal horn length and width.

Parameter	Side	Mean ± S.D (cm)	P value
Length	Left Right	2.71 ± 0.41 2.63 ± 0.40	0.001*
Width	Left Right	0.64 ± 0.28 0.61 ± 0.25	0.068

DISCUSSION

The mean length of the right and left frontal horn in this study was lower than the measurements reported in several earlier studies in different populations (Usman et al., 2012; Arun et al., 2017; Agegnehu et al., 2021; Quarshie et al., 2021; Farheen and Sukre, 2017) (Table 6). The width of the frontal horn was higher than the findings by Agegnehu et al. (2021). These authors also reported larger FHTD compared to our findings. Discrepancies among studies in frontal horn dimensions could stem from methodological variations (using CT versus MRI), differences in sample sizes, diverse measurement techniques, and the age composition of the participants (Arun et al., 2017). Furthermore, variations could be due to the influence of racial and geographical factors (Quarshie et al., 2021). Understanding the population variations in frontal horn dimensions ensures accurate

Table 4. Age differences in the frontal horn parameters.

Parameter (cm)			Age (Years)				P value
	<20	21-30	31-40	41-50	51-60	61-70	
Mean ±SD							
LL	2.60 ± 0.21	2.61 ± 0.45	2.52 ± 0.36	2.82 ± 0.35	2.84 ± 0.37	2.75 ± 0.44	0.001*
RL	2.53 ± 0.29	2.60 ± 0.42	2.46 ± 0.35	2.70 ± 0.37	2.75 ± 0.35	2.66 ± 0.48	0.012*
LW	0.48 ± 0.13	0.59 ± 0.43	0.56 ± 0.20	0.63 ± 0.25	0.69 ± 0.22	0.76 ± 0.29	0.024*
RW	0.39 ± 0.11	0.51 ± 0.24	0.52 ± 0.22	0.59 ± 0.21	0.71 ± 0.21	0.77 ± 0.29	0.001*
FHTD	2.85 ± 0.41	2.90 ± 0.32	2.89 ± 0.33	2.95 ± 0.36	3.01 ± 0.29	2.89 ± 0.30	0.451

LL- left frontal horn length, RL- right frontal horn length, LW- left frontal horn width, RW-right frontal horn width, FHTD- distance between the frontal horn tips, *p considered significant at <0.05

Table 5. Age correlation with the frontal horn parameters.

Parameter	r	P value
LL	0.245	0.001*
RL	0.157	0.026*
LW	0.249	0.001*
RW	0.388	0.001*
FHTD	0.059	0.401

LL- left frontal horn length, RL- right frontal horn length, LW- left frontal horn width, RW-right frontal horn width, FHTD- distance between the frontal horn tips, *p considered significant at <0.05

Table 6. Frontal horn measurements in diffèrent populations.

Author	Country	N	Unit	Side	Mean ± SD		Average
					Male	Female	
Agegnehu et al. (2021)	Ethiopia	169	mm	RL LL	27.79±3.62 28.66±3.67	26.96±3.97 27.95±4.01	
Honnegowda et al. (2017)	Manipal, India	250	mm	RL LL	30.54±3.4 30.14±4.7	28.4±4.2 27.4±3.2	28.7±2.90 29.2±3.72
Moawia et al. (2015)	Saudi Arabia	152	mm	RL LL	28.5±3.8 28.5±3.8	26.16±4.2 26.2±4.2	
Sharmin et al. (2020)	Bangladesh, India	60	mm	RL LL	28.82±2.56 29.31±2.53	26.54±2.9 26.79±2.44	
Farheen and Sukre, (2017)	Aurangabad, India	500	mm	RL LL	28.5±1.06 30.3±1.46	25.9±1.46 29.7±1.22	
Yadav et al. (2015)	Meerut, India	200	mm	RL LL	29.8±2.6 31.1±2.5	28.9±2.3 29.9±2.3	29.3 30.5
Current study	Nigeria	202	cm	RL LL	2.71±0.41 2.82±0.42	2.54±0.36 2.58±0.35	2.71±0.41 2.63±0.40

RL- right frontal horn length, LL- left frontal horn length

diagnostic assessments and treatment planning (Agegnehu et al., 2021). Recognizing population-specific norms allows clinicians to interpret imaging results with greater precision, reducing the risk of misinterpretation and unnecessary interventions (Annongu et al., 2017; Arun et al., 2017). This knowledge is particularly relevant for neurosurgical planning, as variations in frontal horn dimensions can influence the approach and strategies employed in surgical procedures such as endoscopic surgeries or ventriculoperitoneal shunt insertions while minimizing complications (Arun et al., 2017; Quarshie et al., 2021).

