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Hardware Infections in Deep Brain Surgery for Parkinson Disease Over 16 Years: A Retrospective Review

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Abstract

Introduction: The burden of Parkinson's Disease (PD) is expected to increase as Malaysia's population continues to age. Deep Brain Surgery (DBS) is a recognized surgical therapy with excellent outcomes but one of the commonest complications of DBS include Superficial Surgical Site Infection (SSI). We performed a retrospective study to determine the incidence of SSI and the factors associated with it over 16 years at a quaternary university hospital in Kuala Lumpur, Malaysia.

Methods: This is a retrospective database study with ethical clearance from the university committee. All patients who underwent DBS for PD between January 1st, 2004 to December 31st, 2020 were included. The incidence of SSI was defined as per 2012 CDC guidelines and hardware infections were classified as early (<90 days) and late (90 or more days). Patient demographics and variables of interest were tabulated and analyzed.

Results: 153 cases of DBS were performed in 128 patients consisting of 289 lead implantation and 161 Implantable Pulse Generators (IPG) devices. Four patient who had DBS for non-PD were excluded. There were 7 cases of SSI with an incidence of 4.7% per case. Of these 7 cases, 4 were early SSI and 2 were late SSI. One patient's data from 2004 was missing. Patients with prior Traumatic Brain Injury (TBI) and Stevens-Johnson Syndrome (SJS) were found to have significant association with SSI (p=0.047). Five patients (71.4%) were initially treated surgically with debridement, externalization and complete hardware removal however all 7 patients eventually had complete hardware removal. There was zero mortality. Average duration of hospital stay in the SSI group was almost 8-times longer than an uncomplicated case. The commonest location of SSI was on the scalp (42.8%) and the most frequent organism cultured was MSSA.

Conclusion: Rates of SSI have been reducing in recent years likely due to improved sterility practices, better surgical techniques, sturdier hardware. Hardware salvage is not an effective option in our region and there should be lesser resistance to hardware removal for better surgical and patient outcomes.

Keywords: DBS; Parkinson's disease; SSI; Removal; Salvage

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Introduction

Parkinson's Disease (PD) is a complex progressive neurodegenerative disease with long roots in the human history, dating back as early as the Indian Ayurveda Medical system which called it 'Kampavata', the physician Galen as 'the shaking palsy' in AD 175 and finally by a London Doctor James Parkinson in 1817 from which it derived its name from [1].

Pathological diagnosis stems from a loss or degeneration of the substantia nigra and development of Lewy bodies in the dopaminergic neurons [2].

It is a common disease among the elderly with onsets as early as 50's to 60's, affecting 1% of populations older than 60 years old [3]. It is the second most common neurodegenerative disease, second only to Alzheimer's disease. It significantly affects all domains of the health-related quality of life of both the patient and the career and results in significant economic burden [4]. 30% of patients with PD are depressed [5] compared to controlled arms with a 2 to 2.9 higher mortality rate as well [6]. Based on a 2016 systematic analysis for the global burden of disease, Malaysia has a prevalence of 19586, (26.4% ASR) and rate of death of 514 (19.9% ASR) [7]. There is no doubt PD will become

an increasingly substantial health issue as our country's population begins to age.

Surgery for PD patients are generally reserved for those experiencing reduced effects of medical therapy- typically at advanced stages of their disease with uncontrollable motor symptoms like chorea's and dystonia as a result of medication. One needs to familiarize themselves with the 'on-off' terms in motor fluctuations. Good motor control periods are deemed 'on' periods and PD symptomatic control are 'off' periods.

Since 2002, Deep Brain Stimulation (DBS) has been approved for the treatment of advanced PD and in 2016 it went on to be approved for treatment of earlier stages - patients who have suffered for at least four years and have motor symptoms not adequately controlled with medication [8].

