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ORIGINAL ARTICLE

Cerebrospinal fluid drainage in posthemorrhagic ventricular dilatation and its effects on cerebral hemodynamics

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ABSTRACT

Objective: Posthemorrhagic ventricular dilatation (PHVD) is an important complication of intraventricular hemorrhage in preterm neonates. The definitive treatment of PHVD is ventriculoperitoneal shunt application, but being over 2500 g is expected for the operation, and there is still debate on the choice and timing of temporizing interventions until shunt application. In this prospective study, we aimed to observe the effects of ventricular decompression via lumbar puncture or reservoir on cerebral hemodynamics, ventricular measurements, and head circumference.

Material and Methods: A total of 19 cerebrospinal fluid drainage applications in 10 patients ≤34 weeks gestation with PHVD was included. Ventricular size and medial cerebral artery Doppler measurements in ultrasonography, cerebral tissue oxygenation using near infrared spectroscopy, and head circumference of the patients who required ventricular decompression were recorded 1 h before and 2 h after interventions.

Results: Ventricular measurements significantly decreased after intervention. Ventricular dilatation (ventricular index right/left and anterior horn width left/right: p=0.001/p=0.02 and p<0.001/p=0.003, respectively), Doppler measurements (resistivity index: p<0.001, pulsatiliy index: p<0.001), and cerebral tissue oxygenation (cerebral tissue oxygen saturation: p<0,001, fractioned oxygen extraction: p<0.001) significantly improved after intervention. No change in head circumference was observed 2 h and 24 h after decompression (p=0.46 and p=0.571, respectively).

Conclusion: In infants with PHVD, the ventricular enlargement is accompanied by hemodynamic disturbance, which can be corrected with decompression. Doppler studies and ventricular measurements may be considered as "alarming" parameters for ventricular decompression and may contribute to protection of rapidly growing and delicate premature brain from the negative effects of the increased cerebral pressure.

Keywords: Hemodynamics, near infrared spectroscopy, posthemorrhagic ventricular dilatation, prematurity

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INTRODUCTION

Posthemorrhagic ventricular dilatation (PHVD) is referred to as progressive ventricular dilatation due to cessation of cerebrospinal fluid (CSF) flow or absorption as a result of clot formation and extracellular matrix protein deposition in the ventricular system.[1,2] PHVD is still one of the most important intraventricular hemorrhage (IVH) complications in preterm infants. While IVH incidence is reported to be 15%–30% in preterm babies, weighing <1500 g at birth, and even higher in babies with extremely low birth weight, PHVD may develop in up to 80% in patients with grade III–IV IVH.[1]

As ventricular dilatation has been shown to cause white matter damage, cerebral palsy, and neurodevelopmental retardation in infants, treatment is of great importance.[2–4] However, there is still an ongoing debate on treatment modalities of PHVD.[1,5,6] VP shunt operation is not required for all PHVD cases, and spontaneous resolution can be observed.[6–8] Studies have reported the shunt requirement rate to be around 40%.[9] There are some restrictions of shunt placement: high protein levels of CSF and low body weight,[1,6,9] being over 2000–2500 g is expected in many centers for VP shunt operation.[10] For all these reasons, temporizing solutions for ventricular drainage are sought to prevent cerebral damage in this process. Therefore, interventions such as serial lumbar puncture (LP), ventricular reservoir, and tapping are often applied to these patients. Although these workarounds are not thought to prevent the requirement for VP shunt,[6] they have been shown to improve the aEEG pattern, cerebral tissue saturation, and cerebral artery Doppler measurements.[2,9,11]

Another problem encountered in daily practice is the difference in treatment intervention timing approaches between neonatologists and neurosurgeons. In daily practice, neonatologists accept the ventricle measurements obtained by ultrasonographic measurements, the resistivity index (RI), as decompression indication, which develop much earlier than the increase in the head circumference and fontanel tension.[6] However, neurosurgery does not always accept this point of view, and an increase in fontanel tension and head circumference is expected. For this reason, early-stage warning parameters that will be more objective and protect the premature brain that is developing should be identified.[12]

In our study, we aimed to investigate the effects of temporizing decompression applications on ventricular dimensions and cerebral hemodynamics with the combination of near infrared spectrometry (NIRS) and Doppler measurements and evaluate whether these modalities would be helpful in the decision of intervention. The second aim was to evaluate if the head circumference is affected by decompression of ventricles.

