

Normative parameters of the Evans Index using Computer Tomography in the Saudi population

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ABSTRACT

الأهداف: توسع بطينات الدماغ يشار إليه باسم استسقاء الرأس. التصوير المقطعي المحوسب (CT) يستخدم عادة للتحقق من مختلف الأمراض داخل الجمجمة. مؤشر إيفانز (EI) هو مؤشر مهم لتشخيص استسقاء الرأس.

المنهجية: قمنا بإدراج جميع المرضى الذين خضعوا لفحص بالأشعة المقطعية للدماغ والتي تم الإشعار عنها على أنها طبيعية. تم حساب EI بواسطة أخصائي أشعة عصبية مستقل. تم حساب متوسط (EI) للعينة بأكملها حسب العمر والجنس والعرق.

النتائج: تمت مراجعة ما مجموعه 1,330 صورة مقطعية للدماغ تم إجراؤها في مستشفىنا بأثر رجعي من أغسطس 2021 إلى ديسمبر 2021. بعد ذلك، تم فحص ما مجموعه 423 صورة مقطعية بعد استبعاد 25 مريضاً يعانون من نتائج تصوير الدماغ غير الطبيعية و 14 صورة متكررة لنفس المرضى. وهكذا، تم تضمين ما مجموعه 384 مريضاً. كان متوسط EI للعينة بأكملها 0.2550 ± 0.0277 . كان هناك اختلاف بسيط ولكنه ذو دلالة إحصائية بين الذكور والإناث، بمتوسط EI يبلغ 0.2588 ± 0.0274 للذكور و 0.2517 ± 0.0276 للإناث ($p=0.012$). لم يكن هناك فرق ذو دلالة إحصائية بين المرضى السعوديين وغير السعوديين. زاد (EI) تدريجياً مع تقدم العمر في كلا الجنسين.

الخلاصة: وكانت قيمنا (EI) مماثلة لكثير من القيم المنشورة في بلدان أخرى، والتي تدعم استخدام القيمة 0.3 لتشخيص استسقاء الرأس، بغض النظر عن الجنس أو العمر أو العرق.

Objectives: To calculate The Evans Index (EI) in normal Individuals. Ventricular enlargement is referred to as hydrocephalus. Computer tomography (CT) scans are commonly used to investigate such intracranial pathologies. The EI is an important parameter for diagnosing hydrocephalus.

Methods: We included all patients who underwent Computer tomography (CT) scan of the brain that was reported as normal. The mean EI was calculated for the whole sample stratified by age,

gender, and ethnicity. Patients with an initial report indicating any intracranial pathology, such as hydrocephalus, tumors, hemorrhages, or neurodegenerative disorders, were excluded.

Results: A total of 1,330 brain CT scans carried out at our institution were reviewed retrospectively from August 2021 to December 2021. A total of 423 CT scans were screened after excluding 25 patients with abnormal imaging findings and 14 repeated images for the same patients. A total of 384 patients were included. The mean EI for the entire sample was 0.2550 ± 0.0277 . There was a minimal but statistically significant difference based on gender, with a mean EI of 0.2588 ± 0.0274 for males and 0.2517 ± 0.0276 for females ($p=0.012$). There was no statistically significant difference between Saudi and non-Saudi patients. EI increased progressively with age in both genders.

Conclusion: Our EI values were similar to many of those reported in other countries, which supports the use of the 0.3 cutoff for the diagnosis of hydrocephalus, regardless of gender, age, or ethnicity.

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Ventricular enlargement is referred to as hydrocephalus, which is defined based on radiological and clinical parameters. Computer tomography (CT) scans are one of the most commonly used modalities for investigating such intracranial pathologies.

The Evans index (EI) is a widely used measure in the diagnosis of hydrocephalus. It is obtained by calculating the ratio of the maximum width of the frontal horns of the lateral ventricles to the maximum transverse diameters of the skull's inner table at the same level. Hydrocephalus is defined as an EI greater than 0.3. However, gender, age, and ethnicity are biological and physiological factors that can cause variations in this value.