The Subthalamic Nucleus (STN) and Globus Pallidus internus (GPi) which represent hyperactive areas in the cortex in PD progression are targeted by electrodes implanted in them, which produce high frequency electrical stimulation to 'jam' the areas. Although the true mechanism is still unknown, but the disruption hypothesis seems to be more accepted. DBS is thought to disrupt input and output signals through the cortico-basal ganglia loop [9]. A second procedure is performed to implant an Impulse Generator (IPG) battery - which functions like a pacemaker. The STN-DBS method is generally preferred in advanced PD stage due to the big improvements in off time [10].

DBS have been found to have excellent outcomes [11] such as physically reducing tremor, stiffness, bradykinesia, reduces psychosis, recurrent falls, dementia, institutionalization, death and progression of disability [12]. It is also reversible, adjustable and safer, especially in bilateral procedures compared to lesioning/ablative therapies [13].

However, DBS does not come without side effects - risk of general anesthesia, stroke, death, dysarthria, imbalance, and dyskinesia can occur and may require tuning or readjustment of the pacemakers [14]. Notwithstanding, the ongoing risks of breakage, battery depletion, device malfunction, and infection with implanted hardware.

Surgical Site Infection (SSI) or device related infections post DBS is surprisingly common, serious and difficult to manage. It has been reported to be as high as 15.2% despite DBS being a clean procedure [15]. It is difficult to interpret the results of the many studies available now due to differing definitions of infections, timeline and its low incidence. Factoring in the presence of a foreign body, infections of DBS systems are morbid, requiring prolonged hospitalization (at least 6 weeks), salvage therapies such as surgical debridement, electrode externalization and as last resort complete hardware removal. In rare circumstances, intra-cerebral abscesses have been reported [16].

The postulated mechanism in early infection is usually due to intra-operative contamination and late infections by chronic skin erosions which then lead to incision eschar, wound breakdown and ulceration [15].

There are still varying definitions of infection after DBS - reported rates would be higher if the definition includes superficial infections that were not contiguous with any hardware or if it includes long-term device-related infections subsequent to erosion (dehiscence without inflammation).

A large study by Sillay et al. in 2008 encompassing 420 patients, 759 electrodes and 615 Implantable Pulse Generator (IPG) for movement disorder/pain noted a hardware infection incidence of 4.5% per patient over 6 months, mostly within 30 days where 12 out of 19 had infections over the IPG site. Partial salvage was amenable in 64%. Sillay also laid down the foundations to the first algorithm for treating hardware related infections [17].

University Malaya Medical Center (UMMC) is one of the main centers performing DBS both locally and regionally. We conducted a review to assess the incidence of hardware infection among our operated patients over the past 16 years and the factors that were associated with it.

Materials and Methods

Primary objective

To assess the incidence of hardware infection among our operated patients over the past 16 years.

Secondary objective

To investigate the factors that were associated with hardware infection.

Study design

This is a retrospective study with data from an electronic database including all patients (>18 years ago) who underwent primary DBS electrode implantation. Surgery was performed by two surgeons (KA and VN) from a quaternary university hospital in Kuala Lumpur, Malaysia.

Duration

January 1st, 2004 to December 31st, 2020 (16 years).

Location

University Malaya Medical Centre.

Sampling

Convenient sampling. Patients were identified *via* Electronic Medical Records (EMR) to obtain demographics, patient's characteristics, procedural and surgical details, SSI reporting and culture reports.

Inclusion/Exclusion criteria

We only included patients who were receiving DBS implants and those who fulfilled the SSI criteria as per 2012 CDC guidelines.

We excluded those who had repetitive surgeries or staged procedures as well as those who had surgery for non-PD indications.

Definition

SSI were diagnosed based on the 2012 CDC guidelines – with one caveat, where we divided the SSI into early (less or equal to 90 days) and late (>90 days).

Analysis

Categorical variables were presented as frequencies and percentages, while continuous variables were presented as mean and standard deviation, or median and interquartile range, depending on the normality. Normality analysis was performed. Normally distributed variables and variables with a very small sample size was analyzed with parametric analysis.