MATERIAL AND METHODS

This prospective observational clinical study was conducted in the neonatal intensive care unit of a tertiary hospital with 1500 annual admissions between September 2016 and January 2018. Patients who were born ≤34 weeks gestation and who were performed CSF drainage for ventricular decompression were enrolled in the study. Both LP and CSF reservoir tapping were considered CSF drainage procedures. CSF drainage of 10 mL/kg was considered a successful intervention and included in the study. The study was approved by the local ethics committee (2016-137) and conducted in accordance with the principles of the Helsinki Declaration. Written parental consent was obtained for all patients.

Inclusion criteria were: to be born ≤34 weeks gestation, have PHVD, and require decompression of ventricles in the hospitalization period. Exclusion criteria were: chromosomal, cardiac, or cranial anomalies, central nervous system infection or sepsis, and hemodynamic instability. Patients who had ventricular dilatation or hydrocephalus due to other etiologies than IVH were also not included in the study.

Criteria for Intervention

In our unit, IVH screening is performed following the recommended cranial ultrasound schedule for premature infants.[13] Patients who are detected to have IVH are followed closely using cranial ultrasonography in terms of PHVD, and ventricular index (VI) and anterior horn width (AHW) are measured every other day. Also, the head circumference of these babies are measured on a daily basis. Patients with VI >97p and AHW >6 mm are diagnosed with PHVD, and if VI >97p +4 mm, ventricle decompression is considered.[3,14]

In case of the ongoing need for drainage after the third attempt, the patient is consulted with neurosurgery and evaluated in terms of ventricular reservoir or VP shunt. As there is no neurosurgery clinic or neurosurgeon in our hospital and the relevant consultant physicians do not agree to perform the surgical intervention in our hospital or at the bedside, patients are transferred to external centers for reservoir or shunt intervention. On the other hand, consultant neurosurgery clinics accept patients over 2500 g for VP shunt. For reservoir insertion, babies are only expected to be hemodynamically stable and not to have CNS infection.

Cranial and Doppler Ultrasonography

Cranial ultrasonography and cerebral Doppler ultrasonography were performed by the neonatology fellow or neonatology specialist in NICU 1 h before and 2 h after the procedure. The timeline of decision and application processes are depicted in Figure 1. Ultrasonographic evaluations are planned according to the recommended schedule for preterm babies.[13] In our clinic, for cranial and Doppler ultrasonography, Philips Envisor C HD (Royal Philips Electronics, Amsterdam, Netherlands) with phased array 5–12 MHz probe is used. VI (the distance between the falx cerebri and the lateral wall of the anterior horn in the coronal plane) and AHW (widest diagonal width of anterior horn in the coronal plane) are evaluated from anterior fontanelle. The end-diastolic velocity (EDV) and peak systolic velocity (PSV) of the medial cerebral artery are measured from the temporal window. RI is calculated using the formula: (PSV–EDV)/PSV. Pulsatility index (PI) is calculated using the formula: (PSV–EDV)/mean systolic velocity.

Drainage Procedure

For LP, 1 μg/kg fentanyl is used for sedation and analgesia. LPs were performed in sitting or lateral flexed decubitus position. A sterile environment was prepared for performing drainage from the CSF reservoir after local lidocaine and prilocaine application. The amount

