



Ann Med Res

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Annals of Medical Research

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# Evaluation of ventriculoperitoneal shunt infection incidence and preoperative antibiotic prophylaxis in children

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## ARTICLE INFO

### Keywords:

Ventriculoperitoneal shunts  
Antibiotic prophylaxis  
Cephalosporin

Received: Sep 06, 2023

Accepted: May 27, 2024

Available Online: 29.05.2024

DOI:

[10.5455/annalsmedres.2023.09.245](https://doi.org/10.5455/annalsmedres.2023.09.245)

## Abstract

**Aim:** Hydrocephalus is a common condition in neurosurgical practice in patients of all ages. Despite significant advances in the technology and design of ventriculoperitoneal (VP) shunt systems, shunt failure remains a major problem in neurosurgical clinics. Antibiotic prophylaxis is an important step in protocols to prevent VP shunt infections. In this study, we investigated VP shunt infection incidence and VP shunt infection prophylaxis used in pediatric hydrocephalus cases at our center and the parameters that may influence shunt infection.

**Materials and Methods:** Between 01/01/2018 and 01/01/2023, cases younger than 18 years of age who underwent VP shunt surgery in our hospital were included in the study. Clinical data and demographic information were retrospectively obtained from medical records. The primary results of our study were the frequency of VP shunt infection in the first 3 months after surgery and whether there was a difference in shunt infection between antibiotic applications used for prophylaxis. Other factors that may influence VP shunt infection were evaluated as secondary outcomes.

**Results:** Within a 5-year period, 28 cases were identified that met our study criteria. The overall rate of VP shunt infections was 21.4%. In 85.7% of patients, 3rd-generation cephalosporins were used for prophylaxis, and in the others (14.3%), 1st-generation cephalosporins were used. VP Shunt infections did not occur in patients receiving 1st generation cephalosporins. However, possibly due to the limited number of cases, no statistical significance ( $p=0.549$ ) was detected between the groups. There was no statistical difference in other demographic data between the groups with and without VP shunt infection.

**Conclusion:** In our patient group, which was predominantly infants, prophylactic use of 1st-generation cephalosporins to prevent VP shunt infection showed similar efficacy to the use of 3rd-generation cephalosporins. 1st-generation cephalosporins should be preferred, especially in terms of reducing costs and resistant infections.



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## Introduction

Hydrocephalus is a common condition in neurosurgical practice in patients of all ages. Despite the increasing use of endoscopic third ventriculostomy, the ventriculoperitoneal (VP) shunt has been the treatment of choice for hydrocephalus since the invention of the shunt valve by John Holter in 1959 [1]. Despite significant advances in the technology and design of VP shunt systems, shunt failure remains a major problem in neurosurgical clinics.

Infections associated with VP shunt are a serious complication with high morbidity and significant mortality [2]. Infection rates range from 0.33% to 41%, and recent studies report a risk ranging from 1% to 6% per procedure [3].

Infections associated with VP shunt are most commonly caused by coagulase-negative staphylococci [4-8]. Gram-negative bacteria are the second most common pathogens, accounting for 19-22% of cases [4,6,9]. Some independent risk factors for VP shunt-associated infections have been identified in previous studies. These are: previous shunt infections, postoperative cerebrospinal fluid (CSF) leak, prematurity, young age at shunt placement, hydrocephalus due to hemorrhage, presence of gastrostomy, duration of shunt placement, experience of the neurosurgeon, and density of the operating room [3-5,10,11].

There are several protocols and approaches to prevent VP shunt infection. An important step in these protocols is antibiotic prophylaxis. However, there is not yet a universally accepted approach in this regard. Which antibiotic is administered in which access and in which time period

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varies widely from center to center. In this study, we aimed to investigate VP shunt infection prophylaxis in pediatric hydrocephalus at our center and the parameters that may influence shunt infection.

