



Hydrocephalus temporisation with ventricular reservoir or *trans*-fontanelle ventricular taps for intraventricular haemorrhage of prematurity: A retrospective cohort study

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ABSTRACT

Purpose: Hydrocephalus following intraventricular haemorrhage of prematurity (post haemorrhagic ventricular dilation/PHVD) is one of the most common causes of paediatric hydrocephalus. There is little evidence regarding the role of *trans*-fontanelle ventricular taps (TFVT) as a temporising strategy in the early management of these patients. This study aimed to compare the safety and efficacy of TFVT with the use of a ventricular reservoir/access device.

Methods: A retrospective review of prospectively maintained databases was conducted, including all patients who received a diagnosis of intraventricular haemorrhage or PHVD at the two major neonatal intensive care units in the State of Queensland, Australia between 1st January 2016 to 31st December 2022. Followup data was obtained from review of statewide electronic medical records.

Results: The medical records of 910 low birth-weight infants with intraventricular haemorrhage were screened. Of these, 28 patients underwent placement of a ventricular reservoir and 36 underwent serial TFVT alone.

There were no statistically significant differences in rates of ventriculoperitoneal shunt insertion (83 % vs 75 %, $p = 0.41$). There were no significant differences in mortality or two year Paediatric modified Rankin Scale. No clinically significant intracranial haemorrhages occurred in either group. CSF leak was more common from the ventricular reservoir wound (14 % vs 3 %, $p = 0.02$). There was no significant difference in the incidence of CSF infection between the cohorts (6 % vs 4 %, $p = 0.71$).

Conclusion: This study provides level III evidence to suggest that *trans*-fontanelle ventricular taps may have a similar safety and efficacy profile to the use of a ventricular reservoir.

1. Introduction

Hydrocephalus as a result of intraventricular haemorrhage in premature infants is one of the most common causes of paediatric hydrocephalus in developed countries [1]. Intraventricular haemorrhage affects up to 20 % of premature infants with increasing rates and severity associated with lower gestational age and birth weight [2,3]. This is a major cause of neurodevelopmental disability and frequently necessitates neurosurgical intervention in the form of temporary or permanent cerebrospinal fluid (CSF) diversion to manage associated post-

haemorrhagic hydrocephalus or 'post haemorrhagic ventricular dilation' (PHVD) [4–7]. The complications of definitive operative intervention in this vulnerable population are significant and therefore many strategies have been devised to temporise CSF dynamics. These include lumbar puncture, *trans*-fontanelle ventricular tap, ventricular reservoirs, external ventricular drainage and ventriculosubgaleal shunts [4,7]. All of these strategies have the goal of delaying permanent CSF diversion to allow for the neonate to grow and stabilise, CSF protein and blood load to clear, or even to allow time for the PHVD to spontaneously resolve. A number of these techniques have been directly compared – for example

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the use of ventricular reservoirs vs ventriculosubgaleal shunts or external ventricular drains (EVDs) however each of these techniques require the implantation of prosthetic materials with attendant risks including infection, skin erosion or wound CSF leak [4]. While some literature has explored the role of repeated lumbar punctures these often result in relatively low volumes of CSF drainage compared to other techniques [8]. The option of repeated *trans*-fontanelle ventricular taps (TFVT) has not been directly compared to other techniques in any previous literature. While the relative ease of high-volume CSF drainage and the avoidance of prosthetic implantation or general anaesthetic/reintubation make such a technique attractive, there are concerns regarding the risk of iatrogenic parenchymal injury and/or intracranial haemorrhage resulting from the repetitive passage of a needle.

