Magnetic resonance-based evaluation of ventricular indices in South Indian population and its clinical implications

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SUMMARY

Enlargement of the ventricular system of the brain is usually seen physiologically in aged people and in various neurodegenerative disorders. Although ventricular enlargement is assessed clinically, it is highly subjective. To overcome this, the ventricular indices can be used, as evaluating the indices are relatively easy and less time-consuming. Hence, we aimed at evaluating the ventricular indices using MRI. Around 150 MRI images were studied retrospectively. The bicaudate ratio was calculated as the minimum intercaudate distance and diameter of the brain at same level, and the bifrontal ratio was calculated as the maximum distance between the frontal tip and the diameter of the skull at same level. The Evans index was calculated as the ratio between the frontal horn tip and the widest diameter of skull. The bioccipital index was calculated as the widest distance between the occipital horn and the diameter of the skull at the same level; and the cella media ratio was calculated between the narrowest width between the lateral wall of the lateral ventricle and the diameter of the skull at the same level. The indices were calculated using these reference points in MRI in the Picture Archiving and Communication System (PACS). The difference in indices between gender and age groups were estimated. A statistically significant difference between genders was found for all indices except the bioccipital and the bicaudate index. Similarly, a statistically significant difference between genders was found for all indices except the cella media and bicaudate index. Thus, the results of the present study would help the neurologist, psychiatrist, neurosurgeons and radiologists in quick diagnosis and follow-up of various neurological disorders.

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Submitted: July 6, 2024. **Accepted:** September 9, 2024

https://doi.org/10.52083/AMBC1345

Key words: Ventricular indices – Evans's index – Bicaudate index – Bifrontal index – Bioccipital index – Cella media ratio

INTRODUCTION

The ventricular system of the brain comprises the potential spaces embedded within the brain parenchyma, which are the prime site for the circulation of cerebrospinal fluid (CSF). These are congenitally derived from the embryonic neural tube (Kolsur et al., 2018). These spaces are affected either by the pathologies in the ventricles itself or by the pathologies in the brain parenchyma in and around the ventricles (Dhok et al., 2020). Enlargement of the ventricles are the key findings in hydrocephalus (Polat et al., 2019). Apart from that, the enlargement of the ventricles can also be found in other neurological or psychiatric disorders like schizophrenia, Alzheimer's, Parkinson's disease and various tumors of the brain, or in cases of atrophy of the brain parenchyma (Polat et al., 2019). Even in chronic alcoholics, the morphometry of the brain is affected, which reflects as the ventricular enlargement (Apurva et al., 2024). The ventricular indices help in diagnosing and follow-up of cases of hydrocephalus, and in assessing the size of the ventricles during the placement of ventricular shunts (Patnaik et al., 2014).

The ventricular indices can be measured either by planimetry, volumetry or by linear measurements, out of which the linear measurements are considered to be more reliable (Kolsur et al., 2018). In the past, the measurements were done using invasive methods like encephalography, which are obsolete, as they produce lots of artefacts in the lateral ventricle. In the modern surgical era, due to various non-invasive inventions like CT or MRI, these indices can be measured easily (Kolsur et al., 2018). The three-dimensional magnetic resonance allows real-time measurement of various ventricular indices. The ventricular index like Evans's index, cella media ratio helps to differentiate physiological from pathological ventriculomegaly, and also to assess the degree of enlargement. In the literature search, Evans index has been studied extensively, and with that exception the data regarding other ventricular indices are very minimal. The indices of the ventricles of the brain give better knowledge about its morphology, which thereby increasing the success rate of various neurological and neurosurgical procedures. Thus, the present study aims at evaluating the possible ventricular indices of the brain using MRI.

