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ORIGINAL ARTICLE

Post Hemorrhagic Hydrocephalus in Infants: Methods of Treatment and Prognostic Factors

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ABSTRACT

Background: The most prevalent yet dangerous neurological condition in infants is post hemorrhagic hydrocephalus (PHH), which can have life-threatening effects during the acute phase of the newborn period and long-lasting psychomotor and cognitive aftereffects in later life. So, we aimed to investigate the prognostic factors for infants with post-hemorrhagic hydrocephalus and assess the therapeutic approaches. **Methods:** Prospective cohort study included 18 infants with post hemorrhagic hydrocephalus, US and MRI done to all studied participants. Follow up after 12-month post treatment. **Results:** Among the 18 studied infants, 15 (83.3%) had post-hemorrhagic hydrocephalus (PHH), while 3 (16.7%) developed hydrocephalus due to post-subarachnoid hemorrhage. 33.3% had grade 2 IVH, 16.8% had grade 3 IVH, and 50% had grade 4 IVH. PHH was significantly associated with higher Papile grading and lower gestational age. Multivariate analysis identified ultrasound grade and gestational age as independent risk factors for PHH. Mortality occurred in 55.6% of infants, all with PHH, and increased with higher IVH grades, head circumference >2 SD, and lower gestational age. Risk factors for death included high IVH grade, increased head circumference, and low gestational age. Secondary outcomes at two years included speech delay (22.2%), epilepsy (5.6%), visual deficiency (11.1%), and hearing impairment (5.6%). **Conclusion**: While post-hemorrhagic hydrocephalus (PHH) with elevated intracranial pressure (ICP) can happen with any grade of IVF, grade III and IV IVF are more likely to cause it. Once ≥ grade II IVH is detected on ultrasound, monitoring head circumference and daily anterior fontanelle palpation can assist detect worsening hydrocephalus.

Keywords: Post hemorrhagic, Hydrocephalus, Infant, Treatment, Prognosis.

INTRODUCTION

Neonatal intraventricular haemorrhage (IVH) and other causes can result in infantile posthemorrhagic hydrocephalus (PHH), which is characterised by a gradual dilatation of the ventricular system. Numerous issues and developmental delays are frequently linked to infant hydrocephalus. It has been demonstrated that the cause of hydrocephalus affects both surgical and neurodevelopmental outcomes (NDO) **[1].**

It is hypothesised that post-haemorrhagic hydrocephalus, which follows intraventricular haemorrhage of preterm, is linked to worse results than other aetiologies. Proinflammatory cytokines, free radicals from iron owing to haemoglobin breakdown, elevated intracranial pressure (ICP), and hydrocephalus-induced deformation of developing neural pathways all contribute to toxicity and brain damage **[2].**

It is still unknown how hydrocephalus occurs following interventricular hemorrhage caused by the germinal matrix. The most widely accepted theory states that obstructive hydrocephalus is caused by blood clots that first restrict the passage of cerebrospinal fluid (CSF) by obstructing the cerebral aqueduct or the fourth ventricle outlets. It is hypothesized that a delayed communicating hydrocephalus later develops as a result of impaired CSF resorption brought on by an increase in extracellular matrix (ECM) protein synthesis across the cerebroventricular system **[3].**

After a head injury, post-traumatic hydrocephalus (PTH) is a well-known condition. Patients with serious head injuries typically experience the majority of cases a few weeks to months following the initial event. The incidence of PTH ranges from 0.75% to 45%, with significant variation across series.

Ventriculomegaly is linked to an increased risk of periventricular brain injury-related cognitive and motor sequelae. This implies a direct correlation with prolonged pressure and an indirect one with ischemia and inflammation, which cause white matter damage from which there is no recovery capacity **[4].**

IVH usually manifests clinically in three ways: (a) catastrophic deterioration, which happens over minutes or hours and resembles the rapid neurological decline of an elderly patient with large intracranial hemorrhages (which is linked to a very poor prognosis); (b) the saltatory course, which develops over hours to days and includes hypotonia, abnormal tight popliteal angle, abnormal eye movements, respiratory difficulties, and decreased alertness and activity; (c) and a clinically silent course, which supports the use of surveillance cranial ultrasonography. A consistent growth of 2 mm per day is considered an excessive head expansion. It is difficult to identify daily variations in head circumference; instead, one must look at the cumulative growth of the head over a number of days or look for additional signs of elevated intracranial pressure, such as increased cranial suture splaying, a full tense fontanelle, worsening bradycardia and apnea episodes, lethargy, and trouble eating. The reliability of these clinical findings is restricted. Nonetheless, increasing splaying of the sagittal suture is the most trustworthy clinical sign of elevated pressure **[5].**

