REVIEW

Ro J Pediatr. 2024;73(1)
DOI: 10.37897/RJP.2024.1.10

A systematic review of post-operative infections in pediatric ventriculoperitoneal shunt cases

Farhad Bal'afif[1], Tommy Alfandy Nazwar[1,2], Donny Wisnu Wardhana[1], Prisca Anindhita[3], Abdo Rouf El Shadawi[4], Hatim Sultan[5], Mochamad Bashir[5], Mustofa Mustofa[1]

[1]General Surgery Study Program, Saiful Anwar Hospital, Malang, Indonesia
[2]Faculty of Medicine, Brawijaya University, Indonesia
[3]Department of Pediatric Surgery, Brawijaya University, Malang, Indonesia
[4]Department of Microbiology and Parasitology, Medical Faculty, Gharian University, Libya
[5]Medical Center, Sebha University, Sabha, Libya

ABSTRACT

Background. Hydrocephalus is a prevalent condition in children, affecting both developed and developing countries. Neurosurgical interventions such as ventriculoperitoneal shunts are common, but are associated with a high risk of complications, including infections, which can lead to additional issues and costs. This study aims to review the incidence of infection in pediatric patients before and after ventriculoperitoneal shunt placement, in order to address this issue.

Methods. A standard process of analyzing scientific questions using the Population, Intervention, Control, and Outcome (PICO) method was used to develop a protocol for searching research articles in online databases such as PubMed, Cochrane, POPLINE, and ScienceDirect. The articles selected for inclusion in this study met the following criteria: 1) described interventional ventriculoperitoneal shunt placement in pediatrics, 2) focused on cases of ventriculoperitoneal shunt complications with a focus on infection, 3) were published within the last 10 years, and 4) were published in English-language journals with peer review standards.

Results. Sixteen articles were identified for review. Seven of these articles mentioned surgical or mechanical interventions as a means of preventing infections, while six articles discussed medical treatment for infection prevention. Three articles described the microorganisms found in cerebrospinal fluid.

Conclusion. Future studies should focus on the issues related to ventriculoperitoneal shunt complications and interventions related to immunological, neuroendocrine, and biophysical factors to prevent infections, as well as surgical management and medication administration.

Keywords: infection, pediatrics, ventriculoperitoneal, shunt, cerebrospinal fluid

INTRODUCTION

The number of hydrocephalus cases worldwide varies widely; the incidence of hydrocephalus in the United States is estimated to be between 0.5 and 4 per 1000 live births. The prevalence of hydrocephalus ranges from 0.2 to 4 per 1000 live births. Hydrocephalus affects 0.2 out of every 1000 births in Japan. In Indonesia, approximately 2 cases of hydrocephalus are born every 1000 births (Al-Tamimi, et al. 2014).

In pediatric patients with spina bifida, intraventricular hemorrhage, possible hydrocephalus, or fluid space collections, Shunts are the preferred course of action, and their utilization can lower mortalityfrom this situation. Infection of the ventriculoperitoneal shunt is one of the most frequent conditions seen in pediatric surgery. If not treated right away, it can be fatal, especially in children.

However, there are numerous agents that can cause infection. Cerebrospinal fluid (CSF)-related infection is one of the most serious infections treated by neurosurgeons (Sahu 2009). According to studies, the prevalence of all shunt's ranges between 5 and 39% (Conen A, 2008; Kumar R, 2005), and 36% of

Corresponding author:
Farhad Bal'afif
E-mail: nsubfarhad@gmail.com

Article History:
Received: 22 December 2024
Accepted: 30 March 2024

children develop hydrocephalus due to infectious etiology (Kumar, 2005).

As a result, pathologists and microbiologists must pay close attention. The author would like to conduct a literature review on the incidence of ventriculoperitoneal shunt infection in pediatrics over the last ten years. The aim of this research is to expand on the literature review and possibly find appropriate therapies for the various infectious agents discussed below.

METHODS

Research questions and search strategie

The analysis of the study questions this time was carried out using the Population, Intervention, Comparison and Outcome (PICO) formula. Cases of infectious complications due to ventriculoperitoneal shunt treatment in children are an important concern for neurosurgery clinicians. So, in this study, namely: How did the incidence of Ventriculoperitoneal Shunt infection in pediatrics during the last 10 years occur? (P: pediatrics who met the criteria for infection after VPS, I: Ventriculo peritoneal Shunt (VPS), C: not infected, O: Safety or side effects) Analysis of the study questions was carried out using the Population, Intervention, Comparison and Outcome (PICO) formula. Cases of infectious complications due to ventriculoperitoneal shunt treatment in children are an important concern for neurosurgery clinicians. So, in this study, namely: How did the incidence of Ventriculoperitoneal Shunt infection in

