Review Article

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Ventricular lavage in the treatment of ventriculitis in pediatric ventriculoperitoneal shunts: an integrative review

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Introduction/Background: Hydrocephalus is one of the most common neurosurgical conditions in the pediatric population, with ventriculoperitoneal shunt (VPS) as standard treatment. Infectious complications, especially ventriculitis, represent a major therapeutic challenge due to bacterial biofilm formation and limited antibiotic penetration into the CNS. Ventricular lavage (VL) has emerged as a possible adjuvant strategy.
Methods: Integrative literature review following PRISMA guidelines. Search conducted in PubMed, Scopus, Embase, Web of Science, Cochrane, BVS and SciELO using descriptors related to pediatric population, ventricular lavage and CNS infections. Studies published in the last 10 years in English, Portuguese and Spanish were included. After identification of 320 studies, duplicates were removed and screening by title, abstract and full-text reading was performed, resulting in the final inclusion of 9 articles.
Results: The 9 included studies consistently reported favorable outcomes with neuroendoscopic ventricular lavage, including rapid CSF sterilization, reduction of inflammatory parameters, shorter hospitalization, and lower rates of shunt dysfunction and reinfection compared to conventional treatment.
Conclusions: Ventricular lavage represents a promising adjuvant therapeutic strategy in the treatment of ventriculitis associated with VPS in pediatric patients, potentially contributing to better clinical outcomes. However, its incorporation into clinical practice still depends on more robust prospective studies confirming its efficacy and safety.

Keywords: Hydrocephalus; Ventriculoperitoneal shunt; Ventriculitis; Ventricular lavage; Neuroendoscopy; Central nervous system infection.

INTRODUCTION

Hydrocephalus is characterized by pathological accumulation of cerebrospinal fluid (CSF) in the ventricular system, leading to ventricular dilation and increased intracranial pressure. In pediatrics, it constitutes one of the main neurosurgical conditions, resulting from various etiologies such as congenital malformations, intraventricular hemorrhage, infections and tumors [1].

The ventriculoperitoneal shunt (VPS) remains the standard treatment for hydrocephalus. The development of CSF diversion systems resulted from a long historical trajectory, culminating around 1960 in the combination of artificial valves and silicone — a milestone in the management of the condition [2]. The system consists of a unidirectional valve device that diverts CSF from the ventricular system to the peritoneal cavity, restoring the balance between CSF production and absorption [3], [1].

Since its introduction, VPS has promoted an important reduction in morbidity and mortality associated with hydrocephalus. Long-term studies demonstrate overall mortality below 5% after 10 years of follow-up in children treated with VPS [4]. Epidemiological data corroborate this trend: between 1979 and 1998, mortality from congenital hydrocephalus in children in the United States decreased by 66.3%, while acquired forms registered a 67.5% decline in the same period [5].

Despite its efficacy, VPS is associated with relevant complications, especially infectious ones. The incidence of device-related infection can vary between 10% and 20% in pediatric populations, and may reach even higher rates in contexts of lower hospital infection control — a prospective study conducted in a Brazilian public service recorded an infection rate per procedure of 27.6% in children undergoing VPS [6]. A large multicenter prospective cohort confirmed that shunt revisions and younger age are significantly associated with increased risk of CSF shunt infection, reinforcing that infection rates remain a global challenge regardless of healthcare setting [7].

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Among these complications, ventriculitis stands out, frequently caused by biofilm-forming bacteria such as *Staphylococcus epidermidis* and *Staphylococcus aureus*, which adhere to catheter surfaces and hinder infection eradication [8]. Infants under 6 months constitute a particularly high-risk group, presenting significantly higher infection rates than older children, attributed to higher cutaneous bacterial density and selection of coagulase-negative *Staphylococcus* strains with greater adherence capacity in this age group [9].

The management of these infections is complex and generally requires prolonged antibiotic therapy, removal of the shunt system, and external ventricular drainage. Moreover, the blood-brain barrier limits the penetration of various antimicrobials into the CNS, frequently resulting in CSF concentrations below serum levels and potentially insufficient for infection eradication [10]. Bacterial biofilm formation on implanted devices also contributes to greater antimicrobial resistance and persistence of the infectious process.

Faced with these therapeutic challenges, complementary strategies have been investigated. In this context, ventricular lavage (VL) — also called ventricular irrigation or "brain washing" — emerges as an adjuvant therapeutic alternative. The technique consists of irrigation of the ventricular system by endoscopic or non-endoscopic route, allowing removal of inflammatory debris, proteins, purulent material and microorganisms present in the CSF, potentially reducing the infectious burden and improving clinical outcomes.