Many studies have been conducted on how to measure hydrocephalus and its parameters. Volumetric analysis is considered to be a more accurate way of measuring ventricular volume, which is important when diagnosing various neurodegenerative disorders, including normal pressure hydrocephalus. However, the lack of availability of special software and the time-consuming nature of this method make it difficult to use universally. On the other hand, the Evans Index (EI) is a quick and easy surrogate for ventricular volume that can be used on any MRI or CT scan of the brain.

Brix and colleagues conducted a study on 534 participants with Alzheimer's disease and 308 healthy elderly individuals and found a wide range of EI values in different age groups.¹ For example, healthy elderly individuals aged 65 and above had values greater than 0.3. Hence, a uniform cut-off value of 0.3 should not be used for diagnosing hydrocephalus.¹

Jaraj et al² studied 1,235 individuals aged 70 years or older and found that the mean EI was 0.28 (SD: 0.04). For men older than 80, the EI was 0.3 (SD: 0.03), while in patients with NPH the EI was 0.36 (SD: 0.04), and in dementia patients the EI was 0.31 (SD: 0.05).² This study was conducted because having local data on our population is important to our clinical practice and the international literature, allowing for the early and accurate diagnosis of hydrocephalus.

In this study, we aimed to calculate the EI of a patient population treated at King Abdulaziz University Hospital, a tertiary hospital in Saudi Arabia. These patients underwent a CT scan of the brain for various indications, and the CT scans were reported as normal. Specifically, we calculated the EI values based on different age groups, genders, and ethnicities.

Methods. We used PubMed and Google Scholar to conduct a literature search. We also reviewed the reference lists of relevant articles. We obtained ethical approval for our research from the Biomedical Ethics Committee (Reference number 46-23). The study was carried out in accordance with the principles of the Helsinki Declaration. A total of 1,330 brain CT scans carried out at our institution were reviewed retrospectively from August 2021 to December 2021. Subsequently, 423 normal brain CT scans were selected. The brain CT scans were determined to be normal based on 2 radiologists' opinions; thus,²⁵ patients were excluded due to interrater discrepancy (Figure 1). Information regarding the patients, such as age, gender, and clinical indications for CT scans, was gathered. The CT machines used were the Siemens Somatom 64 and 128 slice. All patients had a slice thickness of 2 mm, and images were reviewed on the Paxera Ultima viewer (8th generation). The EI values were determined by dividing the maximum width of the frontal horns of the lateral ventricles in the axial images by the maximum width of the skull from the inner tables (Figure 2).

Inclusion criteria. We included all patients who had a normal brain CT scan carried out for various indications, and no age restriction was applied. Measurements were obtained by an independent neuroradiologist who was different from the one who initially reported the images in the system.

Exclusion criteria. Patients with an initial report indicating any intracranial pathology, such as hydrocephalus, tumors, hemorrhages, or neurodegenerative disorders, were excluded. Cases with incomplete data or with a significant artifact that hindered measurement of EI were excluded as well. Cases were also excluded if the neuroradiologists identified any abnormality aside from age-related atrophic changes. If a patient had multiple scans, only the initial scan was included.

Statistical analysis. Statistical analysis was performed using SPSS software (version 29.0.1.0 (171)). We assumed that the sample was normally distributed. We calculated the mean age for the whole sample and for males and females separately, the mean EI, and the standard deviation. Students' t-tests were used to draw comparisons based on gender and ethnicity as well as between the pediatric and adult populations and those aged 50 or below and more than 50. Additionally, we categorized the study population according to age based on 10-year intervals and calculated the mean EI for each age group separately and stratified by gender. A $p < 0.05$ was considered statistically significant.

Table 1 - Evans index among different age groups stratified by gender. SD = standard deviation.

