# Clinical significance of abnormal electrode impedance readings in deep brain stimulation for treatment of movement disorders.

***Olga Waln, MD[1]; Joohi Jimenez-Shahed, MD[1].***
Parkinson's Disease Center and Movement Disorders Clinic, Department of Neurology[1],
Baylor College of Medicine, Houston, Texas

## Background

- Open circuit (OpC) and short circuit (ShC) are types of deep brain stimulation (DBS) hardware malfunction that present as abnormal electrode and therapy impedance and often require surgical intervention.
- Impedance checks should be routinely performed during programming sessions to check hardware integrity, but the clinical significance of abnormal impedance readings is not well characterized, especially in Activa® devices.
- **Objective: To investigate the clinical correlates of DBS hardware malfunction presenting as abnormal impedance readings in patients with movement disorders.**

## Methods

- Patients with abnormal impedance readings from 1/2010 to 4/2013 were identified through active clinical practice or database search of those referred for surgical intervention.
- Retrospective chart review was performed beginning with the last DBS-related surgery.
- Clinical presentation, type and evolution of the abnormal circuit, and eventual resolution (e.g., surgical correction) or other disposition were recorded.

## Results

**Table 1. Patient demographics, clinical and DBS data**

| Patients (N=9) | |
|---|---|
| **Age** | 51-80 |
| **Gender** | F (N=4), M (N=5) |
| **Diagnosis** | PD (N=7), ET (N=1), ET+PD (N=1) |
| **X-rays done / results** | 6 / all normal |
| **Circuit abnormality** | Open (N=8)<br>Short (N=3) |

*1 patient had OpC and ShC (same side, different contacts, different time)

**1 patient had OpC twice (different side, different time)

| | Open circuit (N=8) | Short circuit (N=3) |
|---|---|---|
| **Time from Sx to abnl impedance (months)** | 0.5 to >36 | 0 to 7 |
| **DBS device** | Kinetra (N=1)<br>Soletra (N=3)<br>Activa PC (N=1)<br>Activa SC (N-3) | Activa PC (N=3) |
| **Clinical manifestation** | Asymptomatic (N=4)<br>Gradual loss of effect (N=3)<br>Never had good DBS effect (N=1)<br>New side effects (N=1) | Asymptomatic (N=1)<br>Fast battery depletion (N=1)<br>Sudden loss of effect (N=1) |
| **Outcome** | Surgical correction (N=3)<br>Pending surgery (N=1)<br>Observe (N=2)<br>Spontaneous resolution (N=1)<br>Resolution post IPG exchange (N=1) | Surgical correction (N=2)<br>Spontaneous resolution (N=1) |

## Results, continued

**Table 2. Clinical manifestations in patients with abnormal impedance readings**

*all subjects had 3387 leads
¥T1 = time from surgery to abnl Imp; T2 = time from abnl Imp to clinical recognition

***OPEN CIRCUIT***

| Code Age/G | Target, IPG type | Imp reading | Contact involved | T1¥ (mo) T2 (mo) | Symptoms | Surgical correction? Location circuit abnormality | Disposition |
|---|---|---|---|---|---|---|---|
| O1 67/M | STN Kinetra | >4,000Ω 0&2, 2&3 → all contact 2 pairs | Active | 24 4 | Gradual loss of effect (wearing-off post programming) →sudden worsening | Yes Connector to IPG | Resolved after surgical correction |
| O2 52/M | STN Activa PC | >20,000Ω 1&3, 2&3 → all contact 3 pairs | Inactive | 0.5 12 | Gradual loss of effect Progression of OpC | Yes Extension wire | Resolved after surgical correction but ShC at different contacts(=S2) |
| O3 77/M | STN Soletra | >2,000Ω (current<7) all contact 0 pairs | Inactive | >36 0 (lost f/u) | Asymptomatic | No (routine IPG exchange) | OC persist; follow-up pending |
| O4 80/F | VIM Activa SC | >10,000Ω all contact 2 pairs | Inactive | 4 n/a | Asymptomatic | No (observe) | Spontaneous normalization of Imp readings |
| O5 63/M | STN Soletra | >2,000Ω (current<7) all contact 3 pairs | Inactive | 22 n/a | Asymptomatic | No (routine IPG exchange) | Resolved after IPG exchange |
| O6 63/M | STN Activa SC | >40,000Ω all contact 2 pairs | Active | 3 0 (no f/u) | Positional tingling left arm/leg Gradual loss of tremor effect | Yes Extension wire | Resolved after surgical correction |
| O7 58/F | L-VIM / R-STN Activa SC | >40,000Ω all contact 0 pairs | Inactive | 2 0 | No effect from DBS since surgery (but electrode also suboptimally placed) | Yes (Pending) | Pending surgery |
| O8 61/F | STN Soletra | >2000Ω (current<7) intermittent, positional | Active | 26 n/a | Asymptomatic (position-related abnl Imp readings) | No (observe) Suspicion: connector to IPG | Spontaneous normalization of Imp readings |

