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CLINICAL ARTICLE
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Hardware-Related Skin Problems of Deep Brain Stimulation

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Purpose: Deep brain stimulation (DBS)-related skin problems such as infection and skin erosion lead to increased patient morbidity. We aimed to evaluate the incidence of skin problems after deep brain stimulator insertion and assess possible risk factors.
Methods: Medical records of 45 patients who underwent DBS surgery at our center, from 2008 through 2017, were retrospectively reviewed. We categorized skin problem as post-operative infection and skin erosion.
Results: Six of 45 patients (13%) had DBS hardware-related infection and two of 45 patients (4%) had skin erosion. In three patients (3/45, 6.7%) with hardware-related infection, initial antibiotic therapy and surgical wound repair alone were successful. Hardware was partially saved in one patient (1/45, 2.2%), but complete removal was performed in two patients (2/45, 4.4%) after the failure of partial hardware removal or wound debridement.
Conclusions: An initial trial of antibiotic treatment could be successful in some cases, but medical treatment sometimes failed to prevent partial or total removal of hardware. None of the patient-related factors (gender, diabetes mellitus or smoking status, staged operation, age at the time of surgery, and body mass index) was significantly associated with an increased risk of infection.

KEY WORDS: Deep brain stimulation · Complication · Skin erosion · Infection · Hardware-related · IPG implantation.

INTRODUCTION

Deep brain stimulation (DBS) is an established treatment option for patients with Parkinson's disease (PD), dystonia, and tremor.[2-4)12)13)15-17)20)] The complication of hardware infection related to deep brain stimulator implantation varies between 0 and 15% in the literature.[5)6)9)18)] Infection after deep brain stimulator insertion or hardware revision is a well-recognized complication that can result in significant patient morbidity including pain, systemic upset, and a requirement for further surgical revision associated with possible exacerbation of the underlying movement disorder.[4)]

In this retrospective case study, we reviewed the incidence and outcome of hardware- related skin problems in patients undergoing deep brain stimulator implantation at a single neurosurgical center.

MATERIALS AND METHODS

All patients underwent DBS surgery between 2008 and 2017 at Korean University Guro Hospital were included in this retrospective study. We reviewed the medical records from admission to out-patient clinic follow-ups of all 45 patients for documentation of post-operative infection, clinical findings, management and risk factors.

We categorized skin problems as post-operative infection and skin erosion.

The criteria for diagnosis of post-operative infection included at least one of the following.[4)]

1) purulent discharge

2) microbiological confirmation of pus cells or growth of bacteria

3) at least one of the following signs or symptoms of infection : pain, tenderness, erythema, swelling, heat or wound dehiscence.

A distinction was made between skin erosion and frank infection.

Skin erosion involved thinning of skin and subcutaneous tissue of the incision without wound dehiscence causing device exposure even if local flap operation was needed to a repair.

We collected patients' demographic data such as age, gender, smoking, diabetes mellitus and body mass index (BMI) which is defined as body mass divided by the square of the body height (kg/m^2) and operation data whether the patient underwent 1-staged or 2-staged operation which

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could be possible risk factor for skin problems. Clinical date included skin problems delay, location, serum C-reactive protein (CRP), computed tomography (CT) - scan, microbiological culture result.

Possible risk factors were first analyzed by group comparisons using Fishers exact test for categorical data and t-test for continuous data. Regression analysis was then performed for possible risk factors. $p<0.05$ was considered statistically significant. All statistical analyses were performed using SPSS version 18.0.

RESULTS

Study population

During 2008 to 2017, a total of 45 DBS surgeries were performed (27 men, 19 women). Table 1 shows the demographic data of the studied patients. The mean age at surgery was 55 years. Eight of the 45 patients (17.8%) had a current or recent history of smoking, and only three of the 45 patients had diabetes mellitus. We also calculated the BMI of each patient. Mean BMI was 22.34, which is in the normal range of 18.5 to 25.

Thirty-four patients were diagnosed with Parkinson's disease. Six out of the remaining 11 patients had deep brain stimulator implantation for temporal lobe epilepsy, three for essential tremor, and two for cervical dystonia. Regarding the target, the most common was the nucleus subthalamicus (STN) in 26 patients (57.8%), followed by internal globus pallidus (GPi) in nine patients (20%), and anterior nucleus thalami (ANT) in six patients (13%). Two cases each had implantation performed in the ventral intermediate nucleus of the thalamus (ViM) and the posterior subthalamic area (PSA).

The four initial patients underwent 1-staged DBS and implantable pulse generator (IPG) implantation under local anesthesia. Subsequently, from 02-Apr-12 to 30-Mar-12, 21 patients had staged operations : deep brain stimulator implantation under local anesthesia, and IPG implantation under general anesthesia. From 01-Feb-13 up to now, our center's deep brain stimulator implantation procedures are 1-staged operations using dexmedetomidine (Precedex) for awake deep brain stimulator implantation followed by general anesthesia for IPG implantation ; 20 out of 45 patients underwent this procedure. Overall, 24 patients underwent 1-staged operations and 21 patients underwent 2-staged operations.