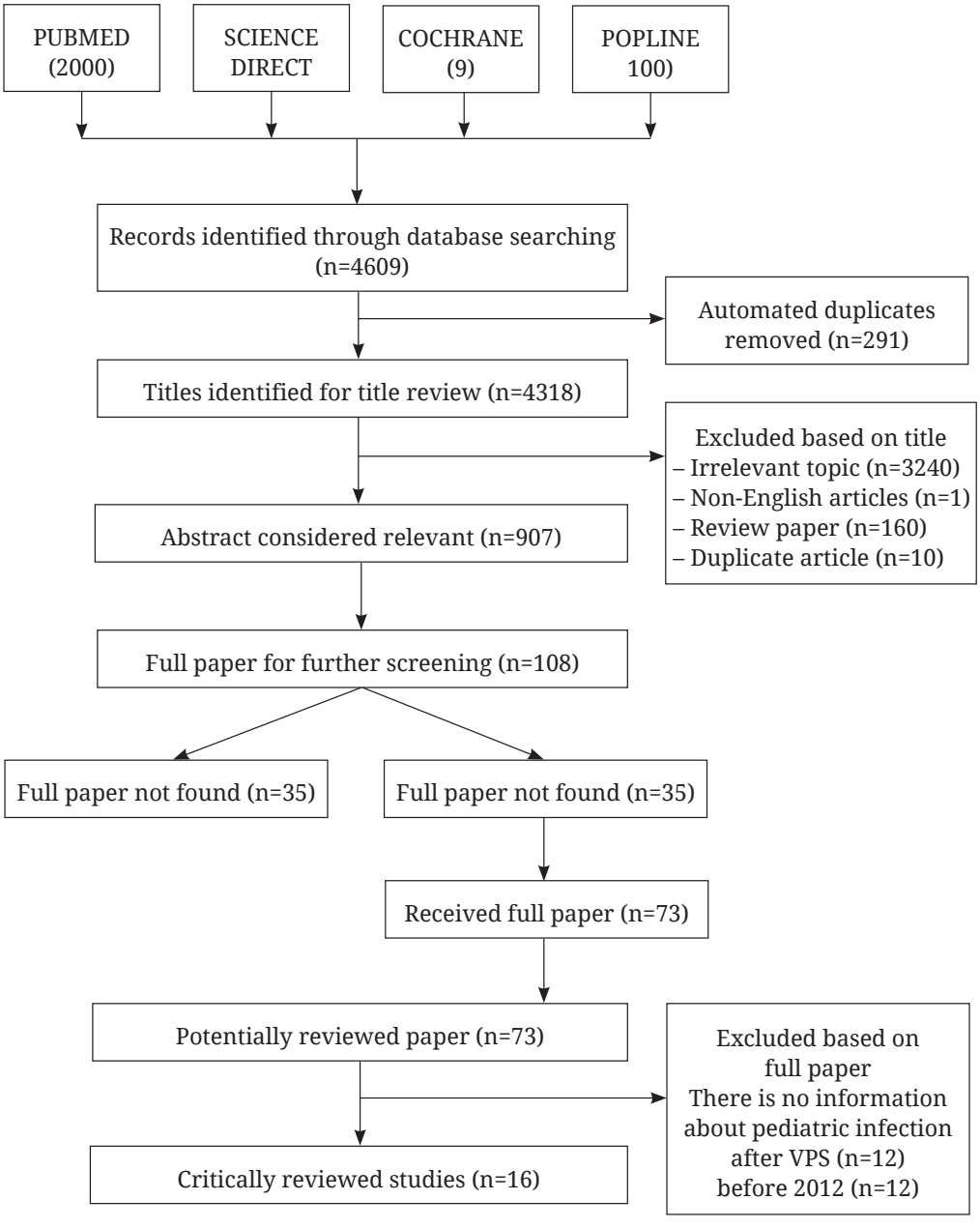

FIGURE 1. Flowchart for the inclusion and exclusion criteria in comprehensive research of pediatric ventriculoperitoneal shunt infection

pediatrics during the last 10 years occur? (P: pediatrics who meet the criteria for infection after VPS, I: Ventriculo peritoneal Shunt (VPS), C: not infected, O: Safety or side effects)

A systematic review search was conducted with reference to the last 10 years of studies by identifying studies describing cases of VPS infection in pediatrics. Literature searches were performed via PubMed, ScienceDirect, Cochrane, and POPLINE. The search strategy was carried out by using a combination of several keywords: Pediatrics, infection, ventriculoperitoneal, shunt.

