Original Article

Evaluation of the Evan's and Bicaudate Index for Rural Population in Central India using Computed Tomography

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Abstract

Introduction: Evans index (EI) and Bicaudate index (BCI) are practical markers of ventricular volume and are helpful radiological markers in the diagnosis of normal pressure hydrocephalus. Worldwide, variation exists in normative studies for both these indices. Most of the studies conducted for EI and BCI are based on the Western population data. No study has been performed on the rural population of Central India. The purpose of this study is to develop normative data on EI and BCI that can be extrapolated for future reference. **Materials and Methods:** This was a retrospective study conducted from December 2018 to May 2019 in MGIMS Hospital, Sevagram, Maharashtra, India, which is a rural hospital in Central India. All patients with either a head injury or neurological complaints although with normal computed tomography (CT) brain were included in the study. Patients with diagnosed neurological disorder, clinical features suggesting hydrocephalus, or intracranial pathology on CT brain were excluded from the study. Five hundred and eleven patients were selected for this study, and EI and BCI was calculated for them. **Results:** The mean value of EI and BCI in our study was 0.2707 and 0.1121, respectively. Both indices showed a statistically significant difference between males and females. The value of both indices increased with age. **Conclusion:** Although our study is in agreement with the cutoff value of EI to diagnose dilated lateral ventricles as 0.3 for age <70 years, cutoff value of EI for the older population should be reconsidered to 0.34.

Keywords: *Bicaudate index, Evans index, normal pressure hydrocephalus*

Introduction

Hydrocephalus is the imbalance in the production and absorption of cerebrospinal fluid (CSF), resulting in the enlargement of the ventricular system.[1] For the diagnosis of hydrocephalus, apart from clinical examination, radiological investigation such as computed tomography (CT) and magnetic resonance imaging plays a very important role. The diagnosis of hydrocephalus on imaging is made by assessing the ventricle size.

CT scan is the most widely used and affordable modality for brain imaging. Ventricular size can be studied by linear ratio measurements on CT. Among these, Evan's index (EI) and Bicaudate index (BCI) are the simplest methods of evaluation.

EI is defined as the ratio of the maximum width of the frontal horns of the bilateral lateral ventricles and maximum internal diameter of the skull at the same level.[2] BCI is defined as the ratio of the width of bilateral lateral ventricles at the level of the head of the caudate nucleus to distance between inner tables of the skull at the same level[3] [Figure 1]. Both these indices are practical marker of ventricular volume and have been proposed as helpful biomarkers in the diagnosis of normal pressure hydrocephalus.

Materials and Methods

This was a retrospective study conducted in the Department of Neurosurgery, Mahatma Gandhi Institute of Medical Sciences, Sewagram, Maharashtra, India, from December 2018 to May 2019. Five hundred and eleven patients with clinical symptoms or history suggestive of neurological ailment but with a normal CT brain were analyzed.

Inclusion criteria

All participants who reported to the neurosurgery department with complaints of

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head injury and neurological disease but with a normal CT brain were included in the study. The youngest child in this series was 6 months, and the oldest patient was 90 years.

Exclusion criteria

1. Participants with intracranial pathology on CT
2. Participants with clinical features suggestive of hydrocephalus
3. Proven case of a neurological disorder.

CT brain of all the patients was performed in Wipro GE multislice CT scanner. Axial sections were obtained at 5-mm slice thickness from the skull base to the vertex along the orbitomeatal plane. Studies were analyzed on ADW workstation. Measurements were taken with inbuilt linear calipers.

Statistical analysis

Statistical analysis was performed using Microsoft Excel 2016. Web-based, open-source application, OpenEpi.com (version 3.01, OpenEpi is a Web-based Epidemiologic and Statistical Calculator for Public Health. It was developed by Kevin M. Sullivan, Andrew Dean and Minn Minn Soe from Atlanta, Georgia, USA) was used for applying unpaired *t*-test.