MATERIALS AND METHODS

The present study was done at JIPMER (Jawaharlal Institute of Postgraduate Medical Education and Research) Puducherry, in the year 2016 to 2017 after getting approval from the postgraduate research monitoring committee and institute ethical committee. A total of 150 MR images with equal gender distribution (75 males and 75 females) were retrieved from PACS (Picture Archiving and Communication System), Department of Radiodiagnosis, JIPMER, Puducherry. The MR images taken for other clinical conditions which were interpreted normal by a neuroradiologist were studied retrospectively. The age group between 18 to 60 years were included in the study. MRI images with evidence of trauma, neoplasm, stroke, cerebral oedema, ventricular pathologies and images with suboptimal quality due to patient movement or altered alignment were excluded from the study.

The 1.5 T MR equipment (Magnetom Avanto Siemens, Erlangen Germany) using 14-channel head coil was used to take images. To acquire 1mm thin sections, high resolution heavily T2- weighted 3D sequence SPACE (Sampling Perfection with Application optimized Contrasts using different flip-angle Evolution) was used. The parameters were scanned with TR/TE–1200/162 ms; section thickness 1 mm; no. of sections–120; FOV 220 mm; flip angle 150*; matrix 192 × 256).

For comparison, another Thin-section T1-weighted MPRAGE sequence was also taken. All the parameters were measured thrice and its mean was taken as final. 25 MR images were measured independently by another observer to assess interobserver variability. 25 MR images which have been done by the principal investigator were repeated again after a month to check intra-observer variability. The data were divided into five groups, based on age as ≤20, 21–30, 31–40, 41–50, 51–60 and evaluated.

Table 1. Difference in the ventricular indices between gender.

S.NO	PARAMETER	Males (n=75) Mean ± S.D	Females (n=75) Mean ± S.D	P value
1	Bicaudate index	0.104±0.023	0.096±0.026	0.007
2	Bifrontal ratio	0.34±0.037	0.32±0.036	<0.001*
3	Evans ratio	0.26±0.029	0.24±0.028	<0.001*
4	Bioccipital index	0.41±0.034	0.42±0.040	0.038
5	Cella media ratio	0.24±0.038	0.23±0.045	<0.001*

(SD- Standard Deviation). Values are represented as Mean ± SD. Independent student t test was used to compare between the gender. *p value < 0.05 was considered as significant

The following parameters were studied in MRI brain in axial view and the measurements were taken:

Ventricular index/ratio:

1. Bicaudate index- ratio of minimum intercaudate distance and diameter of the brain at the same level.
2. Bifrontal ratio: ratio of maximum distance between frontal tip and diameter of the skull at the same level.
3. Evans ratio - ratio of distance between the frontal horn tip and the widest diameter of the skull.
4. Bioccipital index - widest distance between the occipital horn and the diameter of the skull at the same level.
5. Cella media ratio - Narrowest width between the lateral wall of the lateral ventricle and the diameter of the skull at same the level.

Statistical analysis

Normality checks for the continuous data were done using the Shapiro-Wilk test. The data were represented as mean and standard deviation. Independent student t-test was used for normally distributed data, and Mann Whitney test was used for non-normally distributed data to compare between genders. For comparison between the age groups, ANOVA was used for normally distributed data, and for non-normally distributed data, the Kruskal-Wallis test was used. All statistical analyses were performed at a 5 % significance level, and a p-value < 0.05 was considered significant. Statistical analysis was done using IBM SPSS Statistics for Windows, Version 19.0 (IBM Co., Armonk, NY, USA).

RESULTS

Around 150 MR images (75 male and 75 female) were taken and the ventricular indices were studied retrospectively. The bicaudate index for males was around 0.104 ± 0.023 and it was around 0.096 ± 0.026 in females. The bifrontal and Evans ratio were 0.34 ± 0.037, 0.26 ± 0.029 in males, whereas the same were 0.32 ± 0.036, 0.24 ± 0.028 in females respectively. The bioccipital index was

