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Original Research Article

MORPHOMETRIC STUDY OF VENTRICULAR INDICES IN HUMAN BRAIN USING COMPUTED TOMOGRAPHY SCANS IN INDIAN POPULATION

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ABSTRACT

Introduction: Ventricular enlargement is a characteristic physical change that is present frequently in a number of cerebral disorders encountered in neurologic and psychiatric practice. Quantitative assessment of neuroimages for ventricular size is an effective approach to reveal structural changes in conditions such as Alzheimer's Disease, schizophrenia, Huntington's disease, hydrocephalus and many other neurological and psychiatric disorders.

Aim: The present study is being done with the aim to establish normal ventricular indices of brain in both sexes and to find the correlation between these indices in different age groups in Indian population.

Materials and Methods: The data for the present study are 300 CT scan which are collected from department of Radiology, Ramaiah hospitals. The following indices such as Evans index, bifrontal index, bicaudate index, cella media index, third ventricular index , Huckman's index and ventricular index were calculated. The parameters were tabulated and statistically analyzed.

Results: The ventricular indices showed statistically significant difference between males and females in all the indices except for cella media index. There was positive correlation coefficient between age and indices which was statistically significant.

Conclusion: The knowledge of normal anatomy of ventricular system of brain helpful for clinicians, neurosurgeons and radiologists in day to day clinical practice.

KEY WORDS: Linear Ventricular Indices, Evans Index, Bifrontal Index, Bicaudate Index , Cella Media Index , Third Ventricular Index , Huckman Index, Ventricular Index.

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INTRODUCTION

The ventricles of brain consists of a series of interconnecting spaces and channels which are filled with cerebrospinal fluid. It is developed

from the central lumen of embryonic neural tube. The ventricular system in the cerebral hemispheres consists of two lateral ventricles which connect with the third ventricle by interventricular foramen of Monro. The third ventricle is connected with the fourth ventricle by cerebral aqueduct of Sylvius [1]. Enlargement of ventricles is the most common abnormality that is frequently present in a number of neurologic and psychiatric disorders in both children and adults [2].

Assessment of ventricles by the older radiographic methods like gas or contrast encephalography, were highly invasive and also produced artifacts in lateral ventricles [3]. With the advent of newer imaging techniques like CT and MRI which are non-invasive and with no artifacts, evaluating ventricular sizes has become easier [4,5,6]. Though newer imaging techniques like MRI have evolved, assessment of brain ventricles by CT remains the most widely available and relatively affordable tool in Indian scenario [7]. Assessment of brain ventricles can be done by taking linear , planimetric or volumetric measurements, out of which, linear ratios of the width of ventricles to the width of skull or brain are probably the most easily made and reproducible ventricular measurements [8].

Morphometric study of ventricles of brain has been the main focus of study for assessing changes due to growth and ageing which could lead to dementia as well as intrinsic and extrinsic pathologies such as hydrocephalus, schizophrenia, tumors and trauma[9]. Obstruction of cerebral aqueduct due to a tumour or inflammatory swelling is a common cause of hydrocephalus. Morphometric analysis of ventricles is not only useful in the diagnosis and classification of hydrocephalus, but also in the assessment and follow up of enlargement of ventricular system during ventricular shunt therapy. For an early diagnosis of ventricular enlargement a baseline data is essential for comparison[10]. Ventricular measurements in alcoholics showed that ventricular size increases faster in alcoholics than in controls[11]. Understanding the normal and abnormal anatomy of the ventricular system of brain is helpful for clinicians, neurosurgeons, and radiologists in day-to-day clinical practice [12]. There are many indices based on linear measurements, which can be used to describe the ventricular system like Evans' Index, Huckman index, Bicaudate index, bifrontal index, etc [11,13].

The aim of the present study is to

1. Establish normal values for bifrontal, bicaudate, ventricular, Huckman's, Evans , third ventricular and cella media indices in both sexes.

2. To find the correlation between these indices in different age groups.

MATERIALS AND METHODS

This was a retrospective cross sectional study in which CT scans of 300 individuals in the age group of 10 - 70 of either sex attending the Department of Radiology were used.