At the Queensland Children’s Hospital there is relative equipoise between the use of a ventricular reservoir or *trans*-fontanelle ventricular taps in the treatment of neonates with hydrocephalus who are not yet suitable for ventriculoperitoneal shunt placement. New patients with PHVD are allocated to the on-call paediatric neurosurgeon. Approximately half of surgeons prefer the use of a reservoir, while the others do not. This provides the opportunity to compare two similar retrospective cohorts, one with and one without the use of a ventricular reservoir. This has not previously been reported in the neurosurgical literature, and consequently contemporary clinical practice guidelines are not able to make any recommendation for or against the use of such a technique [4]. This study aims to compare the two approaches with respect to early (wound CSF leak, infection, intracranial haemorrhage, probability of shunt insertion) and late (gross developmental outcomes, delayed shunt infection or revision, evidence of parenchymal injury/porencephaly)

complications of the techniques.

2. Methods

A retrospective review of prospectively maintained databases was conducted, including all patients who received a diagnosis of intraventricular haemorrhage or PHVD at the two neonatal intensive care units (NICU) in Brisbane, Queensland, Australia between 1st January 2016 to 31st December 2022. This date range was selected due to the implementation of electronic medical records at both sites at that time and to allow a minimum of two years followup of all patients for their clinical outcomes. These hospitals were selected as neurosurgical services are provided by the visiting neurosurgeons from the Queensland Children’s Hospital – the only quaternary paediatric neurosurgical service in the State of Queensland.

Patients were included in the study if they had undergone a temporising intervention prior to definitive ventriculoperitoneal shunt insertion– *trans*-fontanelle ventricular taps (TFVT) or insertion of a ventricular reservoir. As it is a very rare procedure in this series, cases of ventriculosubgaleal shunt were also included in the ventricular reservoir group. Patients who may have received TFVT prior to insertion of a reservoir (or after removal of an infected reservoir) were dichotomised to the ‘ventricular reservoir’ cohort. In the included institutions, lumbar puncture is not routinely performed in the management of PHVD. Any patient who did not undergo neurosurgical intervention, or proceeded directly to ventriculoperitoneal shunt was excluded. (See Fig. 1).

At the Queensland Children’s Hospital the treatment philosophy is aligned with what has been described as a ‘later intervention or higher