Despite growing interest in this approach, the available scientific evidence is still limited and heterogeneous, composed mainly of case series and observational studies, with a scarcity of well-structured systematic reviews on the topic, especially in the pediatric context. In this scenario, the present study aims to analyze, through an integrative literature review, the use of VL in the management of ventriculitis in pediatric patients undergoing VPS, with emphasis on its efficacy, safety and impact on clinical outcomes.

MATERIALS AND METHODS

Study Design: This is an integrative literature review conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, with the objective of ensuring transparency, reproducibility and methodological rigor throughout all stages of the study.

PICO Strategy: The research question was structured using the PICO strategy, a methodology recommended in evidence-based practice for delimiting the scope of the search and maximizing evidence retrieval [11]:

Population (P): children and infants with ventriculitis, particularly associated with VPS

Intervention (I): ventricular lavage (neuroendoscopic lavage, ventricular washout, brainwashing)

Comparison (C): conventional treatment without ventricular lavage (antibiotic therapy alone, external ventricular drainage)

Outcomes (O): reduction of morbimortality, infection control, decreased need for shunt revisions and improvement of neurological outcomes

Research question: Does ventricular lavage contribute to improved clinical outcomes and reduction of complications associated with ventriculitis in children undergoing VPS?

Databases and Search Strategy: The bibliographic search was conducted in: PubMed, SciELO, Web of Science, Scopus, Embase, Cochrane Library and Biblioteca Virtual em Saúde (BVS). The search strategy was adapted according to the specific language of each database, using terms in English, Portuguese or bilingually. Controlled descriptors (MeSH/DeCS) and free terms were combined with Boolean operators AND and OR: (("child" OR "children" OR "pediatric*" OR "infant*" OR "neonate*" OR "preschool*") AND ("neuroendoscopic lavage" OR "ventricular lavage" OR "ventricular irrigation" OR "ventricular washout"

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OR "brain washing") AND ("ventriculitis" OR "ventricular infection" OR "VP shunt infection" OR "infectious hydrocephalus" OR "meningitis")). Searches were conducted without initial restriction on study design.

Study Selection Process: Study screening was performed in four stages: (1) title reading to identify potentially relevant studies; (2) abstract reading to exclude articles not meeting inclusion criteria; (3) full-text reading of selected studies to confirm eligibility; (4) data extraction from included studies covering author, year, study type, sample size, methodology, main results, conclusions and limitations. Study screening and selection were performed independently by two reviewers at each stage. Disagreements between the reviewers were resolved by consensus; in the event of persistent disagreement, the case was to be referred to a third academic reviewer for arbitration, although no such situation occurred during the process. The Rayyan® platform was used to organize records, identify duplicates, and support blinded screening between reviewers.

Data extraction was conducted by the lead author using a standardized spreadsheet, with the support of the Rayyan® platform for reference management and screening throughout the process. The extracted variables included author, year of publication, study type, sample size, methodology, level of evidence, main results, conclusions, and limitations.

Data Synthesis: Given the methodological and clinical heterogeneity of the included studies — which varied in design, sample size, age range, causative microorganisms, and technical aspects of the intervention — a quantitative synthesis (meta-analysis) was not considered appropriate. Therefore, the results were synthesized qualitatively through a narrative and descriptive approach, organizing the findings according to the type of study, the characteristics of the ventricular lavage technique, and the reported clinical outcomes (microbiological cure, mortality, length of hospital stay, and shunt-related complications). This approach allowed for the comparison and integration of evidence from studies with distinct designs, consistent with the methodological nature of an integrative review.

Inclusion criteria: studies on ventricular lavage in pediatric patients with ventriculitis associated with VPS, published in the last 10 years, in English, Portuguese or Spanish.

Exclusion criteria: studies exclusively in adults, case reports without comparative data, reviews without primary data.

RESULTS

From database searches, 320 records were identified and exported to the Rayyan® platform for screening. After removal of duplicates (n = 163), 157 studies remained for analysis. At the title and abstract screening stage, 142 articles were excluded for not meeting inclusion criteria, leaving 15 studies eligible for full-text reading. At the eligibility stage (full-text review), 6 articles were excluded for not meeting the methodological and eligibility criteria. At the end of the process, 9 studies were included in this integrative review (Figure 1).