Inclusion and exclusion criteria

Inclusion criteria: Studies that describe cases of ventriculoperitoneal shunt infection in pediatric patients. Studies that report an infectious state with gram-positive bacteria or the finding of microbes or contain quantitative results. Studies published in English peer-reviewed journals. Studies published between 2012 and 2022.

Exclusion criteria: Studies that do not describe cases of ventriculoperitoneal shunt infection in pediatric patients. Studies that do not report an infectious state with gram-positive bacteria or the finding of microbes or contain quantitative results. Studies published in non-English or non-peer-reviewed journals. Studies published before 2012. Articles detailing single participant case studies.

Identification of relevant studies and data extraction

Articles were reviewed by all authors between August 2021 and September 2022. The search was restricted to publications published within the previous ten years, or from 2012 to 2022. Potential papers were initially evaluated based on their titles, and then they were evaluated based on their abstracts. A thorough review of pertinent research was done while keeping the inclusion criteria in mind. From the articles they have reviewed, all authors have taken extensive studies.

Quality appraisal

The Newcastle-Ottawa approach for cohort research is required to conduct a critical evaluation in order to assess the validity and reliability of the chosen articles. Following the tabulation of 16 papers, each study's selection, comparability, and outcome (Lo, ckl, 2014) were reviewed. As a quality assessment, quality appraisal data is included into the results table.

Data analysis

Following the exclusion process, the selected results are entered into the RevMan software, which tabulates the data to produce the output of forest plot and funnel plot data. The main data were extracted and tabulated based on the required variables, namely data; demographics, number of samples, subject data, type of research, results of CSF culture, surgical intervention, and medical intervention, and then quality assessment.

RESULT

VPS Infection on Children

A total of 4318 reports were initially screened by title and abstract, 907 of which were taken for full-text evaluation. A total of 108 reports were included in the systematic review. From 108 articles screened back to 51 articles are demographic descriptions of infection and CSF. Then as many as 16 research articles focused on VPS infection in pediatric cases. So that the 16 study articles were used as choices for in-depth discussion.

The results of the demographic study of cases of ventriculoperitoneal shunt infection in pediatrics obtained as many as 16 articles with a retrospective and cohort research design. The data of retrospective research studies are sorted from 2012 to 2021.

Cases of shunt infection in 2012 with 3 results, namely 1) 16 cases from 203 samples, 2) 58 cases from 979 samples, and 3) In the 2013 study there were 71 cases from 1404 samples.

The 2014 study had two results: 1) 135 cases out of 500 samples, 2) 13 cases out of 90 samples.

Then the study in 2015 there were 28 cases of infection from 384 samples.

The study in 2016 contained 24 cases from 246 samples.

The study in 2017 contained 305 cases of infection from 1357 samples.

The study in 2018 showed that there were 50 positive cases and in 2019 there were 30 out of 50 samples.

The 2019 study had 4 results, namely 1) 3 cases of infection from 78, 2) pre and post study 36 infected from 511, then 3) infected 93 out of 103 and 4) 4 cases out of 14.

The 2020 study showed 19 cases of infection from 593 and in 2021 there were 68 cases of infection from 148 cases.

Microorganisms from cerebrospinal fluid (CSF) culture

A total of sixteen articles were found for review. Seven articles mention surgical or mechanical intervention as infection prevention. A total of 6 articles mention advice on medical treatment to minimize infection. Three articles describe and mention microorganisms in cerebrospinal fluid.

A total of 6 studies presented cerebrospinal fluid cultures after ventriculoperitoneal shunts. *S. aureus* (n=3), *S. Epidermidis* (n=4), *Stahpylococcus haemo-*

lyticus (1), methicillin sensitive *staphylococcus aureus* (n=2), Gram negative bacilli (n=4), staphlyocoocus spp coagulase negative (1), methicillin-resistant *staphylococcus aureus* (n=3), post-protocol organisms *Streptococcus mitis* (1), *Streptococcus anginosus* (1), *Cutibacterium acnes* (1), *Escherichia co*li (n=3), *Enterococcus* (n=2), *Enterococcus faecalis* (1), *Propionibacterium acnes* (1), *Enterobacter cloacae* (1), *Serratia, listeria* (1), *mycobacterium tuberculosis,* cytomegalievirus (1), Kelsiella, Extended spectrum beta-lactamase (1), *Acinetobacter baumanni* (1), *Haemophilus infuenzae* (1), *Neisseria meningitidis* (1), *Pseudomonas aeruginosa* (1), Salmonella, Beta-haemolytic streptococcus (1), unknown (1).