Prenatal steroid treatment is the only strategy that effectively prevents IVH. Numerous pharmacologic treatments, including preventive indomethacin and postnatal phenobarbital, have been suggested for the management and control of IVH but have not shown promise. The best way to treat IVH at the moment is to use serial ultrasonography (US) for early diagnosis, control ventricular dilatation through various invasive procedures to remove excess CSF from the ventricular system, and avoid complications later on, which are directly linked to the extent of ventricular dilatation and the ensuing parenchymal damage.

A ventriculoperitoneal (VP) shunt is the definitive treatment for progressive PHH; however, for a number of reasons, including the high risk of shunt malfunction, the frequent need for revision, and the potential for skin ulceration in very low birth weight infants, this procedure is rarely used as a first intervention. Temporising neurosurgery operations (TNPs), such as lumbar punctures (LP), external ventricular drainage (EVD), ventricular access device (VAD) implantation, or ventriculosubgaleal (VSG) shunt, are frequently used to regulate ventricular dilatation. The installation of a VP shunt is recommended in situations where PHH cannot be controlled with conventional techniques. It is extremely challenging to establish a standardised protocol for the treatment of this condition due to the absence of definitive recommendations; instead, most centres base their treatment decisions on institutional guidelines, medical competence, and available resources **[6].**

Although there is limited investigation of prognostic variables, the link between hydrocephalus and poor long-term neurodevelopmental outcomes has been established **[7].**

The purpose of this study is to investigate the prognostic factors for infants with post-hemorrhagic hydrocephalus and assess the therapeutic approaches.

METHODS

This prospective cohort study was carried out at Zagazig University's Neurosurgery Department in the Faculty of Medicine. All patients were included in the study if they meet the inclusion and exclusion criteria. A comprehensive sample of cases were included during the one-year study period. using OPEN-EPI at 80% power and 95% confidence interval. The study was approved by ethical committee of Faculty

of Medicine, Zagazig University (IRB number: 9587-28-6-2022).

The requirements for inclusion were: post-hemorrhagic hydrocephalus in all newborns. During hospitalization, biochemical information on the cerebrospinal fluid was gathered. When persistent hydrocephalus is diagnosed, hospitalization or traceable courses last longer than two weeks.

Criteria for Exclusion: During the course of the illness, an intracranial infection was discovered. Concomitant complex conditions that have a major impact on safety assessment include liver, kidney, gastrointestinal, respiratory, cardiovascular, and others. dangerous infectious illness that is concurrent. issues related to coagulation malfunction or chronic antiplatelet or anticoagulant medication use. rejecting the research.

Every patient endured the following: Take a complete history. Complete clinical and general examination: neurological assessment. Radiological assessment: CT, plain X-ray. Imaging includes: US and MRI.

Methods of treatment According to grading of haemorrhage:

• Conservative therapy for grade I patients with mild hydrocephalus

Conservative therapy is recommended for grade II patients with mild hydrocephalus.

V-Pshunt is used for Grade II and Grade III patients with mild hydrocephalus.

• Massive hydrocephalus in grade III: V-Pshunt, SGDS, EVD

Massive hydrocephalus in Grade IIII: EVD

Twelve months was the follow-up period.

The electronic health record system was used to retrieve clinical data, including neurodevelopmental, surgical, and demographic information. Every patient's data was gathered until their death, loss to follow-up, or the conclusion of the data collection period; each patient's last follow-up date was noted to enable analysis that takes follow-up time into account.

The causes of hydrocephalus were divided into three categories: spontaneous (15) PHH (infants delivered before 37 weeks with IVH identified by cranial ultrasonography), traumatic subarachnoid haemorrhage (3), and a combination of other low-patient-number aetiologies, such as trauma, term IVH, and unidentified reasons.