## Materials and Methods

Between 01/01/2018 and 01/01/2023, cases under 18 years of age who underwent VP shunt placement in our hospital were included in the study. Local ethics committee approval was obtained before the study (Baskent University Institutional Review Board, KA23/234) was conducted. Patients who were treated with therapeutic antibiotics before the procedure for any reason were excluded from the study (flow chart). The data set was created using previously defined demographic data and risk factors associated with VP shunt infection. Clinical data and demographic information were retrospectively obtained from medical records. The primary outcomes of our study were the frequency of VP shunt infections in the first 3 months after surgery and whether there was a difference in shunt infections between antibiotic applications used for prophylaxis. Other factors that may influence VP shunt infections were examined as secondary outcomes. The other factors were age, gender, duration of prophylaxis and hospital stay, duration of surgery, prematurity, preoperative central nervous system infection, etiology, and shunt revision. We also examined the following preoperative laboratory tests: leukocytes, C-reactive protein (CRP), CSF culture.

The hypothesis of our study was that there is a difference in the incidence of VP shunt infections between the 2 most commonly used antibiotics in VP shunt prophylaxis in our pediatric patients. The Fisher exact test was used to test this hypothesis. We used the program G Power 3.1.9.4 for the power analysis. With a margin of error of 0.05 and an effect size of 50%, the power of our study was 91%. Data were analysed with SPSS version 25.0 (SPSS, Inc, Chicago, IL, USA). Normality of data distribution was checked. Descriptive statistics of normally distributed variables were expressed as mean  $\pm$  standard deviation and median (min-max) of nonnormally distributed variables. When the number of groups was two, the t test was used for continuous variables with normal distribution and the Mann Whitney U test was used for continuous variables with nonnormal distribution. The chi-square test was used for categorical variables.  $P < 0.05$  was accepted as the statistical significance criterion for all data.

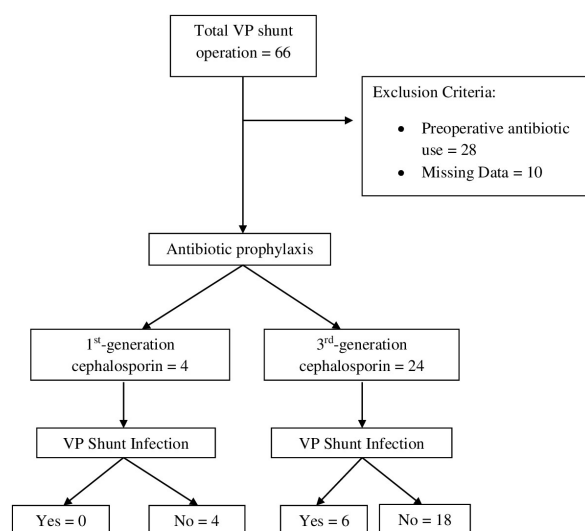
### VP shunt infection definition

**Definite infection:** Definite infection was defined as a patient has growth of pathogenic bacteria in the CSF or in a blood culture, and CSF pleocytosis (more than 50 leukocytes per millimeter) is accompanied by any of the following: fever, neurologic symptoms, abdominal symptoms, or shunt dysfunction [5]. **Possible infection:** It was defined as the detection of CSF pleocytosis in cases with fever and neurologic symptoms, although no pathogenic bacteria have grown in the CSF culture [5].

## Results

Within a 5-year period, 28 cases were identified that met our study criteria. Fourteen (50%) of the patients were

male. The most common etiologic reason for the need for a VP shunt was congenital (75%). Antibiotic-impregnated shunts were not used in any of our patients. Most cases (71.4%) were patients who received a VP shunt for the first time. In 9 cases (32.1%), prematurity (34 weeks and less) was present. The overall rate of VP shunt infection was 21.4%. For prophylaxis, 3rd-generation cephalosporins were used in 85.7% of patients and 1st-generation cephalosporins in the remainder (14.3%). No VP shunt infections were observed in patients receiving 1st-generation cephalosporins. However, possibly due to the limited number of cases, no statistical significance ( $p=0.549$ ) was observed between the groups (Table 1).