Results

Of 511 patients, 345 were male and 166 were female, with a male: female ratio of 2.08:1. Maximum patients were in the age group of 20–40 years [Figure 2]. The average age for the study population was 40.86 years. Figures 3 and 4 describe the distribution of EI and BCI in different age groups.

Table 1 describes the various parameters used in the study and their final values. Table 2 describes EI and BCI with respect to the age and sex of the patient.

The value of EI in the study population was 0.2733 ± 0.0301 in males and 0.2655 ± 0.0306 in females. The overall value of EI in the study population was 0.2707 ± 0.0304. The mean value of BCI was 0.116 ± 0.0339 in males and 0.1041 ± 0.0331 in females. The overall value of BCI for the study population was 0.1121 ± 0.0341. For males and females, the value of EI ($P = 0.006$) and BCI ($P = 0.0002$) was statistically significant [Table 3]. This study shows an increasing trend with age for EI and BCI. There was also statistically significant difference in both EI and BCI with respect to age [Table 4]. Patients of age >70 years have the highest values of EI and BCI.

Table 1: Various computed tomography brain parameters

	Male	Female	Male±female
AHW	3.3533±0.361	3.122±0.3564	3.2781±0.3752
MICD	12.2856±0.5236	11.7739±0.5098	12.1194±0.5714
EI	0.2733±0.0301	0.2655±0.0306	0.2707±0.0304
ICD	1.2731±0.3688	1.0788±0.343	1.2099±0.3716
IMAX	10.9953±0.5263	10.3696±0.4838	10.792±0.5904
BCI	0.115855±0.033334	0.1041±0.0331	0.112±0.03368

IMAX – Distance between inner table at the level of measurement of ICD; AHW – Anterior horn width; MICD – Maximum intracranial diameter; EI – Evan's index; ICD – Intercaudate distance; BCI – Bicaudate index

Discussion

EI and BCI are the practical parameters commonly used in the diagnosis of hydrocephalus. Hydrocephalus can be divided as communicating (or nonobstructive) and noncommunicating (or obstructive). The causes of obstructive hydrocephalus are cystic lesions, tumors,

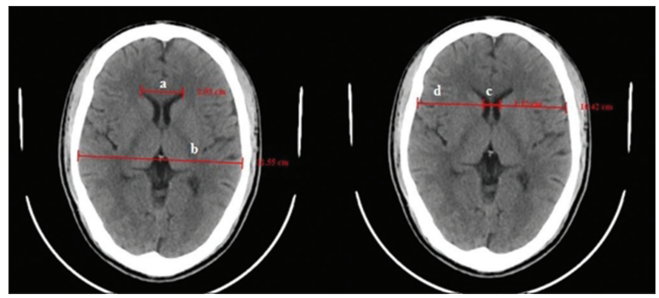

Figure 1: Computed tomography brain axial view a = maximum width of the frontal horns of the bilateral lateral ventricles b = maximum internal diameter of the skull at the same level c = Width of bilateral lateral ventricles at the level of the head of the caudate nucleus d = Distance between inner tables of the skull at the same level

