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Infections of Shunt Systems in Children Hospitalised at the Teaching Department of Paediatric Surgery and Traumatology in 2008-2012

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Abstract

Introduction: Implantation of a shunt system is one of the most common therapeutic methods applied in children with hydrocephalus.

Objective: Objective of the study is to analyse infections of the CNS as a reason for revision of shunt systems in children with hydrocephalus (HC), to determine risk factors of infection of the shunt system and to present a strategy for infection treatment and prevention used in our Teaching Department.

Material: One hundred and seven (107) surgical procedures of a shunt system implantation were performed in 75 patients in 2008-2012.

Method: Case records, surgical reports and radiographic files of children with a shunt system experiencing a CNS infection were retrospectively analysed. In 2008-2012 the frequency of infections of shunt systems per the total number of completed procedures was 10%, and 15% per the total number of patients with shunt systems.

Conclusion: Exchange of the draining system is the therapy of choice.

Keywords: Shunt systems; Paediatric surgery; Traumatology

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Introduction

Implantation of a shunt system is one of the most common therapeutic methods applied in children with hydrocephalus. Unfortunately, function of the ventricular-peritoneal drainage is burdened with numerous potential complications, resulting in numerous revision surgeries throughout a child's life.

Infections of shunt systems are the second common, after mechanical complications, reason for revision of ventricular drainage in hydrocephalic children. However, much more commonly they lead to permanent injuries of the CNS, recurrent CNS infections and death. They also extend the time of hospitalisation and increase associated costs of care. Hence the need for an appropriate antibiotic-based prophylaxis in the perisurgical period, and for early diagnosis and decision regarding further course of treatment.

Objective

Objective of the study is to analyse infections of the CNS as a reason for revision of shunt systems in children with hydrocephalus (HC), to determine risk factors of infection of the shunt system and to present a strategy for infection treatment and prevention used in our Teaching Department.

Material

One hundred and seven (107) surgical procedures of a shunt system implantation were performed in 75 patients in 2008-2012. Eleven (11) shunt systems became infected. There were 6 girls and 5 boys aged between 2 months and 9 years (mean 23 months) at the time of infection detection in that group. Reasons for implantation of a shunt system included: post haemorrhagic hydrocephalus in 6 cases, congenital hydrocephalus in course of meningomyelocele (MMC) in 3 cases, and post inflammatory hydrocephalus in 2 cases.

Table 1: Characteristics of the study group.

No. of boys	5
No. of girls	6
Post haemorrhagic hydrocephalus	6
Congenital hydrocephalus in course of MMC	3
Post inflammatory hydrocephalus	2
No. of children aged <6 months	7
No. of all cases	11

Table 2: Symptoms of infection of the shunt system.

Symptoms	
Dysfunction of the shunt system	4
Neuroinfection	3
Sepsis, respiratory failure	1
Peritonitis	1
Wound infection	2

Table 3: Bacterial flora cultured from CSF cultures, and the number of cases.

MRCNS epidermidis	5
MRCNS haemoliticus	3
E.coli, Pseudomonas aeruginosa, Proteus Mirabilis	1
Acinetobacter baumanii	1
Staph. haemolyticus MRS, Staph. epidermidis	1

Method

Case records, surgical reports and radiographic files of children with a shunt system experiencing a CNS infection were retrospectively analysed. The following data were collected: demographics, age at the diagnosis of infection, symptoms, aetiology of hydrocephalus, and number of procedures performed before the infection developed number of procedures performed until sterility of CSF was achieved, and type of bacteria, applied treatment.

A frequency of infections per a procedure (a number of cases divided by the number of implantations of a shunt system), a frequency of infections per a patient (a number of patients with the infected shunt system divided by the number of patients with shunt systems), infection risk factors, including: age at the time of implantation, perinatal infections, additional conditions, were determined.

Infection of the shunt system was diagnosed based on positive results of CSF culture or clinical signs of CNS infection with negative results of CSF culture but an abnormal result of the general CSF test (cytosis >30 µl, protein >100 mg/dl, glucose < 50 mg/dl).

The applied treatment method involved removal of the shunt system with a single-stage externalisation of drainage and intrasurgical collection of CSF for a general test and for culture aimed at detection of aerobic and anaerobic bacteria. Blood for culture was also collected. Following a week long treatment with antibiotics consistent with the antibiogram, CSF cultures were performed for 3 subsequent days. Depending on the obtained results of CSF and blood cultures, exponents of the inflammation, the child's general condition, and a result of the general CSF test, the child was qualified for exchange of the external drainage or for re-implantation of a shunt system on the contralateral side, with boring of a new trephine opening.

