



Research article

Evans index among adult Ghanaians on normal head computerized tomography scan

Klenam Dzefi-Tettey^{a,*}, Emmanuel Kobina Mesi Edzie^b, Philip Narteh Gorleku^b, Edmund Kwakye Brakohiapa^c, Bernard Osei^d, Abdul Raman Asemah^b, Henry Kusodzi^b^a Department of Radiology, Korle Bu Teaching Hospital, P.O. Box KB 77, Korle Bu, Accra, Ghana^b Department of Medical Imaging, School of Medical Sciences, College of Health and Allied Sciences, University of Cape Coast, P.M.B University of Cape Coast, Cape Coast, Ghana^c Department of Radiology, University of Ghana Medical School, Ghana^d Department of Mathematics, African Institute of Mathematical Sciences, Accra, Ghana

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ABSTRACT

Introduction: Normal-Pressure Hydrocephalus (NPH) is a neurological condition which is made up of a clinical triad of gait disturbance, dementia and urinary incontinence and can be reversed by ventricular shunting. Currently, some guidelines suggest the use of Evans' index (EI) for diagnosis of hydrocephalus radiologically. Most of the studies are based on the Western population data. None of these studies have been performed in the Ghanaian population setting yet. The aim of this study was to quantitatively establish normal borderline value for Evans Index in the Ghanaian adult population with respect to age and sex.

Methods: This study was retrospectively conducted on normal enhanced head CT scan images of 266 males and 241 females. EI was calculated as the linear ratio of Maximum Anterior Horn Width (MAHW) of the frontal horns of the lateral ventricles at the level of foramina of Monroe and the Maximum Intracranial Diameter (MICD) of the inner skull. Student T-test, ANOVA and Pearson's correlation were used to analyze the data. A test for a relationship was performed with a scatter plot and a linear regression was performed based on age, sex and different EI of ventricular size.

Results: The mean and median value of EI was 0.24 ± 0.02 . There was no statistically significant difference in the EI values between males and females, (p -value = 0.61). A steady increase in EI with age was observed. There was a strong correlation coefficient $r = 0.89$ of EI and age, which suggested a strong linear relationship between EI and Age. The overall linear relationship model was $EI = 0.1879 + 0.0011 * Age$.

Conclusions: The mean EI of 0.24 ± 0.02 in our study agrees with adapted international guidelines cut-off value for normal adult patients of (<0.30) and can be a useful tool in determining ventricular enlargement particularly in resource limited settings.

1. Introduction

The ventricular system of the brain consists of a series of inter-connecting spaces and channels. The two lateral ventricles have a large C-shaped configuration each lying within the right and left cerebral hemispheres, and communicates with the third ventricle through the foramina of Monroe. The third ventricle is a slit-like cavity in the midline lying between the right and left halves of the diencephalon and communicates with the fourth ventricle through the cerebral aqueduct [1]. A

number of neurologic conditions can cause hydrocephalus and this is suggested to be the most common brain abnormality in both children and adults [2, 3]. Normal-Pressure Hydrocephalus (NPH) is a neurological disorder which is made up of a clinical triad of gait impairment, dementia and urinary incontinence which can be reversed by shunting of the ventricles. NPH can be classified as secondary NPH and Idiopathic NPH [4]. Currently, some guidelines propose the use EI for diagnosis of hydrocephalus radiologically [5, 6]. Reported in the early 1940s, EI was based on pneumoencephalographic findings for pediatric hydrocephalus,

* Corresponding author.

E-mail address: k.dzefitettey@kbth.gov.gh (K. Dzefi-Tettey).<https://doi.org/10.1016/j.heliyon.2021.e06982>

