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Original Article

Morphometric analysis of lateral and third ventricles by computerized tomography for early diagnosis of hydrocephalus

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ABSTRACT

Introduction: Brain ventricles are dilated with accumulation of excess cerebrospinal fluid in it, which can cause the pressure damage to the surrounding structures. This study aims to highlight the reference range values for lateral and third ventricles of brain for easy diagnosis and management of hydrocephalic patients.

Material and methods: We calculated the frontal horn ratio(FHR), bi- caudate ratio(BCR), Evan's ratio(ER), cella media ratio(CMR), bi-frontal index(BFI), bi- occipital index(BOI), third ventricle width(TVW), third ventricle sylvian fissure ratio index (TSFI), and third ventricle ratio (TVR) in 120 apparently normal CT-Head images and forty hydrocephalic images by taking linear measurements withdicom image software. Descriptive statistics –mean, standard deviation, standard error, 95% confidence interval were calculated for each parameter. Independent student t- test, age regression analysis, and Spearman's rank correlation coefficient were applied accordingly.

Results: BCR, ER, TSFI showed significant correlation with the age and anteroposterior diameter of brain. BCR and TVW were significantly higher in males. In normal images, 95% confidence limits for FHR [0.295-0.309], TVW [6.104–6.92], TSFI [0.538–0.558] were found. The mean FHR and TVR in hydrocephalic patients were 0.42 and 0.072.

Discussion: Since Frontal horn ratio and Third ventricle ratio do not depend upon the age, sex and size of brain, these two parameters can be used as the screening and monitoring tools in patients with hydrocephalus.

1. Introduction

Brain ventricles are the cerebrospinal fluid (CSF) containing cavities which communicate to subarachnoid space superiorly and spinal canal inferiorly. Any blockage in its circulation will lead to accumulation of CSF and initiating a serious clinical condition known as hydrocephalus, which causes pressure damage to the surrounding structures in brain and adds to the harm caused by primary lesions.[1] Normal reference values for size of ventricles are must not only to ease the diagnosis of hydrocephalus, but also for follow up post op cases ofventriculo-peritoneal shunts, since some distinctive parameters of lateral ventricle e.g. Evan's ratio and cella media ratio get reduced to normal.[2] The measurements of lateral ventricle width, third ventricle width and the distance between clivus and basilar artery are imperative requirement to choose the patients for safe endoscopic third ventriculostomy (ETV) without danger of encompassing structures such asfornix, pineal body, optic chiasma, hypothalamus and tegmentum of midbrain.[3] K. Stachuraetalexhibited reduction in ventricle dimensions after ETV in 54% patients of hydrocephalus of differing etiology.[4] There is dearth of literature with respect to linear ventricle brain ratios correlated to age, sex and size of cerebrum in Indian population. We discover six ventricle brain ratios for lateral ventricles and two for third ventricle in addition to the absolute value of maximum third ventricle width.

2. Material and method

It was a retrospective, cross-sectional, non-interventional study, conducted in the department of anatomy with approval of institutional ethical committee, with the assistance of Dicom

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Image Software. The study group comprised of archived CT of patients who reported to the department of Radiology and Imaging for a head CT examination for various indications between January 2014 and August 2015.From archives, normal head CT scans of one hundred twenty patients (60 males and 60 females) with age range 2–60 years, were selected for the measurement of ventricle dimensions. Forty cases of hydrocephalic patients (22 males, 18 females) were also included in the study. The scans were obtained on a plane at an angle of 15° to and 1 cm above the infra-orbitomeatal line with a slice thickness of 8 mm. Scans were selected out of the routinely done investigations. No additional scans were indicated for the purpose of this study, unnecessary radiation exposure were thus totally prevented. Only unenhanced axial CT scan images interpreted by experienced radiologist were included and those showing gross pathological changes affecting the normal anatomy of ventricles. (e.g. due to large metastasis etc.) were excluded from the study group.

2.1. Image and data interpretation

The measurements were taken in the axial CT sections at the following levels:

1 at the level of head of caudate nucleus. Anteroposterior (AP) diameter of the brain in midline as the distance between inner tables of skull and Transverse diameter (TD), perpendicular of the AP diameter at its midpoint were measured.
2 at the level of cella media (central part of lateral ventricle)
3 at the level above cella
4 at the level of superior colliculus
5 at the level of thalamus in its largest dimension, where sylvian fissures are well depicted
6 at the level of foramen of Monro

The images copied, encoded, saved and printed. Frontal horn ratio, bi caudate ratio, Evans' ratio, cella media ratio, bifrontal index, bioccipital index, third ventricle width at superior colliculus level, third ventricle sylvian fissure ratio index and third ventricle ratio were calculated as described earlier. (Patnaik)[5,6].

2.2. Statistics

Mean, standard deviation, standard error and 95% confidence limits were calculated for all the parameters according to descriptive statistics. Gender variations in parameters were calculated by applying independent student t-test. Variation with age was analysed using regression statistics and correlation to diameters of cerebrum was seen by calculating Pearson's Correlation coefficient at p value of 0.05.