Results

In 2008-2012 the frequency of infections of shunt systems per the total number of completed procedures was 10%, and 15% per the total number of patients with shunt systems. Based on the analysed medical files it was concluded that infections of the shunt system were more common in premature babies – 7 cases, and more commonly in girls than boys. In all cases that was the first episode of infection. In 9 cases (82%) the infection developed within first 3 months from installation of the ventriculoperitoneal drainage (range from 1 month to 15 months). Post haemorrhagic hydrocephalus was the type of HC most commonly complicated by infection of the shunt system.

The infection manifested mostly with signs of dysfunction of the shunt system - various, depending on the child's age. Other symptoms included: neuroinfection, sepsis, respiratory failure, and peritonitis and wound infections (Table 2). At the time of diagnosis of the infection, 3 children had body temperature of 38 centigrades, 2 children - 37 centigrades, and in remaining cases the temperature was within the normal range. In the paediatric Glasgow Coma Score the children scored between 9 and 15 points.

Case Presentation

In all cases CSF cultures gave a positive result. Cytosis in the general test was between 3 and 2030 cells/µl (graph 2), protein between 11 and 1279 mg/dl (graph 3), glucose between 0 and 70 mg/dl (graph 4). In 9 cases smears indicated prevalence of lymphocytes, and in 2 cases- of granulocytes. In blood the leukocyte level was between 4 and 30 K/µl, CRP between 0.21 and 9.88 mg/dl. The above mentioned parameters correlated with the general condition. The higher protein and cytosis levels, and the lower glucose level was, the less favourable the child's condition. In 2 severe conditions, with the GCS scores of 10 and 9 there was a simultaneous rise of the protein level (over 1000 mg/dl), cytosis (>1000 cells/µl) and glucose level drop to < 5 mg/dl. Neutrophils prevailed in the CSF smear.

The most common pathogen cultured from the CSF was epidermal methicillin-resistant coagulase-negative *staphylococcus* (MRCNS) – 5 cases. Other pathogens were MRCNS haemoliticus - 3 cases, Acinetobacter Baumanie – 1 case, a mixed flora – other 2 cases (Table 3).

In 2 cases, positive results of CSF culture were accompanied by positive results of blood culture, and in those cases the children's condition was more severe compared to those children, whose blood cultures were negative.

After infection was diagnosed, in 8 cases the shunt system was urgently removed within 24 hours with a simultaneous installation of an external drainage. In a single case, because of sepsis and rapidly deteriorating general condition, the shunt system was urgently removed, with installation of an external drainage and washing of the peritoneal cavity. In two cases a peripheral drain was externalised urgently, because CT of the CNS indicated a significant deformation of ventricle, making correct introduction of a new ventricular drain impossible. Electively the whole system was exchanged into external drainage.

The external drainage was exchanged repeatedly - between 1 and 3 times (Table 4).

Reasons for exchange of the external drainage were: no sterilisation of CSF after a week of treatment, dislocation of the ventricular drain, mechanical damage (Table 4). Only in two cases the shunt system was implanted without a previous exchange of the external system.

Table 4: Characteristics of 11 cases of infections of the ventriculoperitoneal system.

Number of external drainage exchange operations per a single patient	
1 exchange	6 patients
2 exchanges	2 patients
3 exchanges	1 patient
An external drainage mean maintenance time	12 days
A mean sterilisation time from the moment of diagnosis of infection	
>10 years of age	27 days
<10 years of age	66 days
Mean duration of hospitalisation	44 days
Reasons for exchange of an external drainage	
Persistence of infection	6 patients
Dislocation of a ventricular drain	2 patients
Mechanical damage	1 patient
Number of implanted ventriculoperitoneal drainages	9
Number of implanted ventriculoatrial drainages	2

Table 5: The association between development of infection and risk factors.

Risk factor	No. of cases
Age< 6 months	7
Prematurity	6
Infection of the surgical wound	2
Rickham reservoir	1
Additional conditions	
Hydramnion	1
Heart defects	2
Epilepsy	2
CP	3
NEC	2
Perinatal infections Pneumonia	4
Staphylococcal sepsis	1

After 7 days of a targeted therapy, CSF was collected for three subsequent days for general test and culture. Blood for culture was also collected. With preliminary negative results of culture, regular results of the CSF general test, and negative exponents of inflammation the child was qualified for implantation of the shunt system, and with positive results of culture - for exchange of the external system.

Finally, 9 shunt systems were installed contralaterally, and 2 ventriculoatrial systems, because of numerous adhesions in the peritoneum.

The schematic course of action is presented in the (Figure 1).

