



REVIEW ARTICLE

Ventricular shunt infection: strategic issues on the most difficult complication of hydrocephalus treatment

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Abstract

Ventricular shunts (VS) are still the main therapy for hydrocephalus in children. Although many lives can be saved with this procedure, shunts are notoriously prone to complications. Among these, infection is the most difficult to deal with. This paper evaluates most aspects of shunt infection, such as etiology, risk factors, diagnosis, treatment and associated complications. Literature shows that the majority of infections are caused by Staphylococcus, although other microorganisms can be involved, such as Gram-negative bacteria and Mycoplasma. Etiology is thus variable and medical personnel should be aware of it. Due to the potential of VS infection to provoke increasing morbidity and mortality in children, the importance of a correct and fast diagnosis should be stressed out to secure a suitable treatment. Additionally, there isn't a uniform protocol worldwide regarding the use of antibiotics, so it often depends on the physicians suggestion and the preference of the hospital's microbiology team. This situation reinforces the need for frequent update to the most recent literature available. Ventricular shunts (VS) are still the main therapy for hydrocephalus in children. Although many lives can be saved with this procedure, shunts are notoriously prone to complications. Among these, infection is the most difficult to deal with. This paper evaluates most aspects of shunt infection, such as etiology, risk factors, diagnosis, treatment and associated complications. Literature shows that the majority of infections are caused by Staphylococcus, although other microorganisms can be involved, such as Gram-negative bacteria and Mycoplasma. Etiology is thus variable and medical personnel should be aware of it. Due to the potential of VS infection to provoke increasing morbidity and mortality in children, the importance of a correct and fast diagnosis should be stressed out to secure a suitable treatment. Additionally, there isn't a uniform protocol worldwide regarding the use of antibiotics, so it often depends on the physicians suggestion and the preference of the hospital's microbiology team. This situation reinforces the need for frequent update to the most recent literature available.

Key words: Cerebrospinal fluid infection; Shunt infection; Ventricular shunt; Ventriculitis.

Introduction

Cerebrospinal fluid (CSF) shunts are used for hydrocephalus treatment and the most common type of shunt diverts CSF from the ventricles to the peritoneal cavity (ventriculoperitoneal shunt [VPS]). The first modern shunt valves were introduced in the 1950s, definitively improving prognosis for these patients [1, 2]. Shunts generally consist of plastic tubing that runs subcutaneously from the head to the abdomen, with a valve between the ventricular and distal catheters [2].

Among the complications of (CSF) shunts, infection is the most difficult to deal with. Some aspects can contribute to decrease infection rates, like operative team's experience, a broad understanding of the processes involved in the procedure and the quality of the biocompatible materials [3].

Infection is the most frequent cause of morbidity and mortality in children who are submitted to VS [4]. Therefore, protocols must be established and followed in order to reduce risks [3].

Infected shunts can lead to a 30% mortality, increase hospitalization time and expenses. As there is no uniform definition of what constitutes shunt infection the diagnosis is based on clinical and laboratory aspects; estimated incidence is in the range of 0 to 60%, but in most centers these numbers are around 2 to 15%. In the western world, most studies show rates from 3% to 9%, in contrast with 9% to 32% seen in African countries [4]. In other studies, it ranges from 33 to 23,5% [3, 5, 6]. Most studies from developed countries report Staphylococcus epidermidis as the more frequent infectious agent, followed by Staphylococcus aureus [4]. Better knowledge about the pathophysiology, stricter regimens in preventing and combating infections, and reduction in operative time may be useful strategies to reduce this incidence [3].

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Methods

We performed a review of the literature focusing on strategic issues regarding ventriculoperitoneal shunt infections.