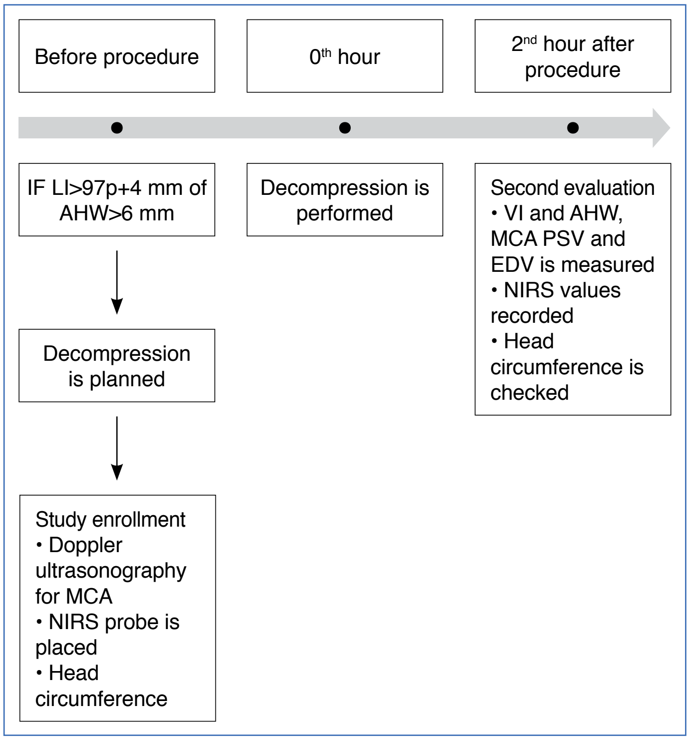

Figure 1: Timeline of decision and application of ventricular decompression and data collection.

of drained CSF is aimed to be 10 mL/kg. During the interventions, patients were monitored, and in case of clinical worsening (desaturation or bradycardia), the procedure was delayed.

Cerebral Oxygenation Assessment

Covidien INVOS (Medtronic, USA) was used to evaluate cerebral oxygenation. The neonatal probe was placed on the glabella 1 h before the decompression procedure, and the mean value was recorded until the application. The mean cerebral tissue oxygen saturation values between the 15th minute and second hour after the application were recorded. Fractionated oxygen extraction (FOE) ([saturation–tissue saturation]/saturation) was calculated with the data obtained.

Head Circumference

Head circumference of the patients was measured 1 h before the intervention and 1 h and 24 h after the intervention. A paper tape is used for measurement, and the tape was passed around the head, just above the eyebrows and over the protuberance of the skull at the back of the head.[15]

Statistical Analysis

Parametric values are reported as mean±SD, nonparametric values are reported as median and quartiles 1–3. As the sample size was below 30, the Wilcoxon test is used to compare before and after values. p-values below 0.05 are considered statistically significant. Statistical analyses were computed with SPSS software (SPSS 18.0 for Windows; SPSS, Chicago, IL, USA).

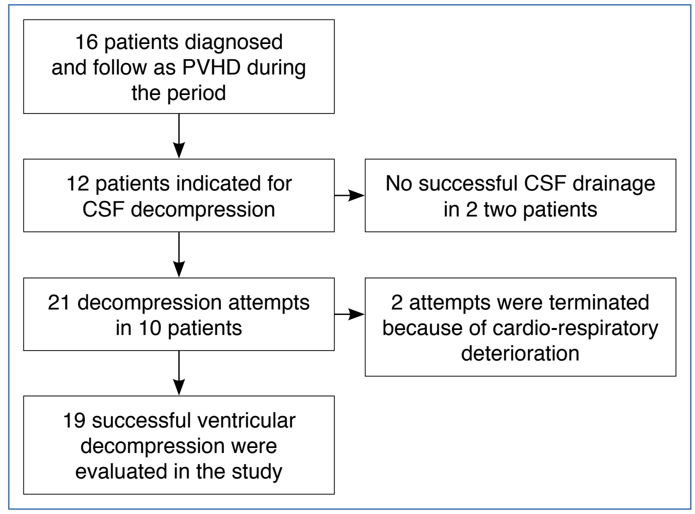

Figure 2: Patient enrollment according to inclusionexclusion criteria.

PVHD: Post-hemorrhagic ventricular dilatation; CSF: Cerebrospinal fluid.

