



Early diagnosis of ventriculoperitoneal shunt infections and malfunctions in children with hydrocephalus

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Received: July 2, 2002 Revised: August 15, 2002 Accepted: September 17, 2002

This retrospective study assessed the parameters of ventriculoperitoneal shunt infection and malfunction found in 129 children with hydrocephalus who had undergone a ventriculoperitoneal shunt placement at Taipei Veterans General Hospital from January 1997 to June 2001. The clinical characteristics and differences among these patients were reviewed to determine the potential predictors of shunt infection and malfunction. Fever (60%, 6/10) and seizure (40%, 4/10) occurred significantly more often in the infection group than in the malfunction and control groups ($p < 0.05$). A higher blood C-reactive protein level was noted in the infection group than in the malfunction and control groups ($p < 0.05$). Examination of the cerebrospinal fluid of infected patients showed significantly higher white blood cell count and neutrophil count, higher protein concentration, and lower glucose levels compared with the other 2 groups ($p < 0.05$). However, the number of patients with cerebrospinal fluid eosinophilia was significantly higher in the malfunction group ($p < 0.05$). The diagnostic usefulness of laboratory parameters in patients with ventriculoperitoneal shunt infection is as follow: cerebrospinal fluid white blood cell count over 100 /mm³, 96% specificity and a positive predictive value of 0.55; and cerebrospinal fluid neutrophils over 10%, 90% sensitivity and a negative predictive value of 0.99. In conclusion, Fever, seizure, high blood C-reactive protein, combined with leukocytosis, neutrophil over 10%, low glucose level, and high protein level in the ventricular fluid are factors that may help in distinguishing shunt infection from shunt malfunction.

Key words: Hydrocephalus, infection, malfunction, ventriculoperitoneal shunt

Infection is still the most common complication of shunt procedures in children [1]. Nosocomial meningitis after ventriculoperitoneal (VP) shunt insertion is a severe infection with 33% overall and 20% attributable mortality rate [2]. The rate of cerebrospinal fluid (CSF) shunt infection has varied considerably in different studies, ranging from 0.33% to 39% [3-5]. Staphylococci, mainly coagulase-negative, are the most prevalent pathogens found (45%-72%) [5-7], followed by gram-negative bacilli (19%-22%) [8]. Fungi have rarely been implicated (2%-17%) [1,4]. Early diagnosis of VP shunt infection in patients with nonspecific signs and symptoms remains difficult due to the lack of data to establish reliable predictive factors [9]. This retrospective study evaluated the clinical characteristics and laboratory data of 129 children with hydrocephalus who had undergone VP shunt placement at Taipei Veterans General Hospital from January 1997 to June

2001. These characteristics were evaluated for their ability to distinguish between VP shunt infection and malfunction.

Materials and Methods

Patients collection

This retrospective study included 129 patients with hydrocephalus who had undergone VP shunt placement at Taipei Veterans General Hospital from January 1997 to June 2001. Sixty-eight patients were boys, and 61 were girls. Their ages ranged from less than 1 month to 16 years (mean, 2.7 years) and 23 patients were premature (gestational age <37 weeks). Data collected from laboratory records included routine blood analysis (complete blood counts and differential counts), serum C-reactive protein (CRP), CSF analysis including white blood cell (WBC) counts and differential counts, protein, glucose, and bacterial culture. The patients were divided into 2 groups based on the clinical picture, CSF bacterial culture results, and final diagnosis when they were readmitted for shunt-related problems. Patients

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with repeated shunt malfunctions and infections were excluded.

Definition of shunt infection

The first group comprised patients with VP shunt infection, defined as clinical signs or symptoms of infection combined with a positive culture from the CSF sample ($n = 10$). The second group comprised patients with shunt malfunction with a negative CSF culture ($n = 28$). The control group comprised 129 patients who received a VP shunt insertion due to hydrocephalus who had no evidence of infection. All of the CSF samples were obtained during surgery or at the reservoir site. The data reviewed included patient's age and sex, clinical manifestations, laboratory finding of the blood and CSF, and microbiological findings.

