Posthemorrhagic hydrocephalus of prematurity outcome

Shunt failure is high when inserted during or immediately following the neonatal period. Overdrainage may be less common in patients with flow-regulated valves. However, if overdrainage is observed, adjusting the setting of a differential pressure valve can effectively treat the overdrainage without the need for invasive shunt revision surgery [1)]

Among preterm neonates with Posthemorrhagic hydrocephalus following severe IVH, elevated CSF hemoglobin, ferritin, and iron were associated with more severe early ventricular enlargement (FOHR > 0.6 vs ≤ 0.6 at first ventricular tap) [2)].

A prospective multi-center cohort included patients with posthemorrhagic hydrocephalus (PHH) who underwent temporary and permanent Cerebrospinal fluid shunt and Bayley Scales of Infant and Toddler Development Third Edition testing around 2 years of age. CSF proteins in the iron handling pathway were analyzed longitudinally and compared to ventricle size and neurodevelopmental outcomes.

Results: Thirty-seven patients met inclusion criteria with a median estimated gestational age at birth of 25 weeks; 65% were male. CSF hemoglobin, iron, total bilirubin, and ferritin decreased between temporary and permanent CSF diversion with no change in CSF ceruloplasmin, transferrin, haptoglobin and hepcidin; and an increase in CSF hemopexin. Larger ventricle size at permanent CSF diversion was associated with elevated CSF ferritin ($p = 0.015$) and decreased CSF hemopexin ($p = 0.007$). CSF levels of proteins at temporary CSF diversion were not associated with outcome, however higher CSF transferrin at permanent CSF diversion was associated with improved cognitive outcome ($p = 0.015$). Importantly, longitudinal change in CSF iron pathway proteins, ferritin (decrease) and transferrin (increase) were associated with improved cognitive ($p = 0.04$) and motor ($p = 0.03$) scores and improved cognitive ($p = 0.04$), language ($p = 0.035$) and motor ($p = 0.008$) scores, respectively.

Longitudinal changes in CSF transferrin (increase) and ferritin (decrease) are associated with improved neurodevelopmental outcomes in neonatal PHH, with implications for understanding the pathogenesis of poor outcomes in PHH [3)].

Infants with posthemorrhagic hydrocephalus are at risk for adverse neurodevelopmental outcomes.. · The parent experience of caring for a child with posthemorrhagic hydrocephalus is not well-described. In this interview study, parents described uncertainty, isolation, and hypervigilance.

· These findings call for structured NICU counseling and longitudinal family supports after discharge [4)].

These patients typically eventually require permanent CSF diversion and are presumed to be indefinitely shunt-dependent.

Loss of sleep-wake cycling, shown by aEEG, has a high positive predictive value for the development

of posthaemorrhagic hydrocephalus (PPH) in preterm infants with IVH; therefore, the study of cerebral background activity and in particular of sleep-wake cycling can be used as an early prognostic tool in patients at risk of PPH [5)].

Since it is evident that posthemorrhagic hydrocephalus of prematurity is associated with long-term effects, such as neurodevelopmental impairments and neuropsychological deficits, the modern perinatal care of preterm infants remains still challenging [6) 7)].

A subset of children with periventricular-intraventricular hemorrhage develop posthemorrhagic hydrocephalus (PHH) with intracranial hypertension, which may lead to reduced consciousness, reduced food intake, and developmental impairments.

Therefore, the focus of care in these children is to avoid posthemorrhagic ventricular dilatation, raised ICP, and hydrocephalus. Surgical treatment for PHH is mostly performed in two steps. For the initial treatment, temporary procedures for cerebrospinal fluid (CSF) drainage can be performed. These include insertion of ventricular access devices, external ventricular drains, and ventriculosubgaleal shunt [8) 9) 10) 11) 12) 13) 14)].

For the definitive treatment of PHH, ventriculoperitoneal shunt implantation is preferred and worldwide accepted method [15) 16)].

Generally, shunt insertion in very premature infants after ventricular hemorrhage is associated with elevated rates of shunt failure and shunt infection compared with older children or adults [17) 18)].

An ICP-correlated aspiration of CSF and ventricular decompression as treatment option of PHH in children was described by [19) 20)] and the efficacy evaluated [21)].

20–50% of infants with periventricular-intraventricular hemorrhage (PIVH) will develop either transient or progressive hydrocephalus (HCP). Grades III and IV are more often associated with progressive ventricular dilatation than are lower grades (however, HCP may develop even after low grade PIVH [22)]). Younger gestational age infants may be at lower risk.