**Figure 1.** Flow chart.

**Table 1.** The relationship between postoperative ventriculoperitoneal shunt infection and antibiotic prophylaxis.

Shunt Infection	Antibiotic prophylaxis		p value
	1 <sup>st</sup> -generation cephalosporin	3 <sup>rd</sup> -generation cephalosporin	
Yes, n (%)	-	6 (100)	0.549
No, n (%)	4 (18.2)	18 (81.8)	

$P < 0.05$  was accepted as the statistical significance criterion for all data.

**Table 2.** Relationship between etiology and postoperative ventriculoperitoneal shunt infection.

Shunt Infection	Etiology			p value
	Trauma	Congenital	Intracranial hemorrhage	
Yes, n (%)	-	4 (19)	2 (33.3)	0.654
No, n (%)	1 (100)	17 (81)	4 (66.7)	

$P < 0.05$  was accepted as the statistical significance criterion for all data.

**Table 3.** Relationship between postoperative ventriculo-peritoneal shunt infection and demographic and clinical characteristics.

	Shunt Infection		p value
	Yes	No	
Age at surgery, month, median (min-max)	2 (1-12)	4 (1-120)	0.214
Gender, Male, n (%)	4 (66.7)	10 (45.5)	0.357
Preoperative CNS infection, yes, n (%)	-	1 (4.5)	1.000
Duration of prophylaxis, days, median (min-max)	4 (2-7)	3 (1-10)	0.427
Shunt revision, yes, n (%)	2 (33.3)	6 (27.3)	0.771
Preoperative leukocytes, cells/mL, median (min-max)	9835 (7890-26900)	12750 (5650-20500)	1.000
Preoperative CRP, mg/dL, median (min-max)	0.72 (0.26-1.90)	0.5 (0.5-13.20)	0.743
Preoperative hospital stay > 48h, yes, n (%)	2 (33.3)	11 (50)	0.468
Postoperative hospital stay > 48h, yes, n (%)	5 (83.3)	14 (63.6)	0.360
Prematurity, yes, n (%)	2 (33.3)	7 (38.9)	0.808
Surgical time > 90 min, yes, n (%)	1 (16.7)	6 (27.3)	0.595

P < 0.05 was accepted as the statistical significance criterion for all data.

The distribution of causative microorganisms in our 6 patients who developed VP shunt infection was as follows: 2 *Klebsiella pneumoniae* (one resistant to cefazolin and the other was not investigated), 2 coagulase-negative staphylococci (both resistant to methicillin and cefazolin), 1 *Enterobacter aerogenes* (resistant to cefazolin), and 1 *Escherichia coli*. Regarding the causes, the risk of shunt infection was highest in the group that developed hydrocephalus after intracranial hemorrhage (33.3%). However, there was no statistical difference (p=0.654) in etiologic causes (Table 2). There was also no statistical difference in other demographic data between the groups with and without VP shunt infection. These data are summarized in Table 3.

## Discussion

Hydrocephalus is a condition in which CSF accumulates in the cerebral ventricles and subarachnoid spaces, resulting in enlargement of the ventricular system and increased intracranial pressure [12]. Intracranial ventricular shunts are siliceous tubes that drain pathologic CSF excess from the cerebral ventricles to the outside (external ventricular shunts) or to other body cavities (internal ventricular shunts), where the fluid can be absorbed by normal physiologic processes. Up to 30% of internal ventricular shunts will need replacement or modification at some point during

a patient's life. VP Shunts are the most commonly used internal ventricular shunt. Infection is one of the most important complications associated with internal ventricular shunts [13]. The mortality rate due to VP shunt infection is approximately 10% and is also associated with a low Glasgow discharge score and school success [14].

In our limited case series, the infection rate of the VP shunt was 21.4%. A wide range of infection rates has been reported in the literature. In some studies, the infection rate was as high as 40%, and rates were generally found to be higher in infants and young children (approximately 20%) [15,16]. The incidence of infection in our patients, most of whom were infants, was similar to that reported in these studies. One reason for the difference in infection rates may be the lack of consensus on the definition of shunt infection.