Outcome definitions Primary outcome

Clinical indicators of elevated intracranial pressure, such as elevated HC > + 2 SD, bulging anterior fontanelle, splayed cranial sutures, strabismus, deterioration in neurological examination, poor feeding, lethargy, and irritability, along with progressive ventricular dilatation observed on serial CT or MRI that necessitates a CSF shunt, were considered to be indicative of PHH.

Statistical Analysis

IBM SPSS 23.0 for Windows was used to computerize and statistically analyse the collected data (SPSS Inc., Chicago, IL, USA). Characteristic statistics: Quantitative data, following normality testing with the Shapiro-Wilk test, is normally distributed data with mean±SD, whereas qualitative data is expressed as numbers and percentages (N.%). Interferential statistics: At the significance value (P value) level, $P > 0.05$ indicates non-significant, whereas $P \leq 0.05$ indicates significant. Fisher's exact test and the chi-square test were used to qualitative data. Based on a collection of independent factors, logistic regression is a valuable tool for predicting whether an outcome occurred or not. Similar to a linear regression model, it works well with qualitative (categorical) dependent variables.

Table 1: Baseline data among studied patients

	All patients (n=18)
Sex (*N. %)*	
Male	11 (61.1%)
Female	7 (38.9%)
Term	
Gestational age (mean±SD)	29.1±3.9
Preterm (*N. %)*	18 (100%)
Etiology of prematurity (*N. %)*	
Maternal hypertension	2 (11.1%)
PROM	10 (55.6%)
Traumatic	3 (16.7%)
Undetermined	3 (16.7%)

Table 2: Type of shunt used among studied patients

	Spontaneous PHH (n=15)	**Traumatic PHH (n=3)**
Medical treatment	1 (6.6%)	1 (33.3%)
VP shunt	5 (33.3%)	2 (66.6%)
VSGS	6 (40%)	0 (0%)
EVD	3 (20%)	0 (0%)

VP shunt: ventriculoperitoneal shunt; EVD:external ventricular shunt; VSGS: ventriculo sub galeal shunt.

Table 3: Risk factors for post hemorrhagic hydrocephalus on univariate analysis

	Total (n=18)	**Spontaneous PHH (n=15)**	**Traumatic PHH (n=3)**	**P-value**
Papile grading				
2	6 (33.3%)	3 (20%)	3 (100%)	**0.04**
3	3 (16.7%)	3 (20%)	0 (0%)	
4	9 (50%)	9(60%)	0 (0%)	
↑ HC > 2SD				
Yes	13 (72.2%)	12 (80%)	1 (33.3%)	0.09
No	5 (37.8%)	3 (20%)	2 (66.7%)	
Gestational age				
<30	10 (55.6%)	10 (66.7%)	0 (0%)	**0.03**
30-70	8 (44.4%)	5 (33.3%)	3 (100%)	
Sex				
Female	7 (38.9%)	5 (33.3%)	2 (66.7%)	0.28
Male	11 (61.1%)	10 (33.3%)	1 (33.3%)	

SD: Standard Deviation, P-Value: Probability value

Table 4: Risk factors for post hemorrhagic hydrocephalus on multivariate analysis

		OR	CI	P
US grade	3 versus 2 4 versus 2	3.25 6.42	1.92 – 15.42 1.89 – 20.21	**0.002** **0.03**
Gestational age	< 30 versus 30-37 30-37 versus <30	0.14 0.25	0.01 – 0.54 0.08 – 0.21	**0.02** **0.01**

OR: Odds Ratio, CI: Confidence Interval, *P-Value: Probability value*

Table 5: Risk factors of death in univariate analysis

	Total (n=18)	**Death (n=10)**	**Alive (n=8)**	**P-value**
Papile grading 2 3 4	 6 (33.3%) 3 (16.7%) 9 (50%)	 0 (0%) 2 (20%) 8 (80%)	 6 (75%) 1 (12.5%) 1 (12.5%)	 **0.002**
↑ HC > 2SD Yes No	 13 (72.2%) 5 (37.8%)	 10 (100%) 0 (0%)	 3 (37.5%) 5 (62.5%)	 **0.003**
Gestational age <30 30-70	 10 (55.6%) 8 (44.4%)	 9 (90%) 1 (10%)	 1 (12.5%) 7 (87.5%)	 **0.001**
Sex Female Male	 7 (38.9%) 11 (61.1%)	 3 (30%) 7 (70%)	 4 (50%) 4 (50%)	 0.39

