NORMAL PARAMETERS OF VENTRICULAR SYSTEM IN HEALTHY INFANTS

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ABSTRACT

Six hundred healthy inborn newborns and infants upto the age of 18 months were studied. Cranial sonography was performed by real time 2D scanner with 5 MHz transducer and images were obtained through anterior fontanelle and temporo—sauamal suture. Various parameters related to ventricular system were measured for different ages till the fontanelle remained open. These values will prove useful for diagnosing hydrocephalus at an early stage of the disease and also to find out the blocks' at various levels in ventricular system.

Keywords: *Cranial ultrasound, Hydrocephalus, Ventricular system.*

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Enlargement of ventricular system in hydrocephalus results from an imbalance between production and absorption of cerebrospinal fluid(l). It is obvious that for early and precise diagnosis of type of hydrocephalus, knowledge of ventricular size including width of lateral ventricle (LVW) and distance between falx to inner table of skull (FH) in coronal plane, ventricular index (VI) and distance between falx to inner tabe of skull (FC) in temporal plane, width of lateral ventricle (C) in parasagittal plane, diameter of 3rd ventricle in coronal plane, width of foramen of monro (FM), length (ADL) and width (AD) of aqueduct, distance between foramen of monro and aqueduct (FMAD) and aqueduct to foramen of magnum (ADFM) is mandatory. Leksell was the first to use ultrasound for Echo-Encephalography(2). Since then due to inherent advatnages of ultrasonography over other diagnostic modalities (angiography, ventriculography, pneumoencephalography, CT scan and MRI scan), it is emerging as a first investigation of choice in all infants with abnormal head size wherever the fontanelle is open(3,4).

Little work has been done on measurement of cerebral ventricular system in our country. A prospective study was, therefore, undertaken.

Material and Methods

This study was carried out in the Department of Pediatrics of Regional Institute of Maternal and Child Health, Dr. SN Medical College, Jodhpur, between July 1992 to April 1994. Six hundred healthy inborn newborns and infants upto the age of eighteen months were studied and divided into 15 groups. The gestational age of the newborns was calculated by modified Parkin's criteria(5) and the age of infants was calculated from their date of birth.

Cranial sonography (CR -USG) was performed by real time 2D scanner SIM 3000 OTC Biomedier with a 5 MHz transducer. Images were obtained using anterior fontanelle (all cases) as window in coronal *(Fig. 1),* both right and left parasagittal, and mid sagittal *(Fig. 2)* plains(6) as well as through temporo-squamal suture(7). Two measurements were made at each examination and averaged.

The various ventricular parameters— LVW, FH, VI, FC, diameter of 3rd, AD, ADL FMAD and ADFM were recorded on specially designed performa for this study. Their age, gestational age (newborn), weight (wt), head circumference and sex were also recorded. The development of infants was assessed by Denver Development Screening test (DDST)(8). Only those infants who were developing normally were included in the study.

The mean and standard deviation was calculated with the help of computer using Mark State Programme.

Results

Six hundred infants were included in this study. The male to female ratio was 1.4 : 1. The range of head circumference and weight varied from 28.64 ± 1.9 to 44.79 ± 1.93 cm and 1.44 ± 0.31 to 8.47 ± 1.23 kg, respectively.

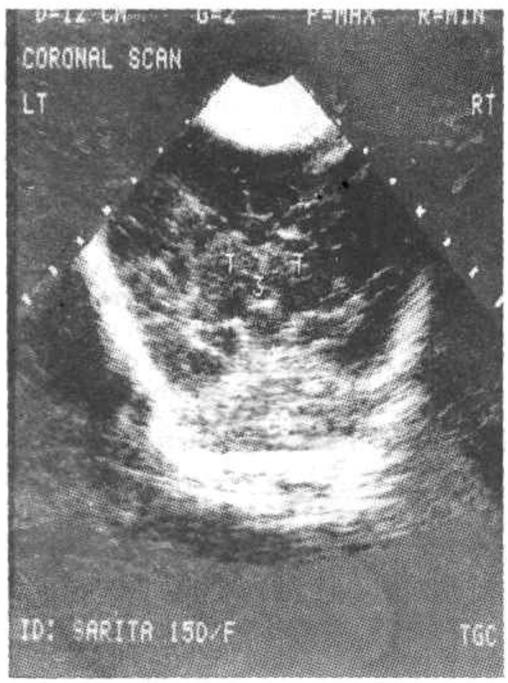

Fig. 1. Mid coronal scan showing falx, both lateral ventricle and the third ventricle.

