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Ventricular Morphometry and Resistive Index in Pre and Post Treatment Evaluation of Hydrocephalus Using Ultrasonogram

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Abstract

Background: Germinal matrix hemorrhage (GMH) represents one of the most important adverse neurologic event for preterm and very low birth weight (VLBW) newborns during neonatal period. Hydrocephalus is a mechanical complication of different pathologic conditions and a disease process in itself. Morphologic imaging is used to evaluate suspected hydrocephalus. Hence; the present study was conducted to measure the size of lateral ventricles using ultrasound and to assess the resistive index of anterior cerebral artery using Doppler sonography. **Methods**: Infants (0-1year age) who presented to the Department of Pediatric Radiology, Indira Gandhi Institute of Child Health, Bengaluru, for neurosonogram with clinical suspicion of hydrocephalus were enrolled in the present study. Transcranial color doppler sonography provides a non-invasive method of monitoring of the blood flow velocities in cerebral vessels. The data was entered in MS Excel 2007 and analysed in Statistical Package for Social Science (SPSS) software, version 20.0 (SPSS Inc., Chicago, IL, USA). **Results:** Out of 50 subjects, 29 were males while the remaining 21 were females. Mean age was 2.3 months. Mean Levene ventricular index during pre-treatment and post-treatment phase was 3.6 cm and 2.3 cm respectively. Mean Ventricular- hemisphere ratio during pre-treatment and post-treatment phase was 0.61 and 0.45 respectively. Mean Davies anterior horn width during pre-treatment and post-treatment phase was 3.7 cm and 2.6 cm respectively. Mean resistive index of the anterior cerebral artery was 0.78 and 0.71 during pre-treatment and post-treatment respectively. **Conclusions:** Duplex Doppler ultrasonography thus provides us with a non-invasive and easily repeatable means of monitoring for further increase in ventricular size as well as a method of monitoring cerebral haemodynamic change in hydrocephalus patients.

Keywords:- Hydrocephalus, Ultrasound.

INTRODUCTION

Germinal matrix hemorrhage (GMH) represents one of the most important adverse neurologic event for preterm and very low birth weight (VLBW) newborns during neonatal period. Pathogenesis is mainly attributed to germinal matrix (GM) inherent vascular fragility and fluctuations in cerebral blood flow (CBF). Among GMH, intraventricular hemorrhage (IVH), defined as blood leakage into the ventricular space, is the main form of presentation with subsequent development of post-hemorrhagic hydrocephalus (PHH) in 35% of cases. Approximately 20% of preterm and VLBW newborns develop IVH. Higher-grade hemorrhages are more common as age and weight decrease. More than 50% of hemorrhages will develop within the first 24 h of life, and 90% of them within the first week of life. Diagnosis is made by cranial ultrasound performed at bedside.[1,2,3,4,5]

Hydrocephalus is a mechanical complication of different pathologic conditions and a disease process itself. The morphologic features are easily recognizable, but the pathophysiology remains incompletely understood. Nearly all hydrocephalus is due to cerebrospinal fluid (CSF) obstruction at some point between the ventricles and the systemic venous circulation. Classification is important for optimal treatment. Optimized imaging is vital to the success of flow diversion. Current treatments are limited and invasive: CSF diversion via catheter or endoscopic third ventriculostomy. Decision-making relies upon high resolution imaging to determine the site of obstruction and anatomic features that may complicate the procedure.[6]

Morphologic imaging is used to evaluate suspected hydrocephalus. Several morphologic measures individually and in combination have shown high positive predictive value in identifying individuals who will respond to treatment with ventricular shunting.

Interpretation of changes in the Doppler curve of the cerebral arteries in pediatric hydrocephalus remains to be a discussed issue. Increase of cerebrovascular resistance of the cerebral arteries due to increased intracranial pressure is reflected in change of blood flow velocity and increased values of qualitative indices in the Doppler curve. Generally, there is good correlation between resistance index and pulsatility index of the cerebral arteries and intracranial pressure. Relationship between intracranial pressure, clinical manifestations of intracranial hypertension, dilatation of the cerebral ventricles, and Doppler parameters of the cerebral arteries is defined by biomechanical properties of the cranium and the brain in various age groups in children. It may be also influenced by many intra- and extracranial factors, which affect cerebral circulation. In critically ill children, several factors are usually combined, which may, but do not have to, affect changes in the Doppler curve of the cerebral arteries. Therefore, cerebral blood flow in this type of patients has to be assessed carefully.[7] Hence; the present study was conducted to measure the size of lateral ventricles using ultrasound and to assess the resistive index of anterior cerebral artery using doppler sonography.