Table 6: Risk factors for Death on multivariate analysis

		OR	CI	P
US grade	3-4 versus 2	12.4	5.23 – 10.89	0.001
↑ HC > 2SD		7.52	4.21 – 9.87	0.004
Gestational age	< 30 versus 30-37 30-37 versus <30	3.25 1.8	2.9 – 3.2 0.9 – 4.5	0.002 0.51

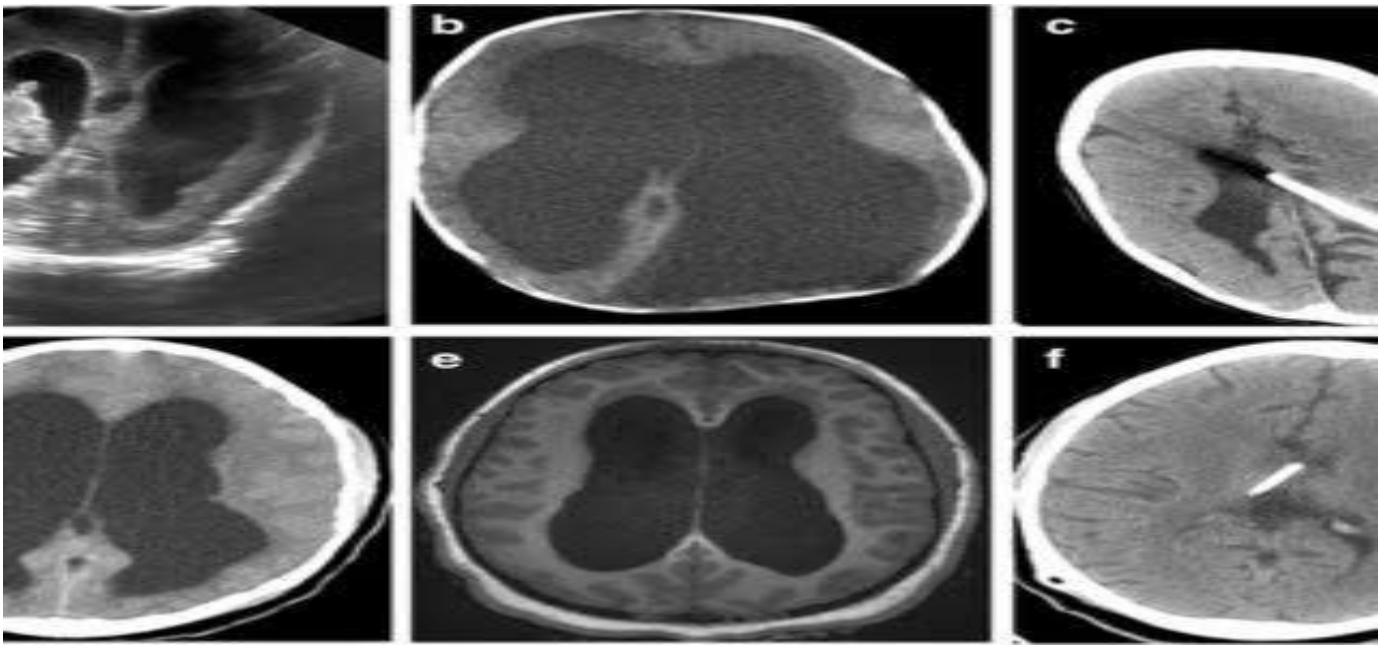

Figure (1): Male infant aged 3 Months, admitted to NICU with dehydration + Vomitting, CT brain showed inter ventricular Hge. Management: After 3 follow up V.P SHUNT, Pre operation (a,b,c,d,e) and Post operation (f).

RESULTS

This cross-sectional study was carried out at Zagazig University's Faculty of Medicine, Neurosurgery Department. Eighteen infants with hydrocephalus were included in the study. Of the newborns, 7 (38.9%) were female and 11 (61.1%) were male. The mean gestational age of all the cases under study was 29.1 weeks ± 3.9 SD, making them all preterm.