RESULTS

During the study period, 12 patients were eligible for enrollment, but 2 patients were excluded because all decompression attempts were unsuccessful. Ten patients were included in the study, and 21 CSF drainage applications were applied. Two decompression attempts were terminated because of hemodynamic and respiratory deterioration. As a result, 19 CSF decompression applications in 10 patients were evaluated in the study (Fig. 2). The median gestational age of the patients was 27 weeks (Q1–Q3: 26–29), while the median birth weight was 1150 g (Q1–Q3: 745–985). The median weight on the procedure day was 1550 g (Q1–Q3: 860–1360), while the median of chronological age was 19 days (Q1–Q3: 15–37). Clinical features of the patients are depicted in Table 1. Five of the patients had IVH grade III and the other five had IVH grade IV. Decompression was performed with LP in 6 of 10 patients (14 of total 19 interventions) and with tapping from the reservoir in 4 of them (5 of total 19 interventions).

There was a statistically significant difference in both right and left VI and AHW values between before and after intervention measurements in the cranial ultrasonography (right VI: p=0.001, left VI: p=0.02, right AHW: p<0.001, left AHW: p=0.003).

Comparing the hemodynamic parameters before and after the intervention, there was a significant difference in StO2 (p<0.001), RI (p<0.001), PI (p=0.001), FOE (p<0.001), and EDV (p<0.001) values of middle cerebral artery (Table 2).

There was no significant difference between head circumference measurements taken before and 1 h after intervention (p=0.46) and between before and 24 h after the intervention (p=0.571).

DISCUSSION

In this study, it has been shown that interventions for ventricular decompression are effective for reducing the size of the ventricular system and subsequent improvement in cerebral hemodynamics. On the other hand, although the size of the ventricles decreased, it was observed that there was no significant reduction in head circumference.

Table 1: Clinical features of the patients

Gender (male/female)	6/4
Gestational age*	27 weeks (26–29)
Birth weight*	890 g (745–985)
Weight at intervention*	960 g (860–1360)
Postnatal age at intervention*	19 days (15–37)
Corrected age at intervention*	30 weeks (29–37)
Patients underwent lumbar puncture/ total number of patients (n)	6/10
Number of drainage with lumbar puncture /total interventions (n)	15/19

Values not normally distributed are given as median and quartile 1–3 and marked with an asterisk.

Table 2: Ultrasonographic measurements, cerebral oxygenation values, and Doppler measurements before and after the intervention

	Before intervention	After intervention	p
Ultrasonographic measurements			
Left VI	16.7±8.2	13.2±3.0	0.002
Left AHW	10.8±4.6	8.8±3.0	0.003
Right VI	16.4±6.7	14.3 ± 4.4	0.001
Right AHW	12.6±5.2	10.3 ± 5.0	0.000
Doppler measurements			
PSV	5.9±2.2	6.1±1.9	0.355
Mean Flow Velocity	2.8±1.2	3.0±1.1	0.107
EDV	1.1 (0.8–1.3)*	1.44 (1.1–1.8)*	0.000
Pulsatility Index	1.8±0.6	0.46±0.16	0.001
RI	0.8±0.1	0.73±0.1	0.000
NIRS values			
StcO2	65±7.1	70±6.8	0.000
FOE	0.31±0.1	0.26±0.1	0.000

Values in normal distribution are given as mean±standard deviation. Values not normally distributed are given as median and quartile 1–3 and marked with an asterisk. VI: Ventricular index; AHW: Anterior horn width; PSV: Peak systolic velocity; EDV: End-diastolic velocity; PI: Pulsatility index; RI: Resistivity index; NIRS: Near infrared spectrometry; StcO2: Cerebral tissue oxygen saturation; FOE: Fractioned oxygen extraction.

Several previous studies investigated the aftereffects of ventricular decompression on regional cerebral oxygenation,[8,10] Doppler measurements,[11] electrocerebral activity,[2,9,16] and visual evoked potentials.[9,16] All these subjects were reported to amend following the decompression procedure.[2,9] In the study of Norooz et al.,[9] aEEG findings improved after intervention, and the discontinuous pattern normalized to the continuous pattern at median day 12.5. Two studies have also reported normalized aEEG pattern after decompression.[2,16] As distinct from cerebral hemodynamics, improvement in aEEG activity had been observed at a later time. It must be highlighted that the normalization occurs at a median of 4.5–12.5 days; therefore, it can be concluded that the success or effect of the intervention can be evaluated earlier with NIRS and Doppler measurements than aEEG. In our study, the improvements in cerebral oxygenation were observed in the first 2 h after the intervention. Also, there was a significant improvement in blood velocities measured in the second hour after decompression.