TABLE 1. Characteristics of inclusion studies

No	Study	N	Age	Number of cases	Cerebrospinal Fluid Cultures	Intervention	
						Surgical	Conventional
1	Thomale, 2012	203	0-27	infect (16) non infect (187)	no info	recommend employing gravity and differential pressure valves in hydrocephalus situations	no info
2	Rogers, 2012	979	–	shunt infection 58, no infection 921	Cohort	no info	no info
3	Hommelstad, 2012	1404	>1	1333 non infect, 71 infected Patient Material A = 31/477 Patient Material B = 40/927	In Patient A, 45% of infections were caused by coagulase-negative staphylococci. In Patient Material B, most common *Staphylococcus aureus,* causing 35% from infection; infection caused by coagulase-negative staphylococci reduced to 22%	no info	preoperative wash: 4% chlorhexidine gluconate, chlorhexidine shampoo, 5% chlorhexidine gluconate in ethanol solution, antibiotic-infused shunt material (Bactiseal®)
4	Romero, 2013	47	–	infected 8	*Escherichia coli*	no info	no info
5	James, 2014	500	infants aged 0-6 months was 12.2%, and in infants aged 7-12	Infected 135 non infected 365	of causative organisms was coagulase-negative staphylococcus (51.9%), *Staphylococcus aureus* (31.6%), streptococcus or enterococcus spp. (8.8%), gram-negative organisms (4.4%), and Propionibacterium acnes (2.2%). Organisms responsible for infections in AIS were *S. aureus* (40%), followed by streptococcus or enterococcus spp. (20%), *P. acnes* and coagulase-negative staphylococcus	no info	The use of an Antibiotic-Impregnated Shunt (AIS) catheter appears to significantly increase the rate of shunt infection in the general pediatric and neonatal population, and is not associated with infection with antibiotic-resistant organisms
6	Wang, 2014	90	90 patients with IVH and PHH	VPS (44) = infect 13 non infect 31	no info	Reduce leakage even further by emptying the subgaleal bag prior to scalp closure, carefully sealing the waterproof skin, and avoiding pressure on the wound with a cap or respirator	no info

7	Wu, 2015	384	The infection rate of ventriculo-peritoneal (VP) shunt was 12.5% in 2006, dropped to 2% and stabilized at a lower level from 2008	VP infection (%) (n = 28) non-infection (%) (n = 356)	*S. aureus, S. epidermidis* and *Staphylococcus haemolyticus*	removing the foreign body equipment from the body allowed 82% of patients to live by skipping intravenous antibiotic therapy and the shunt	Short-term peri-operative antibiotic prophylaxis may be beneficial in preventing shunt infection
8	Ramos, 2016	246	4.36 ± 5.69 years age average	non infected 224, comensal 9, pyogenic 15	*S. aureus,* including certain methicillin-resistant forms, is responsible for the majority of shunt infections. This patient group's CSF has also tested positive for *Enterococcus faecalis, E. coli, S. caprae, Proteus mirabilis, Pseudomonas aeruginosa,* and *S. epidermidis infections*	no info	CSF level monitoring of the sMAC can be a powerful tool in the diagnosis and management of shunt infection. Soluble membrane attack complex (sMAC) by ELISA
9	Erol, 2017	1357	VP shunt was performed in 1357 pediatric patients in our clinic	305 infected, 1052 non infected	no info	Suggest to strengthen strategies and concise so that infection can be prevented	no info
10	Gaderer, 2018	50	A total of 27 patients (control group, CG) were conventionally treated between 2004 and 2010, while 23 patients (neuro-endoscopy group, NEG) were treated between 2010 and 2015	0 non infected, 50 infected; terinfeksi VPS 30, terinfeksi-tanpa VPS 20	*Staphylococcus epidermidis* (12), *Enterobacter cloacae* (5), *Serratia* (4), *Staphylo-coccus aureus* (3), *Esherichia coli* (3), *Entero-coccus faecalis* (3), *Listeria* (3), *Mycobacterium tuberculosis* (3), *Cyto-megalievirus* (2), *Kelsiella* (2), *Extended-spectrum beta-lactamase* (1), *Aci-netobacter baumannii* (1), *Haemophilus influenzae* (1), Neisseria meningitidis (1), *Pseudomonas aeruginosa* (1), *Salmonella* (1), *Beta-hemolytic Streptococcus* (1), unknown (1)	neuroendoscopic rinse is safe and effective in the treatment of infectious hydro-cephalus in children	no info

Surgical or mechanical intervention and medical treatment for shunt infection

Nine studies describe interventions in surgical techniques in a paper that suggests replacing a shunt device, namely: In cases of hydrocephalus, Thomale (2012) recommends using a differential pressure valve in conjunction with gravity. Hommelstad (2012) describes the use of perioperative protocols to significantly reduce infection rates in children.