Three infants (16.7%) had a history of trauma, two patients (11.1%) had a history of maternal hypertension, three children (16.7%) were unidentified, and ten infants (55.6%) had a history of maternal premature rupture of membranes. All of the infants under study were preterm (Table 1).

Regarding clinical presentation, 13 (72.2%) had an enlarged head circumference > + 2 SD, 2 (11.1%) had a bulging fontanelle, 6 (33.3%) had hypotonia, 4 (22.2%) were asymptomatic, and 2 (11.1%) had epilepsy. Six neonates (33.3%) had grade 2 IVH, three (16.8%) had grade 3 IVH, and nine (50%) had grade 4 IVH at radiological evaluation based on ultrasonography and Papile's criteria. Out of the 15 neonates who had spontaneous PHH, five had a ventriculoperitoneal shunt (VPS) inserted as the first device, six had subgaleal shunts (VSGS), three had external ventricular drainage (EVD), and one had medicinal treatment. Two of the three neonates with post-traumatic hydrocephalus had ventriculoperitoneal shunts, and one received medical treatment (Table 2).

Pepile grading was greater among PHH patients (P=0.04), indicating a significant difference between infants with spontaneous PHH and those with traumatic PHH. Additionally, there was a significant difference between the two groups in terms of gestational age, with newborns with PHH having a lower gestational age (P=0.03) (Table 3). On Multivariate analysis; US grade and gestational age were considered as independent risk factors for PHH (Table 4).

Of the 18 infants in the study, 10 (55.6%) perished; all had PHH. The mortality rate rises in tandem with the papile grading. Additionally, newborns with a head circumference greater than 2 SD (P=0.003) and infants with a lower gestational age (P=0.001) had higher fatality rates (Table 5).

On multivariate analysis, risk factors of death were high IVH grade on cUS, increased head

circumference > 2 SD and low gestional age at birth (P <0.05) (Table 6). Four patients (22.2%) had no word association at two years, one patient (5.6%) had epilepsy, two patients (11.1%) had visual deficiencies, and one patient (5.65) had hearing impairment, according to the secondary outcomes among the studied patients.

DISCUSSION

This cross-sectional study was carried out at Zagazig University's Faculty of Medicine, Neurosurgery Department. Eighteen infants with hydrocephalus were included in the study. Of the newborns, 7 (38.9%) were female and 11 (61.1%) were male. The mean gestational age of all the cases under study was 29.1 weeks ± 3.9 SD, making them all preterm.

Three infants (16.7%) had a history of maternal infection, two patients (11.1%) had a history of maternal hypertension, and ten children (55.6%) had a history of maternal premature rupture of membranes. All of the infants in the current study were preterm.

Mohamed et al. [8] indicated that 323 babies in all fulfilled the requirements for participation in the study. With no discernible sex differences between groups, males were more prevalent across all aetiology groups (p = 0.54). Significantly, the PHH group had a lower median gestational age of 27 weeks (p<0.01) and similarly lower birthweights (p<0.01), with a higher proportion of preterm infants than all other aetiologies.

Gilard et al. [9] showed that 122 babies (sex ratio M/F 1.1) had at least one IVH and satisfied the inclusion requirements over the course of the 14-year research (Additional file 1). 28 WG was the median gestational age at birth (min: 23-max: 35).

Regarding clinical presentation, 13 (72.2%) had an enlarged head circumference > + 2 SD, 2 (11.1%) had a bulging fontanelle, 6 (33.3%) had hypotonia, 4 (22.2%) were asymptomatic, and 2 (11.1%) had epilepsy.

Gilard et al. [9] showed that 86 (70.5%) had an enlarged head circumference > + 2 SD, 16 (13.1%) had epilepsy, 28 (22.9%) were asymptomatic, 43 (35.2%) had hypotonia, and 11 (9%) had a bulging fontanelle.

In our study, three infants (167%) had hydrocephalus as a result of post-traumatic stress disorder, and fifteen newborns (83.3%) had PPH.

According to **Alan et al. [10], Lam et al. [11], and Kazan et al. [12],** the PHH rate ranges from 20 to 35%. PHH risk variables included elevated HC at diagnosis and high IVH grade.