Infection & Skin erosion

Over the study period, 45 patients underwent DBS implantation at our institution, of whom six (13%) subsequently received a diagnosis of DBS hardware-related infections. Skin erosion and eschar formation occurred in two patients who were not included in the frank infection group.

Overall, six patients fulfilled the inclusion criteria (5 female and 1 male), for cases of DBS hardware-related infections. In this group, a deep brain stimulator had been implanted for the treatment of advanced Parkinson's disease for all patients (n=6) and was bilateral for 5 patients.

The chest where the IPG implanted was the most common skin problem site followed by the frontal burr-hole site where the lead was fixated and the connector which connected the electrode to the IPG in the postauricular. (4/6). Table 2 shows data on the infection and skin erosion group.

In our study, only one infection developed within the first month (Table 2, Patient 6). Skin problems occurred after the operation at the mean time point of 45.9 weeks (3-148). Six of the eight patients developed skin problems within a year after surgery, and two of the patients developed skin problems later than 1 year after surgery.

None of the patient-related factors (gender, diabetes mellitus or smoking status) was associated with an increased risk of skin problems. The operation-related factor (1-stage or 2-staged operation) was not related to increase risk of skin problems neither (Tables 1, 3, 4). The

Table 1. Number of infections in relation to possible risk factors

	Non-infection, n=37 (82.2%)	Infection & skin erosion, n=8 (17.8%)	p-value
Diabetes mellitus	3	0	1.000
Smoking	7	1	1.000
Age (mean)	54.05	57.38	.363
Sex (Male/Female)	23/14	3/5	.253
BMI	22.34	24.59	.106
Stage op (2-stage/1-stage)	15/22	6/2	.121

Body Mass Index : body mass divided by the square of the body height (kg/m^2)

Table 2. Deep brain stimulation hardware-related skin problems at Korea University Guro Hospital, 2008–2017

	Infection						Skin erosion	
	1	2	3	4	5	6	7	8
Sex	M	F	F	F	F	F	M	M
Age	55	67	62	56	57	59	61	42
Indication	PD	PD	PD	PD	PD	PD	PD	PD
Lesion	Bilateral STN	Bilateral STN/Revision & bilateral GPi	Bilateral STN	Rt. STN	Bilateral STN	Bilateral STN	Bilateral STN	Rt. STN/Lt. STN
Staged op	Y	Y/N	Y	Y	N	N	Y	Y/N
Skin problem delay (wks)	80	36	20	16	28	3	148	36
Location	Lt IPG	Bilateral IPG & Rt lead	Lt IPG & connector	Rt IPG	Bilateral lead	Bilateral lead	Rt IPG	Lt connector
CT	–	–	No intracranial infection	–	No intracranial infection	–	–	–
Serum CRP	59/2.7	13/0.24	67/121.21	28/1.49	26/0.8	41/1.83	–	13/2.57
Culture	No	No	MSSE	MRSA	Enterobacter aerogenes. Staphylococcus capitis	Citrobacter freundii	–	No
Surgery evolution	Wound repair	IPG removal (Rt) & Repositioning (Lt)	Total removal	Total removal	Wound repair	Wound repair	Wound repair	No surgery

PD : Parkinson's disease, STN : subthalamic nucleus, GPi : globus pallidus, IPG : implanted pulse generator, CT : Computed tomography, CRP : C-reactive protein, MSSE : methicillin-sensitive Staphylococcus epidermidis, MRSA : methicillin-resistant Staphylococcus aureus

infections and wound erosion group had a higher BMI at the time of surgery than the non-infection group ; however, the result was not statistically significant. Age at the time of surgery was also not associated with an increased risk of skin problems.

Microbiological culturing of wound swabs and devices grew Staphylococcus aureus, Staphylococcus epidermidis, Enterobacter aerogenes, and Citrobacter freundii. Among the infection group patients, we found no reports of microbiological growth in two (2/6). In one patient whose culture was positive, the identified Staphylococcus Aureus (S. aureus) strain was methicillin-resistant. S. aureus (MRSA).

Only one patient had a markedly increased level of c-reactive protein (CRP). Bain CT scan was performed in two cases and we didn't find any signs of intracranial infection.

Treatment

In the infection group, four patients presented with signs of infection that involved the IPG. One had wound repair with antibiotics and was finally successfully cured. Another (patient 2) had right IPG removal and left IPG repositioning (Fig. 1). The other two patients (3, 4) could not avoid removal of DBS system. Patient 3 had signs of infection in the connector. The other one (patient 4) had the identified MRSA infection. In two cases (patients 5 and 6), frontal burr-hole sites were the only infected areas. They had local debridement and wound repair with antibiotics, and were successfully cured. Skin erosion occurred in two patients (7, 8). One (patient 7) had wound repair and the other one (patient 8) required long-term follow-up.

