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Surgical Treatments for Infantile Purulent Meningitis Complicated by Subdural Effusion

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Background: Infantile purulent meningitis (PM) is a commonly severe intracranial infectious disease in infants under age 1 year. In recent years, several diagnostic and treatment methods were reported, but in these cases the neurological complications and sequel were often observed, among which subdural effusion (SE) is the most common complication in PM. Timely diagnosis and early intervention are vital for better outcomes. In this study, the surgical treatments for infantile PM complicated by SE were investigated.

Material/Methods: Patients who had PM complicated by SE in the Children's Hospital of Hebei Province from June 2000 to June 2012 were retrospectively analyzed and 170 patients were enrolled in the study. Surgical treatment for each patient was adopted according to producing effusion time, leucocyte count, protein content, intracranial pressure, and bacteria culture, coupled with cranial ultrasound examination, CT, and MRI scans.

Results: Nearly, 15 patients were cured using serial taps, with a 50% cure rate. Seventeen out of 30 (56.6%) patients receiving subcutaneous reservoir drainage had better outcome. Nearly 80% of patients (55/69) who underwent minimally invasive trepanation and drainage were positive. Surgical procedure of minimally invasive trepanation and drainage combined with drug douche was effective in 63% of patients (19/30). In addition, 6 patients were cured with subdural-peritoneal shunt. Only 1 patient died, after the recurrence of meningitis, and the remaining 4 patients were cured by craniotomy.

Conclusions: For infantile PM complicated with SE, treatment needs be chosen according to the specific situation. Surgical procedure of minimally invasive trepanation and drainage is a very effective treatment in curing PM complicated by SE. The treatment was highly effective with the use of drug douche. Subdural-peritoneal shunt and craniotomy were as effective as in refractory cases.

MeSH Keywords: **Endocrine Surgical Procedures • Meningitis, Bacterial • Subdural Effusion**

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Background

Infantile purulent meningitis (PM) is a commonly severe intracranial infectious disease in infants under age 1 year. In recent years, several diagnostic and treatment methods were reported, but in these cases neurological complications and sequel were often observed, among which subdural effusion (SE) is the most common complication in PM. The incidence of SE is as high as 50–70%, of which 80–90% of cases showed no clinical symptoms, while another 10–15% of cases showed clinical symptoms. Timely diagnosis and early intervention are vital for better outcomes [1–3].

Three common surgical treatments for infantile PM complicated by SE are: (1) serial taps; (2) constant drainage; and (3) craniotomy with puncture or drainage. PM complicated by SE is common in infants under 1 year of age and mostly occurs within 1–3 weeks of PM [1,4], as also shown by data from cranial ultrasound examination and CT and MRI scans in the cases reported. The main reasons for SE is inflammatory embolism of dura mater, bridging vein, and cerebral superficial veins, which can cause partial osmotic pressure increase, resulting in the surrounding water entering into the subdural space or cause vascular permeability increase in brain and meninges, leading to plasma albumin entry into the subdural space [5,6]. After the formation of SE, the intracranial pressure increases and the fibrins in SE also gradually deposit to form a parcel wall and the SE cannot be absorbed; therefore brain tissue is compressed, which leads to permanent neurological dysfunction in some children [7,8].

Patients who had PM complicated by SE in the Children's Hospital of Hebei Province from June 2000 to June 2012 were retrospectively analyzed and 170 patients were included in this study. Surgical treatments for each patient were adapted

according to effusion time, leucocyte count, protein content, intracranial pressure, bacterial culture, cranial ultrasound examination, and CT and MRI scans. Six treatment methods were used and the results were satisfactory.

Material and Methods

General information

We enrolled 170 patients. The study and treatment methods were approved by the institutional ethics committee of the Children's Hospital of Hebei Province. The male versus female infant ratio was 3: 2, with an age range of 1–11 months and average age of 7.6 months. All the cases were diagnosed as PM by staff of the Department of Internal Medicine by examination of lumbar puncture cerebrospinal fluid. Inclusion criteria were: clinical cure for PM; normal leucocyte count, protein, and glucose contents in cerebrospinal fluid; and subdural fluid depths measured by CT over 1 cm. Exclusion criteria were: craniocerebral trauma, hydrocephalus shunts, excision of intracranial tumor, and other noninfectious causes of SE. The overall clinical features of all the patients are shown in Table 1. Cranial ultrasound examination of type B, CT/MRI scans, and subdural puncture were used to confirm the presence of SE.

Effusion site and properties

There were 140 patients with bilateral effusion and 30 patients had hemi-effusion. By observation through puncture or trepanation, the color of drainage fluid at first was deep yellow, light yellow, or brown, and then turned to pale bloody or meat wash water for puncture hemorrhage, and sometimes became ropy pus. Protein content of SE was 4–20 g/L, with the cell count 50–500×10⁶/L, and intracranial pressure 6.7–9.3

Table 1. Clinical features of 170 PM patients with all ages.