MATERIAL AND METHODS

Infants (0-1year age) who presented to the Department of Pediatric Radiology, Indira Gandhi Institute of Child Health, Bengaluru, for neurosonogram with clinical suspicion of hydrocephalus were enrolled in the present study. Samsung Accuvix XG ultrasound machine with L 5-13 IS and P 3-8 CA probes was used to perform Ultrasound and Doppler. Sample size was 50 cases.

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Inclusion criteria:

1) Infants (0-1year age) presenting to the department of pediatric radiology for neurosonogram and found to have hydrocephalus.
2) Informed consent was given by the parents/guardian.

Exclusion criteria:

3) Infants in whom anterior fontanelle is closed.
4) Children older than 1 year.

Ethical clearance for the study was taken from Institutional Ethics Committee. Consent from the patient/ guardian for clinical photographs were taken at the time of presentation. All the details were being recorded on a predesigned proforma.

Increased intracranial pressure in progressive neonatal hydrocephalus leads to the alteration of cerebral circulation (decreased cerebral blood flow, hypoperfusion and ischemia). Transcranial color Doppler sonography provides a non-invasive method of monitoring of the blood flow velocities in cerebral vessels. In general, there is a good correlation between the increase of intracranial pressure and changes in Doppler curve parameters. Before the drainage procedure there was confirmed increased basal and compressive values of resistive index of cerebral arteries. Ventricular size was assessed using Levene ventricular index, Davies anterior horn width and ventricular-hemispheric ratio. The data was entered in MS Excel 2007 and analysed in Statistical Package for Social Science (SPSS) software, version 20.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were presented as means ± SD and discrete variables as percentages. P value of less than 0.05 was taken as significant.

RESULTS

Out of 50 subjects, 29 were males while the remaining 21 were females. Mean age was 2.3 months. Mean Levene ventricular index during pre-treatment and post-treatment phase was 3.6 cm and 2.3 cm respectively. Mean Ventricular- hemisphere ratio during pre-treatment and post-treatment phase was 0.61 and 0.45 respectively. Mean Davies anterior horn width during pre-treatment and post-treatment phase was 3.7 cm and 2.6 cm respectively. Mean resistive index of the anterior cerebral artery was 0.78 and 0.71 during pre-treatment and post-treatment respectively. While comparing statistically, significant results were obtained.

Table 1: Demographic data

Variable		**Number**
Gender	Males	29
	Females	21
Mean age (months)		2.3

Table 2: Comparison of resistive index

Resistive index	**Pre-treatment**	**Post-treatment**	**p-value**
ACA	0.78	0.71	0.01*

*: Significant

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Table 3: Comparison of Ventricular Morphometry

Ventricular Morphometry	Pre-treatment	Post-treatment	p-value
Levene ventricular index (cm)	3.6	2.3	0.01*
Ventricular- hemisphere ratio	0.61	0.45	0.01*
Davies anterior horn width (cm)	3.7	2.6	0.01*

