Original Article

Evaluation of the Evans' Index in Thailand Population Using Computed Tomography Accompany with Magnetic Resonance Imaging

Masuma Vudhivanich MD[1], Thipthara Tarathipayakul MD[1]

[1] Division of Diagnostic Radiology, Department of Radiology, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok, Thailand

Background: The Evans' index is an indirect marker of ventricular volume helpful in the diagnosis of hydrocephalus. Data on normal or baseline value for the Evans' index for the Thai population are not available.

Objective: The primary objective of the present study was to establish gender- and age-appropriate normal or baseline value of Evans' index for the Thai population. The secondary objective was to assess the correlation between Evans' index derived from computed tomography (CT) brain and magnetic resonance imaging (MRI) of the brain.

Material and Methods: The present study was a retrospective descriptive study conducted between January and June 2020 at the Vajira Hospital. The authors included data from 711 patients with normal brain CT, of these, normal MRI were also available for 40 subjects. Patients with intracranial pathology on CT or MRI brain and neurological disorders were excluded. The Evans' index was defined as the ratio of the maximum width of the frontal horns of the lateral ventricle and the maximal internal diameter of the skull at the same level.

Results: Of the 711 patients, 355 (49.9%) were male and 356 (50.1%) were female, their age ranged from four days to 94 years, and the mean value of Evans' index was 0.2591±0.0355. Evans' index increased with age and was slightly higher among males. The difference in Evans' index values between male and female patients was significant only in individuals aged 61 to 70 years and older than 80 years. The Evans' index calculated from CT and MRI brain showed good correlation with an ICC of 0.919 (95% CI 0.851 to 0.956).

Conclusion: Data from the present study concur with the Evans' index cutoff value for hydrocephalus as greater than 0.3 for age 70 years and younger. For individuals with age of 70 years and older, the cutoff value should be 0.34.

Keywords: Evans' index; Hydrocephalus; Normal pressure hydrocephalus (NPH); Thailand population

Received 14 October 2021 | Revised 20 April 2022 | Accepted 20 April 2022

J Med Assoc Thai 2022;105(6):555-9

Website: http://www.jmatonline.com

Hydrocephalus, defined as enlargement of the ventricular system, is commonly seen in children and adults[1]. Known etiologies include excessive cerebrospinal fluid (CSF) production, abnormal CSF resorption, or obstructive lesion, which result in CSF retention and increased intracranial pressure. Radiological diagnosis typically involves measuring ventricular size or volume using transcranial ultrasound, computed tomography (CT) brain, or magnetic resonance imaging (MRI) brain.

The Evans' index is an indirect marker of ventricular volume[2,3] and is calculated as a linear ratio between the maximum width of the frontal horn and the maximum internal cranial diameter at the same level (Figure 1). This value helps in the diagnosis of normal pressure hydrocephalus (NPH)[3], dementia, during follow-up after VP shunt[4], and in predicting optic atrophy in infantile congenital hydrocephalus[5].

Previous studies have reported mean Evans' index values. They were calculated from CT brain in multiple populations, including in Nigerians[6] with 488 subjects at 0.252±0.04, Indians[7] with 120 subjects at 0.27±0.035, Central Indians[8] with 511 subjects at 0.2707±0.0304, South Indians[9] with 100 subjects at 0.27±0.03, those of Kashmiri ethnicity[10] with 300 subjects at 0.264±0.03, and Ghanaians[11] with 507 subjects at 0.24±0.02. The mean value for

Correspondence to:

Tarathipayakul T.

Division of Diagnostic Radiology, Department of radiology, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok 10300, Thailand.

Phone: +66-2-2443000 ext. 3245

Email: thipthara@nmu.ac.th

How to cite this article:

Vudhivanich M, Tarathipayakul T. Evaluation of the Evans' Index in Thailand Population Using Computed Tomography Accompany with Magnetic Resonance Imaging. J Med Assoc Thai 2022;105:555-9.

