Deep Brain Stimulation Hardware-Related Infections: A Report of 12 Cases and Review of the Literature

Fabien Fily, Claire Haegelen, Pierre Tattevin, Sylvie Buffet-Bataillon, Matthieu Revest, Anne Cady, and Christian Michelet

In this monocentric study, the median delay between deep brain stimulation implantation and infection was 28 days (range, 8–820). Infections limited to generator (n = 4) required partial hardware removal, whereas infections involving frontal or retroauricular sites (n = 7) required total removal. Surgical samples yielded Staphylococcus aureus (n = 6), Staphylococcus epidermidis (n = 2), Propionibacterium acnes, and Micrococcus species.

Since the introduction of deep brain stimulation (DBS) in 1987 for the treatment of advanced Parkinson’s disease [1], its indications have extended to other severe movement disorders and to some psychiatric conditions, including obsessive-compulsive disorders. In parallel, reports of DBS-related complications have emerged over the past 15 years, including series of DBS hardware-related infections [2–9], but no literature review is available to date. The management of this emerging infectious disease remains largely elusive. We aimed to collect data to better define DBS hardware-related infections and their management, from our own experience and from published case reports and series.

METHODS

As described elsewhere [10], DBS hardware-related infections were defined as infections with clinical or microbiological evidence of device involvement. Cases were identified through the registry of patients who underwent DBS at our institution from October 2006 (first DBS procedures in our neurosurgery unit) through December 2008 and through physicians’ interview. Data were extracted from medical charts and are presented as means ± standard deviation or median (range).

DBS implantation procedures were as follows: the frontal area, neck, and chest were shaved and prepped with povidone iodine. First, the Leksell stereotactic fram was used to determine stereotactic coordinates of the chosen target via MRI and CT. A frontal incision was made for electrode implantation. Second, implantable pulse generator was placed in a subcutaneous pocket 1 cm inferior to the clavicle. Finally, a retroauricular incision was done for connection between electrode and electrode extender, which has a distal tunnelling point at subclavicular incision (Figure 1A). One time procedure was the rule, and no leads were temporarily externalized. Cloxacillin was used as perioperative antibiotic prophylaxis (vancomycin, if the patient was allergic to penicillin). No antibiotic prophylaxis was administered for pulse generator changes.

RESULTS

Over the study period, 67 patients underwent DBS implantation at our institution, of whom 6 (8.9%) subsequently received a diagnosis of DBS hardware-related infections (Table 1). In addition, 5 patients for whom DBS had been implanted in another institution received a diagnosis of DBS hardware-related infection and were treated at our institution. Overall, 11 patients fulfilled inclusion criteria (5 female and 6 male), totaling 12 cases of DBS hardware-related infections (ie, 1 patient presented 2 distinct episodes). The mean patient age was 54 ± 12 years. DBS had been implanted for the treatment of advanced Parkinson’s disease for most patients (n = 7) and was bilateral for 9 patients. In 3 cases (cases 7, 11, and 12), DBS hardware-related infection was diagnosed after pulse generator change. The median time between last DBS surgery (DBS implantation or pulse generator change) and infection diagnosis was 28 days (range, 8–820). Most patients presented with local signs of infection (swelling, wound dehiscence, and purulent drainage) that involved pulse generator in 8 cases, frontal incision site in 5 cases, and retroauricular incision site in 5 cases. Two patients had bilateral DBS-related infections (patients 1 and 9). Only 3 patients presented with fever, always <38.5°C, and only 1 patient presented with neurological symptoms (ie, change in...
mental status). All blood cultures returned sterile. Brain CT was performed at admission in 8 cases and was abnormal in 3 cases: abscesses in 1 case and hypodensity surrounding the DBS electrodes in 2 cases (Figure 1B).

Surgery was part of the initial management in 11 cases. It consisted of partial removal (ie, unilateral extender and pulse generator) in 7 cases and total hardware removal in the 3 patients with abnormalities on initial CT. Cultures of surgical samples were positive in 10 cases, yielding meticillin-susceptible *Staphylococcus aureus* (*n* = 6), *Staphylococcus epidermidis* (*n* = 2), *Propionibacterium acnes* (*n* = 1), and *Micrococcus* species (*n* = 1). Of note, no polymicrobial infection was documented. The only case that involved no surgery (case 3) was a recurrence, 6 months after total hardware removal for DBS-related infection (case 2). Antibacterial treatment was administered for 3–12 weeks after hardware removal. It consisted of third-generation cephalosporins for the first 3 weeks in all patients (cefotaxime, 200 mg/kg/j; or ceftriaxone, 70 mg/kg/j). The 4 patients with DBS-related meticillin-susceptible *S. aureus* infections and no CT abnormalities were switched to oral treatment (ie, ofloxacin or levofloxacin combined with rifampin). Overall, the initial management strategy was successful in 7 cases (58%), with a median follow-up time of 13 months (range, 8–30 months), including in the case that involved no surgical treatment (13 months follow-up).