Age was compared between SSI groups using the Mann-Whitney Rank U test as the data were skewed. Categorical factors were

compared between SSI groups using Fisher's Exact test. Binary logistic regression was performed to determine the odds ratio between the categorical factors and SSI groups.

Sex was compared according to the location of the infection using Fisher's Exact test. Age, duration of antibiotic, and duration of surgery were compared between the location of the infection using one-way ANOVA. Similarly, length of hospital stay and duration of antibiotics use were compared between management using one-way ANOVA.

Statistical analysis was conducted with IBM SPSS Statistics 25.0 and statistical significance was set at $p<0.05$.

Result

The total number of cases performed throughout the study period was 153 cases involving 128 patients in total and 26 recurrent surgeries. The cases consisted of 289 lead implantation and 161 IPG. Of the 142 new brain surgeries, 136 patients underwent Subthalami Nucleus (STN) DBS while 6 (4.2%) had Globus Pallidus internal (GPi) DBS. Four patients who underwent DBS for non-PD causes were excluded.

There was a total of 7 cases of SSI with an incidence of 4.7% per case. Out of these 7 cases, 4 were early SSI and 2 were late SSI. One patient's data from 2004 was missing.

More than 90% of the surgeries were performed by a qualified functional neurosurgeon (KA) (Table 1).

Table 2 presents the association between investigated factors and the presence of SSI. The median age at surgery was 65 years old (VAR 97.5, IQR 10) with a predominance of Chinese (75.8%) patients. The median age and age group distributions were similar in both groups (p=0.879, and p=0.502 respectively). More than 61% of the patients were males and the distribution of the sexes across the study group was similar (p=0.706). The average disease duration of a patient was 8.8 years before surgery was performed.

102 patients (66.2%) had no comorbidities other than PD and the commonest underlying co-morbidities were hypertension (12.1%) and Alzheimer's disease (5.4%). The median number of medications each patient was on was 4 (VAR 1.11, IQR 1).

Most of the patients received combined (lead and IPG implantation in single setting) surgeries (n=115, 74.7%) whereas 36 (23.4%) had two stage surgeries. The two stage surgeries included revision surgeries such as IPG change (n=1) and electrode malposition readjustment (n=3). Three (1.9%) patients had missing data.

The median op duration was 270 min (VAR 11896, IQR: 200).

Other complications included wire fracture (n=1, 0.7%), skin erosion (n=2, 1.4%), electrode malposition (n=3, 2.1%) and symptomatic ICH (n=3, 2.1%).

There was no significant association between both groups (SSI or none) in terms of ethnicity, number of medications, intra operative or late complications. Patients with Traumatic Brain Injury (TBI) and Steven-Johnson-Syndrome (SJS) was significantly associated with the presence of SSI (p=0.047).

The mean duration from surgery to date of SSI was 26 days (SD 5.83, CI 16.7-35.3) and the commonest location of SSI was on the scalp – both frontal/auricular region (n=3, 42.8%), followed by chest wall (n=2, 28.6%) with 2 patients having a combination of both scalp and chest wall (n=2, 28.6%).

Table 1: Number of cases performed in UMMC per year.

Year	Total of cases performed
2004	6
2005	4
2010	7
2011	1
2012	7
2013	2
2014	5
2015	5
2016	20
2017	21
2018	24
2019	29
2020	18

Management of the SSI

One patient was managed with antibiotics alone, one was managed with antibiotics plus wound debridement, two were managed with antibiotics, wound debridement and externalization and three had complete removal of the hardware.

The mean hospital stay for patients with SSI was 29 days (SD 16.2, CI 14.1-44.1).

The mean antibiotic duration for these SSI patients (both intravenous plus oral) was 54 days (SD 34.3, CI 22.3-85.7).

As for the culture and sensitivity results, the commonest organism cultured was MRSA (n=4, 50%), followed by MSSA (n=3, 37.5%) and MR CONS (n=1, 12.5%).

Eventually all the 7 patients had removal of the implants prior to discharge.