This is in line with earlier findings by **Heinsbergen et al. [13]** that musculoskeletal issues were more prevalent in myelomeningoceles, whereas cognitive impairment, speech and language impairment, and seizures were more prevalent in PHH. The percentage of severe disability in PHH and hereditary hydrocephalus rose over time, reaching 65.0% and 45.5%, respectively, at ten years. The long-term nature of the care that these kids and teens need is shown by this time-dependent tendency, which has been characterised **[14]**.

Prematurity, ischaemic or inflammatory insults to periventricular brain regions, following white matter injury, or increased shunt problems can all contribute to poor outcomes in PHH. Motor and cognitive impairment are linked to prematurity alone, but this is much more common in newborns with severe IVH and ensuing PHH.

According to a big study by **Hollebrandse et al. [1],** only 12% of infants born before 28 weeks of pregnancy who were evaluated at age 8 had decreased intellectual ability, and only 24% had motor dysfunction. Only premature infants with PHH were chosen for the **Mohamed et al. [8]** group, and their outcomes were thereafter worse. The identical consequences of both aetiologies may be explained by a same pathogenic process, as genetic hydrocephalus has similarly been linked to changes in neural cell fate in the cerebral cortex **[15].**

Six neonates (33.3%) had grade 2 IVH, three (16.8%) had grade 3 IVH, and nine (50%) had grade 4 IVH at radiological evaluation based on ultrasonography and Papile's criteria.

According to **Gilard et al. [9],** 52 neonates (42.6%) had grade 2 IVH, 22 (18%) had grade 3 IVH, and 48 (39.3%) had grade 4 IVH at radiological evaluation based on ultrasonography and Papile's criteria.

The ventriculoperitoneal shunt (VPS) was the first device implanted in five of the 15 babies with PHH in the current investigation, and it was secondary to other devices in ten of the instances. When a different device was placed first, it included external ventricular drainage (EVD) in three cases and ventriculo subgaleal shunts (VSGS) in seven.

In contrast, all three of the neonates with post-traumatic hydrocephalus had ventriculoperitoneal shunts. **Gilard et al. [9]** outlined how the ventriculoperitoneal shunt (VPS) was inserted as the primary device in seven of these 22 babies and as a secondary device in fifteen of them. External ventricular drainage (EVD) was used in three cases, ventriculo subgaleal shunts (VSGS) in ten cases, and ventriculocysternostomy in two cases when another device was put first.

In our sample, there was no discriminant risk factor for shunt reliance based on the type of CSF derivation device. The ventriculo subgaleal shunt and the ventricular access device are the two devices that are advised based on the most recent evidence in the literature **[16].** In 2003, a significant publication addressed the use of CSF washing **[17].** The results of this method were contradictory: a greater frequency of subsequent bleeding but improved neurodevelopmental results at the 2-year mark **[18]**.

According to a meta-analysis by **Mazzola et al. [16]**, The degree of evidence is insufficient to support this tactic. Research has been done to identify an alternative to these tactics, such as using iron chelators on animal models to reduce inflammation and delay the onset of hydrocephalus **[19].** These tactics could be used with patients who are susceptible to PHH. For these young individuals, CSF biomarkers may be useful in predicting when PHH will manifest. For instance, a recent study by **Morales et al. [20]** showed a high correlation between ventricular size and the amount of amyloid precursor protein (APP) in the cerebrospinal fluid.

As the pepile grading was greater in PHH patients (P=0.04), our study demonstrated a significant difference between infants with PHH and non-PHH. Additionally, there was a significant difference between the two groups in terms of gestational age, with newborns with PHH having a lower gestational age (P=0.03).

Gestational age and US grade were regarded as independent risk variables for PHH in multivariate analysis. In a recent study by **Behjati et al. [21]** The grade of the early bleeding was the first significant risk factor for PHH, with a 35% PHH rate based on the outcomes of 97 infants with neonatal IVH. According to the Papile classification, every infant in this series with a permanent VPS had an initial bleeding grade of III or IV. Six of the 22 children in the **Gilard et al. [9]** series who needed VP shunts had an initial haemorrhage grade of 2, whereas the majority of studies only included infants with grades 3 and 4. High IVH grade, late beginning (later than 1 week after delivery) of bleeding, and < 30 WG were risk factors for the onset of PHH in another study by **Kazan et al. [12]** based on 42 newborns with IVH and a 26% PHH rate. Confounding variables and a greater death rate in extremely preterm deliveries may be the cause of the lack of a clear correlation between PHH and gestational age at birth. A HC > + 2 SD at diagnosis was found to be a risk factor for shunt reliance by **Gilard et al. [9].** This finding highlights the necessity of treating PHH as soon as possible, before ependyma lesions develop and cause the ventricles to lose their compliance **[22].**