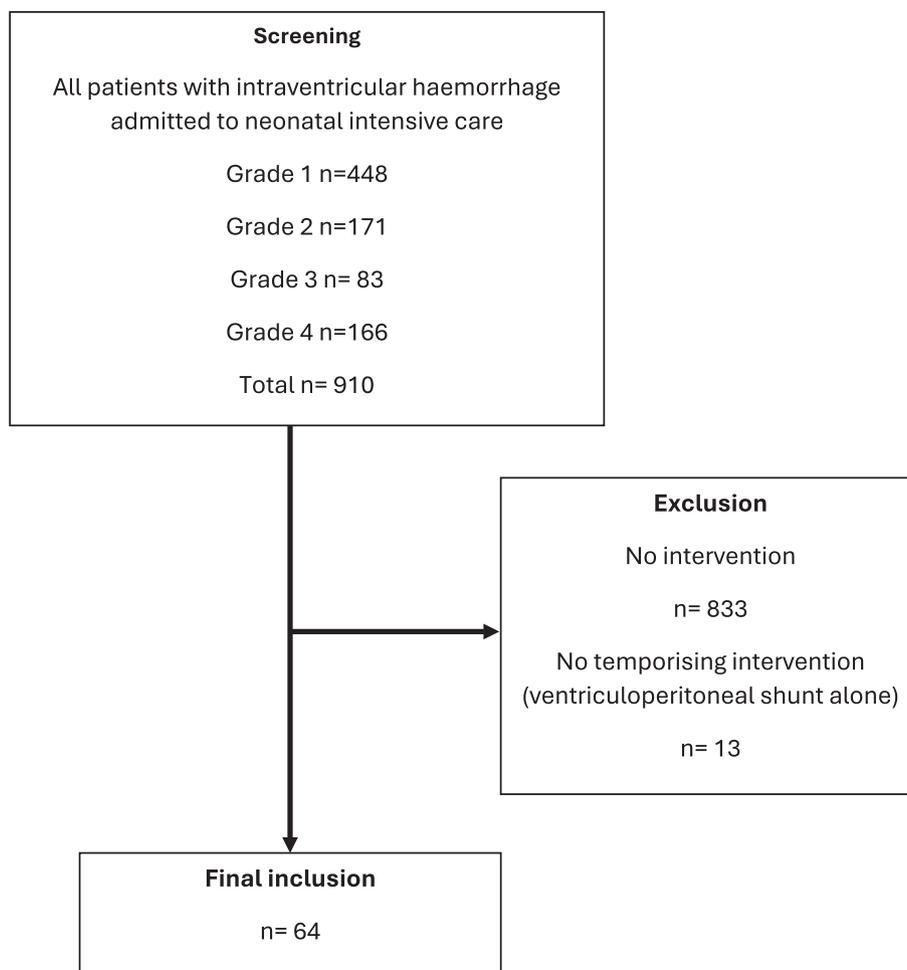


Fig. 1.

threshold' approach [9] where CSF drainage is performed in response to clinical indicators of raised intracranial pressure in patients with a head circumference above the 97th centile + 4 mm line. This threshold was used similarly in both the TFVT and ventricular reservoir groups. TFVT are performed bedside with administration of sucrose solution orally to calm the neonate and the sterile introduction of a 25-gauge needle using a freehand landmark-based technique followed by CSF drainage at a rate of < 2.5 ml/minute until relaxation of the fontanelle is achieved (typically 20–40 ml). The selected landmark for puncture is the lateral apex of the anterior fontanelle in approximately the mid-pupillary line. The needle is introduced in an orthogonal (perpendicular to the skull in all planes) trajectory until CSF drainage is obtained through the needle. Ventricular reservoirs are inserted under general anaesthesia in the operating theatre using a freehand landmark-based technique and an identical infection prevention care bundle as published elsewhere for ventriculoperitoneal shunt procedures [10]. When indicated, ventricular reservoirs are tapped using a 25-gauge needle and CSF drainage until relaxation of the fontanelle is achieved with the same parameters and typical CSF drainage volume as described above for TFVT. Definitive CSF diversion is typically achieved with ventriculoperitoneal shunt insertion when the neonate is at least 2–2.5 kg weight, medically stable and without evidence of active infection.

Data was collected from existing prospectively maintained databases and NICU electronic medical records at the Mater Mothers' and Royal Brisbane and Women's Hospitals, while subsequent followup data was obtained from a review of statewide electronic medical records – with outcomes data obtained from review of paediatric, rehabilitation and neurosurgery outpatient records at the Queensland Children's Hospital.

The primary outcome of interest was probability of shunt insertion. Secondary clinical outcomes were the paediatric modified Rankin Scale (pmRS), complications such as wound infection or CSF leak, cerebrospinal fluid infection and catheter/needle tract haemorrhage. The paediatric modified Rankin Scale (pmRS) is described by Bigi et al (Table 1) [11] and was used as due to the retrospective nature of the data collection few patients had documentation of comprehensive measures such as Griffiths scales. The pmRS was extracted at two years post delivery and at the last available assessment. Complications such as wound infection or CSF leak were included if they occurred prior to discharge from the NICU and related to the temporising procedure or index ventriculoperitoneal shunt. Cerebrospinal fluid infection was defined as a clinical suspicion which resulted in the initiation of antibiotics and (if a shunt or device were present) removal or externalisation of the shunt or device. This included cases where cultures were negative, however the CSF had demonstrated an elevated white cell count and neutrophilia. Catheter/needle tract haemorrhage was defined as any clinically significant haemorrhage resulting in a change in clinical management such as surgical intervention, or a change of selected side for surgery or *transfontanelle* tap.

Secondary radiological outcomes included porencephalic cysts,

Table 1
Paediatric modified Rankin Scale (adopted from Bigi et al).