Statistical analysis

Data are presented as mean \pm standard deviation. Chi-square, Fisher's exact test, and Student t test were used as appropriate to compare between group differences. For all tests, a p value below 0.05 was considered significant. The sensitivity (percent of positives detected and correctly identified), specificity (percent of negatives detected and correctly identified), and predictive value (percent of class matching) of each diagnostic parameter tested were determined.

Results

All cases of shunt infections localized in the central nervous system occurred within the first 5 months following the primary shunt insertion, with a mean time to onset of 23 days (range, 3 days-5 months). The rate of VP shunt infection in children less than 1 year old was 10.7% (6/56); in those from 1 to less than 7 years, 5.3% (2/38); and in those from 7 to 16 years, 5.7% (2/35). In addition, the rate of infection in children born prematurely was 13% (3/23). The organisms causing the infections were distributed among gram-positive

bacilli (80%; coagulase-negative *Staphylococcus* predominant), gram-negative bacilli (40%), and fungi (10%; all *Candida albicans*) (Table 1). Patients with VP shunt infections exhibited a wide variety of signs and symptoms. Fever (body temperature $\geq 38^\circ\text{C}$) was the most common symptom, and was present in 6 (60%) patients. Four (40%) patients had seizure attacks. Both vomiting and drowsiness were present in 3 (30%) of these patients, and 2 (20%) complained of abdominal pain or headache. Only 1 (10%) patient presented with dyspnea. In the malfunction group, fever was present in 2 (7%) cases. Three (11%) patients had seizure attacks. Fever and seizure occurred significantly more often in the infection group than in the malfunction and control groups ($p < 0.05$).

Peripheral blood analysis (Table 2) showed a significant difference in CRP value ($p < 0.05$), but no difference in neutrophils, lymphocytes, and eosinophils between the infection and malfunction groups. Cerebrospinal fluid analysis (Table 2) showed significantly higher WBC counts, neutrophils, and protein levels and lower glucose levels in the infected group than in the malfunction group ($p < 0.05$). Cerebrospinal fluid eosinophilia was more predominant in the malfunction group ($p < 0.05$).

Further examination of those variables showing a statistically significant difference among groups to determine their ability to predict an early diagnosis of shunt infection revealed the following: CSF WBC counts over $100/\text{mm}^3$ had a 96% specificity, and a 0.55 positive predictive value, and CSF neutrophils over 10% had a 90% sensitivity, and a 0.99 negative predictive value (Table 3).

Discussion

Infectious complications following the surgical treatment of hydrocephalus with shunt implantation remain one of the most serious problems in pediatric and adult neurosurgical practice [10]. The vast majority of shunt infections occur within a few months of the operation (within 9 months, 91%) [11]. The risk factors for shunt infection are still controversial. One study found that infants, specifically those less than 6 months of age, have a higher incidence of VP shunt infection, and that this is related both to their immunologic deficiency and to the particular features of the residential bacterial flora in this age group [12]. In this study, children less than 1 year old had the highest rate of VP shunt infections (10.7%, 6/56). Moreover, the rate of infection among children born prematurely was 13% (3/23). A previous study found fever, irritability, meningeal sign, and seizure were the more reliable

Table 1. Pathogens isolated from 10 patients with VP shunt infection

Microorganism	No. of isolates
Coagulase-negative <i>Staphylococcus</i>	6
<i>Acinetobacter baumannii</i>	1
<i>Candida albicans</i>	1
<i>Enterobacter cloacae</i>	1
<i>Escherichia coli</i>	1
Group D <i>Streptococcus</i>	1
<i>Pseudomonas aeruginosa</i>	1
<i>Staphylococcus aureus</i>	1

Note: 3 of the 10 patients had 2 associated pathogens isolated.

