Original Article

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Anatomy Section

Morphometric Analysis of Lateral Ventricles of the Brain using Magnetic Resonance Imaging and Dissection Method: A Cross-sectional Study

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ABSTRACT

Introduction: The lateral ventricle, which is the largest among all ventricles of the brain, can be divided into the frontal horn, body, posterior horn, and inferior horn. Various methodologies may produce different results in measuring the length of the lateral ventricle.

Aim: To determine whether there are any differences in the lengths of the lateral ventricle when measured using formalin-fixed brain specimens and Magnetic Resonance Imaging (MRI) scans.

Materials and Methods: This cross-sectional study was conducted from April 2014 to March 2019 in the Department of Anatomy at Silchar Medical College and Hospital, Assam, India. A total of 127 formalin-fixed cadaveric brain specimens were used to measure the lengths of different parts of the lateral ventricle using a Vernier Calliper. Additionally, MRI scans of 35 patients were used to measure the same lengths. The mean values of the lateral ventricle lengths measured in formalin-fixed brain specimens and MRI scans were compared using Student's t-test to determine statistical significance. Furthermore, variations in the lengths of the lateral ventricle according to age and gender were also measured using MRI.

Results: Among the 127 brain specimens, 78 were from male brains and 49 were from female brains. Out of the 35 MRI scans, 23 were from male cases and 12 were from female cases. The average length of the frontal horn, body, and inferior horn was found to be greater in MRI scans (34.83 mm, 54.37 mm, and 51.09 mm, respectively) compared to the dissection method in cadavers (30.64 mm, 35.49 mm, and 42.29 mm, respectively). All parts of the lateral ventricle measured in MRI scans were found to have greater lengths in males, although the difference was not statistically significant.

Conclusion: A significant difference was observed when comparing the lengths of the lateral ventricle measured in MRI scans and formalin-fixed cadaveric brain specimens.

Keywords: Body, Brain specimens, Horn, Length

INTRODUCTION

One of the extremely conserved features of the vertebrate brain is the ventricular system, which is a network of linked chambers filled with cerebrospinal fluid [1]. The cerebral ventricles have been known since the time of Aristotle [2]. Approximately 2% of the brain's total volume consists of ventricles [3]. Clinicians, Neurosurgeons, and Radiologists can benefit from understanding the normal and abnormal structure of the brain's ventricular system in their day-to-day scientific work [4]. A crucial examination for hydrocephalus in children involves visualising the cerebral ventricles. The diagnosis and classification of hydrocephalus have always relied on morphometric measurements of the ventricular system, as well as the assessment and monitoring of ventricular system expansion during interventions such as ventricular shunts [5,6]. There is a reduction in brain tissue associated with ventricular enlargement and other physical and histological changes in the brain as a result of aging and various dementias [7].

Another explanation for the atrophy of cerebral white matter resulting in ventriculomegaly is diffuse axonal damage. Consequently, abnormal ventricular enlargement has been considered a sign of impending cerebral degeneration. This could be due to the adaptive potential of the ventricular system or a reduction in neuron size [8]. Research on postmortem cases as well as imaging studies have demonstrated the association between increased cerebrospinal fluid areas and decreased cerebral volume during normal aging in humans [9]. Therefore, a comprehensive understanding of age-related physiological changes in the brain is recommended before evaluating abnormal findings [10]. Many authors suggest that there are gender variations in the brain's aging process, with the changes in females being relatively mild compared to males [11]. Typically, the left lateral ventricle is larger than the right lateral ventricle [12]. There is ongoing debate about the most effective method for measuring the various parts of the cerebral ventricular system in the fields of neuroanatomy, psychiatry, neuroradiology, and neurology [12]. Despite an extensive literature search, there is a lack of studies comparing the measurements of lateral ventricle parameters in MRI scans and cadaveric brain specimens. So, the present study was conducted with the aim to measure the length of lateral ventricle using formalin-fixed brain specimens and Magnetic Resonance Imaging (MRI) scans.