Score	Definition
1	No symptoms at all
2	No significant disabilities despite symptoms; behaviour appropriate to age and normal further development
3	Slight disability; unable to carry out all previous activities, but same independence as other age- and sex-matched children, according to gross motor function scale
4	Moderate disability; requiring some help, but able to walk without assistance; in younger patients adequate motor development despite mild functional impairment, defined as reduction of 1 level on the gross motor function scale
5	Moderately severe disability; unable to walk without assistance; in younger patients reduction of at least 2 levels on the gross motor function scale
6	Severe disability; bedridden, requiring constant nursing care and attention
7	Dead

ventriculomegaly and slit ventricles and were defined as follows. Frontal porencephalic cyst was any frontal parenchymal cyst with signal following CSF on all sequences, with size > 2 mm. This definition was adopted to reduce inclusion of porencephaly related to the primary haemorrhage, and attempt to capture parenchymal injury relating to needle or catheter tracts or resolved tract haemorrhages. Ventriculomegaly was defined as an Evan's Index > 0.3. Slit ventricles was defined as qualitatively smaller than expected frontal horns of the lateral ventricles, while 'normal calibre ventricles' were all that did not meet these two definitions.

Distribution of continuous data was assessed for normality using Shapiro-Wilks W test. Student's *T*-test was used for continuous data conforming to a normal distribution. Mann-Whitney *U* test was utilized for continuous data not conforming to a normal distribution. Univariate analysis of categorical variables employed Pearson Chi-squared test. Kaplan-Meier survival curves were used to assess the time from birth to shunt insertion. Cases with missing data were excluded casewise from multivariate analysis. Statistical significance was set at $p < 0.05$. All data analysis was performed using SPSS 30 (IBM Corporation, New York, 2024).

Ethical approval was obtained from the Queensland Children's Hospital human research ethics committee (HREC/22/QCHQ/85809). Additional site-specific approvals were obtained from the Mater and Royal Brisbane and Women's Hospitals.

3. Results

During the study period, 910 low birth weight infants received a diagnosis of intraventricular haemorrhage and/or PHVD. 448 grade 1, 171 grade 2, 83 grade 3, 166 grade 4, and data was missing for 42 patients. Of these, 26 patients underwent placement of a ventricular reservoir, 2 underwent placement of a ventriculo-subgaleal shunt, and 36 underwent TFVT alone. 13 patients proceeded directly to ventriculoperitoneal shunt placement without temporizing intervention. (Fig. 1) Patients with ventricular reservoirs underwent a mean of 7 ± 7 (\pm standard deviation) aspirations of the reservoir, while patients without a reservoir underwent a mean of 6 ± 4 TFVT. Of the patients in the ventricular reservoir group 14 neonates had at least one TFVT either prior to the insertion of the reservoir, or after removal of an infected reservoir. The groups had only minor demographic differences, with the patients undergoing TFVT alone born at a slightly earlier gestational age (27.2 ± 3.3 vs 28.4 ± 4.5 ; $p = 0.02$) and with slightly lower Apgars at 1 (4 ± 2.06 vs 4 ± 1.9 ; $p = 0.02$) and 5 (6 ± 2.6 vs 7 ± 1.5 ; $p < 0.001$) minutes post delivery. The cohorts were otherwise similar for neonate and maternal variables of relevance, and mean duration of followup (4.7 ± 3.4 vs 6.2 ± 2.3 years, $p = 0.16$) (Table 2).