Wang (2014) suggested emptying the subgaleal pouch before covering the scalp and avoiding pressure on the wound or respiratory tract to reduce leakage. Wu (2015) suggested to completely remove foreign bodies in the body and stop antibiotic therapy. Erol (2017) suggests strengthening the more concise handling strategy. Gaderer (2018) says to rinse neuroendoscopy and treat hydrocephalus in pediatric cases. Sweeney (2019) describes removing or removing pre- and post-protocol shunts and using an External ventricular drain (EVD).

Test (2019) investigation focused on the response times of each bacterium that can infect the shunt device and be linked to leukocytes rather than how to handle it. According to Azzolini (2019), patients with complex circumstances need extra surgery to replace the shunt and have the procedure reevaluated to ensure the patient's safety.

A number of six studies explain the administration of drugs or antibiotics, namely James (2014) suggested using an Impregnated Shunt Antibiotic (AIS) catheter, Wu (2015) providing short-term perioperative antibiotic prophylaxis to prevent Shunt

infection. The study that conducted by Ramos (2016) carried out monitoring of CSF from sMAC using dissolved membranes with ELISA. Krause study (2019) provided topical vancomycin in a shunt apparatus. Sweeney study (2019) provides therapeutic antibiotics before and after shunt treatment.

According to the Raygor study, IVT and topical vancomycin administration should be added to the shunt surgery protocol. Sweeney (2019) combining removing the device and giving antibiotic therapy before and after was one of two articles that combined the results of removing the total device and giving antibiotics. To prevent infection, Wu (2015) proposed removing the device and providing short-term perioperative antibiotic prophylaxis.

DISCUSSION

Ventriculoperitoneal shunt treatment is a common procedure for managing hydrocephalus, but it is not without its risks, particularly the risk of infection. This discussion summarizes the findings of a systematic review on ventriculoperitoneal shunt (VPS) infections in pediatric cases. The review included 108 reports, and the data was sorted from 2012 to 2021. The studies reported varying numbers of cases of shunt infection, with some studies reporting multiple results. The most common isolates were *Staphylococcus epidermidis, Staphylococcus aureus,* and gram-negative rods. The standard treatment for shunt infections is to remove the infected hardware and begin intravenous antibiotic therapy. The review can inform the development of strategies to prevent VPS infection in pediatric patients and improve patient outcomes.

Ventriculoperitoneal shunt treatment is commonly used in cases of hydrocephalus, but the risk of complications such as infection must also be considered. Despite the fact that this study is far from complete, the findings reveal infectious and non-infectious cases of ventriculoperitoneal shunt services, particularly in children. In order for the tool that may represent a risk of infection during clinical work can receive more attention. In general, this analysis demonstrates that infections are frequently discovered in children who have received shunts (Figure 1). It is believed that a number of variables contributed to this ventriculoperitoneal shunt infection case. Equipment condition, installation preparation, management, and body condition are all contributing variables that result in this infection.

The paragraph presents the methodology and results of a systematic review of the literature on ventriculoperitoneal shunt (VPS) infection in pediatric cases. The review included 108 reports that were selected from an initial pool of 4318 reports based on title and abstract screening. Out of these 108 reports, 51 were demographic descriptions of infection and cerebrospinal fluid, and 16 research articles focused specifically on VPS infection in pediatric cases.

The included studies had a retrospective and cohort research design, and the data were sorted from 2012 to 2021. The studies reported varying numbers of cases of shunt infection, with some studies reporting multiple results. For example, the 2012 studies reported 16 cases from 203 samples, 58 cases from 979 samples, and an unspecified number of cases from an unspecified number of samples. The 2017 study reported the highest number of cases with 305 cases of infection from 1357 samples, while the 2019 study reported four results, including three cases of infection from 78, 36 infected cases from 511 in a pre- and post-study, 93 infected out of 103 cases, and four cases out of 14.

The systematic review provides a comprehensive overview of VPS infection in pediatric cases and highlights the frequency of infections in this population. The findings of this review can inform the development of strategies to prevent VPS infection in pediatric patients and improve patient outcomes (Majlesi A, et al. 2021)

The systematic review on VPS infection in pediatric cases provides a comprehensive overview of the frequency of infections in this population. The review highlights the importance of several variables that contribute to shunt infections, such as equipment condition, installation preparation, management, and body condition. The findings reveal that infections are frequently discovered in children who have received shunts. The most common causative organisms isolated from shunt-infected patients are *Staphylococcus epidermidis, Staphylococcus aureus,* and gram-negative rods. The review also reveals that complete removal of an infected shunt with placement of an EVD and administration of antibiotics is far superior to immediate replacement with a new shunt or use of antibiotics alone. However, there are limitations to this study, such as the selection of studies with varying time periods and the use of pediatric age categories that are not yet defined.