3. Results

3.1. Lateral ventricle parameters on normal brain CT scans

Tables 1–4 show the results of lateral ventricle parameters of 120 patients (mean age 34.82 +/−13.31 years), with apparently normal morphometry out of which sixty were males (mean age 33.13 +/−15.39) and sixty were females (mean age 36.35 +/−12.18).

Except for frontal horn ratio, the mean value of all the studied parameters of lateral ventricle were greater in males than in females, and difference was significant for mean bi-caudate ratio. It was non-significant for all other parameters. All except frontal horn ratio correlated positively with the cerebrum dimensions (Table 3). BCR and ER showed moderate significant correlation with AP only, whereas cella media ratio showed maximum correlation with both the diameters of brain and was highly significant.

Except FHR, all the parameters showed positive correlation with age (Table 4).

BCR and ER showed very mild but significant correlation with the age.

3.2. Third ventricle parameters on normal brain CT scans

Results of third ventricle parameters measured were as per Tables 5–7. Values of all the measured parameters were higher and showed greater variation in males in comparison to the females. The gender difference was highly significant for Third ventricle width (TVW) and statistically non-significant for TSFI and TVR. Third ventricle width showed only mild correlation with the diameters of brain which was statistically non-significant. Third ventricle sylvian fissure distance index correlated negatively with both the diameters of brain. It showed highly significant correlation with AP (Table 6). Third ventricle ratio showed almost nil correlation with anteroposterior diameter of brain whereas it showed negative very mild correlation with TD, which was statistically non –significant.

TVW and TVR showed almost nil correlation with age whereas TSFI showed mild correlation with age. Though only 6% of variation in TSFI is explained by age factor it is seen that with increasing age,

Table 1
Measurements of antero-posterior and transverse diameter of cerebrum.

	Mean	S.D.	S.E.	Min	Max	95% CI	
						Lower	Upper
AP	155.68	7.26	0.66	139.7	171.6	154.37	156.99
TD	118.21	5.52	0.50	108.8	142.1	117.21	119.21

Table 2
Parameters of lateral ventricles in males, females and total population.

Parameter	Population	Mean+/−s.d. (mm)	S. error	Range (mm)		95% CI (mm)		P-value
				Min	Max	Lower	Upper	
FHR	T	0.302+/−0.04	0.0036	0.17	0.50	0.295	0.309	0.35
	M	0.299+/−0.03	0.003	0.17	0.35	0.291	0.307	
	F	0.305+/−0.04	0.006	0.19	0.50	0.293	0.317	
BCR	T	0.120+/−0.03	0.0026	0.05	0.21	0.115	0.125	0.03*
	M	0.126+/−0.03	0.004	0.05	0.21	0.118	0.134	
	F	0.114+/−0.03	0.003	0.05	0.17	0.108	0.120	
ER	T	0.269+/−0.03	0.003	0.14	0.34	0.263	0.275	0.22
	M	0.273+/−0.04	0.004	0.14	0.34	0.264	0.282	
	F	0.265+/−0.03	0.004	0.16	0.33	0.257	0.273	

*Significant ; T: Total; M: Male; F: Female.

Table 3
Lateral ventricle parameters : correlation with AP and TD.

	r with AP	p-value	r with TD	P- value
FHR	−0.09	0.328	−0.15	0.102
BCR	0.29	0.0013**	0.18	0.049*
ER	0.257	0.0046**	0.058	0.529
CMR	0.30	0.004**	0.27	0.006**
BFI	0.21	0.083	0.21	0.083
BOI	0.12	0.37	0.01	0.837

* Significant; ** highly significant.

TSFI decreases significantly. TVW and TVR do not vary significantly with the age of the patient (Table 8).

4. Discussion

4.1. Lateral ventricle parameters

Frontal horn ratio (FHR) is interpreted as the maximum distance between the apical margins of frontal horns and is normally one third of the width of brain in the same line.[7–9] We report the average values of frontal horn ratio as 0.302, consistent with the literature. It showed very mild negative correlation with anteroposterior and transverse diameter of cerebrum. In our study the average of FHR was slightly higher in females than in males, with no statistically significant difference. However Zlindu,[10] reported FHR values higher in males than in females.Regression analysis with age showed negative non-significant correlation. Decrease in the frontal horn distance in the absence of increase in brain width with advancing age, explains the negative correlation with age. Residual plot shows clumping of residuals along a straight line (Fig. 1). It does not depend upon age significantly ($p > 0.05$). The influence upon the frontal horn ratio, because of variation in the size of ventricle due to anthropometric difference in normal individual is minimized, since Frontal horn ratio is a linear ratio, with no unit. Barron reported slight progression from 4th decade onward, sharp fall in 6th decade and rapid rise in 7th decade.[7] Some studies on normal volunteers reported positive correlation of age to Bi-caudate ratio and Frontal horn ratio.[11] In earlier studies, Bi-caudate ratio and frontal horn ratio have been used to investigate “atrophy of the caudate nuclei in patients with Huntington's chorea and cerebral atrophy”.