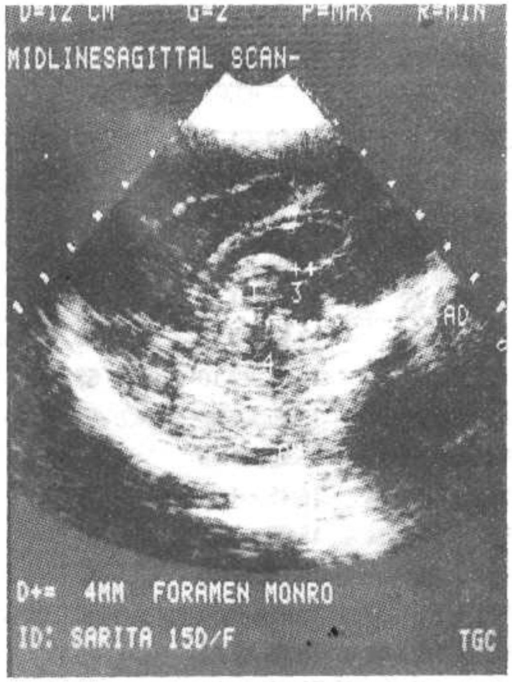

Fig. 2. Mid sagittal scan showing foramen of monro, third ventricle, aqueduct, fourth ventricle, cysterna magna and foramen of magnum.

The size of lateral ventricle LVW gradually increased as age advanced, *i.e.,* from 12.19 ± 1.42 mm at 32 weeks of gestation to 18.54 ± 1.51 mm at 13-18 months of age (*Table I).* The hemispheric width, FH increased from 37.09±3.23 to 57.58 ± 3.17 mm as age advanced from 32 week of gestation to 13-18 months in the coronal plane (*Table I).* The ventricular index (VI) gradually increased as age advanced, *i.e.,* from 9.67 ± 1.17 mm at 32 weeks of gestation to 10.98 ± 1.17 mm at 3 months of age (*Table IT).* The FC increased from 33.89 ± 4.26 to 44.90 ± 2.72 mm with age from 32 weeks of gestation to 3 months of age (*Table II)* in temporal plane.

The ventriculo-hemispheric ratio, LVW/FH ranged between 0.26 ± 0.04 to 0.33 ± 0.05 *(Table I)* whereas VI/FC decreased from 0.285 ± 0.03 at 32 weeks of gestational age to 0.245 ± 0.02 at 3 months of age (*Table II).* The width of lateral ventricle "C" in parasagittal plane ranged between 2.44 ± 0.77 to 3.8 ± 0.96 mm (*Table I).*

The size of foramen of monro ranged between 2.81 ± 0.6 to 4.4 ± 0.62 mm (*Table III).* The width (AD) and length (ADL) of aqueduct ranged between 1.77 ± 0.45 to 2 ± 0.5 mm and 2.80 ± 0.66 to 4.00 ± 1.05 mm, respectively (*Table III).* The diameter of third ventricle and distance between FM to AD and

