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# Battery for deep brain stimulation depletion in Parkinson's Disease and dystonia patients — a systematic review

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## ABSTRACT

**Introduction.** Deep brain stimulation (DBS) therapy for Parkinson's Disease (PD) and dystonia is associated with the possibility of both minor and major complications. One possible side effect is the depletion of implantable pulse generator (IPG) battery and the associated sudden recurrence of PD or dystonia symptoms, which can be potentially life-threatening. Delayed or postponed outpatient visits due to COVID -19 may be a risk factor of battery end-of-life consequences.

**Objective.** To analyse the clinical outcomes in reported PD and dystonia patients treated with DBS, who, as a result of the sudden depletion of the neurostimulator battery, developed life-threatening symptoms.

**Materials and methods.** The databases of PubMed, Scopus, EMBASE and Google Scholar were searched using pre-established criteria.

**Results.** A total of 244 articles was found, of which 12 met the adopted criteria. Selected papers presented a total of 17 case reports of DBS-treated patients — 11 with PD, and six with dystonia — who had depleted IPG batteries and due to rapid worsening of PD/dystonia symptoms required urgent hospital admission. IPG battery replacement was the only effective treatment in the majority of cases.

**Conclusions.** IPG battery depletion can result in fatal outcomes. Sudden recurrence of PD or dystonia symptoms in patients treated by DBS can be potentially life-threatening, so scheduling the replacement of a discharged IPG battery should not be postponed. The COVID-19 pandemic should alert staff at emergency, neurology and movement disorders wards not to postpone the visits of patients with an implanted DBS system.

**Key words:** Parkinson's Disease, dystonia, deep brain stimulation, battery depletion, COVID-19

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## Introduction

Deep brain stimulation (DBS) has become an established treatment option for patients with movement disorders including Parkinson's Disease (PD) and dystonia. In numerous clinical trials, DBS has shown improvement in quality of life, mobility in patients with advanced PD suffering bothersome motor fluctuations, treatment-resistant dyskinesias, the majority of non-motor symptoms, as well as motor symptoms of drug-resistant focal/segmental or generalised dystonia. DBS has been approved by the US Food and Drug Administration as an effective therapy for PD since 2002, and since 2003 for the treatment of dystonia [1–3]. Nevertheless, DBS implantation is associated with the possibility of both minor and major complications due to the implanted system [4, 5].

One possible side effect is the depletion of the implantable pulse generator (IPG) battery and the associated sudden recurrence of PD or dystonia symptoms. These symptoms can be potentially life-threatening, so scheduling the replacement of a discharged IPG battery should not be postponed. During the COVID-19 pandemic, medical centres have postponed scheduled procedures, admitted only urgent cases in order to limit

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the spread of Sars-CoV-2, and allocated hospital resources to control the pandemic [6, 7]. Patients with depleted batteries of DBS systems cannot wait, because the potential consequences of abrupt cessation of stimulation can be fatal, such as parkinsonism-hyperpyrexia syndrome, sudden akinesia with falls and bone fractures, venous thrombosis and pulmonary embolism or aspiration pneumonia in PD, and dystonic state in dystonia patients with rhabdomyolysis and renal failure.

## Materials and methods

We searched the available literature using the PubMed, Scopus, EMBASE and Google Scholar databases for the keywords 'deep brain stimulation', 'depletion', 'withdrawal', 'battery exhaustion', 'hardware failure', 'Parkinson disease' and 'dystonia' in various combinations. A total of 244 articles was found. The literature review included studies published from 1996 (i.e. from the introduction of DBS into clinical practice) to 2020 (31 December). The study did not include cases where brain stimulation was interrupted by infection of IPG system or electrodes, or for reasons other than discharge of the IPG battery. Papers were written in English, published as full-length texts. Abstracts as well as review papers were not included.

## Results

We found a total of 244 articles, from which 12 met the established criteria. Selected papers presented a total of 17 case reports of DBS-treated patients — 11 with PD, six with dystonia — who had depleted IPG batteries (Tab. 1, 2), who required urgent hospital admission. Ten patients with PD developed acute akinetic syndrome. Six of them were finally diagnosed with parkinsonism-hyperpyrexia syndrome (PHS), three had pulmonary embolism, deep vein thrombosis and aspiration pneumonia, and one had disseminated intravascular coagulation (DIC) and consequently multi-organ failure and death. One patient developed a coma as a result of IPG battery discharge. 2/11 patients with PD were reported during the COVID-19 pandemic. In the reported cases, the sudden recurrence of symptoms did not result from a reduction of oral antiparkinsonian treatment.

Among patients treated with DBS GPi for dystonia, six reports of IPG battery depletion and sudden motor deterioration were found (Tab. 2). Of these six patients, three developed acute dystonic state (two required urgent ICU admission - one patient developed cardio-respiratory failure and died despite intensive treatment, the other developed cardiopulmonary failure, rhabdomyolysis-related acute renal failure, and DIC as a result of dystonic state). 3/6 patients had dystonia symptoms worsening as a result of IPG battery depletion. Urgent battery replacement resulted in motor function improvement in two patients; one patient reported during the pandemic postponed their surgical procedure for financial reasons.