Table 6
Third ventricle parameters, correlation with AP and TD.

	r with AP	p-value	r with TD	P- value
TVW	0.124	0.177	0.121	0.188
TSFI	−0.38	0.00001 **	−0.08	0.38
TVR	0.08	0.38	−0.14	0.127

r: correlation coefficient ; AP and TD (Antero-posterior and Transverse diameter of cerebrum : ** : Highly Significant.

4.1.1. Bicaudate ratio (BCR)

The mean bicaudate ratio was 0.12, being consistent with the literature and significantly higher in males than in females ($p < 0.05$). The range were also higher in males. It showed positive significant correlation with age. ($p = 0.000$), moderate but highly significant with anteroposterior diameter of brain, whereas only mild correlation with transverse diameter of brain. Doraiswamy[11] and Robert A Bermal[12] in separate studies showed the positive significant correlation with age ($r = 0.33.p = 0.02$). Yang W. et al found that females and males rely upon different cortical regions to achieve the same level of overall reasoning performance, females more upon verbal processing (inferior frontal cortex) and males on visuospatial ability (dorsolateral prefrontal cortex).[13] The overall information binding occurs in medial frontal cortex. The dominance of different regional areas in parts of frontal cortex in males and females could probably cause the different mean values of BCR with respect to gender. However more research is needed in this area to provide the evidence.

4.1.2. Evan's ratio

To assess the enlargement of lateral ventricles quantitatively, Evan's ratio is a widely used tool based upon the linear measurements. In our study the normal mean ER was 0.269 +/- 0.03, being higher in males than in females, however the difference being statistically non- significant (p=>0.05). The range was also wider in males. It showed mild positive, significant correlation with age ($p = 0.013$) but moderate highly significant correlation with antero-posterior diameter of brain and almost nil correlation with TD. Our

Table 4
Lateral ventricle parameters : regression statistics with age.

	FHR	BCR	ER
Multiple R	0.055	0.44	0.22
R square	0.003	0.19	0.05
t-stat	−0.60	5.30	2.51
P-value	0.55	<< 0.000**	0.013*
Regression equation	Y' = 0.307 – 0.000016 x	Y' = 0.09 + 0.00093 X	Y' = 0.249 + 0.00056

*Significant; ** highly significant.

Table 5
Parameters of Third ventricles in males, females and total population studied.

Parameter	Population	Mean+/−s.d. (mm)	S.E.	Range (mm)		95% CI (mm)		P-value
				Min	Max	Lower	Upper	
TVW	T	6.51 +/−2.25	0.20	2.1	12.7	6.104	6.92	0.0007**
	M	7.2+/−2.41	0.312	2.1	12.7	6.57	7.82	
	F	5.82 +/−1.86	0.240	3.0	9.8	5.34	6.30	
TSFI	T	0.548+/−0.06	0.005	0.44	0.74	0.538	0.558	0.91
	M	0.554 +/−0.06	0.008	0.46	0.74	0.537	0.571	
	F	0.553+/-0.043	0.005	0.44	0.63	0.542	0.564	
TVR	T	0.062+/−0.02	0.002	0.028	0.139	0.058	0.066	0.39
	M	0.064 +/−0.03	0.004	0.028	0.139	0.056	0.070	
	F	0.060 +/−0.02	0.003	0.030	0.108	0.055	0.065	

Table 7
Third ventricle parameters : results of regression analysis with age.

	TVW	TSFI	TVR
Multiple R	0.021	0.248	0.020
R square	0.0004	0.061	0.0004
T-stat	−0.23	−2.78	−0.219
P-value	0.81	0.006 (S)	0.82
Regression equation	Y' = 6.64– 0.0037 x	Y' = 0.587–0.001 x	Y' = 0.063 - 0.000039 x

S: Significant ; x is age.

Table 8
Ventricle parameters in patients with hydrocephalus.

	Parameter	Mean	S.D.	S.E.	Min.	Max.
Lateral ventricle	FHR	0.44	0.041	0.0052	0.38	0.55
	BCR	0.27	0.032	0.0024	0.25	0.30
	ER	0.38	0.034	0.0031	0.30	0.42
	CMR	0.42	0.041	0.0023	0.37	0.52
	BFI	0.56	0.031	0.0012	0.50	0.71
	BOI	0.62	0.022	0.0010	0.58	0.78
3^{rd} ventricle	TVW	8.24	1.043	1.0322	4.26	18.36
	TSFI	0.32	0.021	0.0526	0.30	0.38
	TVR	0.072	0.006	0.0011	0.039	0.14

findings are consistent with those given by Gawler with the upper limit being 0.29 or lower.[14] Ahmed Umagdas et al also reported the nonsignificant difference between the mean value of ER in males and females on their CT head study.[15] The international guidelines for diagnostic cutoff value for hydrocephalus is ER > 0.30 (Toma AK).[16] ChaaraniBedar et al reported that average lateral ventricle volume was significantly larger in normal pressure hydrocephalus (NPH) patients as compared to Alzheimers'disease patients and vascular dementia.[17] Evan's ratio is also increased in NPH. Recently authors have shown the association between ventriculomegaly (taken as BCR > 0.2 and ER > 0.30) with or without hydrocephalus related symptoms after subarachnoid haemorrhage and the Hounsfield unit values of the cancellous bone in the frontal skull in young individuals. They showed that the group comprising of the first tertile of skull Hounsfield unit values showed an approximately four fold increased risk of ventricular enlargement after subarachnoid haemorrhage as compared to the third tertile.[18]

4.1.3. Cella media ratio

Haug (1977) reported **CMR** to be 0.295 (age 61–71) increasing gradually with age.[19] In our finding, it was 0.22 which is due to wider age group in our study. Cella media ratio showed maximum correlation with AP and TD amongst all ratios which suggests that with increase in size of cerebrum, CMR also increases. The correlation was statistically most significant (p = 0.004) with AP as compared with other parameters.