In 5 patients, additional surgical treatment was necessary. In 4 cases, it consisted of total hardware removal after a failure of partial hardware removal (*n* = 3) or wound debridement (*n* = 1). In addition, 1 patient developed a brain abscess during antibacterial treatment, in spite of early total hardware removal, and necessitated abscess drainage. Finally, DBS infection was cured in all patients with prolonged antibacterial treatment associated with total hardware removal in 7 cases and partial removal in 4 cases. After a multidisciplinary meeting, we decided that implantation of a new DBS system would only be contraindicated for the 2 patients in whom DBS-related infections were associated with brain abscesses. Thus, a new DBS system was implanted 6.5–9 months after DBS infection in 5 patients of the 7 who had total hardware removal, including 2 patients who had CT abnormalities. New pulse generators and extenders were implanted in the 4 patients who had partial removal 6–11 months after DBS-related infection. Only 1 patient presented with signs of infection recurrence (case 3; at 6 months). Of note, this suspected recurrence was not documented and had a favorable outcome with medical treatment only.

**DISCUSSION**

DBS-related infections are emerging infectious diseases that came as a consequence of the growing number of DBS hardware implanted over the past 2 decades. By gathering information from the study presented here and from the previously reported cases, we were able to collect data on 93 cases of DBS-related infections diagnosed during 1993–2009. The incidence rate of DBS-related infection per patient varies according to the studies, from 3.8% to 12.6%. Time from DBS implantation to DBS-related infection diagnosis may be as short as 3 days [9] and as long as 45 months [8]. Of note, skin erosion at the pulse generator or connection site is a common finding in patients with late DBS-related infections [2, 8, 10]. *S. aureus* is the predominant bacteria, involved in 40%–100% of documented cases, and skin flora bacteria (*S. epidermidis*, *P. acnes*, and *Micrococcus* species) and Enterobacteriaceae may rarely be encountered [8, 10–11].
<table>
<thead>
<tr>
<th>Case</th>
<th>Sex</th>
<th>Age, years</th>
<th>DBS indication</th>
<th>Infection delay (days after last DBS surgery)</th>
<th>Infection location</th>
<th>CT finding at admission</th>
<th>Serum CRP level, mg/L</th>
<th>Initial surgery</th>
<th>Culture results (c)</th>
<th>Evolution</th>
<th>Antibacterial treatment duration (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>42</td>
<td>OCD</td>
<td>90</td>
<td>Frontal (B)</td>
<td>Abscess</td>
<td>1</td>
<td>Total removal (B)</td>
<td>MSSA</td>
<td>Cure – no further surgery</td>
<td>12</td>
</tr>
<tr>
<td>2a</td>
<td>F</td>
<td>59</td>
<td>Dystonia</td>
<td>32</td>
<td>Chest, retroauricular (L)</td>
<td>Normal</td>
<td>108</td>
<td>Partial removal</td>
<td>MSSA</td>
<td>Cure after second surgery (total removal)</td>
<td>8</td>
</tr>
<tr>
<td>3a</td>
<td>F</td>
<td>59</td>
<td>Dystonia</td>
<td>14</td>
<td>Frontal, retroauricular (L)</td>
<td>Not done</td>
<td>30</td>
<td>No surgery</td>
<td>Not done</td>
<td>Cure – no further surgery</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>61</td>
<td>Parkinson</td>
<td>18</td>
<td>Chest, frontal, retroauricular (R)</td>
<td>Oedema</td>
<td>48</td>
<td>Total removal (R)</td>
<td>MSSA</td>
<td>Brain abscess appeared on treatment Cure after abscess drainage</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>46</td>
<td>Parkinson</td>
<td>28</td>
<td>Frontal (L)</td>
<td>Oedema</td>
<td>1.8</td>
<td>Total removal (L)</td>
<td>No growth</td>
<td>Cure – no further surgery</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>54</td>
<td>Essential tremor</td>
<td>8</td>
<td>Frontal (L)</td>
<td>Normal</td>
<td>20</td>
<td>Wound debridment</td>
<td>PA</td>
<td>Hypodensity on CT scan (day 3) Cure after second surgery (total removal)</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>68</td>
<td>Parkinson</td>
<td>57</td>
<td>Chest (L)</td>
<td>Normal</td>
<td>130</td>
<td>Partial removal</td>
<td>MSSA</td>
<td>Cure – no further surgery</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>60</td>
<td>Parkinson</td>
<td>25</td>
<td>Chest, retroauricular (R)</td>
<td>Normal</td>
<td>3.3</td>
<td>Partial removal</td>
<td>micrococcus</td>
<td>Cure after second surgery (total removal)</td>
<td>NA</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>57</td>
<td>Parkinson</td>
<td>820</td>
<td>Chest, retroauricular (B)</td>
<td>Not done</td>
<td>5</td>
<td>Partial removal</td>
<td>MSSA</td>
<td>Cure after second surgery (total removal)</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>56</td>
<td>Parkinson</td>
<td>18</td>
<td>Chest (R)</td>
<td>Not done</td>
<td>31</td>
<td>Partial removal</td>
<td>MSSA</td>
<td>Cure – no further surgery</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>66</td>
<td>Parkinson</td>
<td>365</td>
<td>Chest (R)</td>
<td>Normal</td>
<td>3</td>
<td>Partial removal</td>
<td>SE</td>
<td>Cure – no further surgery</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>21</td>
<td>Dystonia</td>
<td>90</td>
<td>Chest (R)</td>
<td>Not done</td>
<td>NA</td>
<td>Partial removal</td>
<td>SE</td>
<td>Cure – no further surgery</td>
<td>3</td>
</tr>
</tbody>
</table>