Streptococcus aeurus, S. epidermis, and Gram-negative microorganisms are prominent in this finding. These findings lend credence to the idea that concurrent infections in other parts of the body caused by the same gram-negative microorganisms may contribute to the higher incidence. The most common isolates were S. epidermidis, S. aureus, Staphylococcus haemolyticus, and gram negative (Paff M, et al 2018).

The findings of this systematic review on VPS infection in pediatric cases demonstrate the importance of careful management and prevention strategies in reducing the incidence of shunt infections.

The study highlights the need for greater attention to be paid to infection prevention during clinical work. The results suggest that infections are frequently discovered in children who have received shunts, which indicates the importance of developing strategies to prevent VPS infection in pediatric patients and improve patient outcomes

Fever and unconsciousness, stiffness in the neck, and headache are symptoms that will appear in the patient. This phenomenon occurs as a result of the characteristics of organism replication and virus growth on the surface of the shunt biofilm (McGirt 2003). In order of frequency, the most common causative organisms isolated from shunt-infected patients are *Staph epidermidis, Staph aureus,* and gram-negative rods (Mc Girt, 2003 and McClinnton, 2001).

Staph epidermidis and *Staph aureus* are common skin flora, and skin contamination usually causes infection during shunt placement. As a result, infection from these organisms is usually present relatively soon after shunt placement. McGirt et al. (2003) discovered that previous *S. aureus* shunt infection significantly increased the likelihood that subsequent *S. aureus* shunt infections would produce *S. aureus as* the causative organism, but this trend was not observed with *S. epidermidis* infections.

The standard treatment for shunt infections is to remove the infected hardware and begin intravenous antibiotic therapy. Treatment strategies for shunt VPS infection show that if the shunt is completely removed and antibiotic therapy is also administered, 100% of patients recover. However, if the device is not removed and only antibiotics are used, the cure rate is only 9%. (Shurtlef 1974).

Schreffler et al. (2002) also concluded that complete removal of an infected shunt with placement of an EVD and administration of antibiotics is far superior to immediate replacement with a new shunt or use of antibiotics alone. Antibiotics given for VP shunt infections should be tested for culture sensitivity, so that the dose can be determined afterwards.

The use of preoperative antibiotics (Ratilal, 2008), improving sterile technique (Rotim, 1997), and shortening the duration of the procedure are additional effective approaches to lower shunt infection rates. For instance, Rotim et al. (1997) followed a strict protocol for placing shunts, paying particular attention to skin preparation, prescribing perioperative antibiotics, and limiting the length of the procedure to 40 minutes, and they discovered that their per patient rate of shunt infection decreased from 17.9% to 8% (Rotim, 1997).

The selection of studies with varying time periods and the use of pediatric age categories that are not yet defined are some of the limitations of this study. Therefore, a more thorough search and research on pediatric ventriculoperitoneal infection with additional variables is required.

One of the limitations of this study is the selection of studies with varying time periods, which may impact the accuracy and generalizability of the findings. The use of pediatric age categories that are not yet defined is another limitation. Additionally, the study did not explore other factors that may contribute to VPS infection in pediatric cases, such as socio-economic status, race, or comorbidities.

Future research should focus on exploring additional variables that may contribute to VPS infection in pediatric cases, such as socio-economic status, race, or comorbidities. Further research is also needed to determine the most effective strategies for preventing VPS infection in pediatric patients and improving patient outcomes. Additionally, future studies should consider standardizing pediatric age categories to enhance the accuracy and generalizability of the findings. Finally, more thorough search and research on pediatric ventriculoperitoneal infection with additional variables is required to address the limitations of this study.

CONCLUSION

The potential for treating and preventing VP shunt infections in children is still needed and is crucial for additional research, even though the diversity of therapies in ventriculoperitoneal shunts must be adapted to the symptoms and diagnosis. The therapies employed in the past ten years to treat pediatric vp shunt infections and their microorganism population will be highlighted in this research.