## Discussion

The presented reports of PD and dystonia patients treated with DBS have shown that IPG battery depletion can result in fatal outcomes and must be avoided.

This abrupt cessation of DBS function may be due to delayed or postponed outpatient visits. Two PD patients described by Holla et al. had postponed follow-up visits due to the COVID-19 pandemic, resulting in IPG battery depletion and akinetic state [6]. COVID-19 may be a risk factor because many hospitals have limited access for ambulatory patients and also for planned surgeries. Patients, especially those with chronic diseases and co-morbidities, have avoided hospital and outpatient visits to protect themselves against infection. In some regions, a shortage of medical staff has also forced movement disorder neurologists to provide care for patients with COVID-19 [19].

In severe cases, where symptoms cannot be relieved with increased doses of oral or intravenous/subcutaneous/transcutaneous medications and general treatment, an urgent IPG battery replacement should be performed. This was the only effective treatment in the majority of cases (Tab. 1, 2). The range of PD duration was in reported cases 12–22 years with long-lasting DBS therapy (3–14 years) and in such patients, the replacement of only pharmacological therapy instead of combined treatment with DBS is usually ineffective.

Parkinsonism-hyperpyrexia syndrome is one of the potentially fatal complications in PD patients, most often occurring after a sudden reduction or discontinuation of antiparkinsonian medications, but also DBS battery depletion [20, 21]. This was a main complication in 5/11 patients (Tab. 1) and manifested itself as muscle stiffness, fever, impaired consciousness, and dysautonomia. It is characterised by leukocytosis and elevated levels of creatine kinase (CK) in laboratory tests.

The most common direct causes of death in patients with PHS are aspiration pneumonia, acute renal failure, deep vein thrombosis, pulmonary embolism, and DIC [22]. Nevertheless, akinetic-rigid state as the result of IPG battery depletion, reported in 6/11 PD cases, can also result in pneumonia, falls and bone fractures or head injuries, deep vein thrombosis with pulmonary embolism, and dysphagia with the risk of aspiration pneumonia, and should be recognised and treated vigorously.

Dystonic state (DS), the main complication in 3/6 patients reported (Tab. 2), is characterised by muscle rigidity, muscle pain and fever. Muscle contractions involve also respiratory muscles and abdomen and lead to respiratory failure and hypoxaemia. Abnormal muscle contractions in the gastrointestinal tract can lead to dysphagia and aspiration pneumonia. Another potentially fatal complication of DS is rhabdomyolysis and acute renal failure [23]. Rapidly worsening symptoms are life-threatening. In patients with dystonia treated with DBS-GPi, there have been reports of a dystonic state resulting in cardio-respiratory failure requiring hospitalisation in the ICU.

**Table 1.** Published PD cases with abrupt IPG battery depletion (in all patients bilateral STN was anatomical target)

| Article | Age/sex | PD duration /DBS treatment duration | Battery depletion effect | Treatment/outcome |
|---|---|---|---|---|
| Chou et al. [8] | 63/M | 17 years/4 years | • Acute akinetic state<br>• Deep vein thrombosis, pulmonary embolism | • Oral levodopa treatment/no effect<br>• Inferior vena cava filter, anticoagulation treatment<br>• IPG battery replacement (5 days after hospital admission)/ improvement of motor function |
| | 76/M | 14 years/3 years | • Acute akinetic state | • Oral levodopa treatment/ no effect<br>• IPG battery replacement (a few days after motor function worsening)/improvement of motor function |
| Neuneier et al. [9] | 77/M | 18 years/5 years | • PHS<br>• DIC<br>• Multi organ failure | • Oral levodopa treatment/ no effect<br>• Antibiotic therapy, fluid therapy, amantadine infusion, antipyretic treatment/no effect<br>• IPG battery replacement (10 days after hospital admission)/no effect<br>• Death |
| Artusi et al. [10] | 63/M | 13 years/5 years | • PHS | • Fluid therapy, antipyretic therapy/general improvement<br>• Oral levodopa treatment/no effect<br>• IPG battery replacement (4 days after symptom onset)/improvement of motor function |
| R. Rajan et al. [11] | 51/M | 18 years/7 years | • Acute akinetic state<br>• PHS | • Oral levodopa treatment, amantadine infusion/no effect<br>• Fluid therapy, antipyretic treatment, antibiotic therapy/no effect<br>• IPG battery replacement (11 days after hospital admission)/ general and motor function improvement |
| | 54/F | 22 years/11 years | • Acute akinetic state<br>• Aspiration pneumonia | • Oral levodopa treatment, pramipexol, amantadine infusion/no effect<br>• Antibiotic therapy, CPAP<br>• IPG battery replacement (8 days after hospital admission)/ general and motor function improvement |
| Liu et al. [12] | 69/M | 12 years/3 years | • PHS | • Antibiotic therapy, fluid therapy, antipyretic therapy/no effect<br>• Oral levodopa treatment, bromocriptine, dantrolen, benzodiazepine admission/no effect<br>• IPG battery replacement (2 days after hospital admission)/ general and motor improvement |
| Azar et al. [13] | 67/F | 23 years/7 years | • PHS | • Antibiotic therapy, B1 vitamin admission, fluid therapy/no effect<br>• Oral levodopa treatment/ no effect<br>• IPG battery replacement (17 days after hospital admission)/ general and motor improvement |
| Kamel et al. [14] | 73/M | 21 years/14 years | • Coma (GCS 4) | • Oral levodopa treatment/no effect<br>• IPG battery replacement (urgent surgery)/general improvement |
| Holla et al. [6] | 67/M | 17 years/4 years | • Acute akinetic state | • IPG battery replacement/motor function improvement |
| | 60/F | 17 years/4 years | • Acute akinetic state | • Oral levodopa treatment/minimal motor function improvement<br>• IPG battery replacement/motor function improvement |