TABLE I–*Lateral Ventricular Measurement (Mean ± SD) of Cohort in Coronal View*

Age	No	C (mm)	LVW (mm)	FH (mm)	LVW/FH
Newborn					
≤ 32 wk	18	2.97 ± 0.89	12.19 ± 1.42	37.09 ± 3.23	0.33 ± 0.05
33-37 wk	30	2.58 ± 0.91	12.08 ± 1.86	41.27 ± 4.25	0.29 ± 0.04
≥ 38 wk	172	2.44 ± 0.77	12.41 ± 1.88	43.53 ± 3.35	0.28 ± 0.04
1-2 mo	59	2.81 ± 1.1	12.84 ± 1.69	46.09 ± 2.89	0.28 ± 0.04
2-3 mo	48	3.01 ± 0.98	14.23 ± 1.60	49.05 ± 3.16	0.29 ± 0.04
3-4 mo	39	2.94 ± 0.65	14.26 ± 2.60	50.79 ± 3.57	0.26 ± 0.04
4-5 mo	39	3.24 ± 0.99	15.68 ± 2.10	53.08 ± 3.32	0.29 ± 0.03
5-6 mo	29	3.62 ± 0.94	15.46 ± 2.23	52.88 ± 3.45	0.29 ± 0.04
6-7 mo	26	3.23 ± 1.0	16.20 ± 1.83	53.98 ± 4.50	0.30 ± 0.03
7-8 mo	19	3.83 ± 0.96	16.45 ± 1.28	54.02 ± 4.20	0.30 ± 0.05
8-9 mo	22	3.27 ± 1.0	15.90 ± 1.57	55.91 ± 3.01	0.28 ± 0.03
9-10 mo	22	3.32 ± 1.1	15.70 ± 2.30	55.23 ± 3.17	0.26 ± 0.03
10-11 mo	29	3.61 ± 1.1	15.89 ± 1.36	53.22 ± 3.27	0.30 ± 0.02
11-12 mo	17	3.23 ± 0.56	16.15 ± 1.64	54.17 ± 4.08	0.30 ± 0.02
13-18 mo	31	3.56 ± 1.10	18.54 ± 1.51	57.58 ± 3.17	0.32 ± 0.03

TABLE II–*Lateral Ventricular Measurement (Mean ± SD) of Cohort in Temporal View*

Age	VI (mm)	FC (mm)	VI/FC
Newborn			
≤32 wk	9.67 ± 1.17	33.89 ± 4.26	0.285 ± 0.03
33-37 wk	10.61 ± 1.03	36.17 ± 3.90	0.276 ± 0.03
≥ 38 wk	10.74 ± 1.17	39.39 ± 2.19	0.272 ± 0.03
1-2 mo	10.53 ± 0.94	43.50 ± 2.82	0.243 ± 0.02
2-3 mo	10.98 ± 1.19	44.90 ± 2.72	0.245 ± 0.02

AD to foramen magnum increased as age advanced, i.e., from 3.52 ± 1.2,15.43 ± 1.78 and 33.16 ± 2.8 mm at age of 32 weeks of gestation to 5.59 ± 1.9, 20.63 ± 2.7 and 57.08 ± 2.7 mm at 13-18 months of age *(Table III)*.

Discussion

The development of high resolution 2D real time scanner coupled with increasing expertise has established the role of cranial sonography in the evalua-

TABLE III– *Ventricle, Aqueduct, Foramen of Monro, FMAD and ADFM Measurement (Mean ± SD) of Cohort*

Age	3rd	AD	ADL	FM	FMAD	ADFM
Newborn (weeks)						
≤32	3.52 ± 1.2	1.7 ± 0.45	3.0 ± 0.69	2.88 ± 0.6	15.43 ± 1.78	33.16 ± 2.8
33-37	3.69 ± 1.2	1.8 ± 0.64	2.8 ± 0.66	2.81 ± 0.9	15.93 ± 1.86	34.80 ± 3.7
≥38	4.13 ± 1.4	1.9 ± 0.50	2.9 ± 0.53	3.13 ± 0.8	17.25 ± 1.80	37.30 ± 2.6
Months						
1-2	5.28 ± 1.6	2.0 ± 0.40	3.47 ± 0.60	3.60 ± 0.7	16.60 ± 2.00	40.92 ± 2.6
2-3	4.87 ± 1.3	2.0 ± 0.40	3.4 ± 0.63	3.62 ± 0.8	17.70 ± 1.60	46.15 ± 3.4
3-4	4.69 ± 1.2	1.8 ± 0.50	3.5 ± 0.70	3.70 ± 0.8	17.98 ± 1.90	46.60 ± 3.2
4-5	5.28 ± 1.7	1.9 ± 0.50	3.4 ± 0.70	3.81 ± 0.8	18.97 ± 1.59	49.80 ± 2.1
5-6	6.07 ± 2.0	2.1 ± 0.50	3.5 ± 0.60	3.50 ± 0.8	18.35 ± 2.10	52.80 ± 3.4
6-7	4.91 ± 1.8	1.8 ± 0.60	3.4 ± 0.79	3.80 ± 1.3	19.21 ± 1.60	52.60 ± 3.5
7-8	5.66 ± 2.1	2.2 ± 1.00	3.7 ± 0.53	3.50 ± 1.1	19.90 ± 2.60	53.10 ± 3.2
8-9	6.02 ± 1.3	2.1 ± 0.30	3.7 ± 1.03	4.04 ± 0.6	21.40 ± 2.00	58.18 ± 3.0
9-10	5.80 ± 1.1	1.9 ± 0.40	3.8 ± 0.40	3.60 ± 0.8	20.80 ± 1.90	55.62 ± 3.0
10-11	5.83 ± 1.0	1.8 ± 0.35	3.6 ± 0.50	4.16 ± 0.9	20.16 ± 2.40	56.42 ± 2.2
11-12	5.97 ± 1.6	1.9 ± 0.37	3.7 ± 0.44	3.88 ± 0.2	22.05 ± 1.80	54.70 ± 3.5
13-18	5.59 ± 1.9	2.0 ± 0.50	4.0 ± 1.05	3.93 ± 0.7	20.63 ± 2.70	57.08 ± 2.7