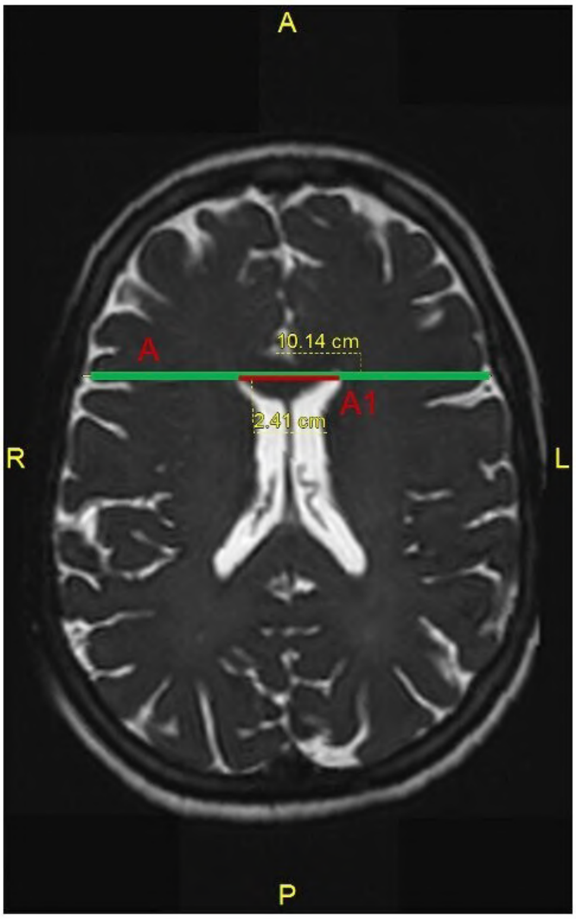

Fig. 1.- The MRI image showing the Bifrontal index. A, A1: Bifrontal index.

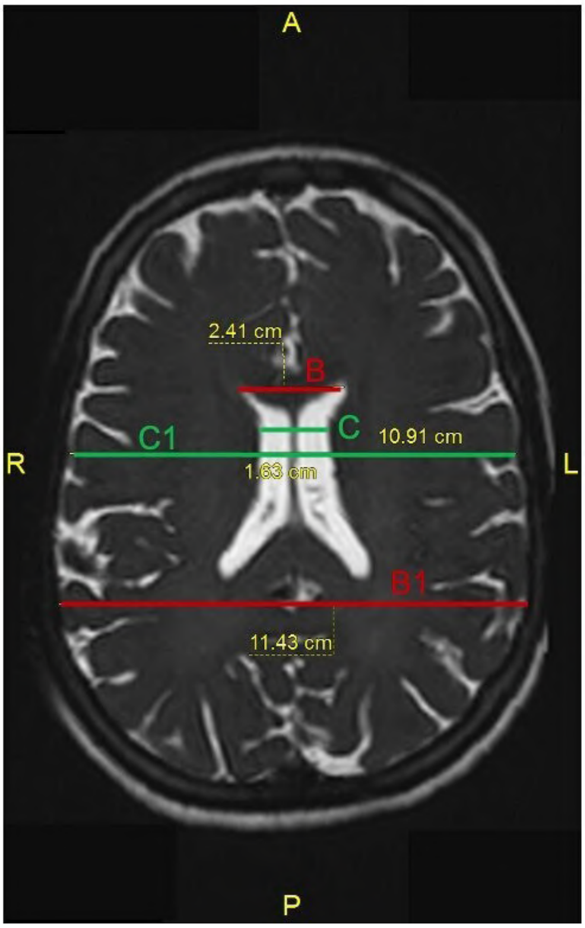

Fig. 2.- The MRI image showing the Evans index and Cella media ratio. B, B1: Evans index; C, C1: Cella media ratio.