In the cases included in our study, 1st- and 3rd-generation cephalosporins were used for prophylaxis. In 85.7% of cases, 3rd-generation cephalosporins were preferred. In 4 cases in which a 1st-generation cephalosporin was used, no postoperative shunt infection was detected, but this situation did not result in a statistically significant difference between the 1st-generation cephalosporin group and the 3rd-generation cephalosporin group (p=0.549). In VP shunt prophylaxis, there is no clear consensus on which antibiotic should be administered, in which way, and for how long. The 2019 Cochrane meta-analysis examined 11 randomized controlled trials in adult and pediatric patients and found that only the use of prophylactic antibiotics by the intravenous route (IV) reduced the incidence of shunt infections. However, no clear results were obtained on which antibiotic is best for prophylaxis and how long it should be given [17]. Nevertheless, some studies show that vancomycin should be preferred over the cephalosporin group. In a study that included adults and children and evaluated a 6-year period, cephalosporin resistance was found to increase over time in VP shunt infections [18]. In addition, the most commonly detected microorganisms in VP shunt infections are staphylococci, and the high methicillin resistance demonstrated in studies makes it more reasonable to prefer vancomycin for prophylaxis. There are also adult studies showing that vancomycin may be more effective than cefazolin in prophylaxis [5]. There is no consensus on the duration of antibiotic prophylaxis. A 2006 Cochrane analysis found that prophylaxis longer than 24 hours had no added benefit in reducing shunt infections. Our study it was determined that very different prophylaxis duration were used in the two groups, but no statistically significant difference was found between the groups in terms of median durations.

In our study, we could not obtain clear data on how long before surgery the antibiotic used for prophylaxis was administered. In our routine practice and in many centers, the IV antibiotic infusion is usually started half an hour or one hour before surgery. In a study examining vancomycin concentration at the surgical site and evaluating 60 patients under 19 years of age who had undergone posterior spinal fusion and VP shunt surgery, it was found that the maximum skin concentration was reached after approximately 330 minutes. This study suggests that if IV vancomycin is preferred for prophylaxis, preoperative

infusion should begin much earlier [19]. Clearly, further studies are needed on this topic.

Previous studies found that patients who underwent VP shunt surgery for the first time were less likely to develop VP shunt infection than patients who had shunt revision [5,20]. Although there was no statistical significance, our results were in the same direction. In one study, it was shown that a postoperative hospital stay of more than 48 hours significantly increased the risk of VP shunt infection [12]. However, in our study, we did not find any effect of hospitalisation longer than 48 hours before or after surgery on VP shunt infection. Whether the etiology of hydrocephalus affects the frequency of VP shunt infection has been investigated in some previous studies [21-23]. As in our study, no significant differences between etiologic causes were found in these studies. Previous studies have shown that surgical duration longer than 90 minutes and prematurity increase the risk of VP shunt infection, but we did not find such a difference in our study [12,24,25]. We think that our limited number of cases may have an influence on this result.

Our study has some limitations. The main limitation is the retrospective nature of the study. Apart from that, we have no cases of hydrocephalus caused by tumor because there is no pediatric oncology in our hospital, and there are also few cases from the meningomyelocele group because almost all cases in this group are treated empirically with antibiotics before surgery. This situation may lead to bias, especially when comparing etiologic causes. The strength of our study is that there are few studies comparing the efficacy of antibiotics in pediatric VP shunt infection prophylaxis.

## Conclusion

Consequently, prophylactic use of 1st-generation cephalosporins in our patient group, in which infants predominate, showed similar efficacy to the use of 3rd-generation cephalosporins in preventing VP shunt infections. First-generation cephalosporins should be preferred primarily for cost reduction and prevention of resistant infections.

## Ethical approval

This study was approved by Baskent University Institutional Review Board (KA23/234).

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