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and was calculated as the linear ratio of Maximum Anterior Horn Width (MAHW) of the frontal horns of the lateral ventricles at the level of foramina of Monroe and the Maximum Intracranial Diameter (MICD) of the inner skull. Since EI determination is based on a ratio of MAHW and MICD, the EI values may vary depending on the morphometry of the human skull. There is unavailability of information relating to Ghanaian human skull morphometry but recent studies have reported cranial morphometric differences among Asians, Africans and Europeans. Since Asian and African crania have smaller biasterionic breadths, this may impact on the EI determination [7]. EI has been established and extensively used in the diagnosis of idiopathic NPH and in the assessment of the outcome of patients with shunt placement [2]. EI values > 0.30 are indicative of hydrocephalus and subsequent studies using head Computerized Tomography (CT), confirmed the diagnostic reliability of EI which serves as an indirect marker of ventricular volume [2, 8]. In Ghana, CT scan is one of the imaging modalities readily available in most imaging centers compared to Magnetic Resource Imaging (MRI) [9]. It is for this reason that we used CT scan in determining the EI among the adult Ghanaian population. There are a number of techniques and software developed to determine ventricular enlargement in literature. However, in the Ghanaian geographical location, to the best of our knowledge, there are no studies in literature that have determined the values of EI among the normal adult population. The aim of this study was to quantitatively establish normal borderline value for EI on head CT scans in the Ghanaian adult population with respect to age and sex and developing this will be useful in the practice of neuroimaging.

2. Materials and methods

This study was retrospectively conducted at the Radiology department of the Korle Bu Teaching Hospital (KBTH) which is a 2000 bed teaching hospital located in Accra, Ghana. Normal enhanced head CT scan images of patients performed from 1st August 2019 to 31st December 2019 which were saved in the Picture Archiving and Communication System (PACS) were retrieved and analyzed by two radiologists independently. The inclusion criteria were patients who had normal head CT scan findings, aged 18 years and above. Patients

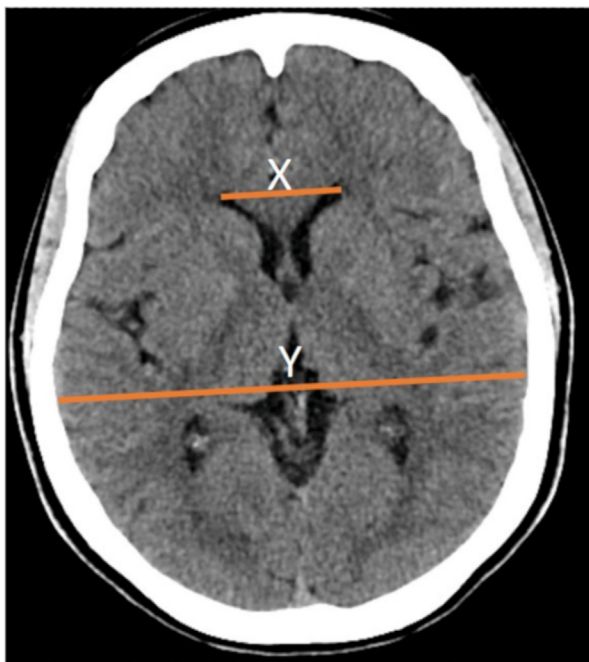


Figure 1. Axial CT scan of the head showing the measurement of Evans Index in one of the patients.

whose head CT Scan images had abnormal findings and patients less than 18 years were excluded. Consecutive sampling was used and a total of 507 images were retrieved during the study period. The radiology department performs an average of 600 head CT Scans in a month (2019 Annual Performance Review KBTH-Department of Radiology). The head CT scan images were performed using Toshiba scanner Aquilion One, model TSX-301A manufactured by Toshiba Medical Systems. The images were acquired from the base of the skull through to the vertex, 0.5mm slice thickness using 300mAs and 120Kv. The study considered patients' variables such as Age, Sex, (MAHW/cm), (MICD/cm) and EI. The EI was calculated by measuring the (MAHW) represented by X and (MICD) represented by Y and finding a ratio X/Y as shown in Figure 1. Data was entered using Microsoft Excel (Excel spreadsheet 2016) software for windows. Statistical analysis was performed with RStudio (version 3.5.7) on the Ubuntu 18 operating system. All data variables were analyzed for mean and standard deviation, expressed as percentages and the results presented in tables. The Student T-test, ANOVA and Pearson's correlation were the statistical techniques used to analyze the data. A test for a relationship was performed with a scatter plot and a linear regression was performed based on age, sex and various EI of ventricular size. Statistical significance was set at P-value ≤ 0.05 .

2.1. Ethical consideration

The institutional review board of the KBTH approved the protocols for this study with approval number KBTH-ADM/00151/2020. Strict anonymity and confidentiality were ensured.