*: Significant

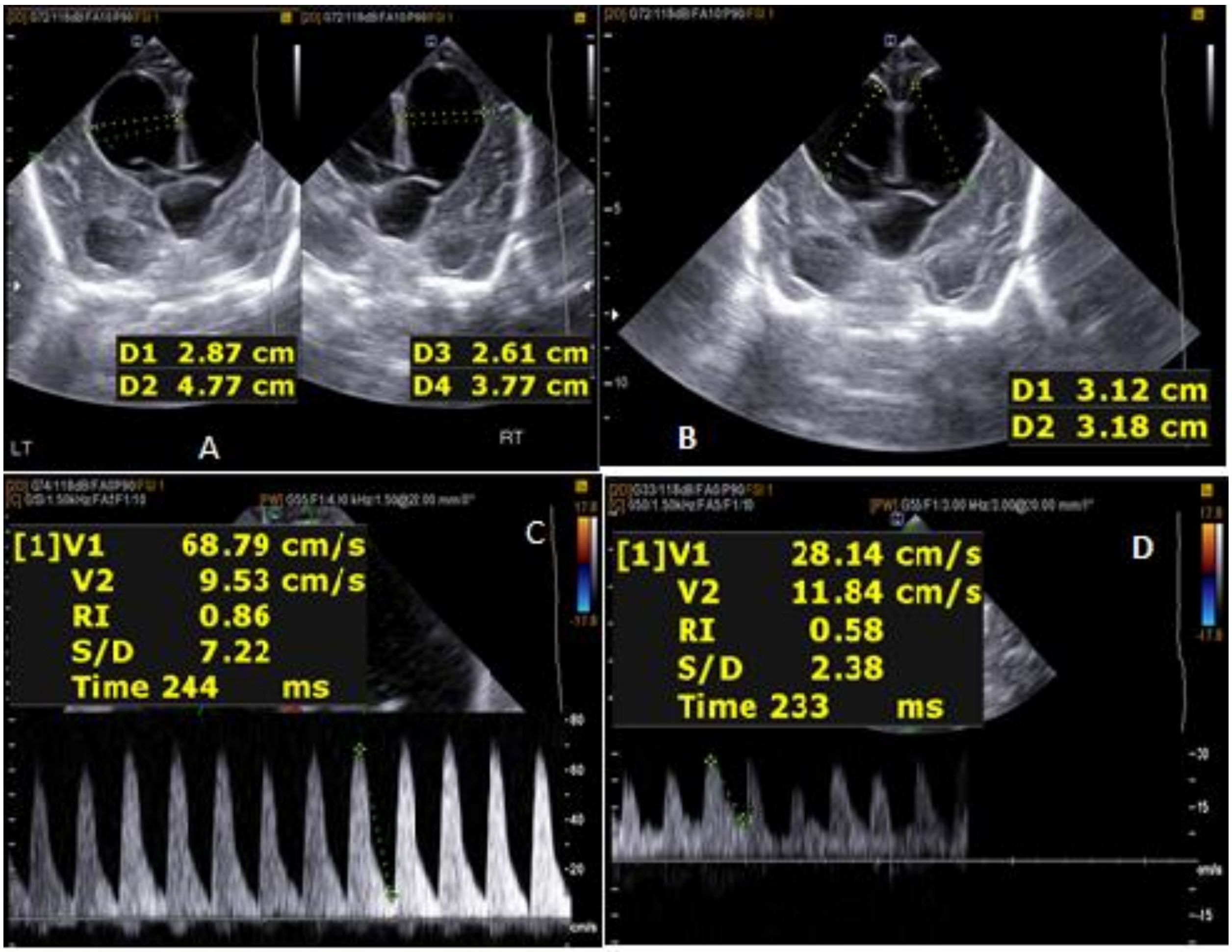

Figure 1: A 40day male child with hydrocephalus. Cranial Ultrasound shows (A) Levene ventricular index of 2.8 cm and Ventricle/Hemisphere ratio of 0.59 (2.8/4.7). (B) Davis Anterior horn width of 3.1 cm. (C) Resistive index of Anterior Cerebral Artery of 0.86 (pre-operative). (D) Resistive index of Anterior Cerebral Artery of 0.58 (7days after VP Shunt insertion).

DISCUSSION

Neonatal hydrocephalus is characterised by an excessive accumulation of cerebrospinal fluid with enlargement of cerebral ventricles that occurs as a result of disturbance of production, flow or resorption of cerebrospinal fluid. The pathophysiological changes of progressive neonatal hydrocephalus include: increased intracranial volume of cerebrospinal fluid, progressive dilatation of cerebral ventricles, decreased intracranial compliance, raised intracranial pressure, alteration of cerebral circulation and subsequent secondary brain tissue damage (decreased cerebral blood flow, hypoperfusion, ischaemia), alteration of energy metabolism (tissue acidosis, higher lactate concentration), changes in neurotransmiter systems, damage of white matter, associative tracts and cerebral cortex. The primary target of injury is periventricular axons and myelin. Secondary changes in neurons reflect the compensation to the stress or ultimately the disconnection. Transcranial color coded Doppler sonography provides a bedside non-invasive and repeatable method of monitoring of the cerebral circulation with good clinical applications. Progressive hydrocephalus leads to the stretching, displacement and compression of cerebral vessels with increased vascular resistance. Doppler parameters reflect good the changes of cerebral circulation. In generall, there is a good corelation between the increase of intracranial pressure and changes in Doppler curve parameters, mainly decreased end diastolic blood flow velocity and increased resistive index and pulsatility index. The mean cerebral blood flow velocity is mainly determined by diastolic blood flow. In the cases of intracranial hypertension, the arterial blood flow is more affected during diastole than during systole, resulting in an increase of resistive index and pulsatility index. Transcranial Doppler ultrasonography can be used as a non-invasive method for the indirect monitoring of intracranial pressure and dynamics in newborns with hydrocephalus.[8,9,10] Hence; the present study was conducted to measure the size of lateral ventricles using ultrasound and to assess the resistive index of anterior cerebral artery using doppler sonography.[11]