tion of neuroanatomy of the brain parenchyma and ventricular system with high precision. The measurement of ventricular area in different planes seems to be the ideal method for early detection of ventriculomegaly, though it is cumbersome and a time consuming procedure. Various ventricular parameters were, therefore, measured by different authors in different planes(2,4).

In coronal scan, lateral ventricle, third and fourth ventricles are clearly visualized in infants till the anterior fontanelle remains open. Both lateral ventricles appear as sickle, with concavity pointing outwards. The size of lateral ventricle LVW gradually increased as age advanced, *i.e.,* from 12.19 ± 1.42 mm at 32 weeks of gestational age to 18.54 ± 1.51 mm at 13 to 18 months of age. Lombroso *et al.(2)* reported the LVW ranged between 15 to 18 mm in newborns and infants up to 12 months of age. Chowdhary *et al.(3)* reported the LVW to vary between 10 ± 0.11 to 8.4 ± 2.5 mm in preterm of 28 to 30 and 35 to 38 weeks of gestational age, respectively.

The hemispheric width, FH increased from 37.09 ± 3.23 to 57.58 ± 3.17

mm as age advanced from 32 weeks of gestation to 13 to 18 months of age. Chowdhary *et al.* reported that FH increased from 36.8 ± 3.3 to 39.5 ± 2 mm in preterm neonates of 28-30 to 35-36 weeks of gestational age, respectively(3). The ventriculohemispheric ratio, LVW/FH ranged between 0.26 ± 0.04 to 0.33 ± 0.05 in newborns of 32 weeks of gestation to 13 to 18 months of-age, respectively. Chowdhary *et al.* reported that LVW/FH decreased from 0.26 ± 0.02 to 0.12 ± 0.06 as age advanced from 28 to 30 to 35 to 36 weeks of gestational age(3), respectively.

The 3rd ventricle appears as a circle and it's diameter ranged between 3.52 ± 1.2 to 5.59 ± 1.9 mm at 32 weeks of gestational age to 13-18 months of age. Lombroso *et al.* reported that the diameter of third ventricle ranged between 4 to 7 mm(2). The size of fourth ventricle is difficult to measure because of it's unique anatomy.

The temporo squamal sutures remain open upto the age of 3 months; so sonography through this acoustic window is possible upto the age of 3 months. The size of lateral ventricle, VI gradually increased from 9.67 ± 1.17 to 10.98 ±1.17 mm as age advanced from 32 weeks of gestation to,3 months of age. Johnson *et al.* reported that VI ranged between 5 to 13 mm in preterm and 9 to 13 mm in term neonates(7). Levene reported that it ranged from 8.5 to 12.5 mm in preterm neonates (26 weeks) to term neonates(9). Soni *et al.* observed that it increased from 9.0 ± 1.4 to 10.7 ± 0.7 mm as age advanced from <32 to ≥38 weeks of gestational age(10).