***SHORT CIRCUIT***

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| S1 51/F | STN, Activa PC | 117-119Ω all contact 0 pairs, 1&2, 1&3, 2&3 | Active | 0 12 | Asymptomatic Rapid IPG drain | Yes DBS lead @ burrhole cap | Resolved after surgical correction |
| S2 52/M | STN Activa PC | 31Ω at 0&1 | Inactive | 0 n/a | Asymptomatic | No (observe) | Spontaneous normalization of Imp readings |
| S3 73/M | STN Activa PC | 104Ω at 1&2 Therapy Imp 100 (current 22.950mA) | Active | 4 2 (no f/u for 2 mo) | Sudden loss of effect after configuration changed to that with ShC | Yes Extension wire | Resolved after surgical correction |

- Abnormal circuits involving either active or inactive electrodes can have similar clinical presentations (Table 2, purple boxes – compare patients O2 and O6).
- Patients with abnormal circuits involving active electrodes can have different clinical manifestation from asymptomatic to sudden loss of effect (Table 2, red boxes – compare patients S1 and S3).

## Discussion

**Clinical presentation of OpC and ShC can include:**

- ✓ No effect of stimulation since surgery
- ✓ Gradual loss of previous effect
- ✓ Sudden loss or change of previous effect [1,2]
- ✓ New side effects from stimulation (often sensory)
- ✓ Intermittent side effects / loss of effect (intermittent open circuits, incomplete disruption of circuit)
- ✓ Asymptomatic abnormal impedance
- ✓ Rapid battery drain

- OpC and ShC can have similar clinical symptoms; therefore clinical manifestation does not predict type of hardware malfunction.
- Abnormal impedance readings do not indicate site of hardware malfunction.
- Spontaneous resolution of abnormal impedance readings is possible.

## Conclusions

- Clinicians should maintain a high index of suspicion of a circuit problem based on clinical manifestations as described.
- Electrode and therapy impedances should be routinely monitored to determine presence and nature of circuit abnormality in symptomatic and asymptomatic patients.
- If an asymptomatic impedance abnormality is detected, patients should be closely monitored over time for gradual loss of effect or rapid battery drain.
- X-rays should be performed but do not always identify a specific location of hardware malfunction.
- Surgical exploration may be required to identify site of circuit malfunction.

**Table 3. Suggested management of patients in DBS clinic.**

| | |
|---|---|
| **Check electrode and therapy impedance at default settings** | - If abnormal, increase voltage/current at which it is checked<br>- If persistently abnormal, suspect OpC (high Imp ) or ShC (low Imp) and change contacts to those uninvolved<br>- If no/insufficient symptom control → X-ray and surgical referral |
| **Check battery drain** | - If greater than expected, suspect ShC (low Imp) and monitor closely for ERI → eventual referral for IPG exchange and system investigation |
| **X-rays** | - If abnormal → directed surgical intervention<br>- if normal → exploratory surgery with "system investigation" to identify site of malfunction |

## References

1. Farris S, Vitek J, Giroux M. Deep brain stimulation hardware complications: the role of electrode impedance and current measurements. Mov Disord 2008;23:755-60.
2. Samura K, Miyagi Y, Okamoto T, et al. Short circuit in deep brain stimulation. J Neurosurg. 2012 Nov;117(5):955-61.