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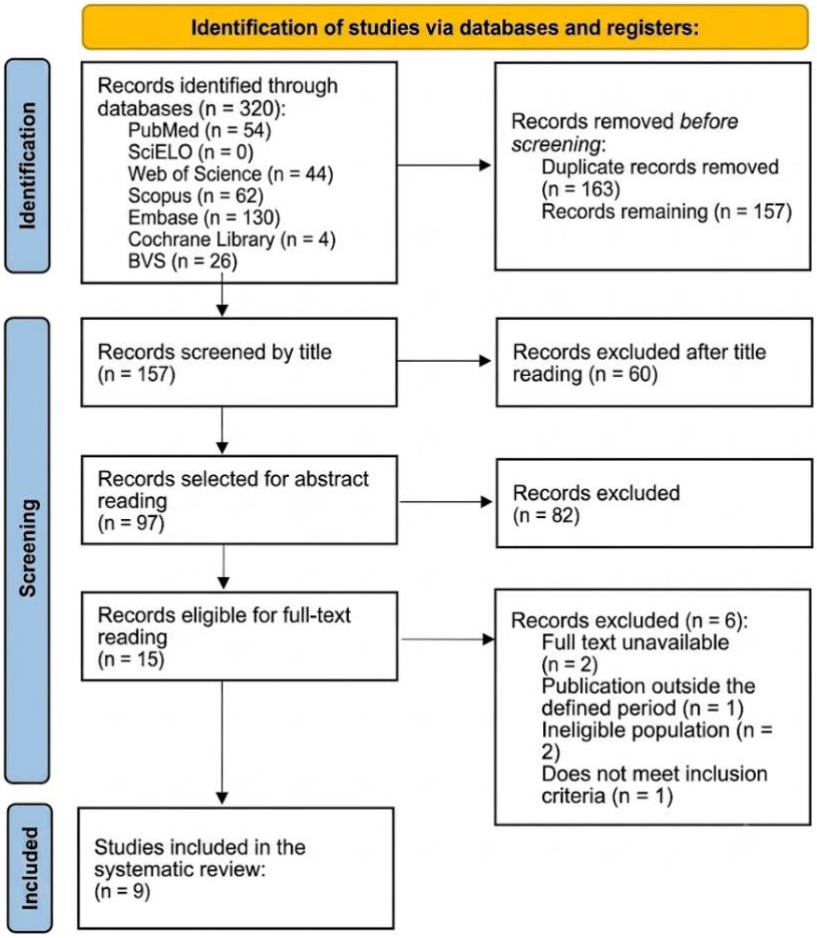

Figure 1 - Flowchart of the selection process for the studies included in the integrative review.

The main characteristics of the included studies — title, year, study type, level of evidence and summary of main findings — are presented in Table 1.

Table 1. General characteristics of included studies

Study	Year	Study Type	Level of Evidence	Main Findings
Terada et al. [17]	2016	Retrospective comparative cohort	Level 2	Neuroendoscopic ventricular irrigation is safe and effective in the treatment of ventriculitis
Abdala-Vargas et al. [21]	2024	Case series	Level 4	Neuroendoscopic ventricular lavage is a useful tool in the management of VPS-associated ventriculitis, with better microbiological isolation and potential functional impact
Maldonado Alejos et al. [22]	2020	Case report	Level 4	Neuroendoscopic ventricular lavage associated with systemic and intraventricular antibiotics proved effective and safe in the treatment of severe ventriculitis by a resistant pathogen in an infant

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Tandean et al. [23]	2018	Case report	Level 4	Neuroendoscopic aspiration and lavage were effective and safe for treatment of intraventricular empyema secondary to device infection in infants, with rapid clinical resolution, CSF sterilization and reduced hospitalization time
Ochoa et al. [24]	2021	Retrospective case series + literature review	Level 4	Neuroendoscopic ventricular lavage allowed rapid CSF sterilization and significant improvement of inflammatory parameters in children with pyogenic ventriculitis, proving to be an effective and minimally invasive approach
Gaderer et al. [19]	2018	Retrospective comparative cohort	Level 2	Neuroendoscopic lavage is safe and effective in the treatment of post-infectious hydrocephalus in children, significantly reducing reinfection and shunt revision rates compared to conventional treatment
Qin et al. [18]	2020	Case report + literature review	Level 4	Neuroendoscopic ventricular lavage was safe and effective for ventriculitis control, with rapid clinical and radiological resolution
Hect et al. [20]	2023	Retrospective case series	Level 4	Serial neuroendoscopic lavage was effective in reducing CSF protein and bacterial burden in infants with Gram-negative rod ventriculitis, associated with infection eradication and potential reduction in device failure risk
Kumar, Agrawal and Sharma [15]	2016	Retrospective case series	Level 4	Endoscopic lavage is an effective strategy as therapeutic rescue in severe purulent Gram-negative multidrug-resistant ventriculitis refractory to IV and intrathecal antibiotics

DISCUSSION

Hydrocephalus is a serious neurological condition associated with symptoms that significantly compromise patients' quality of life. Over recent decades, the development of CSF diversion systems represented a milestone in the management of this condition, especially in pediatric patients. VPS has consolidated itself as the most widely used surgical modality, contributing expressively to the reduction of mortality and morbidity in this population [3, 1].

