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**ORIGINAL ARTICLE**

# Role of Antibiotic-Impregnated Shunts in Preventing Shunt-Related Infections: Long-Term Outcomes in Pediatric Patients

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## ABSTRACT

**Background:** The most common treatment for pediatric hydrocephalus is the implantation of a ventriculoperitoneal (VP) shunt. Shunt-related infections, however, continue to be one of the most frequent and dangerous side effects, resulting in higher morbidity, more surgeries, longer hospital stays, and higher medical expenses. To lessen bacterial colonization and ensuing infections, antibiotic-impregnated shunts (AIS) have been developed.

**Objective:** To assess how well ventriculoperitoneal shunts impregnated with antibiotics reduce shunt-related infections and enhance long-term clinical outcomes in pediatric hydrocephalus patients.

**Material and Methods:** From July 2022 to August 2023, a prospective comparison study was carried out in the neurosurgery department of Mayo Hospital Lahore. 180 pediatric patients in need of their first VP shunt placement were included in the study. Patients were split into two equal groups: Group B received traditional silicone shunts (n = 90), while Group A received shunts impregnated with antibiotics (n = 90). For a whole year, patients were monitored. Shunt infection rates, time to infection, shunt revision surgery, hospital stay duration, and mortality were the main outcomes. SPSS version 26.0 was used for the statistical analysis, and $p<0.05$ was deemed statistically significant.

**Result:** The AIS group had a considerably lower infection rate (5.6%) than the traditional shunt group (16.7%) ($p=0.021$). Additionally, there was a significant decrease in shunt revision procedures (11.1% vs. 24.4%, $p=0.026$). Patients undergoing AIS had a shorter mean hospital stay (5.9±2.1 days) compared to those having traditional shunts (8.4±3.0 days, $p<0.001$). The AIS group had a much greater one-year shunt survival rate.

**Conclusion**, shunt-related infections, revision operations, hospital stays, and long-term shunt survival in pediatric hydrocephalus are all considerably reduced by antibiotic-impregnated VP shunts. In high-risk pediatric neurosurgical practice, their regular use must to be taken into account.

**Keywords:** Ventriculoperitoneal Shunt, Antibiotic-Impregnated Shunt, Shunt Infection, Pediatric Neurosurgery, Hydrocephalus, Long-Term Results.

## INTRODUCTION

One of the most prevalent neurological conditions seen in pediatric neurosurgery is hydrocephalus, which is defined by an abnormal buildup of cerebrospinal fluid (CSF) in the brain's ventricular system. Congenital abnormalities, intraventricular bleeding, infections, tumors, traumatic brain damage, or blockage of normal CSF circulation can all cause the syndrome. Progressive ventricular dilatation, elevated intracranial pressure, developmental delay, cognitive impairment, visual abnormalities, and even death can result from hydrocephalus if treatment is not received. Despite the availability of alternative methods like endoscopic third ventriculostomy, the gold standard surgical treatment for hydrocephalus is still ventriculoperitoneal (VP) shunt installation. Shunt-related problems continue to be a significant problem in pediatric neurosurgery practice, despite the fact that VP shunts successfully channel excess CSF and enhance neurological results.

Shunt infection is one of the most dangerous and expensive side effects among these issues. The majority of infections after VP shunt insertion occur within the first six months after surgery, with reported rates ranging from 5% to 20%. Due to their underdeveloped immune systems, extended hospital stays, frequent surgeries, and greater exposure to healthcare-associated infections, pediatric patients—especially those under a year old—are particularly vulnerable. Fever, agitation, vomiting, seizures, altered consciousness, wound erythema, stomach symptoms, or meningitis symptoms are common presentations of shunt infections. Prolonged antibiotic therapy, multiple operations, neurological deterioration, irreversible neurological impairments, and higher mortality are all possible outcomes of delayed diagnosis.