Bi-frontal index, It is the quotient of maximum distance of most lateral borders of frontal horns to internal diameter of the skull in the same line. In our study Bi-frontal index showed almost equal, non-significant correlation with AP and TD.

Bi-occipital index was found to have mild correlation with AP whereas none with TD(r = 0.03).

4.2. Third Ventricle parameters in apparently normal patients

Third ventricle is present as midline narrow cavity within the diencephalon. It can be enlarged due to narrowing of cerebral aqueduct due to various causes including congenital, traumatic or malignant. The following three parameters need special emphasis to assess cases of ventriculomegaly and cerebral atrophy.

4.2.1. Third ventricle width

The mean width of third ventricle has been reported to vary from 2.25 mm to 9.2 mm, with several studies in between 3.6 mm and 6.2+/−1.9 mm (Fig. 2:)[20–24].

In our study it was 6.51 mm, at the level of superior colliculus with the lower limit of 95% confidence interval being 6.104 mm and upper limit as 6.92 mm. We found mean third ventricle width to be apparently larger in men than that of their women counterparts, with statistically highly significant difference (p = 0.0007) between the two genders (7.2+/−2.41 mm in males and (5.82 +/−1.86 mm in females). The range of TVW was also higher in males, the maximum being 12.7 mm. Earlier also TVW was reported to be slightly higher in males than in females in all Indian studies.[25–27] However Vidya K (2014)[28] in MRI study reported TVW to be same in males and females. Gyldensted and Kosteljanetz (1976) reported significant sex-related differences in measurements of the ventricular system, using a rather small sample of adults.[29] Whereas, Mathew et al. (2012) reported the width of third ventricle, posterior to inter-thalamic adhesions, to behigher in females with significant gender variation from 6 years and above.[30]Usman JD demonstrated no statistical difference (P > 0.05)in width of third ventricle between male and female in age ranges 11–15 to >25.[31]

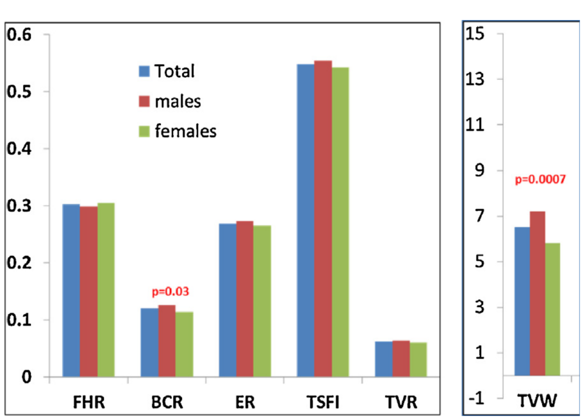

Fig. 1. The mean of parameters showing difference with gender.

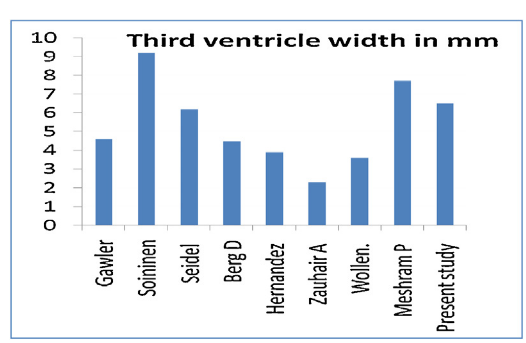

Fig. 2. Third ventricle width as reported by different authors.

When correlated to linear dimensions of cerebrum, TVW showed weak positive non-significant correlation to anteroposterior andtransverse diameter of cerebrum (Table 6). In females TVW showed higher correlation to TD (r = 0.21) than to AP(r = 0.06). In males TVW demonstrated almost equal correlation to antero-posterior and transverse diameters of cerebrum (Fig. 3).

Le May in 1984, reported that on normal CT scans, third ventricle is invisible or minute before fourth decade but is commonly seen clearly by fifth decade.[32] Cotton et al. studied third ventricular size in relation to cranial vault size and concluded that with advancing age there is gradual widening of the third ventricle.[33] According to our study, third ventricle width showed very minimal non significant correlation with age (r = 0.021, p = 0.81). According to Meese (1980) also, the normal size of the third ventricle on CT and MRI was shown to be <5 mm in children, <7 mm in adults <60 years of age and <9 mm in adults above 60 years.[34] This agrees with Celik*etal.*who examined 100 voluntary individuals with no physical or neurological deficit and discovered that the sizes of the cerebral ventricles increase with age in both sexes.[35] Even in clinically severe dementia young patients, in whom the changes because of age are excluded, third ventricular width changes only slightly within one standard deviation of that of width in normal patients.[36] It means that it does not change significantly in CT in atrophy related to dementia. It is not a good indicator of atrophy related to dementia. Third ventricle can also be dilated in atrophic diseases of gray matter including basal ganglion e.g. multiple sclerosis. Therefore, the relation of the cerebral ventricular system to that of the brain tissue as a whole may provide much less error and can be considered more reliable.