Age group	Gender	Mean Evans Index	N	SD
0–10	Female	0.2355	14	0.0277
	Male	0.2408	25	0.0226
	Total	0.2389	39	0.0243
11–20	Female	0.2506	23	0.0234
	Male	0.2562	8	0.0180
	Total	0.2520	31	0.0220
21–30	Female	0.2512	25	0.0186
	Male	0.2480	20	0.0204
	Total	0.2498	45	0.0192
31–40	Female	0.2399	17	0.0352
	Male	0.2460	17	0.0167
	Total	0.2430	34	0.0273
41–50	Female	0.2398	29	0.0202
	Male	0.2571	29	0.0206
	Total	0.2485	58	0.0220
51–60	Female	0.2496	36	0.0221
	Male	0.2612	32	0.0276
	Total	0.2550	68	0.0253
61–70	Female	0.2605	30	0.0236
	Male	0.2766	25	0.0313
	Total	0.2679	55	0.0283
71–80	Female	0.2728	22	0.0332
	Male	0.2721	12	0.0235
	Total	0.2726	34	0.0297
81–90	Female	0.2662	10	0.0417
	Male	0.2888	6	0.0355
	Total	0.2747	16	0.0390
91–100	Female	0.2553	2	0.0115
	Male	0.3051	2	0.0166
	Total	0.2802	4	0.0310
Total	Female	0.2517	208	0.0276
	Male	0.2588	176	0.0274
	Total	0.2550	384	0.0277

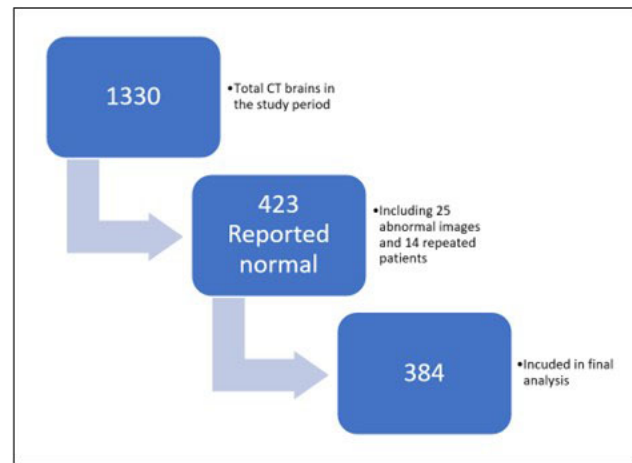


Figure 1 - Flowchart reflecting the total number of patients included in the study.

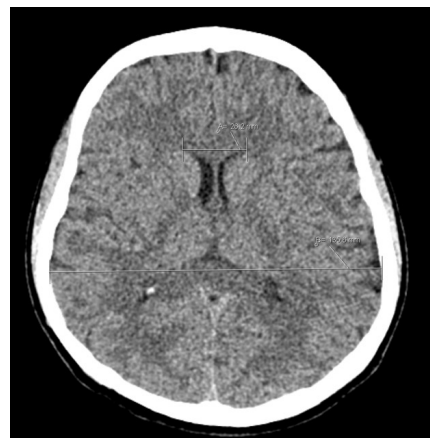


Figure 2 - Image of axial CT scan showing the method of calculating the Evans index; A= total anterior horn width, B= maximum intracranial diameter.

Results. A total of 1,330 brain CT scans carried out at our institution were reviewed retrospectively from August 2021 to December 2021. Of the 423 patients screened, 25 with abnormal image findings and 14 with repeated images were excluded. A total of 384 patients were included in the study (Figure 1). The most common indications for requesting a CT scan were disturbed level of consciousness (21 patients), trauma (16 patients), dizziness and unsteady gait (15 patients), headaches (15 patients), seizures (15 patients), sudden onset of weakness or numbness (10 patients), primary malignancy with suspected metastasis (5 patients), meningitis (5 patients), hypertension emergency (3

patients), and sudden loss of vision (3 patients). Other indications included postcardiac arrest, vertigo and vomiting, unexplained bradycardia, and apnea.