The sample size for this study was calculated based on the study conducted by Zilundu[14] "Morphometric study of ventricular sizes on normal computed tomography scans of adult black Zimbabweans at a diagnostic radiology centre in Harare-a pilot study" it was found that frontal horn tip diameter was 31.82 ± 2.79 mm. In the present study, the sample size was calculated considering relative precision of 1% and desired confidence level of 95%, which was calculated to be minimum of 295 samples.

Inclusion criteria: The brain CT scans included in the study were of normal males and females with age groups between 10 - 70 years which were described as normal by radiologists with respect to normal cerebral ventricular size, form and shape.

Exclusion criteria: CT scans with history of head injury, cerebral infarctions, local mass lesions and previous intracranial surgeries were excluded from the study.

Detailed description of the procedure: The patient was placed on the CT table and the head was centralized and supported for correct positioning and to avoid blurring of images. A lateral scout image was taken to confirm correct positioning of patient and appropriate exposure factors. Orbito-meatal line was drawn and a line at an angle of 15 - 20 degrees to and 1 cm above it was drawn, representing the

lowest tomographic section, which passed through the base of skull. A total of 30 axial image slices of the brain were obtained without any overlap.

The following measurements will be taken:

A: The maximum bifrontal diameter: the transverse distance defined by a line connecting two anterior corners of the frontal horns.

A1: The first transverse diameter of the brain (brain width): the distance measured along the bifrontal diameter .

B: Minimum width of lateral ventricles.

B1: The second transverse diameter of the brain (brain width) - the distance measured along the line of minimum width of lateral ventricles.

C: Maximum inner skull diameter (MISD)

D: The greatest distances between each lateral margin of the third ventricle.

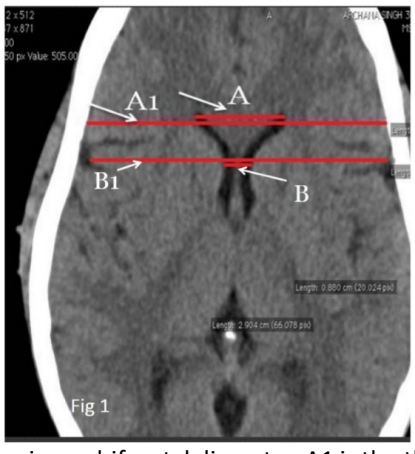
D1: The second transverse diameter of the brain (brain width): the distance measured along the line of D extending from left to the right cortical surfaces.

E: Width of both cellae media.

With these measurements the following indices will be calculated figure 1-4.

Ventricular indices	parameters
Bi frontal index	The maximum bifrontal diameter: the transverse distance defined by a line connecting two anterior corners of the frontal horns (A) / first transverse diameter of the brain (brain width): the distance measured along the bifrontal diameter (A1)
Bicaudate index	Minimum width of lateral ventricles (B) / The transverse diameter of the brain at the level of B (B1).
Evan's index	The maximum bifrontal diameter: the transverse distance defined by a line connecting two anterior corners of the frontal horns (A) / Maximum inner skull diameter (C)
Ventricular index	Minimum width of lateral ventricles (B) / The maximum bifrontal diameter (A) .
Huckman's index	Minimum width of lateral ventricles (B) + The maximum bifrontal diameter (A).
Cella media index	Width of both cella media (E) / Maximum inner skull diameter (C).
Third ventricle Ratio/index	The greatest distances between each lateral margin of the third ventricle (D) / The transverse diameter of the brain measured at the level of D (D1)

Fig 1: CT scan of brain showing the bifrontal (A/A1) and bicaudate index (B/B1)



A is the maximum bifrontal diameter, A1 is the the brain width at the level of maximum bifrontal the level of A. B is the minimum distance between the lateral ventricles, B1 is the brain width at the level of the B.

Fig. 2: Showing the third ventricular index where D is the maximum distance between each lateral margin of third ventricle and D1 is the brain width at the level of D.