Due to the applied treatment, the mean time to CSF sterility was 66 days in children over the age of 10 years, and 27 days in children younger than 10 years. The mean external drainage maintenance time was 12 days. The mean duration of hospitalisation because of infection was 44 days.

The most common risk factor of infection of the ventriculoperitoneal system was age < 6 months, including prematurity.

The association between development of infection and risk factors is presented in the Table 4**.**

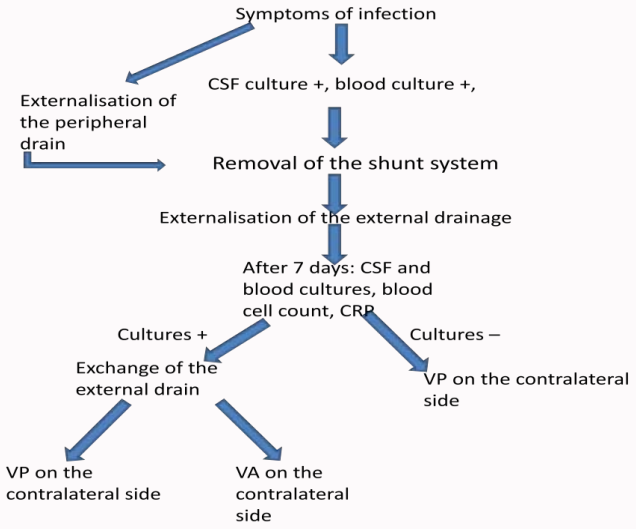

Figure 1: A schematic course of action after the diagnosis of infection.

Discussion

Infections of shunt systems remain the most serious cause of complications of therapy associated with hydrocephalus. Their consequences include permanent injuries of the CNS, recurrent infections of the CNS and death. They are also associated with long hospitalisation periods and expensive treatment. According to Yilmaz et al. [1] prevalence of shunt system infections ranges between 0.17% and 33%. This broad range is a result of various definitions of prevalence, that may be counted as the number of infections per the number of patients [2], or as the number of infections per the number of procedures, including revisions [2]. Some studies report the prevalence of infections considering only the number of procedures [3], or the number of patients.

Risk factors of shunt system infections are: prematurity [4], myelomeningocele [5], post haemorrhagic hydrocephalus [6] and age at implantation of the shunt system [7]. Especially premature infants subject to surgery in first 6 months of their life are at particular risk of infection [8]. In the presented material, infections of the shunt

system occurred twice more often in children with post haemorrhagic hydrocephalus compared to those with congenital hydrocephalus in course of myelomeningocele. That may be associated with the fact that children with MMC are usually born on term, with high body weight at birth, rarely weighing less than 1500g, and therefore their immunological system is more mature. Moreover, implantation of the shunt system performed at our Teaching Department takes place in first 2 weeks of life. After the procedure children remain shortly (only 2-3 days after the procedure) at the Neonatal Intensive Care Unit. Premature neonates, with low body weight at birth, with post haemorrhagic hydrocephalus, remain at the ICU for a much longer period of time, because of their immaturity. That results in colonisation of the skin with methicillin-resistant bacteria. That is confirmed by CSF cultures.

First 8 weeks after the surgery is the period burdened with the highest risk of infection, and as much as 90% of infections manifests during first 6 months after the implantation of the shunt system [9]. It seems that a source of infection is usually associated with the intra- or the early post-surgical period [10].

In the study group, 9 cases of infection (81%) occurred during the first 3 months, which may suggest a peri-surgical source of infection.

Contact with the operating surgeon's skin because of damaged gloves is the main intrasurgical risk factor, and fluid leak from the surgical wound is the risk factor in the post-surgical period [4]. That is why prevention of infections and their early diagnosis are of utter importance.

The following prophylactic techniques are in use in our Teaching Department:

- A shunt implantation surgery as a first in the daily schedule
- Scalp washing after shaving
- Washing of the surgical field three times: separately head and abdomen
- The use of surgical foil with iodine
- The longest possible delay before opening of the shunt system
- Avoiding touching the cerebral drain
- Face mask and caps used by an anaesthesiologist and supporting personnel
- Limited number of people in the operating theatre
- Keeping the time of surgery as short as possible due to a highly qualified surgeon
- Fast qualification for VP
- Limiting the number of punctures, external drainages
- Peri-surgical antibiotic prophylaxis–3rd generation cephalosporins

According to Duhaim et al. [10] the most commonly found pathogens are skin saprophytic bacteria: coagulase-*negative Staphylococcus* and *Staphylococcus aureus*. That aetiology suggests the source of infection in poorly disinfected skin of a surgeon or of a patient. The mycotic and viral etiology has to be considered as well in case of children remaining for longer periods of time in hospitals, especially at ICUs.