4.2.2. Third ventricle sylvian fissure distance index (TSFI)

The sum of the distance between margins of third ventricle and lowermost point of sylvian fissure on both sides is divided by the inner diameter of brain in the same line to calculate the TSFI. In this study it was 0.548+/−0.06, being slightly higher in males (0.554 +/−0.06) than in females (0.543+/−0.048), the difference being statistically non-significant (p > 0.05). TSFI ranges were also higher in males than in females.

TSFI showed negative correlation with both the diameters of cerebrum. With TD it was non-significant (r= −0.08, p = 0.38) but with AP it was highly significant and moderate (r = -0.38, p = 0.00001).i.e., TSFI decreases with increase in anteroposterior diameter of cerebrum. In males, it showed maximum correlation with AP(r= −0.38) and almost negligible with TD (r= -0.08). In females it correlated almost equally with TD and with AP (Fig. 4).

TSFI showed negative moderate (t stat = −2.78, p = 0.006) correlation with age, which was statistically significant. These findings are similar to those given by Gomori et al. 37 in 1984 (r = −0.2438 p = 0.0007). Reduction in brain weight by shrinkage results in compensatory enlargement of ventricles usually in sixth decade as a physiological process of ageing and the earliest signs seen on CT arewidening of anterior ends of sylvian fissures.[32,38] Progressive increase in third ventricle width with reduction in thalamic mass width(reduction in numerator of TSFI) at certain decade of age can explain the moderate negative correlation of TSFI with age. The 95% confidence intervals were from 0.538 to 0.558.

Normal pressure hydrocephalus (NPH), seen in elderly, is a syndrome of triad of dementia, incontinence and gait disturbance. Since the diagnosis of NPH has been based mainly upon the brain CT Scan findings, the large sizes of the ventricles, periventricular lucency and the presence of a small degree of cortical atrophy are considered characteristic evidence of communicating hydrocephalus.[39,40] Thus there is an effect of the size of the ventricles and the cerebral mantle measured in CT images, in the presentations of clinical symptoms and the outcome of patients after drainage procedures. The depth of cerebral mantle, calculated by TSFI has a significant correlation to the severity of symptom especially, gait disturbance. This is again probably the result of dilatation of 3rd ventricle, which causes displacement and stretching of the fibres of the internal capsule, which originate from the precentral motor