DOI: 10.35755/jmedassocthai.2022.06.13321

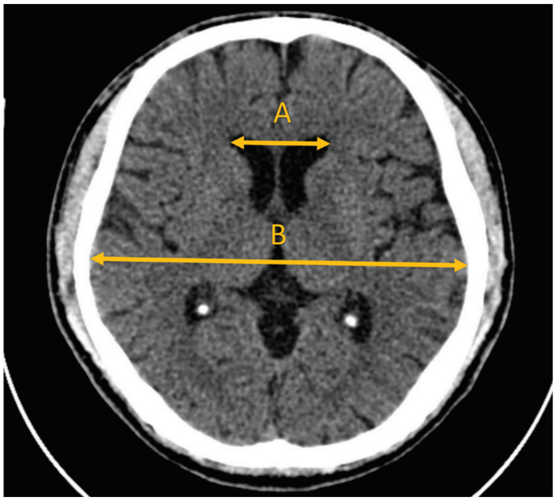

Figure 1. CT brain axial view.

A: the maximum width of the frontal horn, B: the maximum internal cranium diameter, Evans' index = A/B.

Evans' index, calculated from MRI brain in subjects from Turkey[12] with 265 subjects, was 0.280±0.172 for females and 0.276±0.161 for males.

Currently, hydrocephalus in Thailand is diagnosed based on the clinical context and Evans' index greater than 0.3[3]. However, the Brix et al's study[13] showed that a cutoff value of 0.3 cannot be used to differentiate between normal and enlarged ventricles in individual cases as the new cutoff value at a 97.5 percentile threshold with a mean ± 2 standard deviation (SD) showed good sensitivity for idiopathic normal pressure hydrocephalus (iNPH) diagnosis.

Thus, the primary objective of the present study was to establish normal values of Evans' index for the Thai population, classified by gender and age, using CT brain images. The secondary objective was to evaluate the correlation between Evans' index values derived from CT and MRI brain.

Materials and Methods

The present study was a retrospective descriptive study, approved by the Institutional Review Board Office, Research Affairs, Navamindradhiraj University (COA 179/63). The present study was conducted in the Department of Radiology, Vajira Hospital, Navamindradhiraj University, Bangkok, Thailand, between January and June 2020.

Study population

The authors included 711 patients with clinical symptoms, such as head injury, headache, drowsiness, and normal CT brain. The inclusion criteria were presence of normal CT brain findings with or without contrast, or normal MRI brain findings. The exclusion criteria were patients with intracranial pathology on CT or MRI brain, or those diagnosed with a neurological disorder.

Imaging

CT brain was acquired on two multi-slice CT scanners (64 or 128 slices; GE Healthcare, US) with axial sections of 2-mm slice thickness.

MRI brain was performed in a 3T MRI scanner (Philips Medical System, The Netherlands) with axial sections of 3-mm slice thickness. Axial T2W images were chosen for measurement.

Studies were analyzed on the Uniweb workstation. Measurements were acquired using inbuilt linear calipers.

Two authors, neuroradiologists with six and five years of experience (MV and TT), reviewed and measured the maximum width of the frontal horn and the maximum internal cranium diameter by consensus for Evans' index calculation.

Statistical analysis

Data on subjects' characteristics were presented as descriptive statistics; specifically, categorical data as frequency (percentage) and continuous data as mean±SD. Evans' index was expressed as mean and SD. The differences in the mean values of Evans' index were analyzed using the independent t-test for comparison between males and females, and by one-way analysis of variance (ANOVA) with Bonferroni correction in multiple post-hoc tests for age groups. Two-way ANOVA was used to evaluate the effect of gender and age groups on the Evans' index. The paired t-test was used to compare differences in Evans' index between CT and MRI. The mean differences and limits of agreement were plotted on the Bland-Altman plot. The intraclass correlation coefficient (ICC) was used to verify the agreement between CT and MRI. A p-value of less than 0.05 was considered statistically significant. All data analyses were performed with PASW Statistics, version 18.0 (SPSS Inc., Chicago, IL, USA).

Results

The authors included 711 subjects aged between four days and 94 years (51.53±22.61 years). Of these, 355 (49.9%) were males and 356 (50.1%) were females. The distribution of subjects according to age groups and gender is provided in Table 1 and Figure 2.