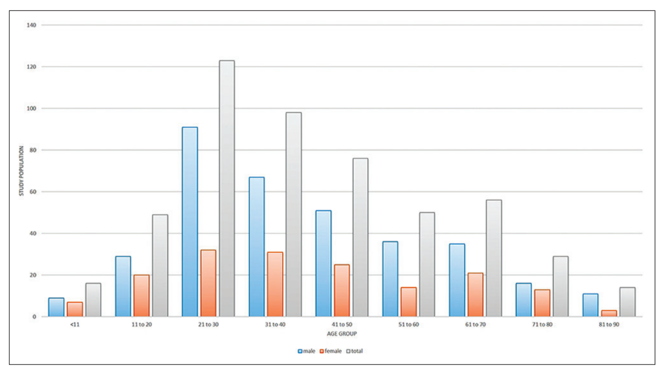

Figure 2: Age-wise distribution of the patients in the case series

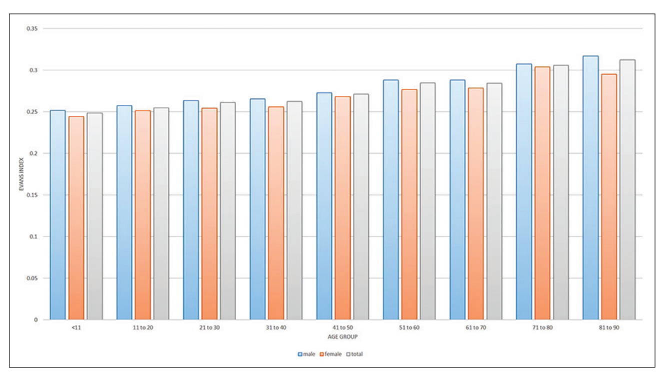

Figure 3: Distribution of Evans index in different age groups

Table 2: Age- and sex-wise distribution of Evans index and Bicaudate index

Age (years)	Sex	EI	BCI
<11	Male	0.251694±0.028651	0.098565±0.036813
	Female	0.244391±0.028503	0.071164±0.01058
	Male + female	0.248499±0.027871	0.086577±0.031059
11-20	Male	0.257285±0.024226	0.087794±0.016077
	Female	0.251148±0.027638	0.087251±0.016818
	Male + female	0.25478±0.025573	0.087573±0.016211
21-30	Male	0.26371±0.026403	0.098445±0.017427
	Female	0.254468±0.031446	0.085204±0.019738
	Male + female	0.261306±0.027966	0.095±0.018896
31-40	Male	0.265397±0.027849	0.104148±0.019844
	Female	0.255797±0.020245	0.09246±0.018706
	Male + female	0.262361±0.025973	0.100451±0.020149
41-50	Male	0.272849±0.028976	0.116552±0.026595
	Female	0.268048±0.022674	0.104827±0.030576
	Male + female	0.27127±0.027008	0.112695±0.02831
51-60	Male	0.287971±0.022762	0.133304±0.031294
	Female	0.276521±0.031615	0.118757±0.025425
	Male + female	0.284765±0.025734	0.129231±0.030241
61-70	Male	0.288042±0.024423	0.148119±0.031764
	Female	0.278487±0.028783	0.127955±0.033678
	Male + female	0.284459±0.026302	0.140558±0.033663
71-80	Male	0.307316±0.026687	0.172134±0.021097
	Female	0.304049±0.023196	0.161488±0.022625
	Male + female	0.305851±0.024796	0.167362±0.022065
81-90	Male	0.317092±0.019107	0.17446±0.014305
	Female	0.295009±0.031505	0.124525±0.048251
	Male + female	0.31236±0.022846	0.163759±0.031108

EI – Evans index; BCI – Bicaudate index

Table 3: Comparison of Evans index and Bicaudate index with respect to sex

	Male (*n*=345)	Female (*n*=166)	*P*
EI	0.2733±0.0301	0.2655±0.0306	0.0064
BCI	0.115855±0.033334	0.1041±0.0331	0.0002

EI – Evans index; BCI – Bicaudate index

Table 4: Comparison of Evans index and Bicaudate index with respect to age

	≤50 years (*n*=362)	>50 years (*n*=149)	*P*
EI	0.262234±0.027381	0.291347±0.027461	<0.0001
BCI	0.098813±0.023266	0.14451±0.034607	<0.0001

EI – Evans index; BCI – Bicaudate index

or membranous obstruction to CSF outflow.[4-6] Rarely, it may due to pathology involving the choroid plexus where CSF production takes place leading to excessive CSF production. Obstructive hydrocephalus is the most common type of hydrocephalus in children and young adults.[7,8] In some instances, there occurs a complex type of hydrocephalus (e.g., meningitis) where both

