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Clinical Study

# Risk factors for recurrent shunt infections in children

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ABSTRACT

Risk factors for recurrent shunt-related cerebrospinal fluid (CSF) infections were analyzed. A total of 58 children were treated for initial shunt infections (ISI): all children were treated with antibiotics and CSF drainage, either by removal of the shunt system and insertion of an external ventricular drainage (EVD) catheter (44 children, 75.9%) or by externalization of the existing ventricular catheter (14 children, 24.1%). Recurrent shunt infections (RSI) were detected in 15 children: nine had been treated with shunt removal and insertion of a new EVD catheter and six had been treated with externalization of the existing ventricular catheter. There was a statistically significant increase in the number of RSI in children treated with externalization of the existing ventricular catheter. Thus, to reduce the risk of RSI, total shunt removal and insertion of a new EVD catheter is preferred.

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## 1. Introduction

Shunt infection, one of the most serious complications of ventriculo-peritoneal (V-P) shunt insertion to treat hydrocephalus, affects from 0.17% to 33% of these patients.[1–4] Inadequate or inappropriate treatment can cause recurrent shunt infections (RSI).[3,5] Despite great effort to prevent initial shunt infection (ISI) and RSI, and to determine the risk factors, there has been neither a randomized prospective clinical study showing an advantage of any one method, nor universal consensus for the preferred treatment.

Various surgical modalities have been employed to manage shunt infection, including removal of the shunt and insertion of a new external ventricular drainage (EVD) catheter, externalization of the existing ventricular catheter, and removal of the shunt followed by antibiotic treatment only.[6,7]

Understanding the risk factors for RSI has been gaining importance in clinical studies and determining these risk factors could have a substantial impact on how shunt infections are treated. The recent literature indicates that the overall rate of RSI ranges from 14.6% to as high as 51.7%.[8–11]

The aim of this retrospective study was to determine the RSI rate after the treatment of ISI and to analyze the underlying risk factors for RSI.

## 2. Methods

The outcomes of 428 children treated for hydrocephalus in our clinic between January 2001 and January 2011 were examined. Among them, 58 children (13.6%) were treated for a shunt infection. Patients were diagnosed with a shunt infection based on the presence of at least one of the following criteria: surgical wound infection or separation; positive culture of cerebrospinal fluid (CSF) aspirated from the shunt valve under sterile conditions; or the diagnosis of peritoneal infection in a child with a V-P shunt. Forty-six children (79.3%) met at least one criterion, with 42 (72.4%) having a positive CSF culture from a shunt aspirate, eight (13.8%) having a surgical wound infection or tissue breakdown, and two (3.4%) having a peritoneal infection. Another 12 (20.6%) children were diagnosed with clinical symptoms that indicated shunt infection, even though their first CSF culture results were negative. However, the removed shunt pieces yielded positive cultures.

Removal of the infected shunt and insertion of a new EVD catheter plus the administration of appropriate antibiotics has been preferred to antibiotic treatment of the shunt infection alone. In some patients, however, the existing ventricular catheter is externalized distally, usually because the ventricles are too small to insert a new EVD catheter. In many cases a blocked catheter, accidental removal, or the presence of infection and subsequent inability to clear the CSF of microorganisms has required removal of the externalized shunt and placement of a new EVD catheter. Once negative culture results are be demonstrated in the CSF, the

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EVD catheter or externalized shunt is removed, and a new shunt system inserted.

Patients infected by either the same or a different pathogen within six months of completion of their initial treatment were defined as having a RSI.

### 2.1. Statistical analysis

Six independent variables were tested separately in a univariate analysis as potential risk factors for RSI using a Cox proportional hazards model: (i) age (⩽12 months, or >12 months); (ii) etiology of hydrocephalus (myelomeningocele, hemorrhage, congenital, meningitis, or prematurity); (iii) ISI microorganisms (*Staphylococcus*, or a non-staphylococcal organism); (iv) initial surgical treatment of the ISI (shunt removed with EVD, or shunt externalization); (v) number of days of external CSF drainage with either an EVD or an externalized shunt (⩽10 days, or >10 days); and (vi) culture-positive CSF at ISI (yes, or no).

All statistical analyses were performed using the Statistical Package for the Social Sciences Advanced Statistics software package (version 8.0) (SPSS, Chicago, IL, USA). Those variables shown to be statistically significant in the univariate analysis ($p < 0.05$) were then entered into a multivariable Cox proportional hazards model.

## 3. Results

The average age (±standard deviation, SD) of 58 children with V-P shunt infection was 16.4 ± 26.4 months (range: 1–160 months). Thirty-six (62%) children were younger than 12 months. Among the etiologies of the hydrocephalus, 23 patients had spina bifida (39.7%), 16 had congenital hydrocephalus (27.6%), 11 had meningitis (19.0%), four suffered from hemorrhage (6.9%) and four were premature (6.9%) (Table 1).

Forty-six of 58 patients with shunt infection had a positive culture at ISI. Microorganisms responsible for the ISI were *Staphylococcus epidermidis* (30 patients, 51.7%), *S. aureus* (six, 10.3%), *S. haemolyticus* (one, 1.7%), *Enterococcus* (three, 5.1%), *Acinetobacter* (two, 3.4%), *Pseudomonas aeruginosa* species (two, 3.4%), *Klebsiella* (one, 1.7%) and *Candida* (one, 1.7%). Culture results of CSF aspirates were negative in 12 patients (20.7%).