Etiology

The majority of VS infections is caused by gram-positive cocci, specially *Staphylococcus epidermidis* and *Staphylococcus aureus*. Besides these *Staphylococci*, some others gram-positive are involved in shunt infections, like *Propionibacterium acnes* and enterococci. In addition, gram-negatives as *Pseudomonas aeruginosa* and *Escherichia coli* can cause VS too, coming from the enteric system [3, 8]. Additionally, Erps et. al., observed that gram-positive infections are more common in VS infections detected up to 6 months after surgery [9]. This is important because the majority of the infecting agents is introduced at the moment of the surgical procedure. There are fewer reports of VS caused by *Mycoplasma* than by gram-positives or negatives, but it should also be considered in the diagnosis in specific groups considering that this type of bacteria is not detected by gram staining [10, 11].

Normally, bacteria produce a biofilm surrounding the catheter. It consists in a complex community of microbes that increases bacterial resistance to conventional antibiotics around 1000-fold and protects it from the immune system. While bacteria have the capacity to proliferate and grow, leukocytes can't perform as well, because they do not adhere to the shunt [3, 8, 12].

According to the literature, young age is an important risk factor for VS infection [13, 14]. A case-control study performed in Tel Aviv showed that patients under 5 years had more chances to develop shunt infections than older patients [9]. History of frequent revisions and prior neurosurgical procedures are known risk factors, due to the fact that new surgical procedures increase the probability to introduce microorganisms [15]. Additionally, some studies affirmed that premature children have a higher risk for shunt infection, given their need for multiple revisions [3, 9].

The presence of gastrointestinal tube conditions, specific causes of hydrocephalus and open malformations with CSF communication with the skin also were associated with higher risk of VS infections [13, 14].

Diagnosis

The clinical picture almost always is characterized by a neurological syndrome associated to an infectious syndrome. Clinical features of ventriculoperitoneal shunt infection are also dependent on the mechanism of infection, the type of shunt and the pathogens involved. The symptoms and

signs are commonly related to the site of infection, that means, proximal being from ventricle to valve and distal, from valve to peritoneum (or the other cavity to which CSF is diverted) [6].

The most common symptoms include headache, nausea, lethargy (65% of infections [16]) and fever [6], but some patients may not experience any neurological symptoms, given that, if the infection is distal, they may present acute abdomen symptoms, such as abdominal pain and tenderness [5, 6].

Kaestner et al. analyzed retrospectively all patients with a ventriculoperitoneal shunt who presented with acute abdomen to the emergency room (ER) in a 10-year period. During this time period, 1679 patients had signs and symptoms of peritonitis, 24 (1.4%) of whom had previous ventriculoperitoneal shunts. Half of them had a previous infection and this was associated to peritonitis. The problem regarding these 12 cases, in which the shunt infection was the primary cause for the peritonitis, is that most of them were misdiagnosed. Seven patients had to undergo abdominal surgery: three appendectomy procedures and four explorative laparotomy procedures, all of them without any histological or imaging proof to support the possible diagnosis and despite the extensive scarring that comes along with previous surgery. Another three had to endure invasive abdominal procedures, with no pathological findings. Only two of the patients that had peritonitis due to shunt infection were properly and timely diagnosed. As the aphorism says: "the clinical picture is supreme", so, in order to be suspicious of shunt sepsis, the clinician first must collect a good history and perform a thorough examination to avoid neglected cases [3, 5].

Moreover, as the history is being collected, the clinician doing so must never forget to ask the timing of shunt placement, for 69% of shunt infections happen within the first month [16].

Two red flags in the assessment of shunt sepsis are fever and features of shunt malfunction such as ventriculomegaly, easily evaluated by imaging studies. Another important red flag is the history of frequent shunt obstruction. Neurosurgeons should always stay alert for case types also, for they come with greater risks if not diagnosed early [3].

CSF indices and peripheral markers of inflammation should be considered carefully during assessment [8]. CSF cultures are mandatory, but they must not become an absolute guidance, given that many patients with ventriculoperitoneal shunt had prior antibiotic treatments. Another problem with CSF cultures is that the most common form of shunt infection is biofilm, being extremely difficult to detect the infection with standard cultures of CSF [8].