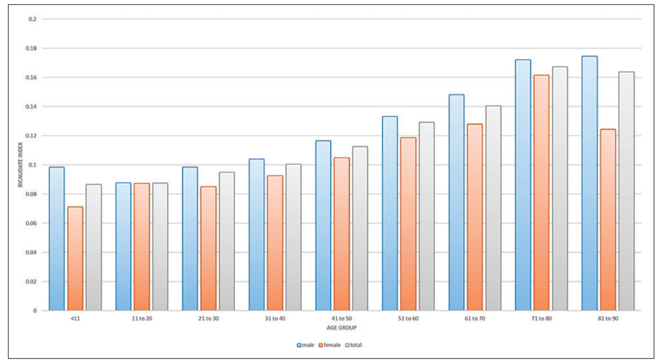

Figure 4: Distribution of Bicaudate index in different age groups

absorption and flow of CSF are interrupted.[9] Several imaging parameters are now under consideration to make a diagnosis of hydrocephalus which includes frontal horn index, occipital horn index, frontooccipital horn ratio (FOHR), frontooccipital horn index ratio, and reduction FOHR. With the advancements in imaging techniques, newer measurement systems such as Huckman number, Bicaudate-Frontal (ventricular) Index, and Schiersmann's Index have also been described.[10,11] Many of these tools are time-consuming and partially operator dependent. EI and BCI, being technically less demanding as well as easily reproducible, remain the most commonly used tool for the evaluation of hydrocephalus.

Evans index

EI gives the assessment of the degree of ventricular enlargement. The diagnostic cutoff value is >0.3.[12] In the present study, the EI value was 0.2707 ± 0.0304 which was slightly more than other studies with mean EI of 0.25.[13,14] This could be attributed to the fact that this study has more percentage of the older population as compared to other studies. In addition, difference could be due to racial and ethnic difference in size of the skull. Takeda *et al*. reported Evans ratio of 0.271 and 0.262 in the Japanese male and female population, respectively.[15] A Turkish study has reported values of 0.27 and 0.28 for males and females, respectively.[16]

Hamidu *et al*. found that mean of EI in males was more than that of the females, but it was not statistically significant.[13] In our study, we found the difference of mean EI between males and females as statistically significant [Table 3]. This observation is supported by the fact that females >15 years of age have smaller ventricular system as compared to males.[17] For EI, values between 0.25 and 0.30 were associated with borderline enlargement, and values above 0.30 were indicative of pathological ventricular dilatation.[2] Although our study is in agreement with the cutoff value, but for age >70 years, our study suggests that the upper limit for EI (95-percentile value) in Central India is 0.34.

Bicaudate index

Apart from the evaluation of ventriculomegaly, BCI is used for the diagnosis of Huntington's chorea, cerebral atrophy, and multiple sclerosis.[3,18,19]

Cutoff value for BCI for hydrocephalus is 0.25. The value of BCI in our study was 0.112 ± 0.0337, which is similar to the study by Dupont and Rabinstein[20] and Park *et al*.[21] The maximum value in our study was 0.22, which was slightly higher than the study conducted by Pelicci *et al*.[22]

In our study, there was a positive correlation between age and BCI. This observation was similar to other studies conducted by Kukuljan *et al*.,[23] Park *et al*.,[21] and Dupont and Rabinstein.[20]

Park *et al*. showed that there is no difference in sex for BCI values.[21] However, our study showed a difference in the mean values of both sexes as statistically significant.

Limitations of the study

The results are from a retrospective analysis of patients from a single center. A multicenter analysis would lead to a more robust conclusion of cutoff indices. Patients aged 70 years or above constituted <10% of the study number. Although this number is higher than the number of older patients in other studies, an independent study of a larger series of this age group should be ideally undertaken.

Conclusion

Our study for Central India concludes that EI and BCI have a significant statistical difference between males and females. Both EI and BCI values increase with age. Although the cutoff value of EI for <70 years' population is 0.3, this should be reconsidered for the older population (>70 years).

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Conflicts of interest

There are no conflicts of interest.

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