Table 3 presents the association between the location of the infection with the age, sex, duration of surgery, antibiotic duration, and intra-op complication. The median age was similar across all locations of the infection (p=0.441). There was also no significant association between the location of SSI with the patients' gender, duration of surgery and mean antibiotic duration.

Table 4 presents the association between the management style with the length of hospital stay and duration of antibiotics. One patient was treated with antibiotics alone, one with debridement, two were treated with wound debridement and externalization and three patients eventually had complete removal of hardware. The mean length of hospital stays and antibiotic duration did not differ between the management types (p=0.626 and p=0.428).

Discussion

Rate of SSI and its implications

We have described the largest cohort in Southeast Asia so far. The results of this study put the incidence of SSI from our center at 4.7% per case over the last 16 years. In this study, we calculated the incidence per case rather than separating leads/IPG implantations as it was a retrospective study.

Table 2: Association between independent factors and the presence of SSI.

Factors		All patients (N=149)	SSI		P value	OR (95% CI)
			No (n=142)	Yes (n=7)		
Age (years)	Median (IQR)	65 (10)	65 (10)	65 (13)	0.879	-
	<40	2 (1.3)	2 (1.4)	0 (0.0)	0.502	1.000
	40 – 50	6 (4.0)	5 (3.5)	1 (14.3)		0.294 (0.22-3.872)
	51 – 60	36 (24.2)	34 (23.9)	2 (28.6)		0.208 (0.018-2.385)
	61 – 70	75 (50.3)	72 (50.7)	3 (42.9)		0.172 (0.009-3.228)
	>70	30 (21.1)	29 (20.4)	1 (14.3)		n/a
Sex	Male	91 (61.1)	86 (60.6)	5 (71.4)	0.706	1
	Female	8 (38.9)	56 (39.4)	2 (28.6)		0.614 (0.115-3.276)
Ethnicity	Malay	12 (8.1)	10 (7.0)	2 (28.6)	0.095	1
	Chinese	113 (75.8)	109 (76.8)	4 (57.1)		0.183 (0.030-1.129)
	Indian	16 (10.7)	16 (11.3)	0 (0.0)		n/a
	Others	8 (5.4)	7 (4.9)	1 (14.3)		0.714 (0.054-9.497)
Comorbids						
Alzheimer disease		8 (5.4)	7 (4.9)	1 (14.3)	0.326	3.214 (0.339-30.472)
Anxiety		2 (1.3)	2 (1.4)	0 (0.0)	0.908	n/a
BPH		2 (1.3)	2 (1.4)	0 (0.0)	1.000	n/a
Breast cancer		1 (0.7)	1 (0.7)	0 (0.0)	1.000	n/a
Colonic polyps		1 (0.7)	1 (0.7)	0 (0.0)	1.000	n/a
CVA		4 (2.7)	4 (2.8)	0 (0.0)	1.000	n/a
Diabetes		6 (4.0)	5 (3.5)	1 (14.3)	0.255	4.567 (0.459-45.430)
Gastritis		1 (0.7)	1 (0.7)	0 (0.0)	1.000	n/a
Hemorrhoids		1 (0.7)	1 (0.7)	0 (0.0)	1.000	n/a
Hiatal hernia		1 (0.7)	1 (0.7)	0 (0.0)	1.000	n/a
HTN		18 (12.1)	17 (12.0)	1 (14.3)	1.000	1.225 (0.139-10.806)
Hyperthyroidism		1 (0.7)	1 (0.7)	0 (0.0)	1.000	n/a
Hypothyroidism		2 (1.3)	2 (1.4)	0 (0.0)	1.000	n/a
IBD		1 (0.7)	1 (0.7)	0 (0.0)	1.000	n/a
IHD		5 (3.4)	5 (3.4)	0 (0.0)	1.000	n/a
Lipid		7 (4.7)	7 (4.9)	0 (0.0)	1.000	n/a
Nil		99 (66.4)	96 (67.6)	3 (42.9)	0.225	0.359 (0.077-1.672)
Moyamoya		1 (0.7)	1 (0.7)	0 (0.0)	1.000	n/a
OSA		2 (1.3)	2 (1.4)	0 (0.0)	1.000	n/a
Osteoporosis		2 (1.3)	2 (1.4)	0 (0.0)	1.000	n/a
Ovarian cyst		3 (2.0)	3 (2.1)	0 (0.0)	1.000	n/a
PID		3 (2.0)	3 (2.1)	0 (0.0)	1.000	n/a
Scoliosis		1 (0.7)	1 (0.7)	0 (0.0)	1.000	n/a
Skin disease		1 (0.7)	1 (0.7)	0 (0.0)	1.000	n/a
TBI		1 (0.7)	0 (0.0)	1 (14.3)	0.047*	n/a
SJS		1 (0.7)	0 (0.0)	1 (14.3)	0.047*	n/a
Number of medications	1	3 (2.1)	3 (2.2)	0 (0.0)	0.152	n/a
	2	24 (16.8)	21 (15.4)	3 (42.9)		
	3	24 (16.8)	23 (16.9)	1 (14.3)		
	4	67 (46.9)	66 (48.5)	1 (14.3)		
	≥ 5	25 (17.5)	23 (16.9)	2 (28.6)		
Intra op complication		4 (2.7)	4 (2.8)	0 (0.0)	1.000	n/a
Late complication		3 (2.0)	3 (2.1)	0 (0.0)	1.000	n/a
Surgery from the date of infection (days)	Mean (SD)	-	-	112.3 (78.8)	-	-
Length of hospital stay	Mean (SD)	-	-	29.1 (16.2)	-	-