Paediatric hydrocephalus frequently results in shunt failures, which are linked to serious morbidity. Shunt survival was lowest in the PHH group in the **Mohamed et al. [8]** study, and revision rates and the number of revisions after a year and within five years were considerably higher in PHH than in congenital or "other" hydrocephalus. **Paulsen et al. [6]**

and **Notarianni et al. [23]** both showed higher 5-year shunt failure rates in PHH compared to congenital and "other" hydrocephalus, with no significant differences between PHH and myelomeningoceles. They also showed more frequent revisions in the PHH group than other aetiologies.

The PHH group's more juvenile immune systems, elevated CSF protein, varied inflammatory responses to CSF blood, tiny abdominal cavity, and thin, easily broken skin may all contribute to their higher shunt revision rates **[24].** However, other research has produced contradictory results; in similar series, the highest shunt failure rates have been linked to myelomeningoceles, trauma, tumours, congenital hydrocephalus, and post-infectious hydrocephalus **[7].** The lack of a PHH group in certain studies, different patient demographics and inclusion criteria, or low numbers for some aetiologies—specifically, tumours, trauma, and post-infectious hydrocephalus—in the **Mohamed et al. [8]** research could all be contributing factors **[25].**

Mohamed et al. [8] found that, in line with the research of **Tuli et al. [26]** and **Appelgren et al. [27]**, both gestational age and corrected age at shunt insertion were independent risk factors for shunt failure in a multivariate survival analysis. This confirms that the low shunt survival observed in PHH is probably caused by prematurity-related variables. According to this series, the probability of shunt revision decreased by 6.9% for each week that gestational age increased and by 2.0% for each week that corrected age at shunt implantation increased. This implies that, if at all feasible, shunt implantation in neonates should be postponed. According to research, PHH infants are more likely to experience numerous shunt failures as they become older, which may indicate that they are predisposed to multiple shunt failures due to other causes such shunt infection **[2].**

Although not statistically significant, PHH had the highest infection rate (17.9% of revisions) in **Mohamed et al. [8],** most likely as a result of weakened immunity and hemorrhagic material leftovers **[24]. Although Nagy et al. [28]** showed significant infection rates in post-infectious hydrocephalus in other studies, the size of this subgroup in the current study was too small to make comparable inferences.

Ten (55.6%) of the 18 infants in the current study died, and all of them developed PHH. Due to varying research follow-up lengths and possibly advances in neonatal care over time, **Mohamed et al. [8]** showed that the PHH mortality rate was 7.3%, lower than the 46% reported in **Lee et al. [29],** and that the mortality was highest in genetic hydrocephalus and lowest in NTDs.

According to the current study, the death rate rises as the papile grading does. Additionally, newborns with a head circumference greater than 2 SD (P=0.003) and infants with a lower gestational age (P=0.001) had higher fatality rates.

According to multivariate analysis, low managerial age at birth ($P < 0.05$), elevated head circumference > 2 SD, and high IVH grade on cUS were risk factors for death.

This is consistent with **Whitelaw et al. [17]** findings in the literature. Over 50% of deaths were from non-neurological reasons as a result of various prematurity-related problems (e.g., enterocolitis, nosocomial infections) that developed in children with a PHH.

De Vries et al. [22] found that 22% of individuals with a PHH had motor impairment in a series of 95 patients. Of the 6000 patients in a different study by Adams-**Chapman et al. [30],** 14% had cerebral palsy out of the 40% who survived for two years. Patients with permanent VP shunts had a worse outcome. Twenty-three percent of the 400 patients in a prior study by van de **Bor et al. [31]** had motor disability. Regardless of whether IVH was present or not, all of these retrospective studies found that the rate of cerebral palsy was higher when compared to the rate in the cohorts of preterm infants. Nonetheless, a number of studies have noted that the incidence of cerebral palsy increases with IVH grading. This finding could assist to explain why patients with IVH

have smaller brain volumes and worse developmental outcomes.