The mean Evan's index values were

Table 1. Demographic data

	All (n=711); n (%)	Male (n=355); n (%)	Female (n=356); n (%)
Age (years)			
Mean±SD (range)	51.53±22.61 (4 days to 94 years)	46.63±22.08 (4 days to 92 years)	56.43±22.09 (2 months, 94 years)
≤10	27 (3.8)	15 (4.2)	12 (3.4)
11 to 20	55 (7.7)	35 (9.9)	20 (5.6)
21 to 30	76 (10.7)	49 (13.8)	27 (7.6)
31 to 40	66 (9.3)	48 (13.5)	18 (5.1)
41 to 50	82 (11.5)	43 (12.1)	39 (11.0)
51 to 60	129 (18.1)	61 (17.2)	68 (19.1)
61 to 70	112 (15.8)	47 (13.2)	65 (18.3)
71 to 80	102 (14.3)	34 (9.6)	68 (19.1)
>80	62 (8.7)	23 (6.5)	39 (11.0)

SD=standard deviation

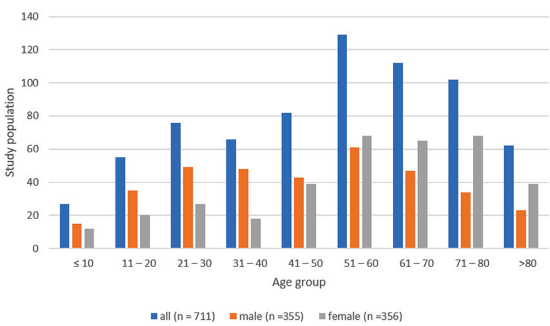

Figure 2. Age-wise distribution of the subjects.

Table 2. Evans' index subgroup by age and sex

Age groups (years)	Evans' index; mean±SD			p-value
	Total#	Male	Female	
Total$	0.2591±0.0355	0.2604±0.0371	0.2577±0.0339	0.313
≤10	0.2254±0.0515	0.2300±0.0452	0.2196±0.0600	0.393
11 to 20	0.2416±0.0359	0.2390±0.0394	0.2461±0.0295	0.420
21 to 30	0.2423±0.0280	0.2460±0.0259	0.2354±0.0310	0.158
31 to 40	0.2477±0.0303	0.2492±0.0320	0.2437±0.0258	0.522
41 to 50	0.2506±0.0254	0.2547±0.0238	0.2461±0.0267	0.215
51 to 60	0.2557±0.0279	0.2607±0.0311	0.2511±0.0240	0.083
61 to 70	0.2686±0.0356	0.2772±0.0392	0.2624±0.0316	0.014*
71 to 80	0.2805±0.0304	0.2884±0.0287	0.2766±0.0307	0.074
>80	0.2876±0.0316	0.3009±0.0314	0.2797±0.0293	0.010*
p-value	<0.001*	<0.001*	<0.001*	

SD=standard deviation

Two-way analysis of variance (ANOVA) and post hoc test by Bonferroni for evaluating the effect of sex and age groups on Evans' index, # One-way analysis of variance (ANOVA) and post hoc test by Bonferroni for comparing across age groups, $ Independent t-test for comparing between male and female

* Statistically significant

0.2591±0.0355, 0.2604±0.0371, and 0.2577±0.0339 for all subjects, males, and females, respectively. No significant difference was found in Evan's index values between males and females (p=0.313). One-way ANOVA revealed a trend of Evan's index values increase with age (p<0.001). Two-way ANOVA showed that age and gender significantly affected Evan's index (p<0.001 for both) (Table 2), apart from the trend of Evan's index values increase with age in both males and females (p<0.001 for both). The mean Evan's index values were significantly different between males and females only in the age groups of 61 to 70 years and older than 80 years (p=0.014 and 0.010, respectively).