*Statistical significance obtained

Table 3: Association between the location of infection with age, sex, duration of surgery, antibiotic duration, and intra op complications.

		Location of infection			P value
		Scalp frontal (n=3)	Chest wall (n=2)	Others/combination (n=2)	
Age (years)	Mean (SD)	68.3 (2.9)	66.0 (26.9)	57.5 (0.7)	0.441
Sex	Male	3 (100.0)	1 (50.0)	1 (50.0)	0.429
	Female	0 (0.0)	1 (50.0)	1 (50.0)	
Duration of surgery	Mean (SD)	170.0 (165.2)	140.0 (134.4)	247.5 (31.8)	0.731
Antibiotic duration (day)	Mean (SD)	37.3 (26.5)	67.0 (55.2)	66.0 (33.9)	0.629
Intra-op complication		0	0	0	n/a

Table 4: Association between management styles with length of hospital stay and duration of antibiotics.

		Management			P value
		1 or 1.2 (n=2)	3 (n=2)	4 (n=3)	
Length of hospital stay	Mean (SD)	31.5 (20.5)	18.5 (16.3)	34.7 (16.8)	0.626
Antibiotic duration (day)	Mean (SD)	67.0 (55.2)	24.5 (24.7)	65.0 (21.9)	0.428

Management keys: 1: Antibiotics alone; 2: Wound debridement; 3: Lead explanation; 4: Total removal

Our SSI incidence is comparable to newer studies such as a meta-analysis by Spindler et al. published in 2022 -they performed a systematic review and meta-analysis of 68 studies including 11,289 patients and 15,956 IPG procedures and found the incidence SSI to be 4.9% [18]. In this study they noticed that the dominant SSI localization was the IPG pocket, which differs slightly from our study where most of our patient's infection occurred in the scalp/frontal region.

Our usual practice for skin preparation involves a thorough wash with chlorhexidine 2% over the scalp region, and povidone-iodine over the chest IPG region. We do not routinely clip the patient's hair as this not only saves operative time but also improves the patient's cosmetic acceptance towards the procedure. Surgery is also performed *via* standard surgical drapes with a dedicated anesthetic, nursing and surgical team.