3. Results

A total of five hundred and seven (507) normal head CT scan images were retrieved and analyzed, comprising 266 (52.5%) males and 241 (47.5%) females. 18 and 97 years were the minimum and maximum ages respectively and the mean age was 48.34 ± 18.28 years. The median age was 47.00 years. The lowest values MAHW and MICD measured were 2.23 cm and 10.96 cm respectively. The overall mean value of EI was 0.24 ± 0.02 ; with a minimum and maximum value of 0.18 and 0.29 respectively. The average ages for males and females were 48.29 ± 17.63 and 48.39 ± 19.00 years respectively. The difference in EI between males and females was not statistically significant ($p = 0.61$), Table 1.

Most of the age groups were within the range of 52–61 years, representing 99 (19.5%). Very few patients 31 (6.5%) were within the age range less than 22 years. About 60 (11.8%) patients aged above 71 years had higher EI, Table 2.

A Student t-test showed that, the estimated EI mean of 0.24 was statistically significant with a p-value of < 0.001 . A steady increase in EI was observed with advancing mean age across both males and females, Figure 3. The correlation coefficient of EI and age was obtained as 0.89, with a Student t-test value of 44.03 and 95% confident interval of [0.87, 0.91] which suggests a strong linear relationship between EI and Age. This was statistically significant with p-value of $P < 0.001$. The overall relationship model $EI = 0.1879 + 0.0011 * Age$ was statistically significant with an F test value of 1938 and p-value of $P < 0.001$. About 79.29% of the variability in the value of EI is explained by the fitted model with age. This indicates that age as a variable is a useful predictor for determining EI.

Figure 2 shows that across all age groups, median EI value increased, and suggesting differences in medians of EI within the various age groups (medians are closely related to the means). The age range of 52–61 years is likely to have less variability and therefore might have Evans index of about 0.24.

In Figure 3 there is a steady increase in EI for both males and females within age group range. Evans Index in older adult (>71 years) do not differ much but tend to increase steadily.

Table 1. Descriptive analysis of ventricular measurement versus sex.

Descriptive Variables	Male (n = 266, 52.5%)	Female (n = 241, 47.5%)	Total (n = 507)	p-values
Age (years)	48.29 ± 17.63	48.39 ± 19.00	48.34 ± 18.28	0.949
MAHW/cm	3.08 ± 0.29	2.95 ± 0.29	3.02 ± 0.30	P < 0.001
MICD/cm	12.76 ± 0.50	12.32 ± 0.48	12.55 ± 0.53	P < 0.001
EI	0.241 ± 0.02	0.240 ± 0.02	0.24 ± 0.02	0.613

Data Source: CT scan images, Maximum Anterior Horn Width = MAHW, Maximum Intracranial Diameter = MICD, Evans Index = EI, Standard Deviation = SD.

Table 2. Descriptive statistics of ventricular parameters versus sex and age groups.