The mean value of the Evan's index for the two imaging modalities, with 40 subjects for each, was 0.2570±0.0307 for CT and 0.2608±0.0388 for MRI. These values were not significantly different (p=0.090). The Bland-Altman plot revealed the value of the inter-method agreement of mean bias ±1.96 SD to be −0.0038±0.0277 (95% limits of agreement −0.0315 to 0.0239) (Figure 3). There was a good agreement in Evan's index between CT and MRI with an ICC of 0.919 (95% confidence interval [CI] 0.851 to 0.956).

Discussion

The Evans' index, measured by CT or MRI, can be used to quantitatively assess the degree of ventricular enlargement, and the recommended international diagnostic cutoff value for this is greater than 0.3[3]. The authors reported the mean Evans' index for the Thai population is 0.2591±0.0355. This value is similar to that reported for the Nigerian population and for those of Kashmiri ethnicity with 0.252±0.04 and 0.264±0.03, respectively[6,10], but slightly less than that of Indian, central Indian, and south Indian

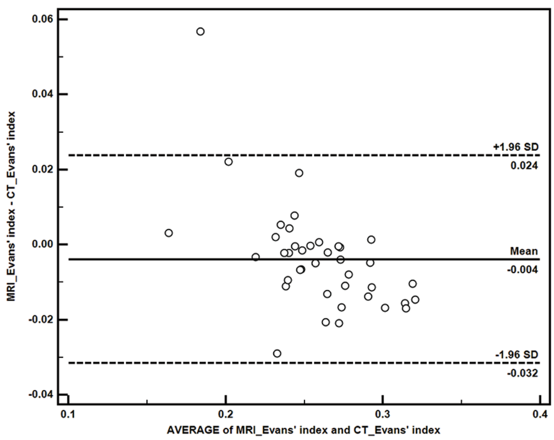

Figure 3. Bland-Altman plots for agreement between CT and MRI.

Table 3. Comparison of different studies measuring Evans' index in different populations

Study/publish year	Ethnicity	Number of subjects	Mean of Evans' index
Present study	Thai	711	0.2591±0.0355
Dzefi-Tettey et al[11]/2021	Ghanaians	507	0.24±0.02
Atul Dhok et al[10]/2020	Central Indian	511	0.2707±0.0304
Jehangir et al[9]/2018	Kashmiri Indian	300	0.264±0.03
Kumar et al[8]/2017	South Indian	100	0.27±0.03
Patnaik et al[7]/2016	Indian	120	0.27±0.035
Hamidu et al[6]/2015	Nigerians	488	0.252±0.04

populations with 0.27±0.035, 0.2707±0.0304, and 0.27±0.03, respectively[7-9], and slightly greater than that of Ghanaians at 0.24±0.02[11]. This discrepancy may be due to racial or ethnic differences in the size of the skull, in the number of subjects, and age distribution of the population surveyed (Table 3). Notably, the present study has the largest number of subjects included. Furthermore, even though most previous studies included all age groups, those on Nigerians[6] and Ghanaians[11] comprised only adults. Moreover, while older patients as older than 70 years of age in the previous studies[8,11] were less than 12% of the population, they accounted for 23% in the present study.

Both age and gender significantly affected the Evan's index value, and the present study shows a trend of increasing Evan's index values with age (Table 2), which concurs with observations from the previous studies[6-11].

The authors show the mean Evans' index is slightly higher in males than in females. However, it was significantly different in the age groups of 61 to 70 years and older than 80 years. Notably, while previous studies[7,8] have reported slightly higher values among males that were statistically significant, the others[6,10,11] found only a similar trend rather than a significant difference. These variations between males and females may be due to a smaller ventricular system in females above the age of 15 years[14].

Evans' index values between 0.25 and 0.3 are associated with borderline enlargement, and values above 0.3 indicate pathological ventricular dilatation[1]. While from the present study results agree with a cutoff value of above 0.3 for hydrocephalus, the older than 70 age group's results suggest the upper limit value (95-percentile value) should be set at 0.34. Incidentally, this cutoff value is identical to that reported by a previous study[8] in the Central India population, which is the second largest ever with 511 subjects.

