The Impact of Silver Nanoparticle-Coated and Antibiotic-Impregnated External Ventricular Drainage Catheters on the Risk of Infections: A Clinical Comparison of 95 Patients

Johannes Lemcke, Felix Depner, and Ullrich Meier

Abstract Background: Infection, i.e. meningitis or ventriculitis, is a major complication of external ventricular drainage (EVD). In order to prevent this complication rifampin-impregnated and clindamycin-impregnated silicone catheters and EVDs impregnated with nanoparticles of silver and an insoluble silver salt have been developed. Sparse data are published concerning the efficacy of these catheters in reducing bacterial colonization.

Methods: Between July 2003 and June 2006, 95 patients (age range 12–84 years, mean 53.6 years) underwent implantation of an EVD catheter for CSF diversion for several indications. All surgeries were performed in a standardized way at a single medical center. We used standard polyurethane catheters in 32 patients, Codman Bactiseal silicone catheters in 31 patients, and Spiegelberg Silverline catheters in 32 patients. Samples of the cerebrospinal fluid (CSF) were taken at the time of implantation, every 10 days and at the time of removal. The samples were microbiologically analyzed.

Results: In 32 standard catheters we saw infections in 5 patients (15.6%). By contrast, 2 of the 31 patients with a Bactiseal catheter (6.5%) and 3 with a Silverline catheter (9.4%) developed an infection.

Conclusion: Rifampin-impregnated and clindamycin-impregnated EVDs as well as silver-impregnated EVDs decreased the infection rate. Randomized studies are needed to assess the advantage of these catheters compared with standard polyurethane catheters.

Keywords External ventricular drainage • Infection • Antibiotic impregnation • Silver impregnation

Background

The implantation of external ventricular drainage for different indications is one of the most common procedures in neurosurgery to achieve an ad hoc reduction and control of the intracerebral pressure (ICP). Often, the cerebrospinal fluid (CSF) is initially sterile. As the EVD perforates the three protective coverings of the intracranial space (skin and galea, skull bone and dura mater), it represents a locus minoris resistentiae for infections. In order to decrease the infection rates of EVDs polyurethane catheters containing a combination of metallic silver and an insoluble silver salt (Silverline®, Spiegelberg, Hamburg) were developed as well as catheters, which were impregnated with rifampicin and clindamycin after maceration with chloroform under increased pressure (Bactiseal®, Codman, Johnson & Johnson, Norderstedt). Sparse data are published concerning the efficiency of these devices. The authors evaluate in a prospective observation study the possibility of a reduction of the infection rate by using coated or impregnated catheters in comparison to standard polyurethane catheters (Spiegelberg, Hamburg).

Materials and Methods

All 95 patients who obtained an EVD between July 2003 and June 2006 in our hospital for the first time and without a previously existing infection were included. Patients with perforating head injuries were excluded. The indications for the implantation of an EVD were closed head injury, subarachnoidal hemorrhage (SAH), intracerebral hemorrhage (ICH) and nonhemorrhagic hydrocephalus internus with an increase in the ICP.
Surgery

The implantation was performed under general anesthesia with a single shot of antibiotics (1,500 mg cefuroxime). After partial hair shaving, skin disinfection and sterile surgical coverage with plastic film a borehole trepanation at Kocher’s point was performed. Following the dural incision the ventricular drainage stabilized by a mandarin was introduced 6 cm into the anterior horn of the lateral ventricle. The EVD was tunneled at least 5 cm subcutaneously. All EVDs were Luer-lock-connected with the same collection bag (Spiegelberg External Ventricular Drainage Kit).

Each type of EVD was implanted in our hospital for 1 year. From July 2003 to June 2004 we used the standard polyurethane catheter in 32 patients, from July 2004 to June 2005 the Codman Bactiseal catheter in 31 patients, and from July 2005 to June 2006 the Spiegelberg Silverline catheter in 32 patients. Thus, no selection of the patients due to the indication of EVD implantation or other parameters took place.

Microbiological Examination

We carried out laboratory tests including cell count, lactate and protein and microbiological examinations of the CSF at implantation and removal as well as every 10 days. In the case of clinical suspicion of CSF infection, like opacity of the CSF, an unexplainable increase in inflammation parameters or clinical symptoms of meningitis, we also took CSF probes. The evidence for ventriculomeningitis was the proven germs in the liquor cerebrospinalis.