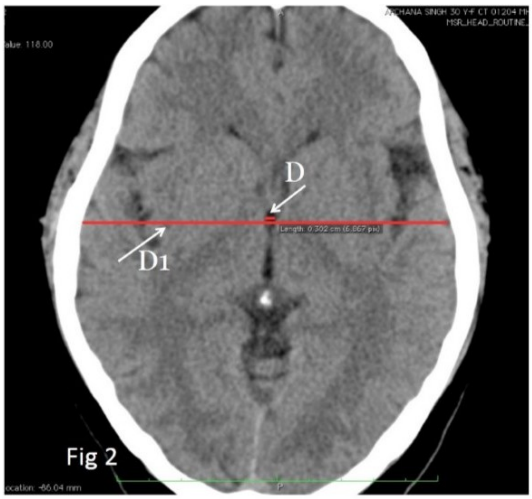


Fig. 3: Showing Evans index, where C is the maximum inner skull diameter.

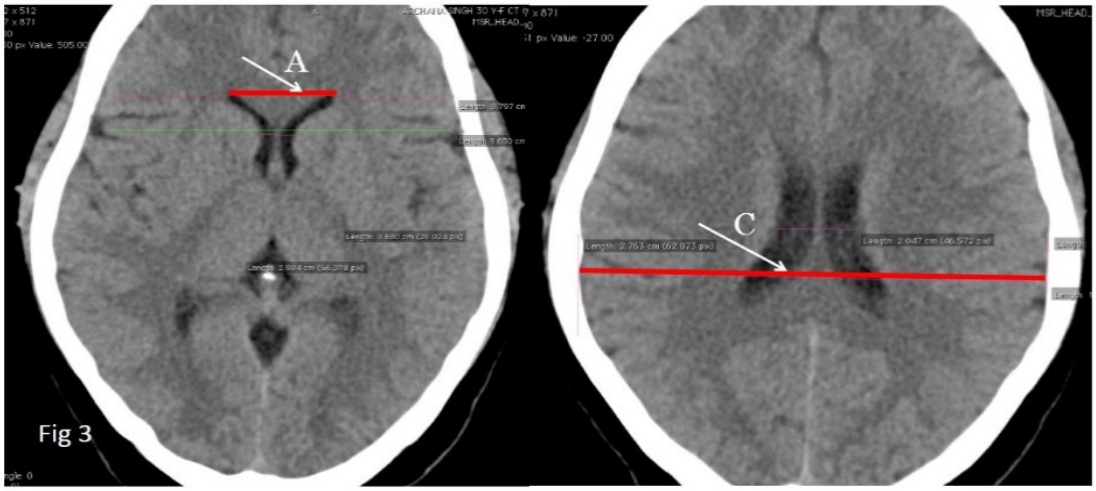
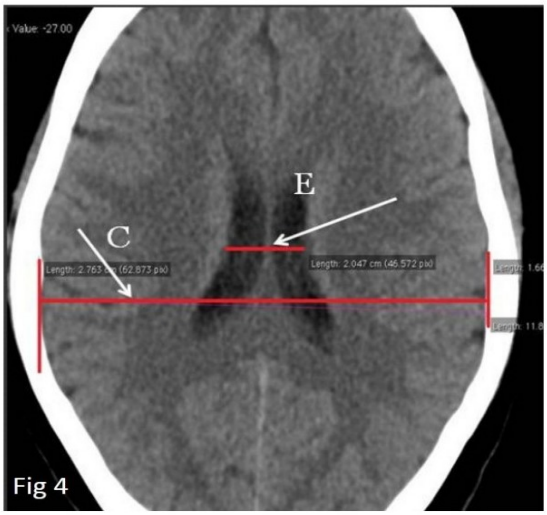


Fig. 4: Showing cella media index where E is the width of both cella media and C is the maximum inner skull diameter.



Statistical measures: All the above ventricular indices were analyzed and presented using descriptive statistics such as mean, standard deviation (SD). Gender - wise comparison in the mean value of these measurements was carried out using T TEST. Age - wise estimate was obtained and was compared for statistical significance difference using ANOVA test.

RESULTS

Table 1: Mean and standard deviation of all the indices.

Indices	Mean ± Standard deviation
Bifrontal index	0.303 ± 0.036
Bicaudate index	0.112 ± 0.033
Ventricular index	0.389 ± 0.098
Huckman index	4.371 ± 0.709
Evans index	0.252± 0.031
Third ventricular index	0.034 ± 0.013
Cella media index	0.227 ± 0.044

Table 2: Genderwise comparison of linear measurements and indices using T - Test.