MATERIALS AND METHODS

This cross-sectional study was conducted from April 2014 to March 2019 after obtaining Institutional Ethical Committee (IEC) clearance (MC/233/2013/217 Dated 5/04/2014). Brain specimens for the dissection method were obtained from deceased individuals who underwent postmortem examinations in the Department of Forensic Medicine, Silchar Medical College, Silchar, as well as from bodies voluntarily donated to the Department of Anatomy, Silchar Medical College, Silchar. In all cases, age, sex, and cause of death was recorded. Normal MRI scans of 35 cases from different age groups, performed in the Department of Radiology, Silchar Medical College and Hospital, were collected for radiological comparison.

Sample size calculation: It was performed using the formula $n=z^2\ \sigma^2/d^2$, where 'z' represents the desired level of confidence, 'd' represents the desired width of the confidence interval, and 'σ' represents the standard deviation. For this study, 'z' was set to 1.96, 'σ' was 26, 'd' was 5, and 'n' was approximately 104.

Inclusion criteria: Postmortem brain specimens and MRI scans of individuals belonging to age groups 10-70 years and above, of both genders, were included in the study.

Exclusion criteria: Postmortem brain specimens with head injury and visible mass lesions were excluded from the study. The MRI scans with a history of head injury, cerebral infarction, local mass lesion, and prior intracranial surgery were also excluded from the study.

The brains were labelled and preserved in a 10% formalin solution after removal during postmortem. Subsequently, the brains were dissected according to Cunningham's Manual of Practical Anatomy [13].

Dissection of Lateral Ventricle

Initially, the brain was split into two hemispheres along the mid-sagittal plane, and the arachnoid and piamater were carefully removed. A vertical cut was made from the interventricular foramen on one hemisphere, passing through the fornix, septum pellucidum, and medial aspect of that hemisphere. The cut was then opened, and a knife was used to extend the cut posteriorly and downwards along the lateral edge of the lateral ventricle, reaching the posterior ramus of the lateral sulcus. The cut was continued and opened. The upper surface of the temporal lobe was slit in the forward direction while holding the knife vertically in the ventricle. This cut was opened onto the roof of the inferior horn of the lateral ventricle. The cut was continued forward, and after confirming that it was in the inferior horn of the lateral ventricle, the frontal lobe was detached from the temporal lobe. Various parameters used in the measurement of the lateral ventricle using the dissection method were as follows [Table/Fig-1-3]:

Frontal horn length: measured from the interventricular foramen to the frontal horn tip on both sides.

Length of the body: measured from the interventricular foramen to the center of the collateral trigone on both sides.

Length of the posterior horn: measured from the center of the collateral trigone to the tip of the posterior horn on both sides.

Length of the inferior horn: measured from the center of the collateral trigone to the tip of the inferior horn on both sides.

Data collection for MRI scans (for radiological comparison):

- Similar points as in the dissection method were considered for the MRI scans [Table/Fig-4-6].
- MRI scans of the patients were performed using the Siemens Abanto Fit 1.5 tesla machine in the Department of Radiology, Silchar Medical College and Hospital. Sagittal and transverse axial planes were used for MRI scanning.