**NOTE**  
B, bilateral; DBS, deep brain stimulation; L, left; MSSA, methicillin-susceptible *Staphylococcus aureus*; NA, not available; OCD, obsessive-compulsive disorder; PA, *Propionibacterium acnes*; R, right; SE, *Staphylococcus epidermidis*.  
* One patient had 2 distinct infections (cases 2 and 3).
Although any component of DBS system may be infected, pulse generator site is the most common [10–11]. In our series, 4 patients had abnormal brain CTs, with hypodensity surrounding the probes (n = 2) or brain abscess (n = 2, including one that appeared during treatment). Only 2 cases of intracranial infection have been previously reported [7, 9]. Brain imaging is obviously indicated when clinical presentation is suggestive of intracranial infection. It should also be considered in case of infection surrounding frontal or retroauricular incision sites. Despite initial concerns that MRI may be at risk in patients with DBS, this imaging technique is more sensitive than CT and well tolerated in patients with DBS devices [7, 12].

No consensual guidelines are currently available for the management of DBS-related infection. The literature [3, 8] and our series suggest that total hardware removal is necessary in case of intracranial infection and when infections signs are present along the frontal incision site. When the infection is clinically limited to the pulse generator site, partial hardware removal, in association with prolonged antibacterial treatment, is associated with high rates of success [2, 10–11]. Surgical strategy is more difficult to define when the connection site is infected in the absence of intracranial infection or frontal incision site involvement. In our series, this was the only situation of partial removal strategy failures. Connection site infection can easily spread to electrodes and lead to intracranial infection. Thus, we would advise total hardware removal in this situation.

Antibacterial treatment must target Staphylococci and P. acnes, pending results of microbiological studies, including susceptibility testing. Antibacterial treatment duration should be 2–6 weeks after hardware removal (6 weeks in case of intracranial infection) [2, 11]. In our opinion, DBS reimplantation can be undertaken in the absence of brain abscess, after sufficient time has elapsed after antibacterial treatment (ie, 3–6 months). No cases of DBS-related infection recurrence was found in the literature review, and the only recurrence that we observed in our series remains questionable given that (1) no documentation was obtained and (2) medical treatment was sufficient to achieve its cure, which would be most unusual in case of hardware-related infections.

The implantation of DBS for an increasing number of neurologic or neuropsychiatric diseases led to the emergence of DBS-related infections. The management of this new hardware-related infection remains elusive, particularly in case of isolated infection of the connection site. Our series supports total removal, followed by prolonged antibacterial treatment in that situation. Additional studies are warranted to confirm this non–evidence-based opinion.

Acknowledgments

Potential conflicts of interest. All authors: no conflicts.

References