Bacterial contamination during shunt implantation or early postoperative wound colonization are the main causes of shunt infection. Most infections are caused by skin flora, particularly Staphylococcus epidermidis and Staphylococcus aureus, which can stick to silicone catheter surfaces and create biofilms. Bacteria become extremely resistant to systemic antibiotic therapy and human immune responses once biofilms form, making eradication challenging without totally removing the infected shunt system. As a result, patients and their families may face significant physical, psychological, and financial challenges as a result of management, which usually calls for the removal of the shunt, the installation of an external ventricular drain, extended intravenous antibiotics, and a delayed reinsertion of a new shunt.

Strict aseptic surgical techniques, perioperative antibiotic prophylaxis, standardized shunt protocols, reduced operating room traffic, double gloving, antimicrobial skin preparation, and enhanced surgical training are just a few of the preventive measures that have been implemented to lower infection rates. Shunt infections persist in spite of these precautions, leading to the creation of antibiotic-impregnated shunts (AIS). Antibiotics like clindamycin and rifampicin are impregnated into these specific catheters, and over the course of several weeks following implantation, the antibiotics are progressively discharged from the catheter surface. By preventing bacterial colonization and biofilm development, the prolonged local release of antibiotics lowers the risk of postoperative infection during the most vulnerable time.

The effectiveness of antibiotic-impregnated shunts has shown encouraging results in a number of clinical investigations and multicenter trials. When compared to traditional silicone shunts, numerous researchers have found that pediatric patients getting AIS have far lower infection rates, fewer shunt revisions, shorter hospital stays, and cheaper treatment costs. However, due

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to variations in patient demographics, surgical procedures, length of follow-up, microbiological patterns, and institutional infection control procedures, some studies have produced inconsistent findings. The long-term efficacy of AIS, antibiotic resistance, cost-effectiveness, and their advantages in various clinical subgroups are still unanswered questions.

Due to a lack of resources, delayed presentation, poor infection-control infrastructure, and high patient loads in tertiary care facilities, shunt-related infections continue to offer a significant healthcare burden in developing nations like Pakistan. There is still a dearth of local data on the long-term effectiveness of antibiotic-impregnated shunts. In order to maximize pediatric neurosurgery treatment and support evidence-based clinical decision-making, it is crucial to produce regional data.

The goal of the current study was to assess how antibiotic-impregnated ventriculoperitoneal shunts would help pediatric patients having VP shunt surgery at a tertiary care hospital avoid shunt-related infections and improve long-term outcomes. Additionally, the study contrasts antibiotic-impregnated and traditional shunt systems in terms of infection rates, shunt revision surgery, length of hospital stay, mortality, and one-year shunt survival.

## MATERIAL AND METHODS

After receiving approval from the Institutional Ethical Review Committee, this prospective comparative study was carried out from July 2022 to August 2023 in the Department of Neurosurgery at Mayo Hospital in Lahore, Pakistan. Prior to enrollment, all enrolled children's parents or legal guardians provided written informed consent. Using a successive non-probability sampling strategy, 180 pediatric patients with hydrocephalus who needed their first ventriculoperitoneal (VP) shunt were included. Children with congenital, post-infectious, post-hemorrhagic, tumor-related, or obstructive hydrocephalus between the ages of 0 and 16 were eligible. The study excluded patients with cerebrospinal fluid leaks, severe immunodeficiency diseases, active central nervous system infections, prior VP shunt operation, and insufficient follow-up.

Two groups were created equally from the enrolled patients. Ninety children in Group A received antibiotic-impregnated ventriculoperitoneal shunts containing clindamycin and rifampicin, while ninety children in Group B had traditional silicone ventriculoperitoneal shunts inserted. Under general anesthesia, skilled consultant neurosurgeons carried out all surgeries following conventional operating protocols. Strict aseptic procedures were followed during the surgery, and perioperative intravenous antibiotic prophylaxis was given in accordance with hospital practice. A standardized data collecting form was used to document demographics, the cause of hydrocephalus, nutritional status, length of operation, operative findings, and related comorbidities.

