COMMON MEASUREMENTS AND PROPOSED GRADING SYSTEM FOR HYDROCEPHALUS IN PEDIATRIC PATIENTS BY USING CT SCAN: A CROSS SECTIONAL STUDY

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ABSTRACT

BACKGROUND: Hydrocephalus is a fatal disorder mostly affecting neonate sand infants. It is treatable in pediatric patients but lacks a grading system for these verity of the disease. This paper proposes a grading system for hydrocephalic pediatric patients based on linear measurements applied on CT scan. **OBJECTIVES:** This study aims to determine average linear parameters of the hydrocephalus brain among pediatric patients by using CT scan, to propose a new grading system for hydrocephalus based on these linear measurement sand to find the most common type and grade of hydrocephalus. **METHODOLOGY:** A cross sectional study was conducted on 37 pediatric hydrocephalus subjects in Abha. Five linear measurements FHR, FOHR, BFI, BCI and VI were applied on CT scan and generated a new grading system. Statistical analysis was done by SPSS (V-21) software. Also classifies the subjects by this system into grades of mild to severe and discovers the most common type and category of hydrocephalus. **RESULTS:** The highest frequency of hydrocephalus was found at two years. The most common type was communicated and most common grades were mild and moderate. The mean measurements (reference value) in mm were found for FOHR=0.63, FHR=0.52, BCI=0.34, BFI=0.60 and VI=0.55. There was significant difference of linear parameters in FOHR, FHR, BFI related to age groups. **CONCLUSION:** The grading system successfully divides pediatric patients in to mild to severe categories, effect of age on each linear measurement can also be evaluated in hydrocephalic patients and this grading can also be helpful to evaluate any mass effect like brain atrophy.

Key words: Hydrocephalus, pediatrics, computed tomography

Introduction

Hydrocephalus is an active distension of the ventricular system of the brain resulting from inadequate passage of CSF from its point of production within the cerebral ventricles to its point of absorption into the systemic circulation.[1]

There are two types of hydrocephalus based on communication; communicating or non obstructive hydrocephalus occurs when CSF flows out of ventricles and into the spinal canal, but it is not reabsorbed normally by the tissues surround brian and spinal cord. Where as non-communicating or obstructive hydrocephalus occurs when CSF does not flow properly between or out of ventricles because of an obstruction, such as malformation or narrowing.[2] The prevalence rate of pedriatric hydrocephalus in the United States and Europe is 0.5 to 0.8 per 1000 live and still births,[3-5] in Saudi Arabia it is 1.6 per 1,000 children born,[6] and in North America it affects1. 1 in 1000 infants[7] and in Africa, it is 0.2 - 0.6 per 1000 infants.[8]

Hydrocephalus is generally evaluated by using Magnetic Resonance Imaging (MRI), Computed Tomo-

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graphy Scan (CT) and transcranial ultrasound. CT scan is one of the validated, popular and most common method available around the world. CT scan provides a variety of linear measurements for analysis of hydrocephalus. They are Frontal to Occipital Horn Ratio (FOHR), Frontal Horn Ratio (FHR), Bi Frontal Index (BFI), Bi Caudate Index (BCI), Ventricular Index (VI).

FOHR is a comparison ratio between lateral border of frontal and occipital horn divided by 2 and multiply by largest brain diameter. In simple words it is a ratio that calculates size of the ventricles in paediatric patients with hydrocephalus. FHR is the ratio of the lateral border of the frontal horn divided by the largest brain diameter. BCI is the distance between medial border of bicaudate nucleus divided by internal skull diameter at the same plane of largest brain diameter. BFI is the largest distance of the lateral horn divided by the largest inner diameter of frontal bone. VI is the distance between medial surfaces of bicaudate nucleus divided by the distance between lateral borders of the frontal horns.[9]

Hydrocephalus is a serious disease which needs monitoring and evaluation during follow ups to avoid any consequences. However, absence of grading system in peadiatric hydrocephalus unables the accuracy of severity through CT scans. Keeping this limitation in mind, this paper proposes a new grading system of hydrocephalus based on linear measurements of CT scan, to determine severity of each patient taken under study by the proposed grading system and to find out the differences in linear measurements between age groups. Another aim of the study was to determine the average dilation of hydrocephalus brain measurements to give reference value for pediatric patients and to find the most common type of hydrocephalus.