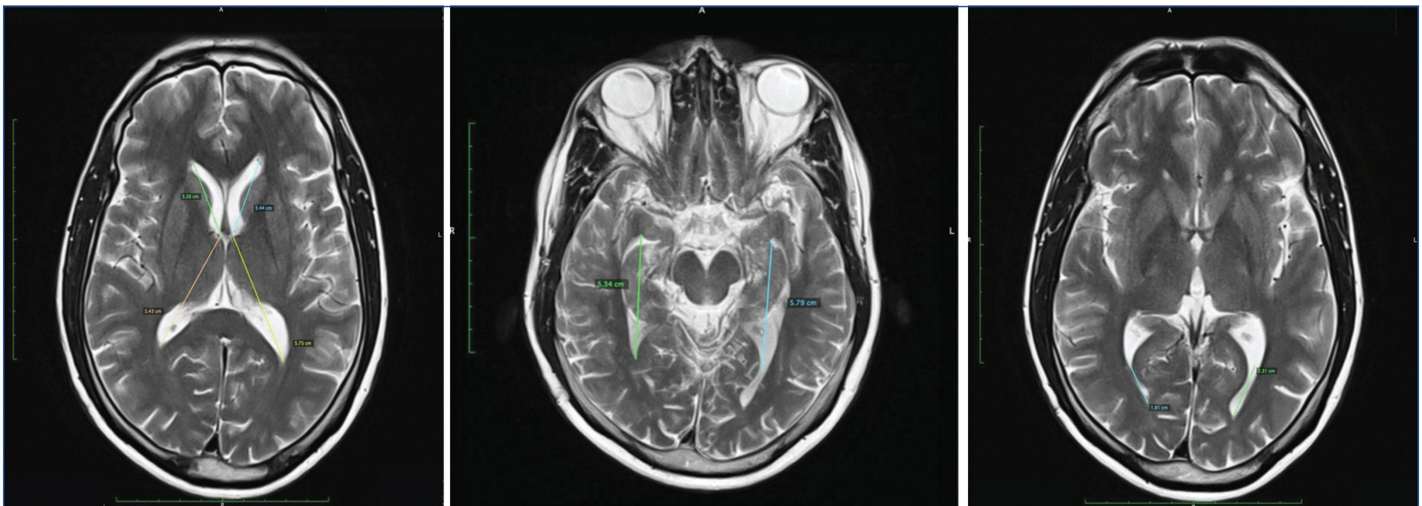
STATISTICAL ANALYSIS

Statistical Package for Social Sciences (SPSS) version 18.0 was used for the statistical analysis of the data. Statistical parameters such as mean, standard deviations, and standard errors of the mean were calculated for all measurements. The data was analysed and compared using Student's t-test to determine significance. Spearman's rank correlation coefficient was used to correlate measurements of different parameters with age. p-value ≤0.05 was considered statistically significant.

RESULTS

During the study, a total of 127 brain specimens were obtained from individuals aged 10 years to 70 years and above. Out of the 127 specimens, 78 were male brains and 49 were female brains.

[Table/Fig-1]: Median sagittal section showing frontal horn of lateral ventricle: I-interventricular foramen, J- tip of frontal horn, IJ-length of frontal horn. **[Table/Fig-2]:** Length of the body of lateral ventricle: measurements taken from inter ventricular foramen (I) to the centre collateral trigone (M) on both sides. **[Table/Fig-3]:** Dissected brain specimen showing posterior and inferior horn of lateral ventricle ML- length of inferior horn, MN- length of posterior horn. M- Centre of collateral trigone. (Images from left to right)



[Table/Fig-4]: Showing measurement of length of frontal horn and body. **[Table/Fig-5]:** Showing measurement of length of inferior horn. **[Table/Fig-6]:** Showing measurement of length of posterior horn. (Images from left to right)

For radiological comparison, normal MRI scans of 35 cases from different age groups were taken, including 23 males brains and 12 females brain. The mean length of the frontal horn, body, posterior horn, and inferior horn measured by MRI were found to be 34.83 mm, 54.37 mm, 23.10 mm, and 51.09 mm, respectively [Table/Fig-7].

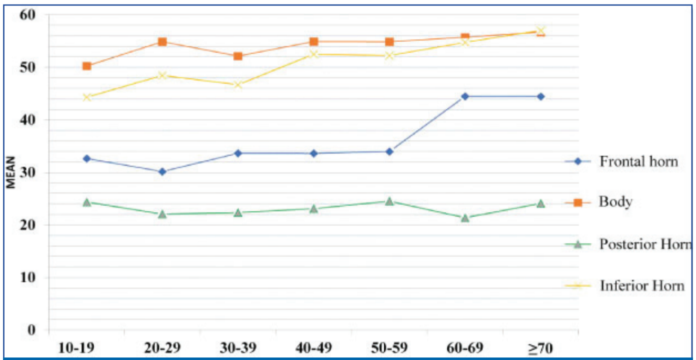
Statistical parameters	Frontal horn	Body	Posterior horn	Inferior horn
Mean (in mm)	34.83	54.37	23.10	51.09
Standard Deviation	4.56	2.48	2.55	4.53
Minimum (in mm)	22.2	49.2	16.3	40.5
Maximum (in mm)	47.9	59.6	28.3	59.7