Indices	Male	female	P value
Bifrontal index	0.310 ± 0.035	0.293 ± 0.036	<0.001
Bicaudate index	0.119 ± 0.035	0.104 ± 0.030	<0.001
Ventricular index	0.401 ± 0.091	0.375 ± 0.103	0.019
Huckman index	4.625 ± 0.704	4.061 ± 0.582	<0.001
Evans index	0.259 ± 0.029	0.243 ± 0.031	<0.001
Third ventricular index	0.037 ± 0.014	0.031 ± 0.011	<0.001
Cella media index	0.230 ± 0.046	0.222 ± 0.040	0.217

P value $\leq$ 0.05 is statistically significant

Table 3: Age wise comparison of linear measurements and indices using ANOVA test.

Age group Indices	10-20	21 – 30	31 - 40	41 - 50	51 - 60	> 60	P value	r value
Bifrontal index	0.292 ± 0.034	0.298 ± 0.031	0.298 ± 0.039	0.296 ± 0.037	0.309 ± 0.031	0.330 ± 0.038	<0.001	0.24
Bicaudate index	0.090 ± 0.026	0.097 ± 0.024	0.106 ± 0.028	0.114 ± 0.023	0.127 ± 0.039	0.148 ± 0.033	<0.001	0.496
Ventricular index	0.332 ± 0.105	0.343 ± 0.074	0.378 ± 0.106	0.410 ± 0.085	0.425 ± 0.096	0.460 ± 0.071	<0.001	0.431
Huckman index	4.08 ± 0.688	4.22 ± 0.696	4.26 ± 0.805	4.21 ± 0.674	4.59 ± 0.734	4.97 ± 0.845	<0.001	0.287
Evans index	0.245 ± 0.030	0.247 ± 0.026	0.246 ± 0.032	0.245 ± 0.033	0.257 ± 0.025	0.273 ± 0.031	<0.001	0.222
Cella media index	0.221 ± 0.049	0.215 ± 0.035	0.216 ± 0.042	0.224 ± 0.040	0.235 ± 0.049	0.260 ± 0.038	<0.001	0.274
Third ventricle index	0.027 ± 0.007	0.030 ± 0.011	0.032 ± 0.015	0.035 ± 0.011	0.040 ± 0.015	0.044 ± 0.012	<0.001	0.381

P value $\leq$ 0.05 is statistically significant

Three hundred brain Computed Tomography (CT) scan soft copies (165 males and 135 females) were obtained from Ramaiah Medical College Teaching Hospital which were certified normal by the radiologist. The statistical analysis was carried out, the mean and standard deviation of the indices was tabulated in table 1. The differences between the indices in males and females was statistically significant in all the indices except for cella media index as shown in table 2. Positive correlation coefficient was present between age and indices which was statistically significant as shown in table 3.

DISCUSSION

Even though ventricular volume is considered as the standard measurement of ventricular size, it is not often possible to get the ventricular volume due to the time constraints of clinical practice. In a study done by Saraha et.al, it was found that a positive correlation was existing between linear measurements of ventricles and ventricular volume in adults, which showed the possibility of using these measurements in place of subjective evaluation of ventricular size [15].

In the present study seven indices were measured which were bifrontal, bicaudate, ventricular, huckman, evans, third ventricular, cella media.

Bifrontal index is normally one third of the width of brain as reported by some authors [16,17,18]**.** In the present study, bifrontal index was found to be 0.30 which was similar with the findings reported by various authors. Poonam Patnaik et al showed that there was a negative correlation of age with bifrontal index. Some authors have found that bifrontal index has a significant influence on gait disturbance which was probably due to displacement of precentral motor cortex fibres on their way to internal capsule caused by ventricular dilatation[19].