Skar et al., performed a study to characterize CSF cytokines in patients with shunt infection and to establish different patterns of chemokine and cytokine profiles between gram-negative and gram-positive infections and to demonstrate the potential of such

markers on the diagnosis of shunt infection. The results showed that INF- γ , TNF- α , IL-6 and IL-8 levels did not differ within the group, but levels of IL-10, IL-17A and vascular endothelial growth factor (VEGF) were elevated in gram-positive bacterial infections when compared to gram-negative, and that pro-inflammatory cytokines IL-1 β , chemokine ligand 2 (CCL2), fractalkine (CX3CL1), and chemokine ligand 3 (CCL3) levels were higher in gram-negative shunt infections. These data indicate that gram-positive and that gram-negative agents provoke different immune responses to shunt infection. This kind of knowledge can impact the way to approach each case and perform the best treatment in the future [8].

Other CSF markers are C-reactive protein (CRP) and soluble membrane attack complex. CRP levels can be elevated due to IL-6 modulation by hepatocytes and adipocytes as an inflammatory response, acting as an adjuvant to the complement system. Its sensitivity is 73% to 97% and its specificity is 73% to 80% for shunt infection. Increase in CSF membrane attack complexes is 93% sensitive and 86% specific for shunt infection [16].

Peritoneal pseudocysts are present in 1 to 4.5% of patients with shunts, but it's not always associated with infection. The pathogenesis of this finding is not completely understood, but it is hypothesized that shunt infection can originate peritoneal pseudocysts [16].

Treatment

The basis of VS treatment is the use of antibiotics, but when used in an isolated way, they might not be enough to achieve infection control. Studies performed in the pediatric age group state that antibiotic therapy with external drainage of the ventricles and the removal of the previous shunts are the best scheme. This strategy has shown the most effective way to eradicate shunt infection. Externalization of the shunt with parts of the system left in place did not prove to be an option as good as complete withdrawal of the shunt, external drainage and intravenous antibiotics [3, 13, 17].

There are no uniform universal protocols regarding the use of antibiotics, so it depends on the individual suggestion of the medical team based on previous experience and the indication of the hospital's microbiology team guided by local protocols [3].

Regarding the choice of which antibiotic should be used, a scheme tailored to age group and probable etiology is usually administered while waiting for the result of the collected cultures. After this information associated to antibiogram, the most appropriate antibiotics have to be prescribed over 2 to 3 weeks until the CSF becomes sterile and the shunt can be reinserted [3].

Antibiotics recommended by the Infectious Diseases Society of America are vancomycin, for broad spectrum coverage of staphylococci and other

gram-positive organisms, and ceftazidime, cefepime or meropenem to provide coverage against gram-negative bacteria. However, the impact of antibiotic therapy alone is limited by pharmacokinetic factors such as drug solubility, pH gradient between the CSF and blood, ionization, protein binding ability, molecular size, drug configuration and the extent of meningeal inflammation. All these issues limit the ability of antibiotics to reach therapeutic concentrations in the CNS [3, 13].

Complications

Treatment of shunt infections can be in some cases an unavoidably long process that requires weeks to months of frequent hospital admissions. The placement of an external ventricular drainage (EVD) is necessary after the removal of the infected shunt, this is to be implemented concurrently with antibiotics administration. Thus, patients with an EVD are in an inevitable state of vulnerability, given the risk of developing more infections associated with long hospital stay. Families are also at risk of becoming financially vulnerable due to medical expenses and need for prolonged exclusive caregiving to the child [18].

Conclusion

VS has a historical importance in the treatment of hydrocephalus, being the therapy of choice in most cases, promoting the removal of excessive fluid from the brain ventricles to the peritoneal cavity, where it will be properly drained and resorbed. Shunt infection is one of the most common complications in VS, the main microorganisms related to it being *Staphylococcus*, presenting mainly in the form of biofilm. In addition, the risk factors most frequently associated with VS infections are younger age and a greater number of revision surgeries.

The significance of a well-collected clinical history should not be underestimated in order to make a proper and early diagnosis, avoiding neglected cases and promoting the appropriate treatment, which consists, in most cases, of antibiotic therapy and shunt removal, until the sterilization of the CSF.

Disclosures

The authors have no personal, financial, or institutional interest in any of the materials, or devices described in this article.

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