Mean Evan's index values were not significantly different between CT and MRI and good agreement was seen between the two imaging modalities (ICC 0.919, 95% CI 0.851 to 0.956). This result implies that the Evans' index measured by CT is similar to MRI.

The strengths of the present study are the large sample size, the relative number of elderly individuals included, and comparison with MRI data. The limitations of the present study are from a single center and retrospective in design.

Conclusion

The results of the present study conform to the currently recommended cutoff value of the Evans' index for diagnosing hydrocephalus at greater than 0.3 for subjects 70 years and younger. The cutoff value for the Evans' index for the elderly subject older than 70 years should be 0.34.

What is already known on this topic?

The normal or baseline value of the Evans' index for the Thai population has not been established, even though similar values for population of other ethnicities are available.

What this study adds?

The present study provides guideline Evans' index values for the Thai population along with a new cutoff value for the elderly subjects that are older than 70 years. These values are of radiological diagnostic value in hydrocephalus.

Acknowledgement

The present study was supported by a grant from

the Navamindradhiraj University Research Fund.

Conflicts of interest

The authors declare no conflict of interest.

References

1. Evans WA Jr. An encephalographic ratio for estimating ventricular enlargement and cerebral atrophy. Arch Neurol Psychiatry 1942;47:931-7.
2. Ambarki K, Israelsson H, Wåhlin A, Birgander R, Eklund A, Malm J. Brain ventricular size in healthy elderly: comparison between Evans index and volume measurement. Neurosurgery 2010;67:94-9.
3. Toma AK, Holl E, Kitchen ND, Watkins LD. Evans' index revisited: the need for an alternative in normal pressure hydrocephalus. Neurosurgery 2011;68:939-44.
4. Hashimoto M, Ishikawa M, Mori E, Kuwana N. Diagnosis of idiopathic normal pressure hydrocephalus is supported by MRI-based scheme: a prospective cohort study. Cerebrospinal Fluid Res 2010;7:18.
5. Idowu OE, Balogun MM. Visual function in infants with congenital hydrocephalus with and without myelomeningocoele. Childs Nerv Syst 2014;30:327-30.
6. Hamidu AU, Olarinoye-Akorede SA, Ekott DS, Danborno B, Mahmud MR, Balogun MS. Computerized tomographic study of normal Evans index in adult Nigerians. J Neurosci Rural Pract 2015;6:55-8.
7. Patnaik P, Singh V, Singh D, Singh S. Age and gender related variations in lateral ventricle brain ratios. Int J Health Sci Res 2016;786:78-84.
8. Dhok A, Gupta P, Shaikh ST. Evaluation of the Evan's and Bicaudate Index for rural population in Central India using computed tomography. Asian J Neurosurg 2020;15:94-7.
9. Arun Kumar S, Meena Kumari S, Vijai Anand M, Saraswathy R, Rajeshwari M. Evaluation of Evan's index in South Indian population using computed tomography. Int J Anat Radiol Surg 2017;6:28-31.
10. Jehangir M, Dar IH, Sahota A, Hassan GH, Mustafa K, Javaid A. Normative parameters of Evans index using computerized tomographic scan in individuals of Kashmiri Ethnicit. Int J Contemp Med Res [IJCMR] 2018;5:F1-3.
11. Dzefi-Tettey K, Edzie EKM, Gorleku PN, Brakohiapa EK, Osei B, Asemah AR, et al. Evans index among adult Ghanaians on normal head computerized tomography scan. Heliyon 2021;7:e06982.
12. Ozandaç Polat S, Öksüzler F, Öksüzler M, Kabakci A, Yücel A. Morphometric MRI study of the brain ventricles in healthy Turkish subjects. Int J Morphol 2019;37:554-60.
13. Brix MK, Westman E, Simmons A, Ringstad GA, Eide PK, Wagner-Larsen K, et al. The Evans' index revisited: New cut-off levels for use in radiological assessment of ventricular enlargement in the elderly. Eur J Radiol 2017;95:28-32.
14. Haug G. Age and sex dependence of the size of normal ventricles on computed tomography. Neuroradiology 1977;14:201-4.