In the present study, out of 50 infants, 29 were males and 21 were females. Our results were in concordance with the results obtained by D Goh et al who also reported that out of 18 infants enrolled in their study, 11 were males and 7 were females.[12]

In the present study, during the pre-treatment phase, mean RI of ACA was 0.78 and during the post-treatment phase mean RI was 0.71. Our results were in concordance with the results obtained by D Goh et al who also reported similar findings. Mean RI among infants with hydrocephalus in their study was found to be 0.79 each for ACA and MCA.[12] In patients with hydrocephalus the RI can clearly be within normal range if ICP is not elevated, such as in those not requiring shunting, or asymptomatic shunted patients with functioning shunts with presumably little compromise in cerebral perfusion.[13] Van Bel et al also found an elevated RI in neonatal post-haemorrhagic hydrocephalus which however was due mainly to increased peak systolic flow velocity with no significant change in end diastolic velocity after CSF drainage. They concluded that the elevated RI was due an increase in vascular compliance with no significant change in cerebrovascular resistance at that stage.[14]

In another study conducted by Leliefeld et al authors analysed the relationship between the trans-systolic time of Doppler waveform of middle cerebral artery and intracranial pressure in infants with hydrocephalus. There was found significant decrease of the intracranial pressure after the drainage procedure ($p<0.005$), accompanied by the significant increase of trans-systolic time ($p<0.005$), significant decrease of pulsatility

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index ($p<0.05$) and significant decrease of resistive index ($p<0.05$). Trans-systolic time has a strong correlation with the intracranial pressure ($p<0.005$). Trans-systolic time reflects the relative changes in the cerebral blood flow velocity caused by intracranial dynamics changes. The results of the study suggested, that the trans-systolic time has a closer relation to intracranial pressure than the pulsatility index and the resistive index.[15]

In the present study, mean Levene ventricular index during pre-treatment and post-treatment phase was 3.6 cm and 2.3 cm respectively. Mean Ventricular- hemisphere ratio during pre-treatment and post-treatment phase was 0.61 and 0.45 respectively. Mean Davies anterior horn width during pre-treatment and post-treatment phase was 3.7 cm and 2.6 cm respectively. While comparing statistically, significant results were obtained. Hill and Volpe first reported an abnormally high RI in the ACA in infantile hydrocephalus. Nine of their 11 patients had raised ICP measured by a transfontanometric method. They however concluded that ventriculomegaly was probably a more critical factor than raised ICP in the pathogenesis of impaired blood flow as 2 patients in their study with normal ICP but marked ventriculomegaly had elevated RI and patients with the most significant ventriculomegaly had the highest RI measurements. However, as their ICP measurements were done by a transfontanometric method there may have been some variance from true intraventricular pressure levels.[16] In a previous study conducted by Goh D et al, authors performed duplex Doppler sonography and direct intracranial pressure (ICP) measurement on 18 patients with infantile hydrocephalus. Their results suggested that the RI provides a reliable measure of cerebrovascular resistance in hydrocephalus. Duplex Doppler ultrasonography thus is a useful non-invasive means of monitoring cerebrohaemodynamic change with simultaneous imaging of ventricular size in infantile hydrocephalus.12 I Ahmad et al evaluate the role of transcranial Doppler sonography and Resistive Index (RI) of Anterior Cerebral artery without and with pressure provocation as a marker of altered cerebral compliance in hydrocephalic children. Resistive index using transcranial Doppler sonography particularly with pressure provocation can serve as a useful and specific marker of altered cerebral compliance thus evaluating the necessity and effectiveness of CSF drainage procedures.[17] In another study conducted by P S Shah et al, authors analysed fifty cases each of preterm (less than 34 weeks), full term and one month to six months age (400 total) and subjected them to cranial ultrasonography for determination of ventricular size and ventriculohemispheric ratio. Ventricular size steadily increased from 4.64 +/- 1.84 mm in preterm to 10.72 +/- 2.92 mm in six months old infant. Ventriculohemispheric ratio increased from 0.12 +/- 0.052 in preterm to 0.17 +/- 0.056 in three months of age. Then steady level was maintained at 0.17 +/- 0.064 upto six months of age.[18]

CONCLUSIONS

Duplex Doppler ultrasonography thus provides us with a non-invasive and easily repeatable means of monitoring for further increase in ventricular size as well as a method of monitoring cerebrohaemodynamic change in hydrocephalus patients.

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