The mean age of the whole sample was 45.07 ± 23.50 years, ranging from 3 months to 95 years. There were 62 pediatric patients and 322 adults. The most common age category was 51–60 years (17.6%), followed by 41–50 years (15%). The least common age category was 91–100 years (1%) (Figure 3). There were 208 females (53.9%) and 176 males (45.6%). The most common nationality was Saudi (227, 58.8%), followed by Yemeni (41, 10.6%) and Burmese (14, 3.6%).

The mean EI for the entire sample was 0.2550 ± 0.0277 . There was a minimal but statistically significant difference based on gender, with males having a mean

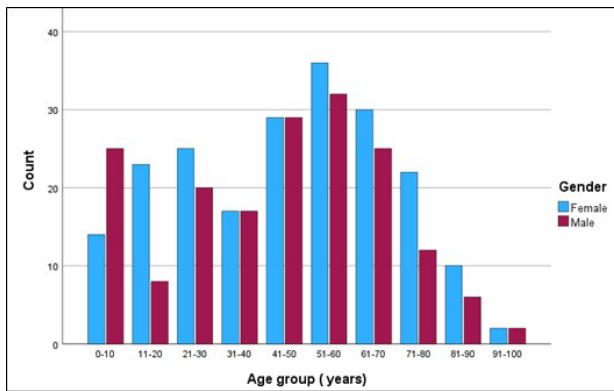


Figure 3 - Clustered bar chart showing the count of individuals per each age category stratified by gender.

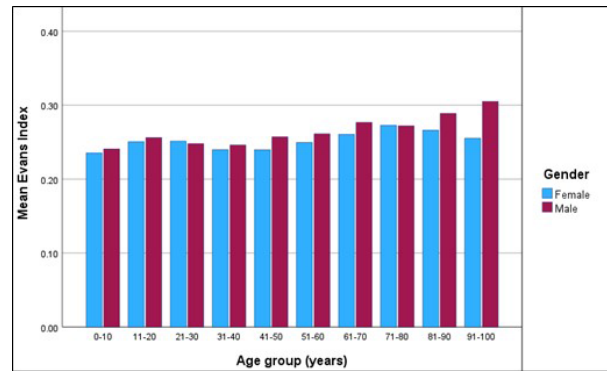


Figure 4 - Evans index for various age groups stratified by gender.

EI of 0.2588 ± 0.0274 and females having a mean EI of 0.2517 ± 0.0276 ($p=0.012$).

In comparing those 50 years of age and under versus those greater than 50 years of age, the mean EI was 0.2466 ± 0.0231 (females: 0.2442 ± 0.0248 and males: 0.2492 ± 0.0209) versus 0.2647 ± 0.0295 (females: 0.2598 ± 0.0284 and males: 0.2712 ± 0.02988), $p=0.001$, showing an increase in the EI value among the older age group regardless of gender. In patients 18 years of age and younger, the mean EI was 0.2440 ± 0.0246 versus 0.2571 ± 0.0279 in adults ($p=0.001$).

Regarding the results per age category, the lowest value was for the 0–10 group (mean= 0.2389 ± 0.0243), and the highest was for the 91–100 group (mean= 0.2802 ± 0.0310) (Figure 4).

Across all age groups, the EI values for females were lower than those for males except for the 21–30 age group, where the mean value for females was 0.2512 ± 0.0186 and that for males was 0.2480 ± 0.0203 (Table 1). A statistically significant difference in the EI was found between Saudis and non-Saudis. Specifically, the EI for 227 Saudi patients was 0.2534 ± 0.0259 , and that for 157 non-Saudi patients was 0.2572 ± 0.0302 ($p=0.191$).