The result that there is no significant change in the head circumference immediately after intervention and 24 h after ventricular decompression can be explained by the fact that the change in the head circumference has not yet occurred, although there is a hemodynamic problem that developed with the enlargement of ventricles which we could correct with intervention. Previous studies have also reported that symptoms and signs of increased intracranial pressure (ICP) develop later than ultrasonographic findings.[17,18] This result shows that the measurement of ventricular dimensions by ultrasonography is superior to other physical examination findings, as reported in the studies.

The development of the premature brain is a delicate process, which cannot be completed in the antenatal period.[12] This exquisite process includes origination, migration, differentiation of neurons and neuroglias, and establishing functional and structural connections.[19] While this process needs to go smoothly in very low birth weight and extremely low birth weight infants, unfortunately, they are also the riskiest patient group for IVH and subsequent PHVD, which are the most severe thread for neurodevelopment.[12] In these patients, PHVD contributes the brain damage by compression of the cerebral mantle and disruption of energy metabolism due to impaired hemodynamics.[20] However, with the increased pressure that occurs, neighboring tissue edema in PHVD and secondary inflammatory processes in the CSF content also contribute to the brain damage process.[12]

Brouwer et al.[19] reported possible relation of deep gray matter volume reduction and raised ICP in infants with PHVD. Besides, in another study by Brouwer et al., increased ICP correlates with myelination and neurodevelopmental delay due to cerebral hemodynamic alteration and cerebral tissue damage.[4] Furthermore, PHVD is accused of interrupting the ventral ganglionic eminence supply of neuron precursors to the thalamus.[19] In addition, decompressing procedures are thought to remove blood components and inflammatory substances.[13]

For all these reasons, while waiting for the time to apply a permanent solution such as a shunt, it would not be wise to accept the head circumference increment as an indication of decompression,[14] which has been shown not to correlate with ventricular volumes in previous studies.[17,18] On the other hand, clinical findings such as apnea, bradycardia, lethargy, and hypertonia are not only the finding of ICP; they are the findings of cerebral compromise due to pressure increase.[18,20] Therefore, PHVD should be intervened before these findings develop.[10,13,20]

Although significant improvement in cerebral hemodynamics was found after decompression as a result of our study, a study with a higher number of patients may be more instructive in this regard. Also, studies collecting data to find out how durable the effect of CSF drainage is and how long the hemodynamic measurements were abnormal before draining CSF would be more helpful to evaluate the effects of CSF drainage in these babies. After the LP or reservoir tap, a follow-up measurement would help determine how fast the values went back to predecompression levels.

Despite all these limitations, the results of our study show the importance of proactively using ultrasonography in the decision of decompression time, without waiting for an increase in head circumference, to preserve cerebral hemodynamics, with significant results.

CONCLUSION

It is thought that the follow-up of PHVD by ultrasonography is of great importance, as shown in our study. In patients with PHVD, interventions should be planned with the "alarming" parameters in ultrasonography without waiting for the increase in head circumference, and the harmful effects of the increase in cerebral pressure during rapid growth and development should be protected.

Statement

Ethics Committee Approval: The Zeynep Kamil Maternity and Children's Training and Research Hospital Clinical Research Ethics Committee granted approval for this study (date: 24.06.2016, number: 2016-137).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – ED, ST, AT, SA, GK, HHT; Design – ED, ST, AT, SA, GK, HHT; Supervision – ED, ST, AT, SA, GK, HHT; Resource – ED; Data Collection and/or Processing – ED, ST, AT, SA, GK; Analysis and/or Interpretation – ED, ST; Literature Search – ED, ST; Writing – ED, ST; Critical Reviews – ED, ST, HHT.

Conflict of Interest: The authors have no conflict of interest to declare.

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