Methodology

A cross-sectional study was conducted on 37 pediatric hydrocephalus patients with different nationalities in maternity and pediatrics hospital located in Abha, Saudi Arabia, during July 2015 to March 2016. The Inclusion criteria included pediatric hydrocephalus subjects with recent diagnosis with age group from birth to 10 years of both genders and a dysfunctional ventriculoperitoneal shunt. Exclusion Criteria; pediatric hydrocephalus subjects with functional shunt, who underwent endoscopic third ventriculostomy and who had a brain CT scan with contrast media.

The demographic characteristics like name, age, gender and type of hydrocephalus were collected from the patient's file and all the information was taken from medical records in the hospital with informed consent. The linear measurements of each patient was taken individually from CT scan which were Frontal to Occipital Horn Ratio (FOHR), Frontal Horn Ratio (FHR), Bi Caudate index (BCI), Bi Frontal Index (BFI) and Ventricular Index (VI) and were entered in to the data entry sheet.

Each measurement's formula is shown in (Fig. 1).

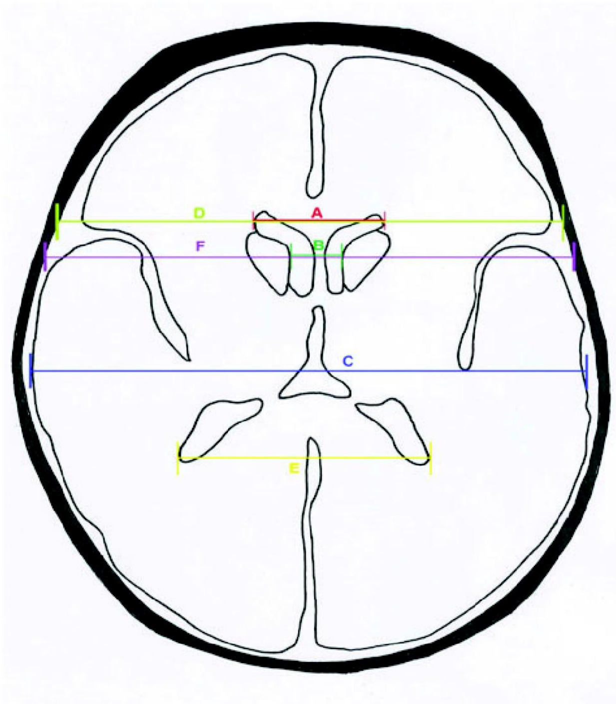

Figure 1: showing regions where measurements were applied; FHR=A/C, FOHR=(A+E) / 2C, BCI = B/F, BFI = A/D, VI=B

SPSS (V/21) was used for statistical analysis of the data. The analysis of ventricular system, gender, age, type of hydrocephalus (communicated or noncommunicated), was done with descriptive statistics. In order to allow better cure and provide a treatment plane on the basis of severity of the disease, a new grading system for hydrocephalus was created with the information of the patient's CT scan's linear measurements. For making a new grading system the most popular and reliable, five linear measure-ments were chosen, frontalto occipital horn ratio, frontal horn ratio, Bicaudate index, Bifrontal index and Bicuadate frontal index (ventricular index). The new grading system will classify these verity of patients based on linear measurements only. Abnormal measurements from lowest to highest for FHR, FOHR, BCI, BFI, VI were taken and then separated into 4 quartiles to divide them into 4 grades of severity.