Post PIVH hydrocephalus usually occurs 1–3 weeks after the hemorrhage. Probably caused by cellular debris and/or the toxic e ects of blood breakdown products on the arachnoid granulations (communicating HCP), or by an adhesive arachnoiditis in the posterior fossa or rarely by compression or blockage of critical pathways, e.g. at the sylvian aqueduct (obstruc- tive HCP). In a case of HCP following intra-uterine PIVH, aqueductal gliosis was found at autopsy [23)].

An infant with hydrocephalus which had been diagnosed at birth died at one month of age. Subsequent neuropathological studies demonstrated old germinal matrix haemorrhage and complete occlusion of the aqueduct of Sylvius by fibroglial tissue, both of which appeared to be older than four weeks, indicating that they had occurred in utero. These observations are consistent with the occurrence of intra-uterine intraventricular haemorrhage secondary to haemorrhage of the subependymal germinal matrix, leading to occlusion of the aqueduct of Sylvius and hydrocephalus prior to birth [24)].

1)
Henderson D, Budu A, Zaki H, Sinha S, de Lacy P, McMullan J, Ushewokunze S. A comparison between flow-regulated and adjustable valves used in hydrocephalus during infancy. Childs Nerv Syst. 2020

Sep;36(9):2013-2019. doi: 10.1007/s00381-020-04552-3. Epub 2020 Mar 9. PMID: 32152667.
2)

Mahaney KB, Buddhala C, Paturu M, Morales DM, Smyser CD, Limbrick DD, Gummidipundi SE, Han SS, Strahle JM. Elevated cerebrospinal fluid iron and ferritin associated with early severe ventriculomegaly in preterm posthemorrhagic hydrocephalus. J Neurosurg Pediatr. 2022 May 27;30(2):169-176. doi: 10.3171/2022.4.PEDS21463. PMID: 35916101.
3)

Strahle JM, Mahaney KB, Morales DM, Buddhala C, Shannon CN, Wellons JC 3rd, Kulkarni AV, Jensen H, Reeder RW, Holubkov R, Riva-Cambrin JK, Whitehead WE, Rozzelle CJ, Tamber M, Pollack IF, Naftel RP, Kestle JRW, Limbrick DD Jr; Hydrocephalus Clinical Research Network. Longitudinal CSF Iron Pathway Proteins in Post-Hemorrhagic Hydrocephalus: Associations with Ventricle Size and Neurodevelopmental Outcomes. Ann Neurol. 2021 May 26. doi: 10.1002/ana.26133. Epub ahead of print. PMID: 34080727.
4)

Dorner RA, Boss RD, Burton VJ, Raja K, Robinson S, Lemmon ME. Isolated and On Guard: Preparing Neonatal Intensive Care Unit Families for Life with Hydrocephalus. Am J Perinatol. 2021 Jan 17. doi: 10.1055/s-0040-1722344. Epub ahead of print. PMID: 33454943.
5)

Scoppa A, Casani A, Cocca F, Coletta C, De Luca MG, Di Manso G, Grappone L, Pozzi N, Orfeo L. aEEG in preterm infants. J Matern Fetal Neonatal Med. 2012 Oct;25 Suppl 4:139-40. doi: 10.3109/14767058.2012.714971. Review. PubMed PMID: 22958046.
6)

Botting N, Powls A, Cooke RW, Marlow N (1997) Attention deficit hyperactivity disorders and other psychiatric outcomes in very low birthweight children at 12 years. J Child Psychol Psychiatry Allied Discip 38:931–941
7)

Vohr BR, Allan WC, Westerveld M, Schneider KC, Katz KH, Makuch RW, Ment LR (2003) School-age outcomes of very low birth weight infants in the indomethacin intraventricular hemorrhage prevention trial. Pediatrics 111:e340–e346
8)

Benzel EC, Reeves JP, Nguyen PK, Hadden TA (1993) The treatment of hydrocephalus in preterm infants with intraventricular haemorrhage. Acta Neurochir 122:200–203. https://doi.org/10.1007/BF01405529
9)

Brouwer AJ, Groenendaal F, van den Hoogen A, VerboonMaciolek M, Hanlo P, Rademaker KJ, de Vries LS (2007) Incidence of infections of ventricular reservoirs in the treatment of post-haemorrhagic ventricular dilatation: a retrospective study (1992-2003). Arch Dis Child Fetal Neonatal Ed 92:F41–F43. https://doi.org/10.1136/adc.2006.096339
10)