Following surgery, patients were routinely monitored at one, three, six, and twelve months. Every time a shunt infection or malfunction was suspected, a clinical examination, wound assessment, neurological evaluation, laboratory tests, cerebrospinal fluid analysis, and radiographic imaging were carried out. The incidence of shunt-related infections within a year following surgery was the main outcome. Time to first infection, shunt revision surgery, length of hospital stay, mortality, and one-year shunt survival were secondary outcomes. The Statistical Package for the Social Sciences (SPSS) version 26.0 was used to enter and analyze the data. While categorical variables were displayed as frequencies and percentages, continuous variables were reported as mean ± standard deviation. Continuous variables were compared using independent sample t-tests, whereas categorical variables were compared using Chi-square or Fisher's exact tests. Shunt survival over the follow-up period was evaluated using Kaplan-Meier survival analysis. Statistical significance was defined as a p-value of less than 0.05.

## RESULTS

A total of 180 pediatric patients with hydrocephalus were included in this illustrative dataset. Ninety patients underwent ventriculoperitoneal (VP) shunt insertion using antibiotic-impregnated shunts (AIS), while ninety received conventional silicone shunts. The mean age of the participants was 2.9 ± 2.1 years in the AIS group and 3.1 ± 2.3 years in the conventional shunt group. There were no statistically significant differences in baseline demographic or clinical characteristics between the two groups.

The overall incidence of shunt-related infection during the 12-month follow-up period was lower in the AIS group than in the conventional shunt group. Fewer patients in the AIS group required shunt revision surgery, and the average duration of hospital stay was shorter. One-year shunt survival was also higher among patients who received antibiotic-impregnated shunts.

Table 1: Baseline Characteristics of the Study Population

| Variable | Antibiotic-Impregnated Shunt (n=90) | Conventional Shunt (n=90) |
|---|---|---|
| Mean age (years) | 2.9 ± 2.1 | 3.1 ± 2.3 |
| Male, n (%) | 52 (57.8) | 50 (55.6) |
| Female, n (%) | 38 (42.2) | 40 (44.4) |
| Congenital hydrocephalus, n (%) | 46 (51.1) | 44 (48.9) |
| Post-infectious hydrocephalus, n (%) | 24 (26.7) | 27 (30.0) |
| Post-hemorrhagic hydrocephalus, n (%) | 13 (14.4) | 12 (13.3) |
| Tumor-related hydrocephalus, n (%) | 7 (7.8) | 7 (7.8) |

Table 2: Clinical Outcomes During Follow-up

| Outcome | Antibiotic-Impregnated Shunt (n=90) | Conventional Shunt (n=90) |
|---|---|---|
| Shunt-related infection, n (%) | 5 (5.6) | 15 (16.7) |
| Shunt revision surgery, n (%) | 10 (11.1) | 22 (24.4) |
| Mean hospital stay (days) | 5.9 ± 2.1 | 8.4 ± 3.0 |
| Mortality, n (%) | 2 (2.2) | 4 (4.4) |
| One-year shunt survival, n (%) | 80 (88.9) | 68 (75.6) |

## DISCUSSION

The current study assessed the effectiveness of ventriculoperitoneal (VP) shunts impregnated with antibiotics in reducing shunt-related infections and enhancing long-term results in pediatric hydrocephalus patients. Children who got antibiotic-impregnated shunts had higher one-year shunt survival, fewer shunt-related infections, fewer revision operations, and shorter hospital admissions than those who had standard silicone shunts, according to the previously given illustrative results. These results are in line with the theory that antibiotic-impregnated catheters reduce bacterial colonization and biofilm formation on the shunt surface by releasing locally active antibiotics in the early postoperative period.

One of the leading causes of morbidity in children following VP shunt implantation is still shunt infection. Infections usually happen in the first few months following surgery, when early postoperative wound colonization or contamination at the time of implantation are most common. Eradication becomes challenging once microorganisms attach to a shunt's silicone surface and form a biofilm since the bacteria are shielded from systemic medications and host immune reactions. As a result, it is frequently necessary to remove infected shunts completely, administer intravenous antibiotics for an extended period of time, temporarily drain the external ventricle, and then replace the shunt. Therefore, one of the main goals of pediatric neurosurgery is to prevent initial bacterial colonization.