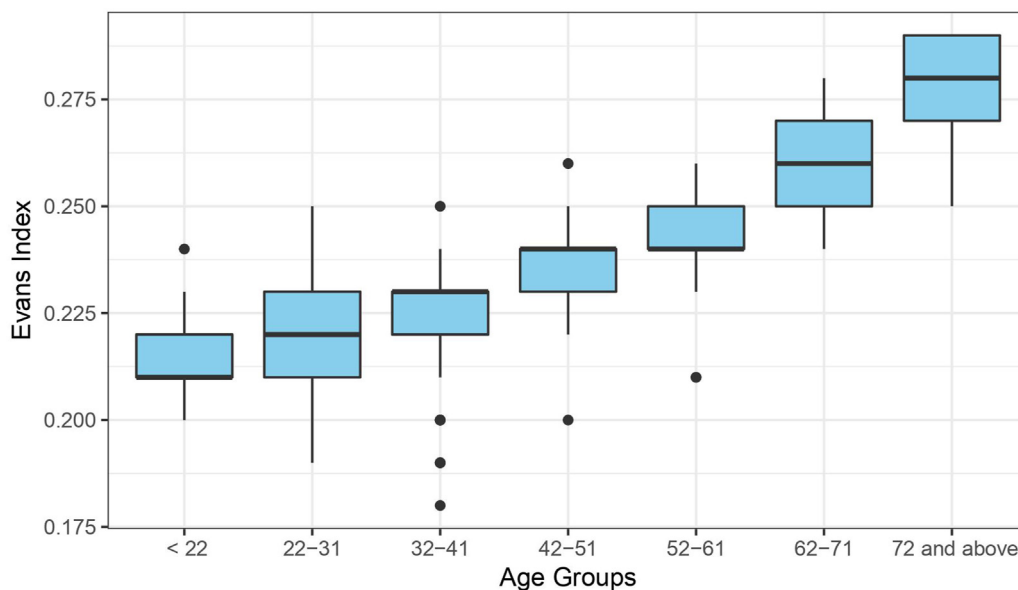
Age Groups (years)	Sex	Size (n)	Ventricular Variables (mean ± SD)		
			MAHW	MICD	EI
<22	Female	15	2.65 ± 0.150	12.40 ± 0.472	0.214 ± 0.011
	Male	16	2.75 ± 0.151	13.00 ± 0.596	0.211 ± 0.007
22–31	Female	46	2.70 ± 0.198	12.30 ± 0.470	0.219 ± 0.013
	Male	38	2.79 ± 0.194	12.60 ± 0.613	0.221 ± 0.011
32–41	Female	36	2.75 ± 0.163	12.30 ± 0.435	0.225 ± 0.015
	Male	51	2.90 ± 0.161	12.80 ± 0.337	0.227 ± 0.011
42–51	Female	34	2.93 ± 0.136	12.50 ± 0.494	0.236 ± 0.008
	Male	44	3.02 ± 0.138	12.70 ± 0.428	0.237 ± 0.009
52–61	Female	45	3.05 ± 0.158	12.50 ± 0.413	0.244 ± 0.009
	Male	54	3.18 ± 0.168	12.90 ± 0.511	0.246 ± 0.009
62–71	Female	30	3.16 ± 0.161	12.10 ± 0.393	0.260 ± 0.011
	Male	36	3.36 ± 0.159	12.90 ± 0.506	0.261 ± 0.011
72 and above	Female	33	3.37 ± 0.227	12.20 ± 0.562	0.276 ± 0.011
	Male	27	3.52 ± 0.210	12.50 ± 0.480	0.280 ± 0.009

Data Source: CT scan images, Maximum Anterior Horn Width = MAHW, Maximum Intracranial Diameter = MICD, Evans Index = EI, Standard Deviation = SD.

4. Discussion

In this group of scans collected from the study cohort, we observed that EI increases with age which is consistent with a study done by Hamidu et al which determined EI in 488 normal head CT scans of adult Nigerian population and showed an increase of EI with advancing age

[2]. Similar finding was reported by Missori and Gyldensted et al [8, 10]. Our study established a mean EI value of 0.24 ± 0.02 which is slightly lower than that found by Hamidu and Dhok et al who had EI of 0.25 and 0.27 respectively [2, 11]. This could be explained by the high percentage of young age groups in our study with a median age of 47 years whilst the other studies had slightly an older age group. In addition, Brix et al in a



Data Source: CT scan Images

Figure 2. Evans index distribution with age groups. The bolded horizontal lines in the boxplots indicate the median EI values. The blue areas in the boxplots show the mean ± SD. The vertical bars represent the varied EI within age groups away from the 50% (median) and the dots explain outliers.