There was no significant difference between the cohorts in primary outcome; rates of ventriculoperitoneal shunt insertion (83 % vs 75 %, $p = 0.41$). There were likewise no significant differences in early (6 % vs 4 %, $p = 0.42$), late (15 % vs 4 %, $p = 0.16$) or hydrocephalus related mortality (15 % vs 4 %) between the two groups (Table 3). All mortalities during followup occurred following placement of ventriculoperitoneal shunt, with 2 (6 %) in the TFVT and 1 (4 %) in the reservoir group relating to complications after CSF infection, and the remaining cases relating to shunt obstruction with a decision not to revise the shunt due to existing severe neurological disability. Both cohorts were temporized for a similar duration prior to ventriculoperitoneal shunt insertion: There was no difference between the cohorts in median time from birth to first intervention (Reservoir median 26, 95 % CI 23–71. TFVT median 29, 95 % CI 22–33, $p = 0.44$). There was likewise no significant difference in time from birth to shunt insertion between the cohorts with or without reservoir insertion with a median interval of 98 (95 % CI 85–111) vs 127 (95 % CI 83–171) days ($p = 0.13$) (Fig. 2).

CSF leak from the puncture site occurred in only one patient undergoing TFVT, while CSF leak was more common from the ventricular reservoir wound and occurred in 4 (14 %), $p = 0.02$. There was no

Table 2
Demographics.

Variable	Fontanelle Taps	Ventricular Reservoir	p value
Gestational age at birth	27.2 ± 3.3	28.4 ± 4.5	0.02
Sex	14 female (39 %)	14 female (50 %)	0.37
Apgar 1 min	4 ± 2.6	4 ± 1.9	0.02
Apgar 5 min	6 ± 2.6	7 ± 1.5	<0.001
Vitamin K administered	34 (94 %)	25 (89 %)	0.45
Birth weight (grams)	1106 ± 517	1211 ± 632	0.24
Highest IVH grade			0.72
1	0	0	
2	4 (11 %)	1 (5 %)	
3	12 (34 %)	7 (35 %)	
4	19 (54 %)	12 (60 %)	
Mode of delivery			
Vaginal	12 (33 %)	13 (46 %)	0.37
Caesarian section	24 (66 %)	15 (54 %)	
Maternal Gravidity	2.5 ± 1.7	2.5 ± 1.5	0.60
Maternal parity	1.3 ± 1.8	0.7 ± 0.0	0.17
Maternal smoking	3 (8 %)	2 (7 %)	0.34
Maternal alcohol	4 (11 %)	2 (7 %)	0.26
Maternal hypertension	0	2 (7 %)	0.04
Years of followup	4.7 ± 3.4	6.2 ± 2.3	0.16
Total	36	28	

IVH- intraventricular haemorrhage. Unless otherwise stated presented figures are means ± standard deviations.

significant difference in the incidence of early (during NICU stay) or late (during entire duration of followup) CSF infection between the cohorts. The patients undergoing insertion of a ventricular reservoir were more likely to undergo shunt revisions during followup (1.0 ± 1.4 vs 5.5 ± 8.3, $p = 0.002$). There were no clinically significant intracranial haemorrhages noted during the study period.

There were no significant differences between the groups in clinical outcomes (paediatric mRS) at 2 years of age, or at last recorded followup. Likewise there were no differences in radiological outcomes of porencephaly/degree of parenchymal injury or ventricular calibre (Table 3).

4. Discussion

This study presents the first comparison between TFVT and conventional use of ventricular reservoir devices in the management of intraventricular haemorrhage of prematurity. The key finding is that in the author's institution TFVT appears at least as safe as the conventional tapping of a ventricular reservoir device in both the short term and at 6 years followup. The absence of significant differences in clinical or radiological outcomes between the two cohorts provides limited evidence to suggest that TFVT alone is a reasonable treatment option in the management of these fragile patients while bridging to definitive management of their hydrocephalus. Several statistically significant differences were found favouring TFVT over the use of ventricular reservoir devices. There was a lower rate of CSF leak from the needle puncture of a TFVT than from the surgical incision required for implantation of a reservoir. As CSF leak from a wound often precedes infection, it follows that infection rates associated with implantation of a reservoir may similarly be higher. Whilst a trend in this direction was identified, the result did not reach statistical significance. The rate of shunt revision surgery for any cause was significantly lower in the TFVT group than those managed with a ventricular reservoir. Some of this may be attributable to an increased rate of infection. Since infection and mechanical shunt failure may co-exist, perhaps clinically unrecognized low-grade infections may contribute to a higher rate of mechanical shunt failure. It is likely that although the sample size is 'population

Table 3
Outcomes of temporising CSF management strategies.