Conflict of interest: none declared
Financial support: none declared

REFERENCES

1. Al-Tamimi YZ, Sinha P, Chumas PD, Crimmins D, Drake J, Kestle J. Ventriculoperitoneal shunt 30-day failure rate: A retrospective international cohort study. *Neurosurgery.* 2014;74(1):29-34. doi: 10.1227/NEU.0000000000000196
2. Sahu RN, Kumar R, Mahapatra AK. Central nervous system infection in the pediatric population. *J PediatrNeurosci.* 2009 Jan;4(1):20-4. doi: 10.4103/1817-1745.49102. PMID: 21887170; PMCID: PMC3162832.
3. Conen A, Walti LN, Merlo A, Fluckiger U, Battegay M, Trampuz A. Characteristics and treatment outcome of cerebrospinal fluid shunt-associated infections in adults: A retrospective analysis over an 11-year period. *Clin Infect Dis.* 2008;47:73-82. doi: 10.1086/588298

4. Kumar R, Singh V, Kumar MV. Shunt revision in hydrocephalus. *Indian J Pediatr.* 2005; 72:843-7. doi: 10.1007/BF02731111
5. Thomale UW, Gebert AF, Haberl H, Schulz M. Shunt survival rates by using the adjustable differential pressure valve combined with a gravitational unit (proGAV) in pediatric neurosurgery. *Childs Nerv Syst.* 2013 Mar;29(3):425-31. doi: 10.1007/s00381-012-1956-9. Epub 2012 Nov 8. PMID: 23135777.
6. Hommelstad J, Madsø A, Eide PK. Significant reduction of shunt infection rate in children below 1 year of age after implementation of a perioperative protocol. *Acta Neurochir (Wien).* 2013 Mar;155(3):523-31. doi: 10.1007/s00701-012-1574-z. Epub 2012 Dec 8. PMID: 23224578.
7. Wang JY, Amin AG, Jallo GI, Ahn ES. Ventricular reservoir versus ventriculosubgaleal shunt for posthemorrhagic hydrocephalus in preterm infants: infection risks and ventriculoperitoneal shunt rate. *J Neurosurg Pediatr.* 2014 Nov;14(5):447-54. doi: 10.3171/2014.7.PEDS13552. Epub 2014 Aug 22. PMID: 25148212.
8. Wu X, Liu Q, Jiang X, Zhang T. Prevention options for ventriculo-peritoneal shunt infections: a retrospective analysis during a five-year period. *Int J Clin Exp Med.* 2015 Oct 15;8(10):19775-80. PMID: 26770643; PMCID: PMC4694543.
9. Erol FS, Ozturk S, Akgun B, Kaplan M. Ventriculoperitoneal shunt malfunction caused by fractures and disconnections over 10 years of follow-up. *Childs Nerv Syst.* 2017 Mar;33(3):475-81. doi: 10.1007/s00381-017-3342-0. Epub 2017 Jan 17. PMID: 28097382
10. Gaderer C, Schaumann A, Schulz M, Thomale UW. Neuroendoscopic lavage for the treatment of CSF infection with hydrocephalus in children. *Childs Nerv Syst.* 2018 Oct;34(10):1893-1903. doi: 10.1007/s00381-018-3894-7. Epub 2018 Jul 11. PMID: 29995267.
11. Sweeney J, Zyck S, Tovar-Spinoza Z, Krishnamurthy S, Chin L, Bodman A. Evidence-Based Perioperative Protocol for Ventriculoperitoneal Shunt Infection Reduction at a Single Institution. *World Neurosurg.* 2019 Aug;128: e814-e822. doi: 10.1016/j.wneu.2019.04.261. Epub 2019 May 10. PMID: 31078805.
12. Test MR, Whitlock KB, Langley M, Riva-Cambrin J, Kestle JRW, Simon TD. Relationship of causative organism and time to infection among children with cerebrospinal fluid shunt infection. *J Neurosurg Pediatr.* 2019 May 3;24(1):22-28. doi: 10.3171/2019.2.PEDS18638. PMID: 31051463; PMCID: PMC6928433.
13. Azzolini A, Magoon K, Yang R, Bartlett S, Swanson J, Taylor J. Ventricular shunt complications in patients undergoing posterior vault distraction osteogenesis. *Childs Nerv Syst.* 2020 May;36(5):1009-1016. doi: 10.1007/s00381-019-04403-w. Epub 2019 Nov 6. PMID: 31696291.
14. James G, Hartley JC, Morgan RD, Ternier J. Effect of introduction of antibiotic-impregnated shunt catheters on cerebrospinal fluid shunt infection in children: a large single-center retrospective study. *J Neurosurg Pediatr.* 2014 Jan;13(1):101-6. doi: 10.3171/2013.10.PEDS13189. Epub 2013 Nov 8. PMID: 24206346.