Regarding the secondary outcomes among the studied patients; where 4 patients (22.2%) had no association of words at 2 years, 1 patient (5.6%) had epilepsy, 2 patients (11.1%) had visual deficiency and 1 patient (5.65) had hearing impairment

Gilard et al. [9] showed that the 77 survivors' GMFCS scores at 2 years old for motor function were 1 in 34 (44.2%), 2 in 27 (35.1%), 3 in 10 (13%), 4 in 3 (3.9%), and 5 in 3 (3.9%) infants. 16 patients (20.8%) were non-ambulatory, and 43 patients had a GMFCS ≥2. Thirty-seven (48.1%) of the 77 survivors at two years old had no word association at 24 months, three (3.9%) had epilepsy, twelve (15.6%) had visual impairment, and six (7.8%) had hearing impairment. One of the 22 children with a PHH passed away from multiple organ failure during the research period. Six, three, and one of the twenty-one survivors had GFCSM scores of two, three, and five, respectively. At 24 months of age, twelve infants had a word association, one had epilepsy, and two had hearing impairment.

The neurodevelopmental outcomes of 484 preterm children born before 32 WG were assessed in a Dutch series by van de **Bor et al. [31].** Of the 294 survivors in this cohort, 45 (15.3%) had a minor handicap at age 2 and 23 (7.8%) had a substantial handicap. A poorer neurodevelopmental outcome was linked to the existence of an IVH. At the age of 14, the same cohort's development was assessed, and 278 of the 304 surviving teenagers' academic performance was recorded **[31].** Of the teenagers in this study, 42 (15.1%) required special education services, 107 (38.5%) were slow learners, and 129 (46.4%) functioned normally. The only factor that was substantially linked to the need for special education was the existence of a prenatal IVH. When comparing patients with grade III/IV and those without IVH, the risk of special education was four times higher. 18 infants (23%) in our cohort had a sensory deficiency, according to **Gilard et al. [9].** Because sensory deficits are linked to subpar academic achievement, they are of interest and need to be identified early.

The intelligence quotient has been used in a number of studies to assess cognitive function in children with hydrocephalic brains **[32].** Hirsch, however, proposed that mainstream school attendance is the best indicator of functional performance **[33].** The NDO results showing the worst outcomes in these aetiologies were supported by the fact that the percentage of children in this series attending special school was highest in genetic and PHH. Consistent with earlier findings that newborns with myelomeningoceles develop and retain enhanced cognition, the study also showed that NTDs had the highest percentage of children attending normal school with support but the lowest percentage entering special school (13.0%). **[33]**. Additionally, this series found that the PHH group had the greatest CP rates (62.6%), most likely as a result of parenchymal infarctions and diffuse post-haemorrhagic brain injury **[34].** Prior research has demonstrated a correlation between the amount of neurological deficits and the number of shunt revisions, which was independently linked to CP **[35].** As anticipated, Mohamed et al. (2021) showed that the risk of epilepsy was much lower in NTDs (11.1%) compared to PHH (43.2%), but it was highest in genetic hydrocephalus (55.2%) because of related cortical abnormalities. **[36]**.

Mohamed et al. [8] revealed that, in line with earlier research by **Heinsbergen et al. [13],** the odds of speech delay were highest in hereditary hydrocephalus, whereas the odds of speech impairment were much lower in congenital and "other" hydrocephalus. This study found that 31.1% of hydrocephalic children had behavioural disorders, which is comparable to the 33% prevalence of behavioural difficulties reported by teachers in studies that employed standardised questionnaires **[37].**

Conclusion: Although it can occur with any grade of intraventricular haemorrhage, our research found that grade III and/or IV haemorrhage are more likely to result in post-hemorrhagic hydrocephalus (PHH), which raises intracranial pressure (ICP). Below are

bulleted lists of the symptoms and indicators of elevated ICP. To help identify deteriorating hydrocephalus, palpate the anterior fontanelle and measure head circumferences every day after a ≥ Grade II haemorrhage is detected on head ultrasonography.

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