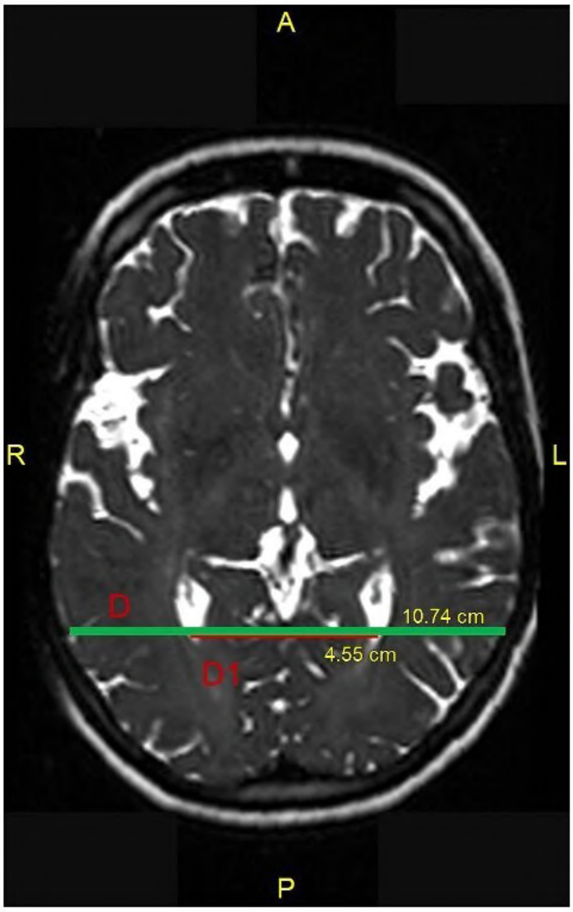

Fig. 3.- The MRI image showing the Bioccipital index. D, D1: Bioccipital index.

0.41 ± 0.034 in males and 0.42 ± 0.040 in females. The cella media ratio was around 0.24 ± 0.038 and 0.23 ± 0.045 in males and females respectively. Table 1 describes the difference in the indices between the gender. All the ratios were statistically significant (p = <0.001) between gender except the bioccipital index (p = 0.038) and the bicaudate index (p = 0.007). When the data were compared between age groups, it was found that all the ratios were statistically significant among the age

Table 2. Difference in the ventricular indices between age groups.

Parameter	Age groups Mean ± S.D					P value
	≤ 20 (n =13)	21-30 (n =50)	31-40 (n=43)	41-50 (n=27)	51-60 (n=17)	
Bicaudate index	0.091±0.024	0.098±0.024	0.103±0.028	0.101±0.025	0.103±0.025	0.55
Bifrontal ratio	0.28±0.031	0.284±0.033	0.289±0.036	0.29±0.034	0.306±0.030	<0.001*
Evans ratio	0.241±0.033	0.243±0.030	0.25±0.034	0.26±0.032	0.27±0.033	<0.001*
Bioccipital index	0.403±0.053	0.42±0.03	0.42±0.03	0.413±0.03	0.405±0.03	<0.001*
Cella media ratio	0.240±0.032	0.238±0.028	0.223±0.034	0.246±0.026	0.256±0.033	0.21

(SD- Standard Deviation). Values are represented as Mean ± SD. ANOVA test was used was used to compare between age groups. * p value < 0.05 was considered as significant groups (p = <0.001) except the cella media ratio (p = 0.21) and the bicaudate index (p = 0.55). Table 2 describes the difference in the indices between the age groups. The MRI image showing the Bifrontal index is given in Fig. 1. The MRI image showing the Evans index and cella media ratio is given in Fig. 2 and Bioccipital index is shown in Fig. 3.

DISCUSSION

Most of the neurological and psychiatric disorders are reflected as the expansion of the ventricles of the brain. The estimation of the size of the ventricles was done subjectively, based on the experience of the clinician (Hamidu et al., 2015). In the past, the ventricular volume was considered as the means of measuring the ventricular size, but, since it was a tedious process, nowadays the ventricular indices are used for determining the ventricular size, a method that is reliable, easy to perform and less time-consuming.

Bifrontal index

The bifrontal index was found to be little higher in case of males (0.34) than the females (0.32) in the present study. The findings were considered to be consistent with the studies like Kolsur et al. (2018) and Prince and Zilundu (2012). In the similar way the index was increasing, as age advances as suggested by Kolsur et al. (2018). Further in a study using CT by Dessai et al. (2024), the bifrontal index was found to be high in the case of chronic alcoholics (0.40) when compared to non-alcoholics (0.32). According to various studies, ventricular dilatation-induced precentral motor cortex fiber displacement on the route to the internal capsule accounts for the major impact of bifrontal index on gait disruption Kolsur et al. (2018). This index is considered the reliable indicator of ventricular size Patnaik et al. (2014).