Despite the technical advances obtained over time, complications associated with VPS remain a relevant clinical challenge. Among them, mechanical dysfunctions and infections continue to be the most frequent, and may manifest at any time during patient follow-up [12]. Infectious complications, in particular, deserve special attention, as their management is complex and multifactorial. Large multicenter data confirm that infection rates remain high across different healthcare settings and that no single preventive strategy has proven universally effective [7].

The treatment of post-VPS infections is conventionally based on prolonged antibiotic therapy combined with removal of the infected device and installation of external ventricular drainage. However,

this protocol faces important limitations: bacterial biofilm formation on implanted components reduces antimicrobial efficacy, while restricted antibiotic penetration into the CNS hinders adequate control of the infectious process, favoring its persistence and recurrence [8]. In this scenario, intraventricular antibiotic administration has been explored as an adjuvant route; a multicenter retrospective cohort reported a CSF sterilization rate of 88.4% with intraventricular antimicrobials, and noted that early administration was associated with better outcomes, although standardized protocols are still lacking [13].

Faced with these limitations, endoscopic VL has been investigated as a complementary strategy in the therapeutic arsenal for VPS-associated ventriculitis. Reports contemplating its use in the literature are still scarce, which limits the consolidation of robust evidence on its clinical applicability.

In this context, although limited to the description of the technique and not included in the results of this review, the study by Dezena et al. (2023) characterizes VL as a neglected approach. The authors highlight its practical relevance especially in developing countries — where access to conventional endoscopy is restricted — and describe the technique in a systematized manner, concluding that it represents a viable alternative to improve the prognosis of intraventricular infections and hemorrhages [14].

Kumar, Agrawal and Sharma (2016), in a series of seven cases, observed microbiological eradication in all patients submitted to VL, with clinical cure achieved in 86% of them. This finding reinforces the potential of the technique as an adjuvant strategy, although the fatal outcome recorded in one patient, attributed to white matter edema after infection resolution, evidences that morbimortality in this context is not reduced exclusively to infectious control. From a pathophysiological standpoint, the authors attribute the efficacy of VL to its capacity to promote complete drainage of infected CSF, with consequent significant reduction of the infectious burden and elimination of intraventricular infection foci. This mechanism would potentiate the action of intravenous and intrathecal antibiotics, configuring a combined strategy potentially superior to passive drainage via isolated external ventricular drainage [15].

Al Menabbawy et al. (2020), in a prospective controlled study of 33 patients with cerebral ventriculitis, reported better functional outcomes (modified Rankin Scale < 3 in 68.8% vs. 23.5%; $p < 0.05$) and shorter hospital stay (20.5 vs. 39.7 days; $p < 0.05$) with ventricular irrigation/lavage versus conventional drainage plus antibiotics, providing the strongest controlled evidence to date in favor of the technique [16].

Other studies reinforce these findings. Terada et al. (2016), comparing neuroendoscopic ventricular irrigation with conventional treatments for ventriculitis, observed better clinical outcomes in the endoscopic group, including lower mortality and shorter ventricular drainage catheter dwell time [17]. Convergent results were described by Qin et al. (2020), who reported significant clinical improvement after VL in patients with ventriculitis associated with intraventricular rupture of brain abscess [18].

In line with these results, Gaderer et al. (2018), in a comparative study, demonstrated that patients submitted to endoscopic lavage presented lower rates of valve dysfunction and reinfection compared to those treated exclusively with external ventricular drainage [19]. The consistency of these findings across different groups and clinical contexts strengthens the hypothesis that VL offers benefits that transcend isolated microbiological control.

Corroborating this perspective, Hect et al. (2023) report that incorporation of serial neuroendoscopic lavage as a supplement to standard treatment can contribute to relief of acute manifestations of CSF infection, including reduction of microorganisms, infectious debris and inflammatory cells, as well as reducing hospitalization time and accelerating resolution of the infectious process. The authors further highlight the potential benefit of this approach in the treatment of persistent hyperproteinorrachia, a complication that may persist even after clinical resolution of severe ventriculitis [20].