Discussion. In this study, we aimed to calculate the EI of a patient population treated at King Abdulaziz University Hospital, a tertiary hospital in Saudi Arabia. Our goal was to have local data of EI based on gender and various age groups and to compare this data to the available literature in other countries and different ethnic backgrounds. The EI is one of the most commonly used quantitative parameters to assess ventricular size and diagnose hydrocephalus, regardless of etiology. A value of more than 0.3 is considered abnormal.³ A value between 0.25 and 0.3 is considered borderline

abnormal.^{4,5} Other parameters are used to diagnose hydrocephalus, such as the frontal horn index, occipital horn index, and fronto–occipital horn index ratio.^{6,7} For the diagnosis of normal pressure hydrocephalus, an essential parameter is the callosal angle.⁸

Evans index in the entire group. In our study, the mean EI for the entire sample was 0.2550 ± 0.0277 . This is similar to the results of another Saudi study that investigated 100 normal and 50 hydrocephalic patients who underwent CT scans and were shown to have a mean EI of 0.23 to 0.28.⁴ Similarly, a study conducted on a Nigerian population showed an EI of 0.252 ± 0.04 .⁹ However, these values are smaller than those found in 2 studies on the Indian population that reported EI values of 0.27 ± 0.035 and 0.27 ± 0.035 .^{10,11} This could be explained by the higher percentage of elderly patients in these studies. Additionally, these differences could be attributed to racial and ethnic differences.

Evans index based on age group. We also calculated the EI for patients who were 18 years of age and younger compared to adults; the EI for these groups were 0.2440 ± 0.0246 and 0.2571 ± 0.0279 ($p=0.001$), respectively. In 2 previous studies on the pediatric population, the values were 0.218–0.312 and 0.23–0.28.^{12,13}

The EI values increase with age, as noted in our study and reported by others.^{9,14–16} For instance, in patients older than 90 years, the EI was 0.2802 ± 0.0310 while in patients less than 10 years old, it was 0.2389 ± 0.0243 .

A study conducted in central India suggested a cutoff of EI 0.34 for patients >70 years of age, based on the reported normal value in that age group.¹⁴ In our study, for patients >70 years of age, EI was 0.2726 ± 0.0297 , while for patients >80, EI was 0.2747 ± 0.0390 . Only 4 patients were >90 years of age, with an EI value of 0.2802 ± 0.0310 . Two of them were male, with a mean

EI of 0.3051 ± 0.0166 . It is possible that accepting higher index numbers is needed when diagnosing hydrocephalus in older age groups.

Evan Index based on gender. Our study showed a small but statistically significant difference based on gender; similarly, a study in central India showed an EI of 0.2655 ± 0.0306 and 0.2733 ± 0.0301 ($p=0.0064$) in females and males, respectively. A study conducted in Turkey reported EI values of 0.27 and 0.28 in females and males, respectively,¹⁷ and a Japanese study reported EI values of 0.262 and 0.271 in females and males, respectively.¹⁸ Previous Saudi and Nigerian studies showed no gender differences.^{4,9}

With aging and brain atrophy, the size of the ventricles increases, but usually, this increase does not lead to an EI exceeding 0.3. Thus, using the EI in isolation without considering the degree of atrophy could be misleading.

Some studies have investigated integrating volumetric measurement of the ventricles in the assessment of hydrocephalus and have found a strong correlation between the EI and ventricular volume.^{19,20} Identifying the normal range for this value in our population is important, particularly in the elderly, to differentiate early hydrocephalus from other conditions, such as degenerative disorders, Alzheimer's disease, and normal aging.

The results of this study can aid in improving our understanding of the radiological parameters specific to our region. It is recommended that these findings be validated with a larger number of patients drawn from diverse ethnic backgrounds and different geographic regions. This will enable the accurate and timely diagnosis of hydrocephalus and prevent unnecessary misdiagnosis, especially in the elderly population.

Limitations. This single-center study was conducted retrospectively. To obtain a more accurate representation of the EI of the Saudi population, additional multicenter studies that incorporate a greater number of patients from both genders and all age categories could lead to a better representation of the EI. In our study, only 4 patients were older than 90. More patients in this age group need to be studied to determine if the 0.3 cutoff point is valid for this age group.

Conclusion. Our results showed a similar EI to many of the reported values in other countries, which supports the use of the 0.3 cutoff for the diagnosis of hydrocephalus, regardless of gender, age, or ethnicity. EI values increase progressively with age and are slightly higher in males than in females.

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