Table 2. Laboratory data in patients with VP shunt infection, malfunction, and controls

Category	Infection (n = 10)	Malfunction (n = 28)	Control (n = 129)
Blood			
WBC counts /mm ³	14 323 ± 3462 (5200-23 500)	10 865 ± 6752 (2300-22 600)	10 730 ± 4268 (5000-26 400)
Neutrophils (%)	62 ± 18 (25-88)	63 ± 22 (13-90)	58 ± 12 (10-90)
Lymphocytes (%)	34 ± 18 (8-68)	26 ± 17 (8-85)	30 ± 16 (8-96)
Eosinophils (%)	0 ± 1 (0-4)	1 ± 2 (0-8)	1 ± 1 (0-2)
CRP (mg/dL)	7.7 ± 5.8 (0.8-20.4) ^a	2.4 ± 2.0 (0.3-16.0)	2.0 ± 1.7 (0.6-5.6)
CSF			
WBC counts /mm ³	496 ± 1020 (15-4230) ^a	20 ± 121 (0-1212)	1 ± 4 (0-25)
Neutrophils (%)	68 ± 26 (2-98) ^a	5 ± 10 (0-45)	1 ± 5 (0-30)
Lymphocytes (%)	24 ± 16 (2-74)	15 ± 29 (0-85)	6 ± 21 (0-96)
Eosinophils (%)	1 ± 2 (0-8)	5 ± 9 (0-40) ^b	0 ± 1 (0-8)
Protein (mg/dL)	387 ± 820 (30-2800) ^a	28 ± 6 (15-66)	28 ± 9 (10-56)
Glucose (mg/dL)	33 ± 21 (8-71) ^a	67 ± 15 (22-90)	54 ± 9 (12-80)

Abbreviations: WBC = white blood cell; CRP = C-reactive protein; CSF = cerebrospinal fluid

^aInfected group significantly different from the other 2 groups at $p < 0.05$.

^bMalfunction group significantly different from the other 2 groups at $p < 0.05$.

Note: values are mean ± standard deviation (range).

manifestations of shunt infection [12]. This study revealed that fever (60%, 6/10) and seizure (40%, 4/10) occurred significantly more often in the infection group than in the malfunction and control groups ($p < 0.05$). This finding is also comparable to previous studies. Davis *et al* [13] found a trend of relative increase in the incidence of *Staphylococcus aureus* infection and relative decrease in coagulase-negative staphylococci between 1985 and 1994. In this study, however, coagulase-negative staphylococcus (60%, 6/10) was the major organism of VP shunt infection. *S. aureus* was an uncommon isolate, found in only 10% (1/10) of all cases.

In agreement with this study, Tung *et al* [14] also reported that CSF eosinophilia is an important and common finding in patients with VP shunt malfunction and infection. Children with CSF eosinophilia have a higher risk of developing shunt malfunction and shunt infection than those without CSF eosinophilia. In this study, CSF eosinophils were significantly increased in the shunt malfunction group ($p < 0.05$) but not in the infection group compared with patients with shunt

malfunction and controls. We also found a high blood CRP level in patients with shunt infection. Leukocytosis, neutrophilia, a high protein level, and a low glucose level in the CSF were also found with increased frequency in the shunt infection group. Among the parameters studied, CSF WBC over 100 /mm³ had a 96% specificity, and a positive predictive value of 0.55 for shunt infection. However, CSF neutrophils over 10% had a 90% sensitivity and negative predictive value of 0.99.

In summary, children with shunt placement in an emergency setting may be at increased risk of shunt infection if they present with the following conditions: fever, seizure, high serum CRP, combined with leukocytosis, neutrophil over 10%, a low glucose level, and a high protein level in the ventricular fluid. These characteristics may help in distinguishing shunt infection from malfunction.

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Table 3. Predictors of VP shunt infection

Variable(s)	% Sensitivity	% Specificity	Predictive value	
			Positive test	Negative test
History of fever	60	85	0.24	0.96
History of seizure attack	40	87	0.19	0.95
Serum CRP >10 mg/dL	40	95	0.36	0.95
CSF WBC >100 /mm ³	60	96	0.55	0.97
CSF neutrophils >10%	90	85	0.33	0.99
CSF protein >50 mg/dL	80	84	0.42	0.98
CSF glucose <40 mg/dL	60	93	0.40	0.97

Abbreviations: CRP = C-reactive protein; CSF = cerebrospinal fluid; WBC = white blood cell count

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