In the study group the shunt system infection occurred most often in premature children, burdened with perinatal infections, hospitalised because of those conditions for longer periods of time.

Infections of the shunt systems most commonly manifest by failure of the system, and associated intercranial hypertension [11]. In case of younger children those would manifest with increasing circumference of the head, tension of the anterior fontanel and unrest; and in older children with vomiting, headaches, consciousness disorders. They may be accompanied by signs of neuroinfection: fever, nuchal rigidity, deterioration of the general condition. Symptoms of peritonitis and paralytic ileus, indicating infection of the shunt system, should also be considered. Children with the ventriculoatrial drainage may develop glomeluronephritis, even several years after implantation of the drainage. Differentiation between dysfunction of the shunt system and infection is often difficult; therefore exponents of the inflammation should always be determined, including leukocytosis with smear, PCT, CRP. The deciding factor in the diagnosis is a positive result of CSF culture that should be collected from the retention tank or (if absent) from lumbar puncture or lateral ventricles in children with non-fused fontanel. In cases of infection of the surgical wound, especially in young children with impaired immunity, infection extension onto the shunt system should always be considered. In the study material, there was a single case of infection following a 0.5 cm dehiscence of the wound on the neck, and exposure of the peripheral drain. In another case, infection of the head wound and following infection of the shunt system was preceded by fluid leak around the valve. Also non-sterile ventricular punctures and other methods of decompression of the ventricular system may be risk factors. In a single case of post haemorrhagic hydrocephalus, implantation of the shunt system was preceded by several days of decompression of the ventricular system via the Rickham reservoir on the contralateral side that caused formation of a bed sore and suppuration of the wound. Despite sterile CSF cultures, normal results of the general CSF test, a severe purulent peritonitis and neuroinfection developed in 7 days after implantation of the shunt system. Also in those kinds of cases, wound swab should be performed before the shunt system implantation, along with CSf cultures, blood culture and determination of exponents of the inflammatory condition.

In case of an existing infection, the general CSF test demonstrates increased pleocytosis (over several dozens of cells, with presence of RBCs) and increased protein level (over 100 mg/dl), and the glucose level may be decreased.

The therapy of choice is removal of the shunt system [12] with a simultaneous externalisation of the external drainage and introduction of a broad-spectrum antibiotic therapy.

In the Teaching Department, in case of the diagnosis of the shunt system infection we introduce Vancomycin in age-adjusted doses. Unfortunately, Vancomycin administered intravenously only poorly infiltrates cerebrospinal fluid. Therefore an intraventricular supply is also necessary to achieve the therapeutic level of the drug [13]. However, no side effects and toxicity of intraventricular Vancomycin have been defined yet [14,15]. Therefore, if sterility of CSF is not achieved within a week, besides exchange of the shunt system we administer also Vancomycin intraventricularly at the dose of 0.1 of the intravenous dose, with a simultaneous closure of the drainage system for 3 hours.

The control of the course of infection consisted in determination of exponents of inflammation (PCT, CRP), blood cell count every other day, or in case of deterioration of the general condition. After 7 days, and for subsequent 3 days, CSF was collected for culture and the general test. After obtaining 3 sterile CSF and blood cultures, with a good general condition and low levels of inflammatory exponents, a decision was made on implantation of the shunt system.

Sterility principles were observed in sample collection process, considering possible false positive results and resulting delay of implantation of the shunt system. In case of lack of sterility, the external drainage was exchanged. The procedure was repeated 7 days later. According to Whitehead et al. [16] the mean drainage sterilisation time was between 5 and 24 days. In the study group, achievement of CSF sterility depended on age. In children under the age of 10 years, the sterilisation time was longer and was associated with a higher number of exchanges of external drainages. A mixed flora of MRCNS epidermidis and MRCNS haemoliticus was cultured in CSF, contrary to younger children from whom only single strains were isolated.

Achieved outcomes of treatment of the shunt system infections should be considered satisfactory. No child died because of neuroinfection. Among 11 discussed cases there has been a single episode of the shunt system infection.

Conclusion

1. In 2008-20012 the frequency of infections of shunt systems per the total number of completed procedures was 10%, and 15% per the total number of patients with shunt systems.

2. Saprophytic bacteria are the most common pathogen.

3. Exchange of the draining system is the therapy of choice.

4. Infections occurred more commonly in premature infants, with perinatal infections and post haemorrhagic hydrocephalus.

5. The mean age of HC children subject to surgical treatment because of infection was 2.5 years.

6. Most commonly, symptoms of the shunt system infection are associated with its failure.

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