All patients were treated with antibiotics and CSF drainage was maintained either with new EVD catheter insertion after the removal of the shunt system in 44 (75.9%) children or with externalization of the existing ventricular catheter in 14 (24.1%). Due to blockage of the catheter, accidental removal, or persistent infection, 17 children (29.3%) required revision of their EVD system. Of the 44 children with an EVD catheter, 12 required revision (a rate of 0.27 per patient): one revision in nine patients, and two revisions in three patients. Between days six and 10, five of the 14 children with externalized ventricular catheters required catheter replacement with an EVD catheter due to failure of treatment for infection (rate of 0.35 per patient): one replacement in three patients and two replacements in two patients.

The total treatment time from diagnosis of ISI ranged from eight to 45 days (mean ± standard deviation [SD], 11.5 ± 9.16 days). The duration of CSF drainage for 24 patients was 10 days or fewer, and for 34 patients, the duration of CSF drainage was for more than 10 days. The mean treatment time for patients in whom an RSI developed was 13.4 ± 10.2 days, and it was 9.2 ± 7.6 days for those who did not develop RSI.

While the mean treatment time in children who had an externalized existing ventricular catheter was 13.3 ± 5.6 days, the mean duration of treatment in children whose shunt was exchanged for an EVD catheter was 9.6 ± 3.2 days. The mean difference in the duration of CSF drainage between these two treatment methods was 3.7 days (Table 2). The duration of treatment in the EVD group was significantly shorter than that in the externalized shunt group ($p < 0.05$).

Of the 58 children who were treated for ISI, 15 were diagnosed with a RSI. Nine (60%) of the 15 children were under 12 months of age. In terms of hydrocephalus etiology, spina bifida was the cause in six, congenital in four, meningitis in three and hemorrhage in two patients. The microorganisms responsible for ISI were typically staphylococcal species (nine patients: six were infected with *S. epidermidis*, three with *S. aureus*), and four were non-staphylococcal species (*Enterococcus*, *Klebsiella*, *Pseudomonas aeruginosa*, *Acinetobacter*). Nine out of 15 patients (60%) were treated with the removal of the shunt system and insertion of a new EVD catheter, and six (40%) were treated with the externalization of the existing ventricular catheter. While 10 out of 15 (66.7%) patients with RSI were treated with an EVD for more than 10 days during the treatment for ISI, five (33.3%) were treated with an EVD for fewer than 10 days. Thirteen (86.7%) patients with RSI were culture-positive at ISI, while two were culture-negative at ISI. The microorganisms detected in the RSI were the same as those found at the ISI in 11 of 13 patients (84.6%) and different from those at the ISI in the other two (15.4%) (Table 3). One (6.7%) of the children with a RSI died during the second month of treatment due to cardiac arrest.

The survival analysis comparing risk factors for RSI are summarized in Table 1. According to this analysis, only the CSF drainage method had a significant effect on RSI ($p = 0.032$). Externalization of the existing ventricular catheters had a negative effect on treatment of ISI.

**Table 1**
Potential risk factors for recurrent shunt infection in children

| Risk factor | | Cumulative risk of RSI (%) | $p$ value* |
|---|---|---|---|
| Age (months) | ⩽12 ($n = 36$) | 25.0 | 0.931 |
| | >12 ($n = 22$) | 23.4 | |
| Initial organism | *Staphylococcus* ($n = 37$) | 27.0 | 0.173 |
| | Non-staphylococcal ($n = 9$) | 46.7 | |
| CSF drainage method in ISI | Shunt removal + EVD ($n = 44$) | 20.5 | 0.032 |
| | Shunt externalization ($n = 14$) | 37.7 | |
| CSF culture result in ISI | Positive ($n = 46$) | 30.9 | 0.206 |
| | Negative ($n = 12$) | 0 | |
| Duration of CSF drainage | 10 days or less ($n = 24$) | 14.3 | 0.482 |
| | More than 10 days ($n = 34$) | 25.8 | |
| Etiology of hydrocephalus | Spina bifida ($n = 23$) | 27.2 | 0.479 |
| | Congenital ($n = 16$) | 25.0 | |
| | Meningitis ($n = 11$) | 27.3 | |
| | Hemorrhage ($n = 4$) | 50.0 | |
| | Prematurity ($n = 4$) | 0 | |

CSF = cerebrospinal fluid, EVD = external ventricular drainage, ISI = initial shunt infection, RSI = repeat shunt infection

* $p < 0.05$ defines statistical significance.

## 4. Discussion

Most children with hydrocephalus are treated by shunt insertion. CSF shunts, however, are associated with several complications, one of the most common being infection, which occurs in nearly 10% of patients.[2,12–18] Several independent risk factors for infection have been identified, including a previous shunt-associated infection, shunt revision for dysfunction, postoperative cerebrospinal fluid (CSF) leakage, older age in children, the duration of the operation to place the shunt, the experience of the neurosurgeon and the use of a neuroendoscope.[19,20]

There is debate about whether patient age is a risk factor for ISI and RSI. Some studies have implicated young patient age as a possible risk factor for shunt infection; factors such as a poorly developed immune system, generally more fragile skin condition, and

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