Statistical Analysis

Explorative statistics were performed using the Wilcoxon test in the Statistical Package for the Social Sciences (SPSS) software version 15.0. \( p \leq 0.05 \) was defined as the level of significance.

Results

Fifty-one men (54%) and 45 women (46%) with a mean age of 53.6 (12–84) years were included. Neither the sex distribution nor the age in the three groups showed statistically significant differences.

Indications

Ten patients (11%) had a severe head injury, 36 patients (38%) suffered from SAH, and 43 (45%) from ICH. Six patients (6%) underwent EVD implantation because of expansion lesions. The distribution of the indications to the three groups showed no relevant differences.

The duration of drainage was 13.7 days on average. No statistically relevant differences were recorded for the three patient groups (standard EVD 13.2 days, Bactiseal EVD 13.0 days, Silverline EVD 14.8 days) (Fig. 1).

Infections

We diagnosed infections of the CSF in 10 patients (11%). All infections occurred between the 8th and the 19th day after surgery. Even though we did not find a specific time pattern of the infections in the three groups of patients (standard EVD days 8, 9, 13, 16, 17/Bactiseal EVD days 10, 17/ Silverline EVD days 10, 13, 19), the authors observed distinct differences in the number of infections. Whilst 5 out of 32 patients with standard EVDs had an infection (15.6%), only 2 out of 32 patients with Bactiseal catheters (6.5%) and 3 out of 32 patients with Silverline catheters (9.4%) showed infected CSF. Regrettably, the difference was not statistically significant (Fig. 2).

All patients had ventriculitis with typically catheter-associated bacteria (Staphylococcus and Enterococcus). Mixed infections were only observed in patients with a standard EVD (Table 1).
Fig. 2 Infection rates in the three patient groups

Table 1 Staphylococcus and Enterococcus were observed to be causative agents

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Standard</th>
<th>Bactiseal</th>
<th>Silverline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulase-</td>
<td></td>
<td>EVD</td>
<td>EVD</td>
</tr>
<tr>
<td>negative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staphylococcus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. haemolyticus</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>mixed infection</td>
<td>(+ E. faecalis)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. simulans</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mixed infection</td>
<td>(+ E. faecalis)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coagulase-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>positive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staphylococcus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. aureus</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Enterococcus</td>
<td></td>
<td>E.VD</td>
<td>EVD</td>
</tr>
<tr>
<td>E. faecium</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>E. faecalis</td>
<td>See above</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussion

Owing to the perforation of the physiological barriers by the external ventricular drainage, infections of the cerebrospinal fluid are one of the most common complications of EVDs [1, 7, 8, 11, 14, 18]. Gram-positive coccoid of physiological skin flora dominate the microbiological findings in our patients as well as in the international literature [2, 4, 6, 9, 10, 12, 13, 15–17, 21–26]. The published infection rates range from 0% to 50% [3, 5] because of the different diagnostic methods and patient populations. Against this background the combination of external ventricular drainage with antimicrobial substances is a reasonable approach. The strategy was pursued on the one hand by the impregnation of silicone catheters with antibiotics that are suitable with regard to their pharmacological stability and their spectrum of activity and on the other hand by the bactericidal effect of the release of cations from a nanosilver coat and a silver salt not specified by the manufacturer.

The patients with standard EVD in this study clearly exceeded the infection rate of 8.8% which Lozier [9] found in his meta-analysis of 23 publications. With 6.5% the group of patients with Bactiseal catheters were below this threshold. The patients with the Silverline EVD met this value with 9.4% of infections. Comparing the groups in our own patients, both antimicrobially coated catheters showed an advantage over the standard EVD.

The populations in the studies published by Schade et al. [19] and Sloffer et al. [20] showed the best correlation with our patients. Schade et al. [19] compared the infection rates of ventricular and lumbar drainage and found an infection rate of 14.4%. Sloffer [20] published four infections in 100 patients with a Codman Bactiseal EVD.

To the best of our knowledge no studies on patients with Silverline EVDs have been published as yet.

Altogether we found a decrease in the infection rate of 40% for the Silverline EVD (9.4% versus 15.6%) and of 58% for the Bactiseal EVD (6.5% versus 15.6%) compared with the standard EVD. From the view of the clinical neurosurgeon both products can be recommended in order to prevent EVD-associated infections.

Conclusion

Antibiotic impregnated EVDs as well as silver-impregnated EVDs seem to be able to decrease the infection rate of EVDs. Patient safety can be increased by the use of these products.

Conflict of interest statement We declare that we have no conflict of interest.

References