Bicaudate index

The bicaudate index is used as the indicator to measure the amount of degeneration of the caudate nucleus in case of Huntington's chorea, multiple sclerosis and brain atrophy. Furthermore, this index is also used to denote the chronicity of the Huntington's chorea (Kolsur et al., 2018). Nevertheless, the bicaudate index is also used in order to diagnose hydrocephalus. The reference value of the bicaudate index for hydrocephalus is 0.25 (Dhok et al., 2020). In our study, the value was ranging from 0.091 to 0.104, which was consistent with previous studies like Dhok et al. (2020), Kolsur et al. (2018) and Patnaik et al. (2016). The value was slighter higher in the male population (0.104) than in the female (0.096). The maximum index was found among the age groups of 31-40 and 51-60 (0.1.03). The values were not significant between genders, like in previous study by Park et al. (1990). In the studies by Dhok et al. (2020), Patnaik et al. (2016) and Kolsur et al. (2018), the values were significant between genders. The values of the bicaudate index were high in chronic alcoholics (0.19) than non-alcoholics (0.11) (Dessai et al., 2024).

The increase in the intercaudate distance is usually reflected in the bicaudate ratio. The disruption of the subcortical white matter fibers are usually the causes of the widening of the anterior horn leading to increase in bicaudate ratio. Furthermore, in patients with multiple sclerosis, the white matter fiber around the caudate nucleus and the frontal horn atrophies, leading to increased bicaudate ratio thus causing cognitive dysfunction (Patnaik et al., 2016).

Evans's index

Evans's index has been widely utilized to measure the ventriculomegaly. According to international guidelines the reference value of Evans index is considered to be < 0.3, with a normal range of 0.20 to 0.25. Values between 0.25 to 0.30 is considered to indicate the early expansion of ventricles (Pradhan et al., 2021). In the present study the value was ranging from 0.24 to 0.27. The values were higher in males (0.26) than in females (0.24), which was statistically significant. These findings were found to be consistent with various previous studies. Comparison of Evans index in the present study with various previous studies is given in Table 3.

Evans index is a valid indirect measure of ventricular volume in both CT and MRI (Lohani et al., 2020). Because Evans index was one of the first ventriculographic indices to indicate ventricular volume, it was frequently used in order to diag-

Table 3. Comparison of Evans index of present study with various previous studies.

Author / sample size / type of study / population /	Evans index (Mean ± S.D)
Kolsur et al., 2018 / 300 / CT / India	0.259 ± 0.029 – M 0.243 ± 0.031- F
Dhok et al., 2020 / 511 / CT / India	0.2733 ± 0.0301- M 0.2655 ± 0.0306 - F
Pradhan et al., 2021 / 500 / CT / Nepal	0.253 ± 0.037 – M 0.250 ± 0.034 - F
Alomar and Ghoneim, 2024 / 384 / CT / Saudi	0.2588 ± 0.0274 – M 0.2517 ± 0.0276 - F
Lohani et al., 2020 / 100 / CT / India	0.23 ± 0.02 – M & F
Dessai et al., 2024 / 86 (43 – chronic alcoholic, 43 – non-alcoholic) / CT / India	0.33 ± 0.02 – chronic alcoholic 0.26 ± 0.02 - non-alcoholic
Karimi et al., 2024 / 47 preterm children, 22 controls / MRI / Sweden	0.27 – Preterm children 0.24 – Full term children
Patnaik et al., 2016 / 120 / CT / India	0.28 ± 0.04 – M 0.26 ±0.03 - F
Ambarki et al., 2010 / 46 / MRI / Swedan	0.281 ± 0.027
Kumar et al., 2017 / 100 / CT / India	0.27 ± 0.04 – M 0.26 ±0.03 - F
Jehangir et al., 2018 / 300 / CT / India	0.264 ± 0.03
Reddy et al., 2015 / 326 / CT / India	0.25 ± 0.02
Takeda et al., 2003 / 205 / MRI / Japan	0.271 – M 0.262 - F
Hamidu et al., 2015 / 488 / CT / Nigeria	0.257 ± 0.04 – M 0.256 ± 0.04 - F
Polat et al., 2019 / 265 / MRI / Turkey	0.276 ± 0.161 – M 0.280 ± 0.172 - F
Turner et al., 2001 / 40 patients (20 – relapsing remitting multiple sclerosis, 20 – secondary progressive multiple sclerosis) 10 controls / MRI / Malaysia	0.260 ± 0.036 – Control 0.255 ± 0.031 - relapsing remitting multiple sclerosis 0.246 ± 0.027 secondary progressive multiple sclerosis
Ng et al., 2009 / 9 Patients (Normal pressure hydrocephalus), 9 controls / MRI / Singapore	0.33 – Hydrocephalic patients 0.27 - Controls
Present study / 2023 / 150 / MRI / India	0.26 ± 0.029 – M 0.24 ± 0.028 - F