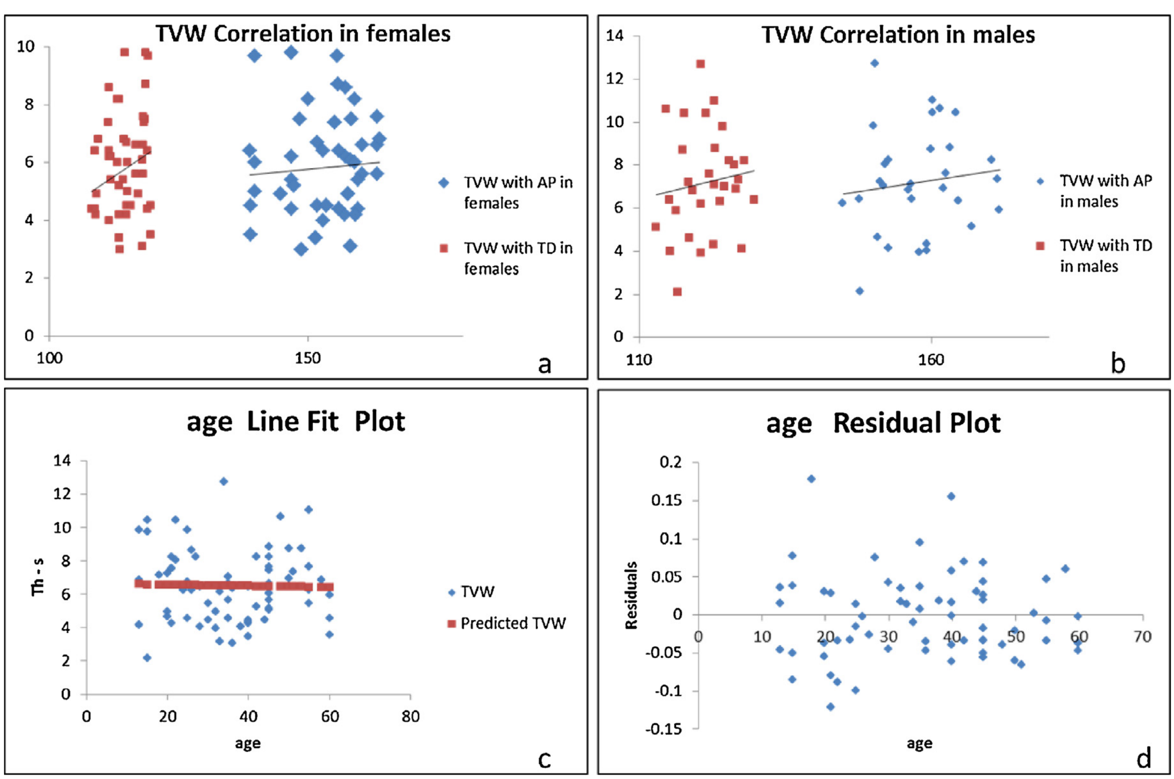

Fig. 3. Correlation of TVW with diameters of cerebrum and age. (a): in females; (b) in males; (c, d): regression analysis with age.

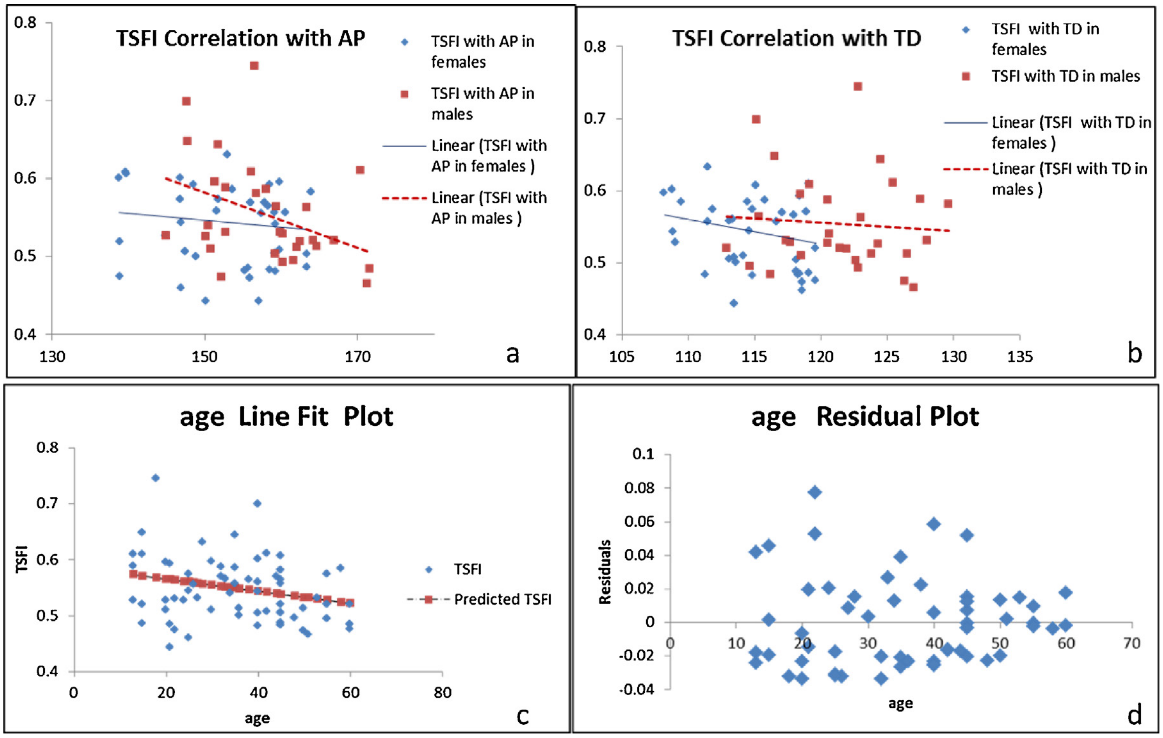

Fig. 4. Correlation of TSFI with diameters of cerebrum and age; (a): with anteroposterior diameter; (b): with transverse diameter ; (c,d): Regression analysis with age.

cortex. Additionally, alterations in the vascularity of the periventricular parenchyma structure can explain the mobility dysfunction.[41] E Chatzidakis observed the complete inability to walk in the patients whose TSFI was less than 0.50.[42] Thus TSFI helps to predict the outcome for improvement after shunt surgery based upon their symptoms.

4.2.3. Third ventricle ratio

Third ventricle enlargement is best studied by third ventricle ratio calculated as the product of third ventricle width at the level of foramen of monro divided by the internal diameter of the skull in the same line. Certain surgical procedures for leisons in this region, there is need to widen the foramen of monro, which is done mostly by opening the choroidal fissure from the rear of foramen without damaging fornix or thalamus.[43] Thus preventing memory dysfunction and avoid injury to anterior thalamus, avoiding memory loss and conscious impairment. We found TVR to be 0.062+/−0.02, mean being slightly higher in males than in females, though statistically non-significant (p = 0.39). In our study, 95% confidence interval for TVR was 0.058 to 0.066.