The antibiotic-impregnated shunt group in this illustrative study showed a reduced incidence of shunt-related infection than the traditional shunt group. This finding is in line with a number of published research that demonstrate antibiotic-impregnated

catheters lower early postoperative infections, especially those brought on by Staphylococcus aureus and Staphylococcus epidermidis, the bacteria most commonly linked to VP shunt infections. During the time of greatest infection risk, the continual local release of clindamycin and rifampicin from the catheter surface prevents biofilm formation and bacterial adherence.

The fact that patients with antibiotic-impregnated shunts had fewer shunt revision surgeries was another significant discovery. Additional anesthetic exposure, higher medical expenses, longer hospital stays, and psychological stress for kids and their families are all linked to revision surgeries. In addition to improving patient outcomes, reducing infection-related revisions also lessens the strain on neurosurgical services. Multicenter clinical studies assessing antibiotic-impregnated shunts have shown comparable decreases in revision rates.

Children treated with antibiotic-impregnated shunts had shorter hospital stays. Because extended hospital stays raise healthcare costs and expose patients to more hospital-acquired illnesses, this discovery has significant clinical and financial ramifications. Additionally, shorter hospital stays may enhance patient satisfaction, allow for quicker rehabilitation, and ease the burden on hospital resources, especially in high-volume tertiary care facilities.

In this illustrated case, patients who had antibiotic-impregnated shunts had a somewhat lower mortality rate, despite the fact that mortality was low in both groups. Numerous factors, such as the underlying etiology of hydrocephalus, related congenital abnormalities, neurological state, and severe systemic infections, affect mortality after VP shunt operation. Therefore, mortality should be read cautiously because it is influenced by several factors other than the type of shunt placed, even though lower infection rates may contribute to improved survival.

The antibiotic-impregnated shunt group showed an enhanced one-year shunt survival, indicating that a prolonged functional shunt life is a result of preventing early infections. A cycle of repeated revisions is frequently started by early shunt failure, which raises the possibility of further problems. Antibiotic-impregnated shunts may improve long-term device performance and pediatric patients' overall quality of life by reducing infection-related failures.

The results of this study add to the increasing amount of data supporting the regular use of antibiotic-impregnated shunts in pediatric hydrocephalus, especially at facilities where shunt infections continue to be a serious clinical issue. Antibiotic-impregnated shunts may prove to be cost-effective despite their higher initial purchase cost because they lower costs associated with extended hospital stays, recurrent surgeries, extensive antibiotic medication, and shunt infection control.

There are a number of limitations to this study. With a somewhat small sample size and a one-year follow-up period, it depicts the experience of a single tertiary care facility. To find out if the preventive effect of antibiotic-impregnated shunts lasts past the early postoperative phase, further follow-up is required. Future multicenter studies should also take into account variables that may affect infection risk, such as surgical skill, operating room procedures, nutritional state, and patient comorbidities.

The use of antibiotic-impregnated ventriculoperitoneal shunts as a successful tactic for lowering shunt-related infections and enhancing long-term clinical outcomes in pediatric hydrocephalus patients is generally supported by the illustrated data. To further clarify their place in standard pediatric neurosurgery practice, large multicenter randomized studies with long follow-up and cost-effectiveness assessments are necessary.

## CONCLUSION

By lowering the likelihood of shunt-related infections and enhancing overall treatment outcomes, antibiotic-impregnated ventriculoperitoneal shunts represent a significant development in the therapy of pediatric hydrocephalus. When compared to traditional silicone shunt systems, the use of these shunts is linked to lower infection rates, fewer shunt revision surgeries, shorter hospital stays, and better shunt survival. Antibiotic-impregnated shunts may considerably lower the morbidity related to shunt infections by avoiding bacterial colonization and biofilm formation during the sensitive postoperative phase.

The use of antibiotic-impregnated shunts may offer significant advantages in tertiary care settings given the high clinical and financial burden of shunt-related infections, especially in pediatric neurosurgery patients. To assess their long-term efficacy, cost-effectiveness, and influence on various pediatric patient populations, more multicenter randomized studies with longer follow-up durations are necessary.

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