Regarding the solution used during the procedure, Abdala-Vargas et al. (2024) describe Ringer's lactate as the most frequently employed in endoscopic ventricular lavages. However, the concomitant use of intraventricular antibiotics remains controversial, with no consensus in the literature regarding its indication, dosage or clinical efficacy [21].

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Similarly, Maldonado Alejos et al. (2020), in a case report of an infant with severe ventriculitis by a resistant pathogen, described resolution of infection after neuroendoscopic lavage associated with systemic and intraventricular antibiotic therapy, reinforcing the viability of the technique even in difficult-to-manage cases [22]. A similar result was reported by Tandean et al. (2018), who observed CSF sterilization and reduced hospitalization time after neuroendoscopic aspiration and lavage of intraventricular empyema secondary to VPS infection in infants [23]. Ochoa et al. (2021), in a retrospective case series associated with literature review, reported rapid CSF sterilization and significant improvement of inflammatory parameters in children with pyogenic ventriculitis, classifying neuroendoscopic VL as an effective and minimally invasive approach [24].

Despite the promising results presented by different groups, endoscopic VL is not yet formally recognized as a first-choice technique in the management of VPS-associated infections. This gap stems mainly from the scarcity of studies with representative samples and standardized methodology, which hinders the formulation of high-grade evidence-based recommendations. Nevertheless, the available findings are consistently favorable to the technique and suggest that its early adoption may positively impact the clinical outcomes of these patients.

Limitations

This integrative review presents limitations that should be considered when interpreting its findings. The most relevant limitation concerns the quality and design of the available evidence. The majority of the included studies were case reports and retrospective case series, with only two retrospective comparative cohorts and no randomized controlled trials. As a result, the body of evidence is predominantly of low methodological quality (Level 4), which limits causal inference and increases the risk of selection and reporting bias, since favorable outcomes are more likely to be published than negative or inconclusive ones.

The small and heterogeneous samples constitute an additional limitation. The included studies involved variable numbers of patients, different age ranges within the pediatric population, distinct causative microorganisms, and diverse clinical severities, which hampers direct comparison between them and precludes the pooling of data through meta-analysis. This clinical and methodological heterogeneity also extends to the intervention itself: the technique of ventricular lavage was not standardized across studies, varying in terms of route (endoscopic versus non-endoscopic), type of irrigation solution, volume and frequency of lavage, and the concomitant use of intraventricular antibiotics, making it difficult to define an optimal protocol.

There are also limitations inherent to the review process. Although the search strategy was structured according to PRISMA guidelines and conducted across multiple databases, the restriction to studies published in the last ten years and in English, Portuguese and Spanish may have excluded relevant publications in other languages or time periods. Furthermore, as is characteristic of integrative reviews, no formal critical appraisal instrument or quantitative assessment of risk of bias was applied to the included studies, and the absence of a meta-analysis means that the synthesis remains essentially qualitative and descriptive.

Finally, the scarcity of long-term follow-up data limits conclusions regarding the durability of the clinical benefit, the impact on neurodevelopmental outcomes, and the late complications potentially associated with the technique. Taken together, these limitations reinforce that the present findings should be interpreted as preliminary and hypothesis-generating, underscoring the need for prospective, multicenter, and ideally randomized studies to confirm the efficacy and safety of ventricular lavage in this population.

CONCLUSION

The present review allowed us to conclude that VL constitutes a promising therapeutic alternative in the management of ventriculitis in pediatric patients undergoing VPS. The technique demonstrated

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potential to improve infection control, reduce complications related to the shunt system and contribute to better clinical outcomes, especially in scenarios of refractory infection.

However, the available scientific evidence is still limited by small samples, absence of randomized studies and methodological heterogeneity, which restricts the consolidation of standardized clinical recommendations. Thus, although the results are encouraging, the broad incorporation of VL into pediatric neurosurgical practice still depends on the conduct of more robust studies. Until such evidence is available, the use of the technique should be considered individually, as an adjuvant strategy in selected cases.

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DISCLOSURES

Ethical approval

This study is an integrative review of the literature based exclusively on previously published and publicly available data. As it did not involve human participants, animals, or the collection of any identifiable personal information, ethics committee approval and informed consent were not required. In accordance with the principles of the Declaration of Helsinki, all sources used were appropriately cited and the academic integrity of the original works was respected throughout the review.

Conflict of interest

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Artificial intelligence

The authors affirm that no artificial intelligence tools were used in the writing, editing, or content generation of this manuscript.

Author Contributions (CRediT)

Carolina P. Kolberg: Conceptualization; Data curation; Formal analysis; Methodology; Writing – original draft.

Matheus Ballestero: Conceptualization; Formal analysis; Investigation; Supervision, Writing – review & editing.)

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