DISCUSSION

In our series of surgical site infections, initial antibiotic

Table 3. T-test for continous data (age, body mass index)

	N	Mean	t-test p-value
Age			
Infection & Skin erosion	8	57.38	
Non-infection	37	54.05	.363
Total	45	54.64	
Bdoy mass index			
Infection & Skin erosion	8	24.59	.106
Non-infection	37	22.34	
Total	45	22.74	

Table 4. Fishers exact test for categorical data (diabetes mellitus, smoking, Sex, stage op)

	Total n=45 (100%)	Infection & Skin erosion n=8 (17.8%)	Non-infection n=37 (82.2%)	Fishers exact test p-value
Diabetes mellitus				1.000
DM	3 (100.0)	0 (0.0)	3 (100.0)	
Non-DM	42 (100.0)	8 (19.0)	34 (81.0)	
Smoking				1.000
Smoking	8 (100.0)	1 (12.5)	7 (87.5)	
Non-smoking	37 (100.0)	7 (18.9)	30 (81.1)	
Sex				.253
Male	26 (100.0)	3 (11.5)	23 (88.5)	
Female	19 (100.0)	5 (26.3)	14 (73.7)	
Stage op				.121
2-Staged	21 (100.0)	6 (28.6)	15 (71.4)	
1-staged	24 (100.0)	2 (8.3)	22 (91.7)	

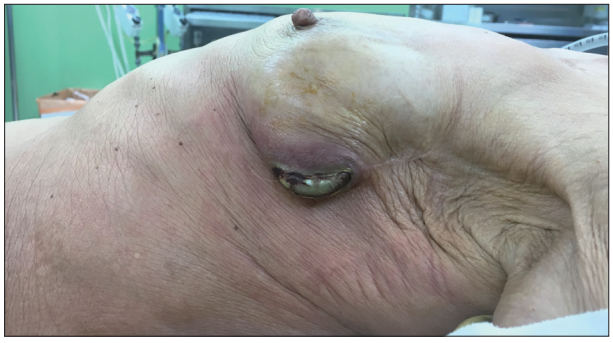

Fig. 1. Patient 2 (Table 2) was about to have a repositioning of left implantable pulse generator, due to hardware exposure after wound dehiscence.

therapy and wound revision alone was successful in two of six patients (33%) in which removal of hardware then could be avoided.

Hardware was partially saved in one of the six infected patients, but complete removal was performed in two of the six after failure of partial hardware removal or wound debridement.

The incidence rate of DBS-related infection per patient varies according to published studies.[4)]

Caution in interpretation of the data is required since the numbers in each group are relatively small compared to some of the larger series in the literature. We did not include two patients with only erosion and discoloration. Some authors define erosions as non-infections, whereas others view them as likely manifestations of an underlying infection with a less virulent organism.[6-8)] A clear definition of device infection is needed.

Some literature suggests that if infection signs are present along with the lead and connector incision sites, total hardware removal is necessary in case of intracranial infection.[10)14)19)] We identified three cases with involvement of the lead or connector incision site and none of them had neurologic symptoms related to deep brain stimulator infection. Two of the three underwent CT scan, which revealed no intracranial infection.

Reported time until onset of surgical site infection was a median of 17.0 days post-surgery, ranging from 6.2 to 41.4 days.[11)] Only one infection developed within the first month. Most of the infections were found during long-term follow-up at out-patient clinics. This could be because implantation of a foreign material increases potential risk of delayed infections. However, we believe that these infections developed due to chronic erosion of the skin such as pressure sore. We hypothesize that a lower-BMI patient with a lack of subcutaneous tissue has more risk of erosion of skin which potentially increases surgical site infection after DBS implantation. For example, we identified one patient with BMI 19.5 who underwent several wound revisions. In contrast to the case above (Table 1), after calculating BMI of the non-infection and infection group, we found that the infection group had a higher BMI than the non-infection group. Many articles reveal that obesity is associated with surgical site infection regardless of what kind of surgery a patient goes through. Arwa, et al. showed from the systematic review and meta-analysis there was good evidence that obesity was associated with a significantly higher risk of developing surgical site infection.[1)] However, BMI was not a significant risk factor for DBS-related infection in our study.

CONCLUSION

In our series, six of 45 patients (13%) had a DBS hardware-associated infection and two of 45(4%) had skin erosion. In hardware-related infection, initial antibiotic therapy and surgical wound repair alone was successful in three patients (3/45, 6.7%). Hardware was partially saved in one patient (1/45, 2.2%), but complete removal was performed in two patients (2/45, 4.4%) after failure of partial hardware removal or wound debridement.

In our opinion, initial antibiotics treatment should be considered at first when it comes to skin problems of DBS implantation in prior to removal of hardware. In case of antibiotics treatment failure, partial removal of hardware together with antibiotics should be attempted. In uncontrolled hardware-related infection, total removal of DBS system could be the last treatment.

None of the patient-related factors (gender, diabetes mellitus or smoking status, age at the surgery, and BMI) and the operation-related factor was significantly associated with an increased risk of infection in our study. However it should be noted that the numbers are small and our study is retrospectively designed so that caution is required when interpreting the statistical results. Further publication will be needed.

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