Correlation to cerebrum size demonstrated negative weak statistically non-significant (r= −0.14, p = 0.127) correlation with transverse diameter, whereas almost nil with anteroposterior diameter (r = 0.08,p = 0.38).With transverse diameter, third ventricle ratio showed moderate positive correlation (r = 0.39) in females, whereas in males it was mild and negative. (Fig. 5)

TVR showed almost nilcorrelation with age. TVR does not depend uponage (r square = 0.0004, p > 0.05,). TVR remains almost constant, changing only in pathological conditions. Thus TVR may be an important objective indicator of stabilisation, deterioration or improvement of individual patient's clinical outcome

Anterior inferior 3rd ventricle is dilated in advanced hydrocephalus, but it remains normal in cerebral atrophy patients. The appearance of the anterior third ventricle is a helpful feature in distinguishing atrophy from CSF obstruction.[44] The posterior part of third ventricle and upper aqueduct may also dialate with significant atrophy of the quadrigeminal plate.[45]

The third ventricle width increases in patients with multiple sclerosis, including regional brain atrophy, but greater intellectual enrichment done by educational attainment moderates the negative effect on cognition (Daniela Pinta)[46] thus necessitating base line data on these parameters in the present intellectually active society.

4.3. Ventricle parameters in hydrocephalic patients

All the nine parameters in hydrocephalic patients were significantly high as compared to normal reference range values (Fig. 6).

4.4. Significance and Implications of the findings

- The maximum distance between frontal horn tips at the level of head of caudate nucleus, greater than 50% or less than 17%, of the width of the brain on the corresponding plane and line should to be considered highly suspicious of abnormal ventricles.
- The minimum width between the lateral walls of frontal horns in the line of caudate indentations less than 5% or more tham 21% of the width of brain in the same line should be considered highly suspicious of abnormal ventricles and caudate atrophy.
- The maximum third ventricle diameter at the level of foramen of Monro greater than 14% or less than 2.8%, of the width of the brain on the corresponding plane and line should be considered highly suspicious of abnormal ventricles.
- Evans' ratio beyond 0.14 and 0.34; CMR beyond 0.28 and 0.48 ; should be taken to indicate abnormal lateral ventricle size.
- There is 95% chance that in apparently normal persons, TSFI falls within the ranges of 0.538 and 0.558.
- The maximum third ventricle width at superior colliculus level lies between 2.4–12.4 mm.
- The overall frontal horn ratio of forty hydrocephalus patients varied from 0.38 to 0.55 with an overall mean of 0.44; and the ventricular dimensions in this group were generally greater than

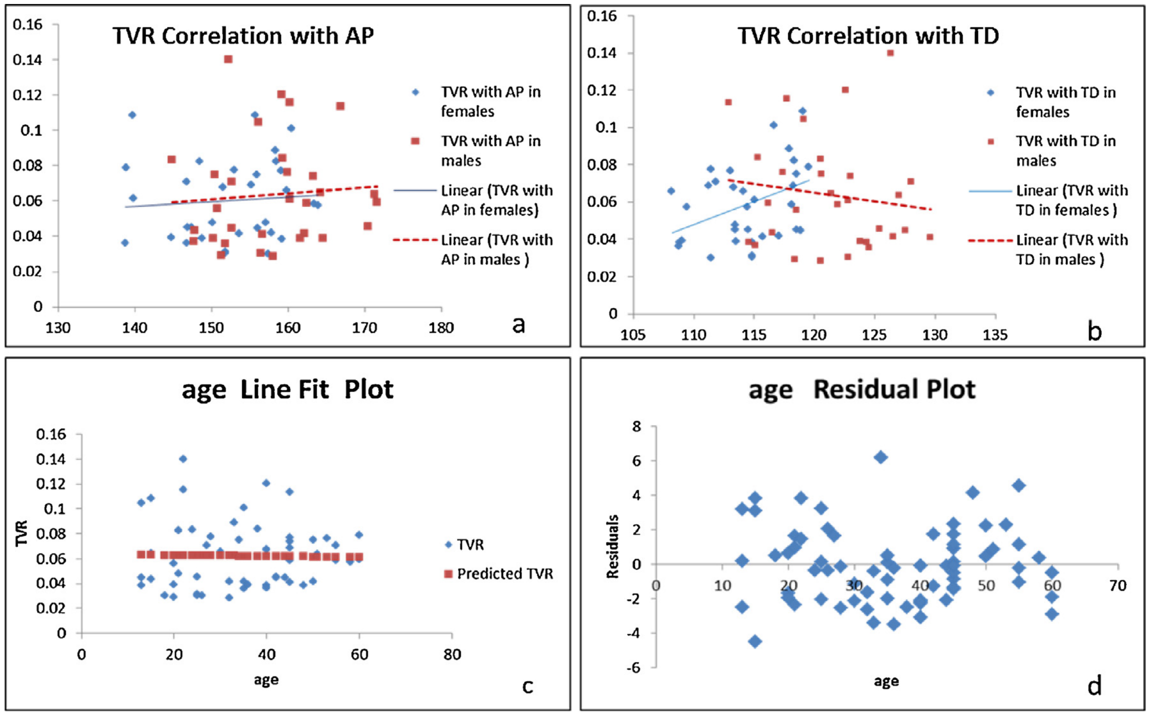

Fig. 5. Correlation of TVR with diameters of cerebrum and age (a): with anteroposterior diameter; (b): with transverse diameter ; (c,d): Regression analysis with age.