Linear measure ment	Formula	Normal range
FOHR[10]	Largest width of frontal horn+largest width of occipital horn / 2×largest width outer brain diameter	0.27-0.37
FHR[11]	largest width of frontal horn / largest width of outer brain diameter	0.19 -0.39
BCI[11]	lowest bicaudate nucleus distance / inner skull diameter with the same line	0.06 -0.15
BFI[11]	largest distance between frontal horns / largest inner diameter of frontal bone	0.26 -0.38
BCFI(VI)[11]	lowest distance of bicaudate nucleus / largest frontal horns distance	0.21 -0.43

Abbreviations: FOHR: Frontal to Occipital Horn Ratio, FHR: Frontal Horn Ratio, BCI: Bi Caudate index, BFI: Bi Frontal index, VI: Ventricular Index

Table 1: Formulas and normal values oflinear hydrocephalus measurements

For grading the hydrocephalus from mild to extreme, the highest value of normal range for each measurement and the highest abnormal value scored by the sample was taken which was divided into percents. From a maximum normal range to 25th percentile is considered as mild, from 25th percentile to 50th percentile is considered as moderate, from 50th percentile to 75th percentile is considered as severe, any values greater than 75th percentile are considered as extreme grades. Every measurement has a range of values to classify into these 4 grades.

To make them into one particular grade of severity either all the five measurements should be there in the given range or at least two of the FOHR, FHR and BFI should be in the given range. These three mea-surements have high sensitivity and give clear idea about brain dimensions and ventricular dilation. The ranges on each measurement for ages 0-8 are mentioned in (Tab. 2).

Linear parameters related to age groups						
Age		FOHR	FHR	BCI	BFI	VI
0 -2 Years	Mean	0.667	0.574	0.357	0.644	0.548
	Std. Deviation	0.137	0.161	0.133	0.180	0.178
	Minimum	0.320	0.208	0.096	0.261	0.199
	Maximum	0.863	0.836	0.694	0.987	0.899
2 -4 Years	Mean	0.419	0.234	0.149	0.275	0.606
	Std. Deviation	0.127	0.171	0.087	0.204	0.127
	Minimum	0.289	0.089	0.077	0.103	0.507
	Maximum	0.544	0.424	0.246	0.502	0.750
4 -6 Years	Mean	0.744	0.596	0.474	0.706	0.468
	Std. Deviation	0.272	0.191	0.095	0.212	0.086
	Minimum	0.552	0.461	0.407	0.556	0.407
	Maximum	0.937	0.732	0.542	0.857	0.529
6 -8 Years	Mean	0.603	0.529	0.319	0.626	0.478

Table 2: The ranges on each measurement for ages 0-8.

Result

The highest frequency among the 37 patients was two years, the minimum age was 1 day and maximum was 10 years in the sample included. (refer to Fig. 2).

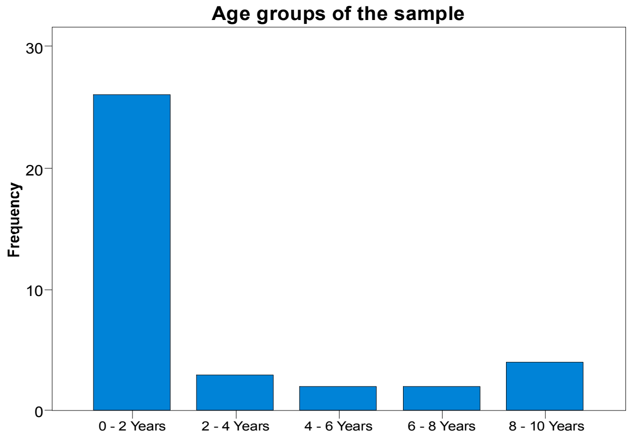

Figure 2: Age groups of the hydrocephalus sample

The most common type of hydrocephalus was communicated type the details are provided in (Tab. 3).

Type of Hydrocephalus	Frequency	Percent	Valid Percent
Communicated	20	54.1	54.1
Non Communicated	17	45.9	45.9
Total	37	100.0	100.0

Table 3: Type of hydrocephalus in the whole sample

The classification details of the new grading system for pediatric hydrocephalus patients based on linear measurements through CT scan are described in (Tab. 4).