[Table/Fig-7]: Average lengths of different parts of lateral ventricle (by MRI).

In the 35 MRI cases, almost similar lengths of the frontal horn were observed in the age group of 30-59 years. The maximum length was found in the age group of 60-69 years (44.47 mm), although the length remained almost similar in the age group of ≥70 years [Table/Fig-8,9]. The maximum length of the body (56.7 mm) was found in the age group of ≥70 years, while the minimum was found in the age group of 10-19 years (50.25 mm) [Table/Fig-8,9]. The maximum length of the posterior horn was found in the age group of 50-59 years (24.53 mm). In the case of the inferior horn, the maximum length (57.02 mm) was observed in the ≥70 years age group [Table/Fig-8,9].

Age group (years)	Mean values of different parts of lateral ventricles in mm							
	Frontal horn	p-value	Body	p-value	Posterior horn	p-value	Inferior horn	p-value
10-19	32.65	7.85	50.25	1.72	24.35	1.85	44.3	1.44
20-29	30.16		54.88		22.06		48.46	
30-39	33.64		52.14		22.35		46.68	
40-49	33.61		54.9		23.1		52.5	
50-59	33.97		54.86		24.53		52.23	
60-69	44.47		55.72		21.37		54.75	
≥70	44.45		56.7		24.1		57.02	

[Table/Fig-8]: Average length of different parts of lateral ventricle in various age groups (in MRI).



[Table/Fig-9]: Line diagram showing age wise changes in mean length of different parts of lateral ventricle (MRI).

For gender comparison, although the frontal horn length was found to be slightly greater in male cases (35.1 mm, with a range of 28.2 to 45.4 mm) than in female cases (34.13 mm, with a range of 28.5 to 47.9 mm), the difference was statistically non-significant [Table/Fig-10].

The average lengths of the frontal horn, body, and inferior horn were found to be greater in MRI (34.83 mm, 54.37 mm, and 51.09 mm, respectively) than in the dissection method in cadavers (30.64 mm, 35.49 mm, and 42.29 mm, respectively) [Table/Fig-11].

DISCUSSION

The issue of volumetric measurement in normal subjects has been resolved with the development of MRI scanning [14]. Assessing the normal dimensions of cerebral ventricles in living humans is crucial for the diagnosis and monitoring of various diseases [14]. There is growing interest among researchers in the morphometric studies of human brain ventricles due to their association with conditions such as hydrocephalus, schizophrenia, tumors, injuries, etc., as well as gender and aging, which can lead to dementia or other senile brain disorders [Table/Fig-12,13] [14]. Radiological methods like CT, MRI, ventriculography, and pneumoencephalography provide indirect and two-dimensional results, and magnification factors may distort the results. On the other hand, measurements taken from casts provide direct and three-dimensional orientation, reducing the chances of error and ensuring more accurate measurements. Casts of the ventricular system were prepared from 20 formalised cadaveric human brains by injecting an epoxy resin+hardener (BOND TITE) mixture [19]. Therefore, future studies are needed to determine the discrepancy between MRI measurements and the true morphometry of the lateral ventricle, which would enable neurosurgeons to plan surgeries involving the lateral ventricle more effectively.