Bicaudate index have been used in several studies to evaluate the caudate atrophy in patients with Huntington's chorea, cerebral atrophy or in multiple sclerosis [20-22]. Some authors have found significant correlations between bicaudate index and duration of the Huntington's chorea [23]. In the present study, the bicaudate index was found to be 0.112 ± 0.033. Previous investigators have stated that bicaudate ratio is more sensitive in showing change than other linear ratios. In the present study, bicaudate index was significantly higher (table 2) in males than in females. Recently there have been studies on gender-specific neural basis of reasoning which includes visuospatial ability, verbal processing and information binding which was done using voxel based morphometry. These studies showed males rely more upon visuospatial ability which is related to dorsolateral prefrontal cortex and females depend on verbal processing and information binding which is associated with inferior frontal cortex is related to verbal reasoning ability whereas medial frontal cortex is engaged in information binding[24]. Thus the difference in bicauate ratio in males and females can be explained by difference in the regional volumes in parts of frontal cortex.

William Evans was the first person who felt the need to define normal limits of the cerebral ventricles, and linear measurements were adopted in children. He found that the normal range of Evans index was 0.20 to 0.25, 0.25 to 0.30 represented early ventricular enlargement and value more than 0.30 suggested ventricular enlargement. Evans index was one of the older ventriculographic indices which represented ventricular volume[14], hence widely used in the diagnosis of idiopathic normal pressure hydrocephalus, in the assessment of outcome of patients with shunt placement which is the primary mode of treatment [25]. In the present study mean Evans index was 0.252± 0.031, which was due to shrinkage of brain parenchyma, compensated by the increase in size of ventricles.

Cella media index is measured as the ratio of width of the cella media and the maximum inner skull diameter. It is useful in diagnosis and treatment of obstructive hydrocephalus($r=0.274$, $p=<0.001$). In previous studies done by Haug , mean cella media index was found to be 0.295 ,which was gradually increasing with age[26] In the present study , the cella media index was 0.227 which was similar to the values in the study done by Poonam Patnaik et al ,due to wider age group used [7].

Third ventricle index is a ratio the greatest

distances between each lateral margin of the third ventricle and the transverse diameter of the brain measured at the same level. Third ventricular index is indicator of third ventricle enlargement due to tumor or cyst at this region. Zilundu et al reported that the third ventricular index was 0.03 which was similar to the present study.

Huckman index is the sum of minimum width of the lateral ventricle and maximum bifrontal diameter. It is a useful parameter to evaluate the diameter of anterior horn of lateral ventricle.

Ventricular index is a ratio of minimum width of lateral ventricles to the maximum bifrontal diameter. Knut Kohlmeyer studied these indices in demented and non-demented groups and found that there was a strong statistically significant relation between the clinical diagnosis of dementia and mean values of these indices. It was also stated that these indices were significantly higher than those of non-demented groups statistically [27]. Yi Zhang et al used these indices as a diagnostic tool to differentiate Alzheimer's patients from normal subjects [28].

The ventricular indices in the present study is compared with previous studies Table-4.

Table 4: Comparison of ventricular indices of present study with previous studies.

Indices	P. Patnaik and Vishram Singh	Elena et al values of control group	Yi Zhang et al values of control group	Present study
Bifrontal index	0.30 ± 0.04	0.28 ± 0.05	---	0.302 ± 0.037
Bicaudate index	0.12 ± 0.03	0.13 ± 0.03	0.130 ± 0.023	0.113 ± 0.033
Evans index	0.27 ± 0.035	0.25 ± 0.05	---	0.252 ± 0.031
Cella media index	0.22 ± 0.04	0.37 ± 0.07	**0.205** ± 0.041	0.223 ± 0.042
Huckman index	---	4.92 ± 0.75	**5.46 ± 0.69**	4.424 ± 0.713

Swati et.al has proved that combination of these indices measured gives a better grading of dilatation of ventricle than a single index. These indices measured using CT scan provides a valuable tool in differentiating obstructive and non-obstructive hydrocephalus, determining level of obstruction and also the etiology of hydrocephalus [29]

Thus these indices can be used as diagnostic and prognostic indicator in normal pressure hydrocephalus, brain atrophy in alcoholics, in diagnosing Alzheimer's disease, schizophrenia and dementia

CONCLUSION

The present study provides baseline values of linear indices of ventricles which have positive correlation between sexes and ages. Thus knowledge of these indices are of immense importance while diagnosing various neurological and psychiatric disorders associated with ventriculomegaly. Thus this study will be useful to the radiologists, neurologists, neurosurgeons and psychiatrists.

Conflicts of Interests: None

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