15. Ramos TN, Arynchyna AA, Blackburn TE, Barnum SR, Johnston JM. Soluble membrane attack complex is diagnostic for intraventricular shunt infection in children. *JCI Insight.* 2016 Jul 7;1(10):e87919. doi: 10.1172/jci.insight.87919. PMID: 27699221; PMCID: PMC5033849.
16. Krause M, Mahr CV, Schob S, Nestler U, Wachowiak R. Topical instillation of vancomycin lowers the rate of CSF shunt infections in children. *Childs Nerv Syst.* 2019 Jul;35(7):1155-7. doi: 10.1007/s00381-019-04185-1. Epub 2019 May 20. PMID: 31111179.
17. McGirt MJ, Zaas A, Fuchs HE, George TM, Kaye K, Sexton DJ. Risk factors for pediatric ventriculoperitoneal shunt infection and predictors of infectious pathogens. *Clin Infect Dis.* 2003 Apr 1;36(7):858-62. doi: 10.1086/368191. Epub 2003 Mar 18. PMID: 12652386.
18. Paff M, Alexandru-Brams D, Muhonen M, Loudon W. 2018. Ventriculoperitoneal shunt complications: A review. Interdisciplinary Neurosurgery. 2018 Sept;13:66-70. https://doi.org/10.1016/j.inat.2018.04.004
19. McClinton D, Carraccio C, Englander R. Predictors of ventriculoperitoneal shunt pathology. *Pediatr Infect Dis J.* 2001 Jun;20(6):593-7. doi: 10.1097/00006454-200106000-00009. PMID: 11419501
20. Shurtleff DB, Foltz EL, Weeks RD, Loeser J. Therapy of Staphylococcus epidermidis: infections associated with cerebrospinal fluid shunts. *Pediatrics.* 1974;53:55-62.
21. Schreffler RT, Schreffler AJ, Wittler RR. Treatment of cerebrospinal fluid shunt infections: a decision analysis. *Pediatr Infect Dis J.* 2002 Jul;21(7):632-6. doi: 10.1097/00006454-200207000-00006. PMID: 12237594.
22. Ratilal B, Costa J, Sampaio C. Antibiotic prophylaxis for surgical introduction of intracranial ventricular shunts: a systematic review. *J Neurosurg Pediatr.* 2008 Jan;1(1):48-56. doi: 10.3171/PED-08/01/048. PMID: 18352803.
23. Rotim K, Miklic P, Paladino J, Melada A, Marcikic M, Scap M. Reducing the incidence of infection in pediatric cerebrospinal fluid shunt operations. *Childs Nerv Syst.* 1997 Nov-Dec;13(11-12):584-7. doi: 10.1007/s003810050144. PMID: 9454973.
24. Lo CKL, Mertz D, Loeb M. Newcastle-Ottawa Scale: comparing reviewers to authors' assessments. *BMC Med Res Methodol.* 2014;14:45. https://doi.org/10.1186/1471-2288-14-45
25. Raygor KP, Oh T, Hwang JY, Phelps RRL, Ghoussaini K, Wong P, Silvers R, Ostling LR, Sun PP. Ventriculoperitoneal shunt infection rates using a standard surgical technique, including topical and intraventricular vancomycin: the Children's Hospital Oakland experience. *J Neurosurg Pediatr.* 2020 Jul 24;26(5):504-12. doi: 10.3171/2020.4. PEDS209. PMID: 32707540.
26. Rogers EA, Kimia A, Madsen JR, Nigrovic LE, Neuman MI. Predictors of ventricular shunt infection among children presenting to a pediatric emergency department. PediatrEmerg Care. 2012 May;28(5):405-9. doi: 10.1097/PEC.0b013e318252c23c. PMID: 22531186.
27. Romero L, Ros B, Ríus F, González L, Medina JM, Martín A, Carrasco A, Arráez MA. Ventriculoperitoneal shunt as a primary neurosurgical procedure in newbornposthemorrhagic hydrocephalus: report of a series of 47 shunted patients. *Childs Nerv Syst.* 2014 Jan;30(1):91-7. doi: 10.1007/s00381-013-2177-6. Epub 2013 Jul 24. PMID: 23881422.
28. Sabeti M, R. Boostani, E. Moradi, Z. Habibi, F. Nejat, Predicting shunt infection in children with hydrocephalus. *Intelligence-Based Medicine.* 2021;5:100029. ISSN 2666-5212, https://doi.org/10.1016/j.ibmed.2021.100029.
29. Wang JY, Amin AG, Jallo GI, Ahn ES. Ventricular reservoir versus ventriculosubgaleal shunt for posthemorrhagic hydrocephalus in preterm infants: infection risks and ventriculoperitoneal shunt rate. *J Neurosurg Pediatr.* 2014 Nov;14(5):447-54. doi: 10.3171/2014.7.PEDS13552. Epub 2014 Aug 22. PMID: 25148212.
30. Majlesi A, Seyed Toutounchi SJ, Karkhaneh Yousefi N et al. Ventriculoperitoneal Shunt Infections in Children: A Systematic Review and Meta-Analysis. *Iran J Pediatr.* 2021;31(4):e116732. doi: 10.5812/ijp.116732