M – Males; F - Females; S.D- Standard Deviation

nose idiopathic normal pressure hydrocephalus and evaluate the results of patients receiving shunt placement, which is the main course of treatment (Kolsur et al., 2018). Additionally, this index is used to comprehend how visual function correlates with hydrocephalus in youngsters, and it is utilized in follow-up of ventriculo-peritoneal shunt procedures (Polat et al., 2019). Also Evans index is found to be high in young adolescents who were born preterm (Karimi et al., 2024). According to Jehangir et al, the Evans index is a reliable approximated index in posttraumatic ventriculomegaly as well (Jehangir et al., 2018). Recently in a study by Talbot Stetsko et al shunt dependent hydrocephalus was evaluated in the patients with acute subarachnoid hemorrhage before and after clamping the external ventricular drain using Evans index (Talbot-Stetsko et al., 2023).

As suggested by other studies like Jehangir et al. (2018), Pradhan et al. (2021), Alomar et al. (2024) and Hamaidu et al. (2015), in our study we also observed that the Evans index was increasing with age. This can be explained by the fact that with advancing age there is loss in brain tissue, which is further reflected in the ventricular size leading to increased value of indices (Kolsur et al., 2018). As suggested by Dhok et al. (2020) for the age group > 70 years the reference value of Evans index can be considered as 0.34 for Central India. In contrary no such changes with age groups were appreciated with Evans index in the study by (Reddy et al., 2015).

Cella media ratio and bioccipital ratio

The cella media ratio was slightly higher in males (0.24) than in females (0.23), and it was gradually increasing with age (0.256 in 51-60 years of age), similar to the studies by Kolsur et al. (2018) and Haug et al. (1977). This ratio can be used in the diagnosis and management of obstructive hydrocephalus. The Bioccipital index measured by Patnaik et al. (2014) was 0.42, which was consistent with the present study.

The size of the brain in women is around 110-115 grams smaller than those of men. They also have smaller lateral ventricles and, consequently, smaller brain hemispheres. This explains why the ventricular indices are more among males than females (Pradhan et al., 2021).

Though atrophy of the brain tissue is a physiological process, it can be also seen in certain neuropathologies, which usually manifest as widening of the sulci of the brain and as the enlargement of ventricles (Ghorbanlou et al., 2024). With the help of brain imaging techniques like CT and MRI, the ventricular indices can be calculated easily. Thus, the ventricular indices can be also widely used clinically to diagnose the neurodegenerative diseases, in assessing the ventricular volume in case of chronic alcoholics, and to determine the shunt dependency in post-traumatic hydrocephalus. Thus, the findings of the present study would help the neurologist, radiologist and psychiatrists to diagnose and follow-up of various neurodegenerative disorders.

Limitation

Our study does not involve the age group cohort of less than 18 and beyond 60 years. since age-related changes are present in ventricular enlargement, a study considering all decades could be considered. Further correlation of the ventricular indices with the dimensions of the cerebrum and the sulci of the cerebrum can be done.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the PCAS technicians for their help and support.

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