The ventriculo-hemispheric width, FC increased from 33.89 + 4.26 to 44.0 ± 2.72 mm as age advanced, from >32 weeks of gestation to. 3 months of age. Jhonson *et al.* reported the mean value of FC to be 24 to 43 mm in preterm and 31 to 49 mm in term neonates(7). Soni *et al.* reported the mean value of FC ranged between 31.2 ± 2.9 to 36.2 ± 3.5 mm in newborns of <32 to >38 weeks of gestational age(10).

The ventriculo-hemispheric ratio, VI/FC (Evan's ratio) decreased from 0.285 ± 0.3 at 32 weeks of gestational age to 0.245 ± 0.02 at 3 months of age. Johnson *et al.* from their study observed that the mean value of Evan's ratio ranged between 0.24 to 0.34 in preterm and 0.24 to 0.30 in term neonates(7). Soni *et al.* reported this ratio to be 0.32 ± 0.3 in preterm and 0.3 ± 0.3 in term neonates(10).

The para-sagittal scan shows body, frontal occipital and temporal horn of lateral ventricle. The width of lateral ventricle "C" is measured above the thalamus and the values ranged between 2.44 + 0.77 to 3.8 ± 0.96 mm.

The mid sagittal scan shows—septum pellucidum, foraman of Monro, third ventricle, aqueduct, fourth ventricle and cystema magna. The size of foramen of Monro ranged between 2.81 ± 0.6 to 4.4 ± 0.62 mm *(Table III).*

The width (AD) and length (ADL) of aqueduct ranged between 1.7 ± 0.75 to 2 ± 0.5 mm and 2.8 ± 0.66 to 4 ± 1.05 mm, respectively. Haslam *et al.* reported the approximate width and length of aqueduct to be 2 and 3 mm, respectively(l).

The distance between foramen of Monro and aqueduct (FMAD) increases when there is dilatation of third ventricle due to blockage of aqueduct. The distance between aqueduct and foramen of magnum (ADFM) increases in Arnold-Chiari malformation. Therefore, there distance were also measured, probably, for the first time.

In conclusion, the diagnosis of hydrocephalus is difficult clinically and by measuring head circumference in the early stage of disease. By measuring all parameters by real time sonography, one can diagnose it at an early stage of diseases. The ventricular size can be monitored after shunt surgery and shunt failure can be detected at an early stage.

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REFERENCES

1. Haslam RHA. Hydrocephalous. *In:* Nelson Text Book of Pediatrics, 14th edn. Eds. Behrman RE, Kliegman RM, Nelson WE, Vaughan VC. Philadelphia, W.B. Saunders Co, 1992, p 1487.
2. Lombroso CT, ERba G, Yogo T, Logowitz N. Two dimensional ultrasonography: A method to study normal and abnormal ventricle. Pediatrics 1968, 42:157-174.
3. Chowdhary V, Culati P, Arora S, Thirupuram S. Cranial sonography in preterm infants. Indian Pediatr 1992, 27:411-415.
4. Shah PS, Sarvaiya JB, Rawal JR, Kabra SK, Patel VB, Joshi RN. Normal ventricular size and ventriculo-hemispheric ratio in infants upto 6 months of age by cranial ultrasonography. Indian Pediatr 1993, 29: 439-442.
5. Parikn JM, HeyEN, Clowes JS. Rapid assessment of gestational age at birth. Arch Dis Child 1976, 57: 259-263.
6. Cremin BJ, Chiton SJ, Peacock WJ. Anatomical landmarks in anterior fontanelle ultrasonography. Brit J Radiol 1983,56:517-526.
7. Johnson ML, Mack LA, Rumack CM, Forst M, Kdshbaum C. B-Mode echoencephalography in the normal and high risk infants. Am J Radiol 1979,133:375-381.
8. Franknburg WK, Dodds J, Archer P, Shapiro H. The Denver II: A major revision and restandardization of the Denver Development Screening Test. Pediatrics 1992, 89:91-97.
9. Levene MI. Wigglesworth JS, Dubowitz V. Cerebral structure intraventricular hemorrhage in the neonate: A real time ultrasound study. Arch Dis Child 1981, 56: 416-424.
10. Soni JP, Singhania RU, Sharma A. Measurement of ventricular size in term and perterm infants. Indian Pediatr 1992, 29:55-59.