Significant gender differences were observed in the length of the frontal horn and the FHTD, which were larger in males than in females. Agegnehu et al. (2021) reported significantly larger width and FHTD in males compared to their female counterparts. Yadav et al. (2015) and Sharmin et al. (2020) also reported larger frontal horn lengths in males, and this was contrary to the observations by Farheen and Sukre (2017). In Ukraine, the width of the frontal horn lacked significant association with gender (Polat et al., 2019). Gender differences in the size of the lateral ventricles can be attributed to larger skull capacity and brain volumes in males that influence the ventricular size (Bijaylakshmi et al., 2014; Yadav et al., 2015; Annongu et al., 2017). This is because the sex hormones impact the brain structure and fluid dynamics, which is crucial in maintaining brain homeostasis. There could also be sex-specific genetic influences that may contribute to the observed sexual dimorphism in the ventricular size (Yadav et al., 2015). This dimorphism in ventricular size may have implications for diagnosis and management of neurological disorders such as dementia or neurodegenerative diseases, which may exhibit sex-related variations in their impact on brain structures including the ventricles (Usman et al., 2012). Additionally, neurosurgical procedures need to account for sex-related variations in ventricular size (Arun et al., 2017; Quarshie et al., 2021).

The left frontal horn length was significantly larger than the right, aligning with results reported by some earlier studies (Bijaylakshmi et al., 2014; Quarshie et al., 2021). Conversely, Farheen and Sukre (2017) and Annongu et al. (2017) did not observe any significant side differences in the frontal horn length. No significant side difference was observed in frontal horn width in our study, in contrast to the findings of Agegnehu et al. (2021) and Zhuravlova and Montgomery, (2023) who reported significantly wider frontal horn on the left and right side respectively. Asymmetry in normal lateral ventricle size is influenced by various factors such as functional lateralization of cognitive functions, handedness, neurodevelopmental processes, genetic and environmental factors (Bijaylakshmi et al., 2014; Arun et al., 2017; Quarshie et al., 2021). While some degree of asymmetry is considered normal, extreme or consistent, asymmetry may prompt further investigation to rule out underlying neurological conditions or abnormalities (Arun et al., 2017). This knowledge informs diagnostic assessments and helps avoid unnecessary interventions related to normal anatomical variability in the human brain.

The length and width of the bilateral frontal horns exhibited significant differences across various age groups while the FHTD did not. Among the Ethiopians evaluated by Agegnehu et al. (2021), the frontal horn length, width and FHTD showed significant differences between the age-groups. On the contrary, Fareen and Sukre (2017) did not observe any significant differences age-wise. This discrepancy might be attributed to variations in sample size and gender distribution within each age group (Arun et al., 2017; Quarshie et al., 2021).

This study identified a significant weak positive correlation between the length and width of the frontal horns and age bilaterally. The FHTD had no significant correlation with age. Agegnehu et al. (2021) observed a strong positive correlation between each of the three dimensions (length, width and FHTD) with age. The population examined by Sharmin et al. (2020) showed an increasing frontal horn length up to the age of 40 years, while later a reduction was observed. Zhuravlova and Montgomery (2023) also reported increasing frontal horn width with age. The increase in ventricular sizes with age is attributed to natural changes in brain structure and volume during the aging process (Yadav et al., 2015). Brain atrophy or shrinkage is associated with compensatory enlargement of CSF spaces (Bijaylakshmi et al., 2014; Annongu et al., 2017). Understanding these age-related variations aids in distinguishing normal age-related changes from potentially pathological conditions, guides treatment planning in neurosurgery, and informs the interpretation of neuroimaging results in different age cohorts, contributing to more accurate diagnoses and choice of interventions (Quarshie et al., 2021; Zhuravlova and Montgomery, 2023).

In this current study, the use of a CT and a standardized methodology for measurements enhance the reliability and reproducibility of the findings. The inclusion of gender- and age-specific analyses provide valuable reference for clinicians and researchers in neurology and neurosurgery. However, the retrospective nature of the research limited the sample size which may impact the generalizability of the findings. Additionally, the study does not associate the dimensions measured with clinical symptoms or conditions. The future research endeavors can assess the clinical implications of frontal horn variations in relation to neurological symptoms or disorders. The age-related changes in frontal horn dimensions could be tracked over-time to aid in the early detection of pathological conditions.