Linear measurement	Mild	Moderate	Severe	Extreme
FOHR	0.38 -0.53	0.54 - 0.64	0.65 - 0.75	≥0.76
FHR	0.39 -0.41	0.42 - 0.52	0.53 - 0.69	≥0.70
BCI	0.17 -0.24	0.25 - 0.33	0.34 - 0.45	≥0.46
BFI	0.39 -0.50	0.51 - 0.60	0.61 - 0.76	≥0.77
VI	0.43 -0.48	0.49 - 0.54	0.55 - 0.69	≥0.70

FOHR: Frontal to Occipital Horn Ratio, FHR: Frontal Horn Ratio, BCI: Bi Caudate index, BFI: Bi Frontal index, VI: Ventricular Index.

Table 4: The grading system classification

The most common grade was mild and moderate with 13 patients in each and dominant accumulative percent (70.3%), 5 patients had severe grade with (13.5%) and 6 patients with(16.2%) in the extreme The patients included in the study are classified according to the newly proposed classification system. The details of patient classification is provided in (Tab. 5).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Mild	10	27.0	27.0	27.0
	Moderate	9	24.3	24.3	51.4
	Severe	11	29.7	29.7	81.1
	Extreme	7	18.9	18.9	100.0
	Total	37	100.0	100.0	

Table 5: Most common grades of hydrocephalus

The mean measurements (reference value) in mm was found for FOHR = 0.63 , FHR = 0.52, BCI = 0.34, BFI = 0.60 and VI = 0.55. There was significant difference three of linear parameters between age groups by 0.04 in FOHR, 0.012 in FHR, 0.021 in BFI as mentioned in (Tab. 2 & 6).

	Sum of Squares	df	Mean Square	F	Sig.
FOHR Between (Combined) Groups	.243	4	.061	2.835	.040
Age_N Within Groups	.687	32	.021		
Total	.930	36			
FHR Between (Combined) Groups	.390	4	.097	3.839	.012
Age_N Within Groups	.813	32	.025		
Total	1.202	36			
BCI Between (Combined) Groups	.155	4	.039	2.236	.087
Age_N Within Groups	.555	32	.017		
Total	.710	36			
BFI Between (Combined) Groups	.439	4	.110	3.376	.021
Age_N Within Groups	1.040	32	.033		
Total	1.479	36			
VI Between (Combined) Groups	.081	4	.020	0.686	.607
Age_N Within Groups	.945	32	.030		
Total	1.026	36			

Table 6: ANOVA Table

Discussion

Using the propsed grading system, the most common grade was found to be mild and moderate hydrocephalus with 13 patients in each, 5 in severe grade and 6 in extreme grades. The mean of FHR according to Le May and Hochberg, (1979)[12] was 0.5 in non-communicated hydrocephalus. According to Hahnand Rim, (1976)[13] the FHR was from 0.34 to 0.78 and mean was 44.8 ± 0.78 as compared to the mean FHR of this study 0.52 proves accuracy of the range proposed. According to Zilundu Prince, (2012)[14] the FHR was from 0.36 to 0.52 with mean 0.42 for hydrocephalus patients, which should be considered low attributed to the small sample size of 18 hydrocephalus patients with no one below 10 years compared to the sample in this study where 37 patients, from age of 1 day to 10 years the FHR extend from 0.19 to 0.83 with mean 1.52. Because medically proved, hydrocephalus causes more distortion in younger pediatrics than patients near maturity as neonatal with hydrocephalus with severe ventricular dilation will give higher measurements as compared to patient near maturity but presence of fontanel in neonates they can adapt with VP shunt and will improve with time but a patient near maturity or any adult has mature structures so any damage is irreversible and compression may be fatal.[15]

According Hahn and Rim, (1976)[13] and Zilundu Prince, (2012)[14] there was significant difference in FHR related to age groups similar to our results where significant differences in FOHR, FHR, BFI between age groups were found. Although in contrast with BCI and VI there are no significant differences among age groups.
The non-communicated hydrocephalus was found out to be the most common according to Mohamed E. El Awadetal., (1997)[16] in southern region of Saudi Arabia, with 16 postnatal patients with maximum age of one year compared to our study in Abha region, with sample of 37 patients; 20 patients of communicated type (54.1%) and 17 patients with (45.9%) non communicated type. Therefore communicated type was more prevalent in the region of our study. This study also enabled to classify hydrocephalus according to severity with 13 patients in mild and moderate each with dominant accumulative percent (70.3%), rendering it the most common grade in Abha region, 5 patients were found with severe grade (13.5%) and 6 patients in extreme grade with (16.2%). Age group 0-2 was found to be the most affected by hydrocephalus which is in correspondence with the global statistics.[3-8]