There is abundant meta-analysis over the years which have shown that preoperative hair removal does not decrease SSI rates [19,20], hence we do not think a change in practice will affect the outcome. However, given that the prevalence of diabetes mellitus is not high in this cohort, it does not explain why the incidence was higher in the scalp region compared to the IPG pocket. It was interesting to note how Xu et al. in his retrospective study among Han Chinese population demonstrated a low SSI incidence of 0.89%. In his paper, he depicts how the surgical area is clipped thoroughly, usage of specialized drapes, as well as modified surgical techniques and avoidance of direct hardware implantation under the suture line [21].

Rubelli et al. found that introduction of an Infection Prevention Bundle (IPB), routine surveillance and personal feedback in cranial neurosurgery was associated with a 53% reduction in infection rates [22]. A similar reduction in SSI was found by Arocho-Quinones who implemented an IPB at his center [23]. We propose a similar approach to reduce the incidence of SSI at our university and await the results of a future study.

Our patients who had undergone DBS would routinely have been warded for a total of three days (1 day prior to surgery, and 2 days post operatively), however, the patients with SSI had a mean hospitalization of 29 days. This no doubt increases the burden on hospitals and patients – both financially and psychologically.

Traumatic Brain Injury (TBI) and Steven Johnson Syndrome (SJS) – Associations with SSI

Whilst Xu et al. [21] found that hypertension was significantly associated with postoperative complications, Werner et al. and Rughani et al. have found that medical comorbidities (1 or more) increase the observed risk of wound infections [24] and in hospital complications [25]. However, no study has actually found any associations of TBI and SJS to an increased risk of SSI.

Piacentino in his cohort reported that all his patients with exfoliative dermatitis incurred an infection although this was not statistically different between two patient groups [26].

We do not know the exact mechanism how both conditions have a significant association with SSI; however, we think it may be due to the presence of scarring and fibrous tissue on a previously injured skin. In patients with prior TBI (He had a craniotomy performed) and prior SJS (where there was extensive inflammation and scarring of the skin including the scalp) the normal healing and protective barrier of the skin is proposed to be lost, replaced by fibrous tissues and reduced vascularity hence reducing delivery of antibiotics to the skin and nutrients required in wound healing. As a result, this predisposes the patient to a higher risk of SSI. However due to the small number in this study, we advise the results to be interpreted with caution.

Cultured organisms

All culture samples were obtained *via* sterile methods. The commonest organism cultured was Methicillin-Resistant *Staphylococcus aureus* (MRSA), followed by Methicillin-Susceptible *Staphylococcus aureus* (MSSA) and Methicillin-Resistant Coagulase-Negative Staphylococci (MR CONS). This is reflected in an audit performed by the department and is likely due to local antibiogram practices where usage of prophylactic cephalosporin is performed.

We administer IV Cefuroxime 1.5 g and IV Gentamycin 5 mg/kg routinely as prophylactic antibiotics pre-operatively. This dosage is re-administered at its half-life intra-operatively. The IPG pocket is then flushed with IV Gentamicin intraoperatively.

The usage of topical vancomycin initiated in spinal surgery [27] has certainly led to an interest in its usage in implantable devices in neurosurgery. Spindler et al. in his meta-analysis showed a trend

towards beneficial effects of vancomycin powder over standard wound closure [18]. Despite Bhatia et al. [28] showing a reduction in SSI post IPG replacement by changing prophylactic antibiotics to vancomycin and gentamycin, more recent publications seem to favor the use of topical vancomycin to avoid its systemic side effects [29].

Pepper et al. [30] in his study screened his DBS patients for MRSA and eradicated them if positive, later following them up for 24 months. He also practiced intraoperative vancomycin pouch wash and reported an SSI incidence of 0% [20]. These results are excellent however it needs to be balanced with the cost of routinely swabbing patients for MRSA in a cohort with low rates of colonization.

In summary, we suggest a higher index of suspicion in patients post DBS who had TBI or SJS or any skin incompetency – to be started on empirical Vancomycin whilst awaiting formal culture results. We also suggest a change of practice to consider using topical vancomycin intraoperatively.

Management options

All 7 patients were eventually treated with complete hardware removal with or without reimplantation despite attempts of wound debridement and salvage at the beginning.