CONCLUSION

The study provides the standard reference values of the dimensions of the frontal horns on CT based on age and gender groups. This has important implications for accurate diagnostic interpretation in clinical settings, and is therefore useful to neurosurgeons, psychiatrists and neurologists, and neuroradiologists in Delta State.

ACKNOWLEDGEMENTS

We thank the staff in the Radiology Department for their technical help in accessing the database. We also extend our gratitude to Emmanuel Akpoyibo, who assisted with data collection and analysis.

REFERENCES

AGEGNEHU A, TENAW B, GEBREWOLD Y, JEMBERIE M (2021) Morphometric study of frontal horn of the lateral ventricles of the brain and its correlation with age, gender and side among adults in the University of Gondar Comprehensive Specialized Hospital, Gondar, Northwest Ethiopia, 2019. *Aust J Anat,* 8(1): 1096.

ANNONGU IT, MOHAMMAD H, ACHINGE G, MAGAJI OG, IYUA K, IKUBOR JE (2017) Morphometric study of the adult human brain ventricular sizes on computed tomography scans in Nigerian. *Eur J Biomed Pharm Sci,* 4(6): 95-98.

ARUN KS, KUMARI SM, ANAND MV, SARASWATHY R, RAJESHWARI M (2017) Evaluation of Evan's index in South Indian population using computed tomography. *Int J Anat Radiol Surg,* 6(3): 28-31.

BIJAYLAKSHMI P, NIRANJAN SR, RABINDRA NP (2014) Age related changes in ventricular system of brain in normal individuals assessed by computed tomography. *Siriraj Med J,* 66: 225-230.

BLINKOUSKAYA Y, WEICKENMEIER J (2021) Brain shape changes associated with cerebral atrophy in healthy aging and Alzheimer's disease. *Front Mech Eng,* 7: e705653.

FARHEEN SF, SUKRE SB (2017) Morphometric study of frontal horn of lateral ventricle by computerised tomography. *Int J Anat Res,* 5(3.1): 4063-4066.

HONNEGOWDA TM, NAUTIYAL A, DEEPANJAN M (2017) A morphometric study of ventricular system of human brain by computerised tomography in an Indian population and its clinical significance. *Aust J Anat,* 4(4): id1075.

MOAWIA G, ABDALRAHIM A, AMIR A, AL-RADDADI M (2015) Morphometric analysis of the brain ventricles in normal subjects using computerized tomography. *Open J Radiol,* 5: 13-19.

OLAWANDE T, AJAYI MP, AMOO EO, OLAWOLE-ISAAC A (2020) Treatment pathways of Alzheimer in Nigeria. *Heliyon,* 6(12): e05724.

PATNAIK P, SINGH V, SINGH D, SINGH S (2016) Age and gender related variations in lateral ventricle brain ratios. *Int J Health Sci Res,* 6(5): 7884.

POLAT S, OKSUZLER FY, OKSUZLER M, KABAKCI AG, YUCEL AH (2019) Morphometric MRI study of the brain ventricles in healthy Turkish subjects. *Int J Morphol,* 37(2): 1-5.

QUARSHIE JT, MENSAH EN, QUAYE O, AIKINS A (2021) The current state of parkinsonism in West Africa: A systematic review. *Hindawi,* 2021: 1-4.

SHARMIN S, AKHTARI A, ATIQUR R, SYED AI (2020) Morphometric study of lateral ventricles of brain by MRI in healthy adults in Northern zone of Bangladesh. *Ibrahim Card Med J,* 10(1&2): 45-50.

SINGH S, BHOJ RS, URUSHA P, PUJAN S, MANOJ B, NAWARAJ P (2020) Estimation of ventricles size of human brain by Magnetic Resonance Imaging in Nepalese population: a retrospective study. *J Gandaki Med Coll Nepal,* 13(1): 45-50.

USMAN JD, YUNUSA GH, SAIDU SA, BELLO SM, ABDULHAMEED A, BELLO SS, TRADROS AA (2012) Morphometric study of the lateral ventricles using computerized tomography. *Afr J Online,* 14(1): 1-5.

YADAV A, SHARMA A, NIGAM GL, YADAV A, CHAUHAN K, PANDEY VD (2015) Morphometric study of frontal horn of the lateral ventricles of the brain by computed tomography in Western population. *J Anat Sci,* 23(2): 22-27.

ZHURAVLOVA I, MONTGOMERY A (2023) The anatomic variability of the lateral ventricles of the human brain depending on age and sex. *Cureus,* 15(9): e45915.