Clinical features	Age (months)			Total
	1–3	3–6	6–11	
Number of patients	30	75	65	170
Bregmaticeminance	7	52	28	87
Hypoevolutism	2	6	2	10
Dyskinesia	5	10	5	20
Vomit	10	15	5	30
Screaming and crying	15	45	10	70
Epilepsia	5	10	3	18
Low vision	2	3	6	11
Cortical blindness	1	1	2	4

Table 2. First treatment results of 170 PM Patients complicated with SE.

Treatment	Results			Total
	Cured	Better	Invalid	
The intermittent puncture	15	0	15	30
The subcutaneous reservoir drainage	17	0	13	30
The minimally invasive drainage hole	55	11	3	69
The minimally invasive drainage hole with drug douche	19	0	11	30
The effusion cyst- peritoneal shunt	6	0	0	6
The craniotomy	4	0	1	5

mmHg. Bacterial culture was positive in 13 patients, including 2 patients with *Klebsiella pneumoniae*, 6 with *Pneumococcus* sp, 3 with *Meningitis diplococcus*, 1 with *Haemophilus influenza*, and 1 with *Salmonella* sp.

Therapeutic method

All the patients received routine drug therapy for more than 3 weeks in the Department of Internal Medicine. Except for subdural-peritoneal shunt and craniotomy, the patients were kept for observation for 2 weeks. The treatment groups were: 30 patients with serial taps, 30 patients with subcutaneous reservoir drainage, 69 patients with minimally invasive trepanation and drainage, 30 patients with minimally invasive trepanation and drainage with drug douche, 6 patients with subdural-peritoneal shunt, and 5 patients with craniotomy.

Statistical analysis

All data were analyzed using SPSS 17 (SPSS Package, USA). The data was further analyzed by *t* test and $P < 0.05$ was considered as statistically significant.

Results

Assessment standards of therapeutic effects were divided into "cure", "better", and "ineffective". "Cure" was defined as complete disappearance of the original symptoms and satisfactory expansion of the brain tissue during follow-up. "Better" was defined as mild functional disorder of the nervous system but significantly improved expansion of brain tissue. "Ineffective" was defined as continuous deficiency in part of the neural function and CT scans showing no re-expansion of brain tissue. All the patients were followed up for 1–3 years, and average follow-up time was 2 years. During follow-up, 15 patients showed alleviated nerve dysfunction and 5 patients showed no relief. For the children with postoperative neural dysfunction,

drugs (monosialotetrahexosyl ganglioside+rat nerve growth factor) that could nourish the brain nerve cells were administered for 2–3 weeks as a single course, with 4–5 courses each year. Hyperbaric oxygen therapy for an hour each day for 10 days as a single course, with 4–5 courses each year was also given. Pressure inside the capsule was determined according to the age and weight of the child, and oxygen concentration was controlled at 65–75%. Treatment results are shown in Table 2. Fifteen patients with serial taps and 13 with subcutaneous reservoir drainage were cured after being treated with minimally invasive trepanation and drainage. Three patients who had been classified as ineffective when treated with minimally invasive trepanation and drainage were classified as cured after combined treatment with drug douche. Eleven patients classified as ineffective when treated with minimally invasive trepanation and drainage with drug douche; of these, 6 were cured by further treatment using subdural-peritoneal shunt and 4 were cured by craniotomy. Only 1 patient died due to recurrence of PM after craniotomy.

Discussion

For the patients with infantile fontanel and sutura not closed with the thin skull, the image was easily displayed in general cranial ultrasound examination, which accurately reflected the degree of SE [9,10]. Therefore, patients confirmed by cranial ultrasound examination and puncture in clinical examination were not examined further by CT or MRI scans, which could reduce the brain damage caused by use of X-rays in infants.

Analysis of patient data showed a positive correlation among subdural fluid depth, leucocyte count, and protein content. Furthermore, leucocyte count, protein content, and intracranial pressure all reached a plateau about 10 days after trepanation and drainage. High protein content causes inadequate drainage and high leucocyte count can be reduced by antibiotic treatment. High intracranial pressure may lead to relapse of

encephalitis. Thus, the relationship between these 3 indicators is essential because they may change the course of disease and are considered as references for individual clinical therapy.

Surgical treatments for each patient with PM complicated by SE were chosen based on: time of effusion formation, leucocyte count, protein content, intracranial pressure, bacteria culture, cranial ultrasound examination, and CT and MRI scans.