There have been increasing reports of attempts for hardware salvage over the years. Bernstein et al. in 2019 conducted a retrospective review of 203 patients who underwent DBS for PD out of which 14 patients developed an infection (10 early, 4 late). Complete hardware removal was performed in 8 patients. Interestingly the use of intraoperative vancomycin powder was not shown to reduce the risk of infection after implantation of IPG replacement [31].

Kim et al. in their retrospective review of 246 DBS surgeries reported a hardware infection rate of 7.1% of patients and 4.9% of DBS over a follow up period of 2 years. Salvage was possible in 9 patients and removal of hardware in 3 patients who then went on to have re-implantations successfully. Additionally, they also assessed extra hospital admission days which amounted to 18 days and an extra $4066 in cost [16].

Piacentino et al. reported an incidence of SSI of 8.5% of patients and 4.2% of procedures. All his infected patients underwent a 2-stage procedure with a mean interval of 8 days between electrode and IPG implantation. Eight out of 9 patients had IPG and extensions removed, and re-implanted 3 months later. Rate of salvage was 88.8% of the case [26].

Dlouhy et al. attempted lead preservation using antibiotic impregnated catheters after hardware infections, in combination with incision and drainage - he was successful in 7 out of 8 patients (87.5%) however we note that most of the cultures were non-MRSA and the author mentioned, failure of this therapy was seen in a (presumably) more aggressive species of *Pseudomonas aeruginosa*, and there were certainly limitations to the small study [32].

Fenoy et al. reports perhaps one of the largest cohorts of hardware salvage in DBS surgeries. His study involved 728 patients, 1,333 new DBS leads and 1,218 IPG implants, out of which 16 patients had atraumatic device related infection within 12 months from implantation. Despite attempts of salvaging the cranial leads, 9 of the 16 patients required additional surgery after antibiotic failure and 8 patients eventually had total hardware removal [33].

The novelty of being able to salvage hardware in DBS have been reported with fair outcomes [17,33] and it is what we attempted to perform for all our patients initially. In our experience so far, attempts to salvage were met with failure likely due to resistant organisms such as MRSA and MRCONS. It is also principally erroneous to keep a focus of infection *in situ*. However, due to limitations in healthcare financing in our country, we find that in the real-world scenario patient themselves often request for device salvage as they find that the implant is functioning well and their quality of life is improving. It would be costly to have to purchase a new implant/lead as it is not borne by medical insurances. Patients would rather opt for wound debridement, lead re-positioning, trial of prolonged antibiotics, bear the risk of overwhelming sepsis and recurrent surgeries than have upfront hardware removal. Nevertheless, the results speak for themselves as all patients required hardware removal in the end. Plus, we find that there were no statistical differences with regards to length of hospital stay and duration of antibiotics between operative and nonoperative managements. Hence, we strongly propose upfront hardware removal followed by re-implantation later in the setting of an infection.

Limitations and Strengths

This is a retrospective, non-blinded study. Data collection was inadequate especially in the previous decade. Many patients were lost to follow up. There is also no formal video protocol for pre and post DBS testing and lack of a clinical psychologist for thorough cognitive evaluation and administration of rating scales.

However, this study remains the first to provide an idea into the scenario of DBS amongst the multi-racial Malaysian population as well as providing an insight into the Southeast Asia region.

Conclusion

In recent years we have seen a reduction in the incidence of SSI among DBS where most centers quote an incidence of <10%. This could be due to improvements in surgical sterility and surgical techniques, advancements in durability of electrode and implants, application of topical antibiotics, implementations of infection prevention bundles, and most recently due to changes post COVID-19 infections. However, we stress that early surgical removal of an infected implant could not be any less important as a method of early source control and to improve patient's mortality and morbidity, especially in a resource-limited setting.

Acknowledgment

Ethical approval was obtained from the University Malaya Research Ethics Committee (UMREC) with the registration number 2021615-10243. Consent was given by all patients to participate in all studies as approved by the UMMC ethical committee.

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