Outcomes	Fontanelle Taps	Ventricular Reservoir	p value
Shunt insertion	30 (83 %)	21 (75 %)	0.41
Mortality during NICU	2 (6 %)	1 (4 %)	0.42
Mortality during followup	5 (15 %)	1 (4 %)	0.16
Hydrocephalus related mortality	5 (15 %)	1 (4 %)	0.16
Morbidity			
Wound CSF leak	1 (3 %)	4 (14 %)	0.02
CSF infection (during NICU)	2 (6 %)	1 (4 %)	0.71
Catheter/needle tract haemorrhage	0	0	n/a
Shunt revisions during followup	1.0 ± 1.4	5.5 ± 8.3	0.002
Shunt infection during followup	6 (17 %)	10 (36 %)	0.09
2 year pmRS			
1	0	0	0.23
2	4 (12 %)	0	
3	8 (24 %)	10 (39 %)	
4	5 (15 %)	2 (8 %)	
5	7 (21 %)	8 (31 %)	
6	7 (21 %)	6 (23 %)	
7	2 (6 %)	0	
Last recorded pmRS			
1	0	0	0.11
2	4 (12 %)	0	
3	8 (24 %)	10 (39 %)	
4	5 (15 %)	2 (8 %)	
5	6 (18 %)	10 (39 %)	
6	5 (15 %)	3 (12 %)	
7	5 (15 %)	1 (4 %)	
Radiological outcome – parenchyma			0.58
Frontal porencephalic cyst	8 (22 %)	8 (29 %)	
No frontal parenchymal injury	26 (72 %)	17 (61 %)	
No followup imaging	2 (6 %)	3 (11 %)	
Radiological outcome – ventricular size			0.45
Ventriculomegaly	16 (44 %)	8 (29 %)	
Slit ventricles	10 (28 %)	8 (29 %)	
'normal' ventricles	8 (22 %)	9 (32 %)	
No followup imaging	2 (6 %)	3 (11 %)	
Total	36	28	

NICU – neonatal intensive care unit, pmRS – Paediatric Modified Rankin Scale, CSF- cerebrospinal fluid, ventriculomegaly (Evan's Index > 0.3). Unless otherwise specified presented figures are mean ± standard deviation

level' these events are sufficiently rare that the study is underpowered to detect such a difference in infection rates.

Although no clinically significant intracranial haemorrhages were detected in this series, one concern with the serial TFVT approach is that this would pose a higher risk of haemorrhage than reservoir use. The presence of porencephalic cysts in both cohorts implies that parenchymal injury does occur adjacent to needle or catheter tracts, however these events are clinically occult. Importantly, our case series demonstrates no higher rate of porencephalic cyst with TFVT than that seen with ventricular reservoirs.

There is little previous literature on the use of TFVT and in most series it is grouped together with lumbar puncture – despite having a clearly separate risk profile [8]. It is notable that this technique does not currently warrant a mention in clinical practice guidelines as a treatment option [4]. While other techniques have been assessed in more rigorous prospective clinical trials, the current study represents the highest level (level III) of existing evidence to support this technique, and it may be reasonable to consider a prospective comparison with a more established technique such as the use of ventricular reservoir or ventriculo-subgaleal shunt. There is emerging evidence which would suggest that a more aggressive/earlier intervention approach may lead to more favourable neurocognitive/developmental outcomes in PHVD [12]. The role of TFVT in such an approach is uncertain, as the higher frequency of interventions required under that paradigm may alter the