Parts of lateral ventricle	Mean value of lengths in males and females		p-value
Frontal horn	Male	35.1±3.79	0.677
	Female	34.31±5.83	
Body	Male	54.78±2.66	0.143
	Female	53.6±1.92	
Posterior horn	Male	23.43±2.24	0.34
	Female	22.49±2.9	
Inferior horn	Male	51.32±3.87	0.719
	Female	50.66±5.6	

[Table/Fig-10]: Comparison between gender wise measurements of mean length of different parts of lateral ventricle (in MRI).

Lateral ventricle	MRI		In cadaver		p-value
	Mean (mm)	SD	Mean (mm)	SD	
Frontal horn length	34.83	4.56	30.64	4.63	<0.001
Body length	54.37	2.48	35.49	2.43	<0.001
Posterior horn length	23.10	2.55	26.21	4.24	<0.001
Inferior horn length	51.09	4.53	42.29	5.91	<0.001

[Table/Fig-11]: Comparison of mean measurements of ventricles on MRI and dissection method.
Statistical test used: student's t-test; p-value<0.001 considered highly significant

Name of the study and Year	Sample size	Changes in lateral ventricle
Kwon YH et al., (2014) [15] (South Korea)	60 subjects	Ventricular enlargement with normal aging and its related changes in periventricular white matter. Diffusion tensor imaging was used in the study.
Parija B et al., (2014) [16] (India)	120 subjects	Sizes of all three ventricles increased with aging which was specifically accelerated in subjects above 50 years of age Computed Tomography (CT) scan of brains were used for measurements of lateral, third and fourth ventricles.
Sulimana ASM et al., (2017) [14] (Sudan)	80 patients	Size of the right and left anterior horn of lateral ventricle was increasing with age. Slight increase in its size with age, with marked reduction in size of the body of lateral ventricle in age group 36-48 years. Descriptive analytical study was conducted for head MRI examination for various indications
Sharmin S et al., (2020) [17] (Bangladesh)	60 individuals	Length of frontal horn of the lateral ventricles increases in size upto the early middle-age and thereafter shrinks, the length of ventricular body bears a linear relationship with age. Cross-sectional study was conducted with MRI brain to study the lateral ventricles.
Present study	35 normal individuals	Mean length of all parts of the lateral ventricle shows gradual increase in pattern as the age increases and the maximum length is seen in the age group of more than 70 years.

[Table/Fig-12]: Changes in lateral ventricle with aging according to different studies.

Name of the study and Year	Sample size	Difference in lateral ventricle according to gender
Parija B et al., (2014) [16] (India)	120 subjects	Males had higher ventricular size than that of females. CT scan of brains was used for measurements of lateral, third and fourth ventricles.
Mallika B et al., (2016) [18] (India)	200 individuals	Measurements of the lateral ventricles the frontal horn, body and posterior horn are more on left-side when compared to right-side in both male and female patients CT scans of patients were collected and measurements of lateral ventricle were performed.
Sulimana ASM et al., (2017) [14] (Sudan)	80 patients	There is significant statistical difference between genders where the body of lateral ventricle was found to be larger in male than female. Descriptive analytical study was conducted for head MRI examination for various indications.
Sharmin S et al., (2020) [17] (Bangladesh)	60 individuals	All the parameters of lateral ventricles (length of frontal horn, length of ventricular body) were significantly larger in males than those in their female counterparts. Cross-sectional study was conducted with MRI brain to study the lateral ventricles.
Present study	35 normal individuals	All parts of the lateral ventricle were found to have greater lengths in male than female but the difference was found to be non significant.

[Table/Fig-13]: Gender variation in lateral ventricle according to different studies.

Limitation(s)

Due to time constraints and experimental challenges, ventricle size data was collected from multiple cases with different ages rather than from a single case at different ages.

CONCLUSION(S)

All parts of the lateral ventricle, except the posterior horn, increased in size from the age group of 10 years to 70 years. There was a statistically non-significant gender variation in the lengths of the lateral ventricle, with greater length observed in males. The average lengths of the frontal horn, body, and inferior horn were significantly greater in MRI than in the dissection method using cadavers. The data obtained from this study will be useful for neurosurgeons in planning brain ventricular surgeries.

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