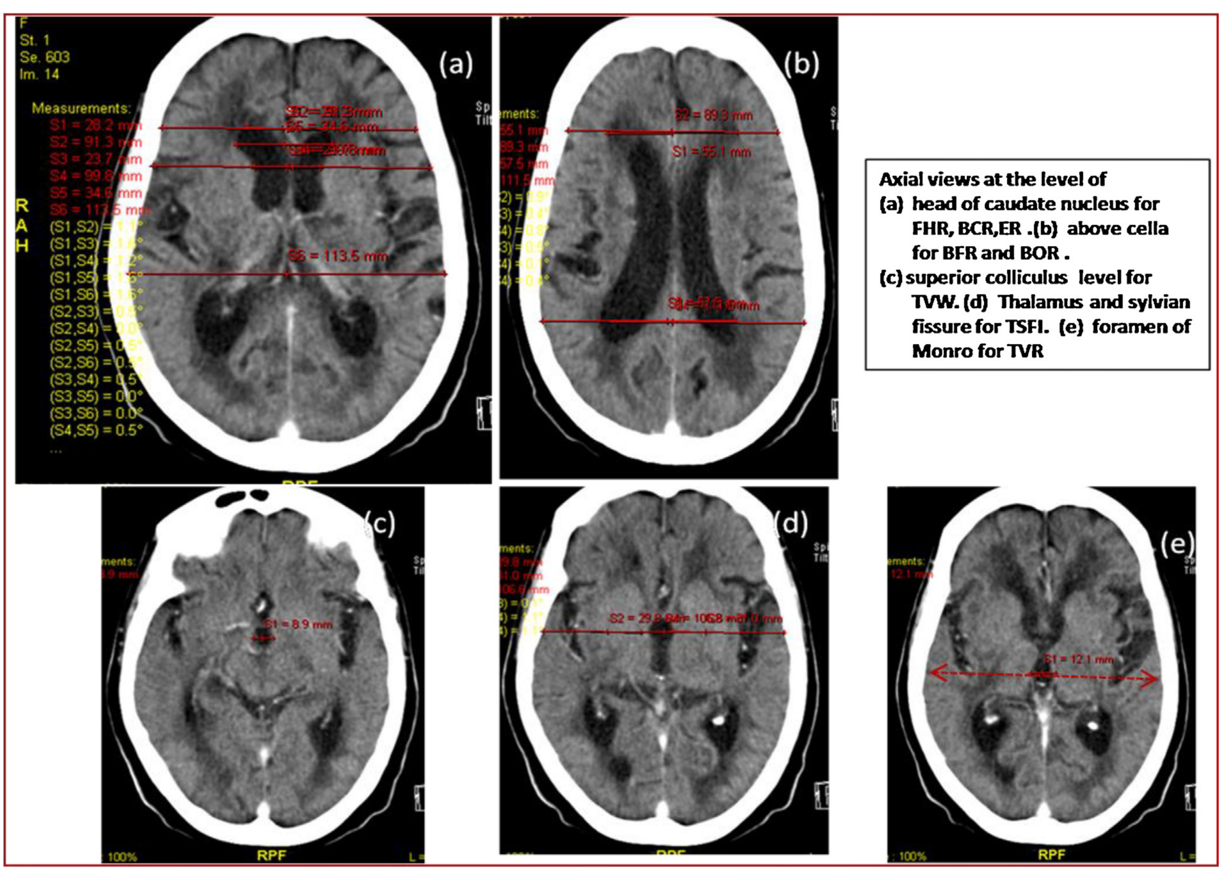

Fig. 6. Representative images in patient with hydrocephalus.

that observed in the main study group of those with normal brain CT scans.

- The present study reported that there was a significant relation between mean BCR, ER, TSFI and age ($p < 0.01$), whereas others did not depend upon age.
- In light of the above research limitations and recommendations, the current study can not reject the null hypothesis and state that there is no significant difference between the mean ventricular brain ratios as described as, FHR, BCR, ER, CMR. BFI, BOI, TVW, TSFI, TVR of a sample drawn as compared to normative reference values drawn from other populations whose averages have been published in available literature at 5% level of significance.
- BCR, ER, CMR and TSFI showed significant correlation ($p << 0.00$) with anteroposterior diameter of cerebrum, whereas others showed almost nil or mild correlation with the diameters of brain which was non-significant.
- The attending physician, with accurate measurements of these parameters in the radiology reports by specialists, will be able to better correlate the results of treatment, compare the follow up CT scans and judge specifically status of the patients' disease and precisely conclude progression or deterioration of clinical conditions and success of treatment provided. This shall act as solid evidence for successful treatment, reduce medico legal litigations.

Specific morphometric understanding of the ventricular system, may be utilized for the size, shape, design and flexibility of bionic implants, telemetric micro-devices for CNS related disorders.

5. Conclusion

With the present study we conclude that since frontal horn ratio and third ventricle ratio do not vary with age, sex and diameters of cerebrum, these can be used as screening tools for hydrocephalus in suspected patients.

Conflicts of interest

None.

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