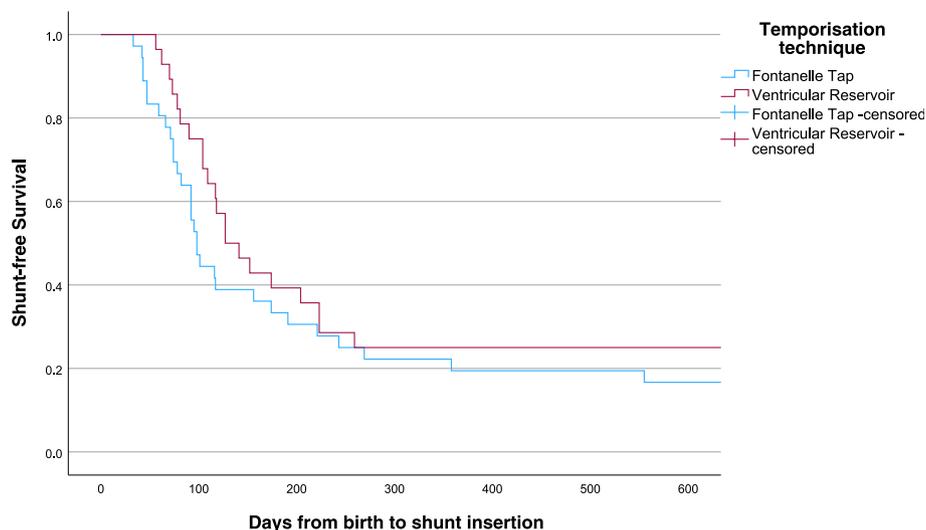


Fig. 2.

risk profile from that presented in this dataset, and if strong evidence favoring that approach continues to emerge TFVT may be rendered a historical technique. A prospective comparison of TFVT with lumbar puncture with an earlier intervention/lower threshold approach would be required to address the relative risks/benefits of the two techniques in that context. The threshold for intervention is indeed the key factor in assessing the generalizability of this dataset. For example, our overall rate of ventriculoperitoneal shunt insertion is quite similar to that reported in other observational series of ‘late intervention’ (up to 92 %), but higher than that in the ‘early intervention’ groups (approximately 40 %) despite demographic similarities in age and grade of intraventricular hemorrhage with our series [5].

There are some subsets of patients where TFVT may have specific advantages, specifically those where a general anaesthetic/reintubation may be particularly problematic relating to the severity of their neonatal lung disease and those with active sepsis where prosthetic implantation should be avoided. Additionally, the cost savings may be very significant when comparing interhospital transfer, operating theatre/anaesthetic time and prosthetics to the costs of a 25-gauge needle and syringe. While this is a minor consideration in many developed countries, in developing nations or isolated neonatal units without ready access to paediatric neurosurgeons such factors are of critical importance. The technique for TFVT is relatively simple and with appropriate training could certainly be performed by neonatologists, especially in a low-resource setting. Further prospective evidence may be best developed in the context of a ‘global neurosurgery’ collaboration [13].

5. Conclusions

This study provides level III evidence to suggest that *trans*-fontanelle ventricular taps may have a similar safety and efficacy profile to the use of ventricular reservoir devices in the temporising management of intraventricular haemorrhage of prematurity when part of a high threshold/late intervention management paradigm.

6. Statements and Declarations

The authors have no relevant financial or non-financial interests to disclose. No funding was received to assist with the preparation of this manuscript.

This project has received approval from the Children’s Health Queensland human research ethics committee (HREC/22/QCHQ/85809).

CRediT authorship contribution statement

Michael J. Stuart: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Adam Burnett:** Writing – review & editing, Writing – original draft, Data curation. **Liam G. Coulthard:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Data curation. **Peter S. Cunningham:** Writing – review & editing, Formal analysis, Data curation. **Pita Birch:** Writing – review & editing, Supervision, Project administration. **Robert AJ. Campbell:** Writing – review & editing, Supervision, Resources, Project administration. **Annabelle M. Harbison:** Writing – review & editing, Data curation. **Craig R. Vonhoff:** Writing – review & editing, Supervision, Methodology, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jocn.2025.111225>.

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