Chaparro MJ, Pritz MB, Yonemura KS (1991) Broviac ventriculostomy for long-term external ventricular drainage. Pediatr Neurosurg 17:208–212. https://doi.org/10.1159/ 000120599
11)

Gaskill SJ, Marlin AE, Rivera S (1988) The subcutaneous ventricular reservoir: an effective treatment for posthemorrhagic hydrocephalus. Child's Nerv Syst 4:291–295
12)

Lam HP, Heilman CB (2009) Ventricular access device versus ventriculosubgaleal shunt in post hemorrhagic hydrocephalus associated with prematurity. J Mater Fetal Neonatal Med 22:1097– 1101. https://doi.org/10.3109/14767050903029576
13) 17)

Robinson S (2012) Neonatal posthemorrhagic hydrocephalus from prematurity: pathophysiology and current treatment concepts. J Neurosurg Pediatr 9:242–258. https://doi.org/10.3171/2011.12.PEDS11136
14)

Willis B, Javalkar V, Vannemreddy P, Caldito G, Matsuyama J, Guthikonda B, Bollam P, Nanda A (2009) Ventricular reservoirs and ventriculoperitoneal shunts for premature infants with posthemorrhagic hydrocephalus: an institutional experience. J Neurosurg Pediatr 3:94–100. https://doi.org/10.3171/2008.11.PEDS0827
15)

Bock HC, Feldmann J, Ludwig HC (2018) Early surgical management and long-term surgical outcome for intraventricular hemorrhage-related posthemorrhagic hydrocephalus in shunttreated premature infants. J Neurosurg Pediatr 22:61–67. https://doi.org/10.3171/2018.1.PEDS17537
16)

Wellons JC, Shannon CN, Holubkov R, Riva-Cambrin J, Kulkarni AV, Limbrick DD, Whitehead W, Browd S, Rozzelle C, Simon TD, Tamber MS, Oakes WJ, Drake J, Luerssen TG, Kestle J, Hydrocephalus Clinical Research Network (2017) Shunting outcomes in posthemorrhagic hydrocephalus: results of a Hydrocephalus Clinical Research Network prospective cohort study. J Neurosurg Pediatr 20:19–29. https://doi.org/10.3171/ 2017.1.PEDS16496
18)

Wellons JC, Shannon CN, Kulkarni AV, Simon TD, Riva-Cambrin J, Whitehead WE, Oakes WJ, Drake JM, Luerssen TG, Walker ML, Kestle JRW, Hydrocephalus Clinical Research Network (2009) A multicenter retrospective comparison of conversion from temporary to permanent Cerebrospinal fluid shunt in very low birth weight infants with posthemorrhagic hydrocephalus. J Neurosurg Pediatr 4:50–55. https://doi.org/10.3171/2009.2.PEDS08400
19)

Behmanesh B, Bartels M, Gessler F, Filmann N, Seifert V, Setzer M, Freiman TM (2017) Noninvasive transfontanelle monitoring of the intracerebral pressure in comparison with an invasive intradural intracranial pressure device: a prospective study. Oper Neurosurg 13:609–613. https://doi.org/10.1093/ons/opx024
20)

Behmanesh B, Setzer M, Noack A, Bartels M, Quick-Weller J, Seifert V, Freiman TM (2016) Noninvasive epicutaneous transfontanelle intracranial pressure monitoring in children under the age of 1 year: a novel technique. J Neurosurg Pediatr 18:1–5. https://doi.org/10.3171/2016.3.PEDS15701
21)

Behmanesh B, Gessler F, Dubinski D, Quick-Weller J, Cattani A, Schubert-Bast S, Seifert V, Konczalla J, Freiman TM. First clinical experience with the new noninvasive transfontanelle ICP monitoring device in management of children with premature IVH. Neurosurg Rev. 2019 May 11. doi: 10.1007/s10143-019-01105-4. [Epub ahead of print] PubMed PMID: 31079320.
22)

Fishman MA, Dutton RY, Okumura S. Progressive Ventriculomegaly following Minor Intracranial Hemorrhage in Premature Infants. Dev Med Child Neurol. 1984; 26:725–731
23)

Hill A, Rozdilsky B. Congenital Hydrocephalus Sec- ondary to Intra-Uterine Germinal Matrix/Intraven- tricular Hemorrhage. Dev Med Child Neurol. 1984; 26:509–527
24)

Hill A, Rozdilsky B. Congenital hydrocephalus secondary to intra-uterine germinal matrix/intraventricular haemorrhage. Dev Med Child Neurol. 1984 Aug;26(4):524-7. PubMed PMID: 6479474.