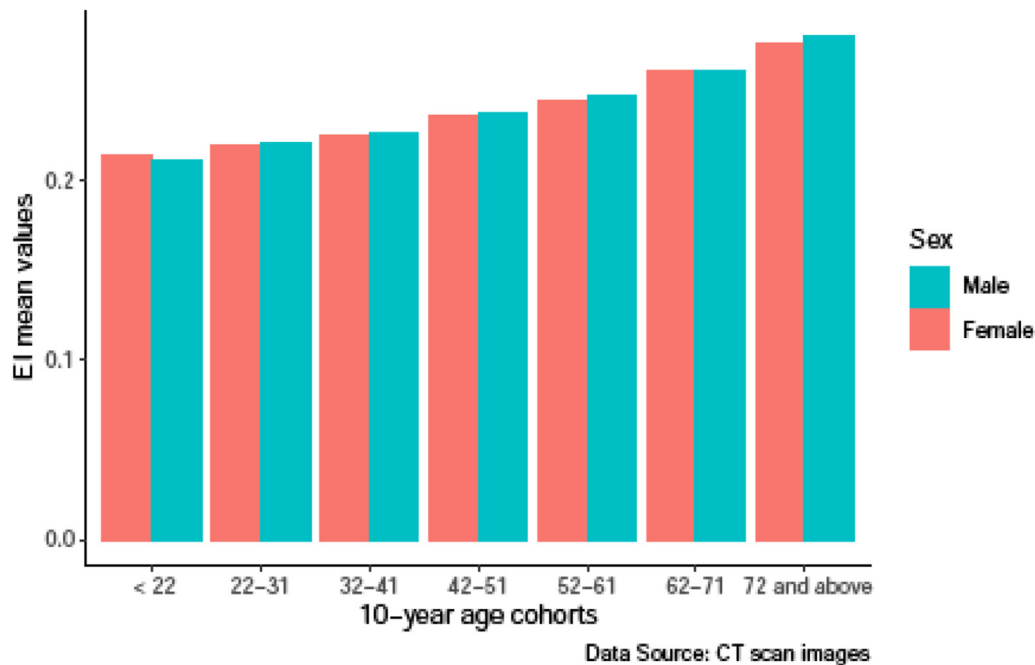


Figure 3. Distribution of mean EI and age groups across sex.

study measuring EI in healthy elderly controls and Alzheimer's disease patients aged 65–84 years proposed an EI 0.3 or greater [12]. This does not agree with our study, but again can be due to the high percentage of the young age group in our study and in addition they did not have co-morbidities like Alzheimer's disease, vascular or neurodegenerative diseases.

In our study, those who were aged 70 years and above had higher values of mean EI but this value did not exceed 0.30, this disagrees with a study done by Dhok et al which reported that, the cutoff value (95-percentile value) for age >70 years in Central India was 0.34. This difference could be due to racial and ethnic differences in size of the skull [11]. In terms of EI and sex, we found no significant difference in EI value between men and women which corroborates with a study done by Fjell et al which concluded that sex has negligible effects on the age slope of brain volumes of healthy adults and Alzheimer's Disease patients [13]. Studies done by Kumar and Hamidu et al also found no statistically significant difference in the value between males and females and this is in agreement with our study [2, 14]. This is however, contrary to findings by Jaraj et al., who reported lower mean EI for males in the age group between 75–79 years [15]. It may be difficult to associate exact reasons for such difference in mean EI values in both males and females. Finally, the increase in EI with age observed in our study suggests that normal aging causes gradual ventricular enlargement but EI values remain within normal range [16]. However, neurological conditions which result in a reduction in brain volume or abnormal cerebrospinal fluid flow occur more with aging. Therefore, individuals presenting with EI > 0.30 should be screened for degenerative diseases like Alzheimer's disease, vascular diseases, Parkinson's disease and other primary dementias causing NPH [8]. EI alone is not sufficient to alert for a neurological condition, but when associated with other abnormal measurements it becomes a strong predictor [8, 16].

The Frontal Horn Index, Occipital Horn Index, Fronto Occipital Horn Ratio (FOHR), Fronto Occipital Horn Index Ratio, and Reduction FOHR are now measuring parameters being considered for use in diagnosing hydrocephalus. Other newer measurement systems like Schiersmann's Index, Bicaudate-Frontal (ventricular) Index and Huckman Number developed, are partially operator dependent [11]. Also, these advanced neuroimaging measuring techniques for ventricular volume consume a lot of time, require specialized software and skill, and above all are not

readily available in most resource-limited countries, hence, not helpful for use in routine quantitation of ventricular size [16]. EI is technically simple, easily reproducible and is the most frequently used tool for the evaluation of ventricular enlargement [11].

4.1. Limitation

The aged (more than 71-years) were few (11.8%) in our study and although this factor is likely to have influenced the absolute value of the EI in Ghanaians, the value and findings observed in this study are consistent with those found in literature. The comparatively small sample size is a notable limitation in addition to being a single center retrospective study. Further studies may also be required to assess the effects of co-morbidities on EI values.

5. Conclusions

In this study, the normal value of EI in the Ghanaian adult populace was determined using computerized tomography. The mean EI of 0.24 ± 0.02 in our study is consistent with those found in literature. Also, it is technically simple, easily reproducible and is the most frequently used tool for the evaluation of ventricular enlargement. The overall linear relationship model was $EI = 0.1879 + 0.0011 * Age$.

5.1. Recommendation

Further studies will be required to determine the value of EI in the aged population in Ghana.

Declarations

Author contribution statement

Klenam Dzefti-Tettey, Emmanuel Kobina Mesi Edzie, Philip Narteh Gorleku and Edmund Kwakye Brakohiapa: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Bernard Osei, Abdul Raman Asemah and Henry Kusodzi: Contributed reagents, materials, analysis tools or data; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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