Serial taps

Serial taps can be performed in the early stages of effusion formation, within the first 3 weeks when the parcel wall has not fully developed, to induce the oppressed brain tissue to expand. Serial taps are suitable for patients who have protein content of effusion lower than 5 g/L and depth of maximum area less than 1.5 cm. In each puncture, the effusion volume should not exceed 30 ml, and it should not exceed 50 ml if bilateral puncture was performed. With the initial puncture regimen scheduled every other day, the time between punctures can be gradually extended, depending on the reduction of effusion volume. Diluted antibiotics targeted towards specific bacteria were injected into the effusion cavity if the test culture was positive. No further punctures are needed when clinical symptoms decrease, protein content is below 2 g/L, and cranial ultrasound examination, CT, and MRI scans reveal less than 1-cm effusion thickness. This treatment is simple, easy to perform, and puncture position can be adjusted with the help of cranial ultrasound. However, repeated punctures may lead to subdural hemorrhage and iatrogenic intracranial infection. With repeated punctures, even after 2 weeks, if there is no decrease in effusion volume and leucocyte count, but there is increased protein content, the patient needs to be further treated with minimally invasive trepanation and drainage. Fifteen patients had better clinical outcome and the other 15 patients were further referred for minimally invasive trepanation and drainage treatment.

Subcutaneous reservoir drainage

Subcutaneous reservoir drainage can be performed within the first 3 weeks after the appearance of effusion, with the protein content 5–10 g/L and depth of maximum area more than 1.5 cm. Here, when parcel wall formation occurs, subcutaneous reservoir drainage seems to be more suitable than repeated puncture because it may lead to bleeding due to hyperemia and edema. This method is highly advantageous because it avoids bleeding caused by repeated punctures and is convenient for drainage, irrigation, and injection of antibiotics. The disadvantages of this method have not been clearly defined; indwelling time should not be over 2 weeks, especially in fontanelle position with bilateral anterior at same time. Daily drainage volume of hemi-drainage should be under 60 ml and the

bilateral drainage volume should not exceed 100 ml. Patients can be treated further by minimally invasive trepanation and drainage after 2 weeks if there is no decrease in effusion volume, leucocyte count, protein content, and intracranial thickness of drainage fluid. In this group, 17 patients who did not improve in the earlier serial taps treatment showed good improvement by subcutaneous reservoir drainage, and the 13 patients who did not show any further improvement were treated with minimally invasive trepanation and drainage.

Minimally invasive trepanation and drainage

Minimally invasive trepanation and drainage can be performed when effusion occurred within 3 weeks, with the average depth of the maximum area greater than 2 cm or if effusion was purulent, and with higher protein content (>10 g/L), or intermittent intravenous and subcutaneous reservoir drainage if the patient shows no improvement after 2 weeks. According to cranial ultrasound examination results and CT and MRI scans, a 1–1.5 cm incision was made on the projecting surface of the thicker effusion (seen more commonly in 2–3 cm side midline of head-top behind the anterior fontanelle). The scalp was opened sequentially, the periosteum was separated, a 0.5-cm hole was drilled using an osteotome, purple-brown dura mater was observed, and the effusion was extracted for determination by puncture. Pale bloody or deep yellow effusion flowed out when bipolar-electrocoagulated dura mater was cut with “+” style, and a minimally invasive drainage tube (STR, China) was placed about 2 cm into the effusion cavity, and the subcutaneous drainage tube was pushed 3 cm outside of incision and the wound was sutured to fix the drainage tube. The effusion cavity is washed with warm saline until effusion is clear. The far end of the drainage tube was connected to a detection system to control the drainage volume and observe changes in intracranial pressure. Daily drainage volume of hemi-drainage should be below 60 ml and the bilateral drainage volume should not exceed 200 ml. From continuous drainage post-surgery, the intermittent specimens on day 1, 3, 7, and 10 and after 2 weeks were collected for routine examination. Biochemical and culture tests were performed to detect changes in leucocyte count, protein content, and intracranial pressure in SE, and reviewed by cranial ultrasound examination and CT and MRI scans. Based on the effusion property, protein content, leucocyte count, intracranial pressure, and level of brain tissue expansion, the drainage tube was removed.

Decrease in leucocyte count, protein content, and intracranial pressure was observed gradually from the 7th day, and it reached a plateau at the 10th day, with the stability from 2nd week after surgery showing a significant improvement in the clinical symptoms, with normal drainage fluid. Cranial ultrasound examination and CT and MRI scans of the 55 patients

Table 3. The change of white blood cell, protein content and intracranial pressure in SE of 69 cases (mean \pm SEM).