CPAP — continuous positive airway pressure; DIC — disseminated intravascular coagulation; GCS — Glasgow Coma Scale; IPG — internal pulse generator; PHS — parkinsonism hyperpyrexia syndrome

**Table 2.** Published dystonia cases with abrupt IPG battery depletion

| Article | Age/sex | Dystonia type/dystonia duration/DBS treatment duration | Anatomical target | Battery depletion effect | Treatment/effect |
|---|---|---|---|---|---|
| Li et al. [15] | 17/F | PKAN/6 years/5 years | STN | • Dystonic state | • IPG battery replacement/motor function improvement |
| Rohani et al. [16] | 41/F | TD/8l years/3 years | GPi | • Dystonic state<br>• Cardio-pulmonary failure= | • ICU admission<br>• Mechanical ventilation<br>• Death |
| Sobstyl et al. [17] | 15/M | DYT1/6 years/5 years | GPi | • Dystonic state<br>• Cardio-pulmonary failure<br>• Rhabdomyolysis, acute disease failure<br>• DIC | • Mechanical ventilation circulatory support<br>• Dialysis therapy<br>• IPG battery replacement (1 day after hospital admission)/motor function improvement |
| Yanni et al. [18] | 25/F | Secondary dystonia/7 years/2 years | GPi | • Worsening symptoms of dystonia | • IPG battery replacement (urgent surgery at admission day)/motor function improvement |
| | 9/F | Idiopathic dystonia/6 years/2 years | GPi | • Worsening symptoms of dystonia | • IPG battery replacement (urgent surgery)/motor function improvement |
| Holla et al. [6] | 33/M | Idiopathic generalised dystonia/9 years/3 years | GPi | • Worsening symptoms of dystonia | • Postponing procedure due to patient's finances, optimising pharmacological treatment |

DIC — disseminated intravascular coagulation; DYT1 — early onset torsion dystonia; GPi — Internal Globus Pallidus; ICU — intensive care unit; IPG — internal pulse generator; PKAN — Pantothenate Kinase-Associated Neurodegeneration; STN — subthalamic nucleus; TD — tarditive dystonia

In one case described, the battery was discharged and resulted in the death of the patient. Dystonic state should be treated as a neurological emergency and battery depletion has a worse prognosis in patients with dystonia than with PD: in PD patients with sudden DBS shutdown, symptoms can be partly relieved with increased doses of antiparkinsonian medications, while in dystonia patients there is no such emergency treatment and the only effective treatment is battery replacement.

Mitchel et al. analysed patient satisfaction with rechargeable IPGs. Patient experience, especially those with dystonia, was positive, and they especially valued the fewer surgeries [24]. Considering the above, and the higher total electrical energy delivered and higher battery consumption in dystonia than in PD, the implantation of rechargeable batteries should be considered in every patient with dystonia treated with DBS.

## Conclusions

This situation should warn medical staff at emergency, neurology and movement disorders wards against postponing the visits of patients with an implanted DBS system. Despite the progress and development of DBS technology, there are still no programmes or applications available for remote battery checking. Manufacturers of equipment for deep brain stimulation should also ensure smooth delivery of the necessary elements of DBS systems, especially during a pandemic, to ensure constant access to depleted IPGs and shorten possible replacement delays. To avoid a sudden shutdown of DBS pacing due to battery depletion, battery status and electrical integrity may be checked through telemedicine or telephone consultation [7]. If the battery power is low, the elective procedure of IPG replacement should be planned and performed as soon as possible. One possible solution would be replacing IPG batteries as an outpatient procedure. To minimise the risk of sudden cessation of stimulation, reduction of amperage and frequency of the stimulation should be considered to reduce temporarily total electrical energy delivered and battery consumption [25].

Despite many years of practice of using DBS in patients with PD and dystonia, no studies including larger groups of patients with battery depletion were found in our search of databases. It is difficult to assess the percentage of patients with battery depletion, and the number appears to be underreported. Nevertheless, all presented case reports are valuable and show the potentially fatal risks of delaying battery replacement.

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