Conclusion

The mean measurements was found for FOHR=0.63, FHR=0.52, BCI=0.34, BFI=0.60 and VI=0.55. There was significant difference in linear parameters among age groups in FOHR, FHR, BFI. These linear measurements are sensitive and specific hence give accurate results of the severity of hydrocephalus and this grading system provides a treatment plane for hydrocephalic pediatric patients based on severity. The introduced categories of mild to extreme hydrocephalus are also applicable. The most common grade were mild and moderate while the most common type was communicated type. Any distortion or shifting in the brain will influence the linear measurements which will allow classification accoding to the proposed grading system and it might also be helpful to evaluate any mass effect in the brain and diseases such as brain atrophy successfully.
Since there is lacking in the grading system depending on CT scan that can determine the grade of hydrocephalus, now with this grading system the issue can be solved based on the clinical linear measurements applied on CT scans.

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References

1. Rekate, H.L. (2008). The definition and classification of hydrocephalus: a personal recommendation to stimulate debate. Cerebro spinal Fluid Res, **5(2):** 2.

2. Philip. A. Roberts, Neuroanatomy, 1987

3. Fernell, E., Hagberg, G., & Hagberg, B. (1994). Infantile hydrocephalus epidemiology: an indicator of enhanced survival. Arch Dis Child Fetal Neonatal Ed. **70(2):**123-8.

4. Jeng, S., et al. (2011).Prevalence of congenital hydrocephalus in California, 1991-2000. Pediatr Neurol. **45(2):** 67-71.

5. Garne, E.,et al. (2010). Congenital hydrocephalus prevalence, prenatal diagnosis and out come of pregnancy in four European regions. Eur J Paediatr Neurol. **14(2):** 150-5.

6. Persson, E. K. (2007). Hydrocephalus in children. Epidemiology and outcome. Inst of Clincial Sciences. Dept of Pediatrics. Sweden

7. Tully, H. M.,& Dobyns, W. B. (2014). Infantile hydrocephalus: A review of epidemiology, classification and causes. Eur J Med Genet. **57(8):** 359-68.

8. Garton, H. J. L., & Piatt, J. H. (2004). Hydrocephalus. Pediatric Clinics of North America, **51(2):** 305-25.

9. Fabijanska, A. et al. (2014) Assessment of hydrocephalus in children based on digital image processing and analysis, Int. J. Appl. Math. Comput. Sci. **24(2):** 299-312.

10. Ragan, D. K., etal. (2015). The accuracy of linear indices of ventricular volume in pediatric hydrocephalus: technical note. J Neuro surg Pediatr. **15(6):** 547.

11. Wilk, R., et al. (2011). Normative values for selected linear indices of the intra cranial fluid spaces based on CT images of the head in children. Pol J Radiol. **76(3):** 16.

12. Le May, M., & Hoch berg, F. H. (1979). Ventricular differences between hydrostatic hydrocephalus and hydrocephalus exvacuo by computed tomography. Neuro radiology, **17(4):** 191-5.

13. Hahn, F. J., & Rim, K. (1976). Frontal ventricular dimensions on normal computed tomography. AJR AmJ Roentgenol. **126(3):** 593-6.

14. Zilundu, P. L. M. (2013). Morphometric study of ventricular sizes on normal computed tomography scans of adult black zimbab weans at a diagnostic radiology centre in harare-apilot study.

15. Rizvi, R. Anjum, Q. (2005). Hydrocephalus in children. JPMA **55:** 11.

16. El Awad, M. E.,& Al-Barki, A. A. (1997). Infantile hydrocephalus in southern Saudi Arabia. Journal of Family & Community Medicine, **4(2):** 71.