Time	Number		
	White blood cell ($\times 10^6$)	Protein content (g/L)	Intracranial pressure (mmHg)
Number of patients (n)	69	69	69
In operation	249 \pm 126	13 \pm 3.8	6.7 \pm 2.6
1 st day post surgery	200 \pm 107	12 \pm 3.5	5.7 \pm 2.2
3 rd day post surgery	100 \pm 40	9 \pm 2	5.1 \pm 1.9
7 th day post surgery	60 \pm 22	6.9 \pm 1.4	3.4 \pm 1.2
10 th day post surgery	50 \pm 15	5.3 \pm 1.3	3.2 \pm 0.8
2 weeks post surgery	40 \pm 13	5.1 \pm 1.2	3.0 \pm 0.6

No significance difference was observed in the white blood cell count on the 7th, and 10th day and 2 weeks post surgery ($P > 0.05$). Similar results were observed in group protein content and intracranial pressure. Between the three groups i.e white blood cell, protein content and intracranial pressure, statistically significant difference was observed when compared with the results of 7th, 10th day and 2 weeks to the results of 1st and 3rd day ($P < 0.05$).

in this group during the first 2 weeks after surgery showed significant improvement in brain tissue, with decreased leucocyte count and protein content in SE patients being stabilized, and drainage fluid being normal; therefore, the drainage tube was removed from these patients. Follow-up results of these patients after 1 year showed the disappearance of SE. Examination of the other 20 cases by CT showed a significant increase in brain tissue, with higher leucocyte count in SE. They were reviewed again after continuous treatment with drainage tube for 3 weeks and the results showed decreased leucocyte count, with no significant change in brain tissue (Table 3). Disappearance of SE was observed during the follow up after the drainage tube was removed. Longer presence of the drainage tube can increase the risk of intracranial infection and 2-week treatment by minimally invasive trepanation and drainage is better for PM complicated by SE [11,12].

Minimally invasive trepanation and drainage with drug douche

After 3 days of minimally invasive trepanation and drainage, if leucocyte count remains higher than $100 \times 10^6/L$ or increased protein content (> 10 g/L) or effusion samples were positive for bacterial culture, then the combined treatment of minimally invasive trepanation and drainage with drug douche administration was performed. Appropriate sensitive antibiotics were diluted in 250 ml saline and administered. If the effusion samples were negative for bacterial culture and the patients appeared to have fever with leucocyte count higher than $10 \times 10^9/L$, then 20 000 units gentamicin was diluted in 250 ml saline along with the routine drug douche and administered. Careful and effective drug douche can effectively

control partial inflammation, shorten the course, and reduce the cost of hospitalization [13,14].

Subdural-peritoneal shunt

After minimally invasive trepanation and drainage with drug douche, if the symptoms improved with no bacterial growth in SE, protein content was less than 1 g/L, leucocyte count was less than $20 \times 10^6/L$, there was no reduction in the drainage volume, and there is incomplete decompression of brain tissue, then subdural-peritoneal shunt is performed, depending on whether there is a connection between the subdural and cavum subarachnoidale. Six patients in this study underwent subdural-peritoneal shunt. Effusion cavities disappeared at 3–6 months after surgery with the brain tissue expanded completely. Subdural-peritoneal shunt can reduce the time of hospitalization. A low-voltage shunt is suitable for the shunt tube [15].

Craniotomy

Completely formed parcel wall was observed 3 weeks after SE appearance and it can limit child brain development. If minimally invasive trepanation and drainage with drug douche is ineffective, with no reduction in drainage volume and brain tissue expansion, and no elevation in clinical symptoms, craniotomy can be considered for PM complicated by SE [16]. Bilateral effusion should be performed by bilateral craniotomy; the operation needs to be carried out under a microscope, including cleaning effusion, resection of parcel wall, and repeated flushing by using saline with antibiotics. A few mossy cells may appear on the surface of the brain, which should not be forcibly stripped. If the arachnoid is ruptured during the process of

stripping, it is important to get through the cavum subarachnoidale to avoid formation of a valve. To prevent subdural hematoma, dehydrating agent should not be used after surgery.

Non-pyogenic SE

Most cases of SE in infants in our center were caused by PM and non-pyogenic SE, mostly referred to as spontaneous SE, which is caused by brain trauma. For some infants with non-pyogenic SE in involuting and stable type, whose subdural fluid depth was no more than 1 cm shown in CT simultaneously, without obvious pressure and brain symptoms, conservative treatment was applied with hyperbaric oxygen, administration of drugs that nourish the brain nerve cells and physical training with a course of 10 days being applied, with 3–4 courses a year. The patients underwent regular examinations and 100 patients were followed up and observed once. Results showed that the brain tissue expanded completely without the loss of neurological function and prognosis was good through several courses of conservative treatment.

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Conclusions

PM in infants is easily to complicate by SE, making treatment difficult. Individualized surgical treatments should be selected according to the time of effusion formation, leucocyte count, protein content, intracranial pressure, and bacteria culture, as well as cranial ultrasound examination and CT and MRI scans. Minimally invasive trepanation and drainage is an effective method to treat PM complicated by SE and, when necessary, combination with drug douche, the outcome is better. Using subdural-peritoneal shunt and craniotomy, refractory cases can also achieve satisfactory results.

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