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

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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) 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) Soletra (N=3) Activa PC (N=1) Activa SC (N-3)	Activa PC (N=3)
Clinical manifestation	Asymptomatic (N=4) Gradual loss of effect (N=3) Never had good DBS effect (N=1) New side effects (N=1)	Asymptomatic (N=1) Fast battery depletion (N=1) Sudden loss of effect (N=1)
Outcome	Surgical correction (N=3) Pending surgery (N=1) Observe (N=2) Spontaneous resolution (N=1) Resolution post IPG exchange (N=1)	Surgical correction (N=2) 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 - If persistently abnormal, suspect OpC (high Imp) or ShC (low Imp) and change contacts to those uninvolved - 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 - 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.