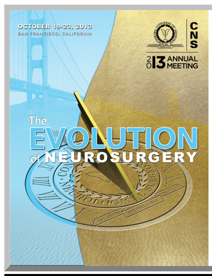

Variation in Deep Brain Stimulation Electrode Impedance over Years Following Electrode Implantation

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Introduction

Significance

- Deep brain stimulation (DBS) electrode impedance is a major determinant of current delivery to target tissues [1], but long-term changes in impedance have received little attention
- Variation in impedance has implications for long-term programming, development of closed-loop DBS devices, and understanding of the electrode -tissue interface

Prior research

- Studies of impedance over hours to days after implantation report early fluctuations with acute decrease in impedance in response to stimulation [2-4]
- Recent human studies carried out over 1-4 years following surgery have found that impedance decreases with time and is lower in active contacts [5-8]

Present study

- Our objective was to assess the relationship between electrode impedance and time since implantation in a large DBS patient population and characterize the relationship between contact activity and impedance

Table 1. Demographics

	Electrodes (patients)
Diagnosis	
Parkinson's disease (PD)	98 (64)
Essential tremor (ET)	20 (14)
Mixed PD and ET features	1 (1)
Dystonia	9 (5)
Total	128 (84)
Target	
STN	94
GPi	14
VIM	20
Electrode	
Medtronic #3387	38
Medtronic #3389	90
Hemisphere	
Left	75
Right	53

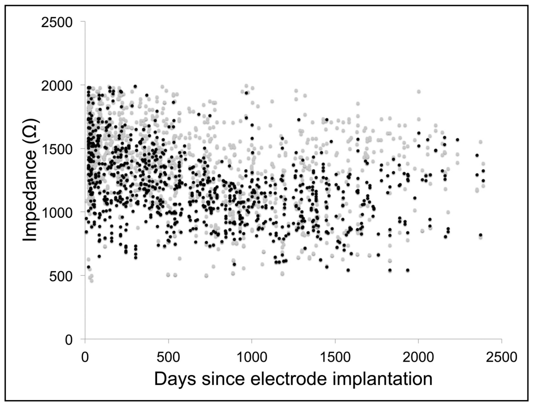

Figure 1. Impedance versus time since electrode implantation. Black points = active contacts; gray points = inactive contacts.

Methods

- Retrospective impedance and programming data from patients with Soletra implantable pulse generator
- 128 electrodes in 84 patients with Parkinson's disease (PD), essential tremor (ET), or dystonia (Dys)
- Mixed linear regression model used to assess effects of time, contact activity, diagnosis, anatomical target, electrode model, contact laterality, and contact number on impedance
- Impedance changes following contact activation and deactivation examined, as well as the effect of stimulation voltage on impedance

Table 2. Mixed linear regression results

	Impedance			Effect (Ω)	P
Time				-73/year	< .001
Contact activity	Inactive	>	Active	163	< .001
Diagnosis	PD	>	ET	171	< .001
	PD	>	Dys	310	< .001
	ET	≈	Dys	-	.08
Anatomical target	STN	>	GPi	246	< .001
	STN	>	VIM	173	< .001
	GPi	≈	VIM	-	.30
Electrode	#3389	>	#3387	181	< .001
Hemisphere	Left	≈	Right	-	.18

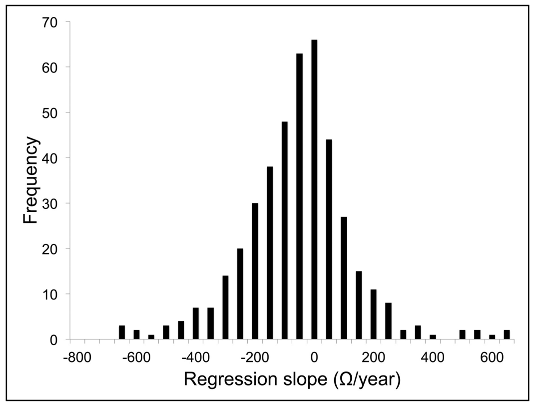

Figure 2. Variation in impedance trends by contact. Figure shows distribution of slopes from individual simple linear regression calculated for each contact. Mean = -80 ohms/y, SD = 183 ohms/y. 72% of the slopes were negative.

Results

- Impedance declined by 73 ohms/year ($P < .001$), and decreased in 72% of contacts
- Impedance was on average 163 ohms lower in active contacts ($P < .001$)
- Activation of a contact was associated with a more rapid decline in impedance (121 ohms greater of a decline at the follow-up visit relative to a contact left off, $P < .001$) and inactivation was associated with a less rapid decline in impedance (81 ohms less, $P = .016$)
- Higher voltages were associated with lower impedances ($P < .001$)
- Contact number and electrode model also predicted impedance

Table 3. Impedance vs. contact number

Contact	Usage[a]	Mean impedance (Ω)[b]
0	44%	1347*
1	49%	1265†
2	51%	1230†
3	29%	1309*

All differences were significant. (a) $P < .001$. (b) $P < .05$ if same symbol, $P < .001$ if different symbols.

Conclusions

Time and stimulation

- Impedance decreased over time in a stimulation-dependent manner
- Electrode encapsulation is known to be associated with increases in impedance [1], while stimulation-induced oxidation at the electrode-tissue interface [2] and accumulation of CSF around the electrode may account for the observed decreases in impedance

Electrode model

- Diagnosis, target, and electrode model had identical impedance relationships
- Geometric difference between electrode models is the simplest explanation
- Higher impedance in more closely spaced contacts and with monopolar stimulation may be related to electric fields around inactive contacts [9]

Contact location

- Middle contacts (1 & 2) were used more frequently than outer contacts (0 & 4) and had lower impedances
- More frequent stimulation and placement in grey matter may explain these trends

References

1. Butson CR, Maks CB, McIntyre CC. Clin Neurophysiol. 2006;117(2):447–454.
2. Lempka SF, Miocinovic S, Johnson MD, Vitek JL, McIntyre CC. J Neural Eng. 2009;6(4):1–11.
3. Johnson MD, Otto KJ, Kipke DR. IEEE T Neur Sys Reh. 2005;13(2):160–165.
4. Rosa M, Marceglia S, Servello D, et al. Exp Neurol. 2010;222(2):184–190.
5. Hemm S, Vayssiere N, Mennessier G, et al. Neuromodulation. 2004;7(2):67–75.
6. Abosch A, Lanctin D, Onaran I, Eberly L, Spaniol M, Ince NF. Neurosurgery. 2012;71(4):804–814.
7. Sillay K a., Rutecki P, Cicora K, et al. Brain Stimulat. 2013:1–9.
8. Cheung T, Nuño M, Hoffman M, et al. Brain Stimulat. 2013.
9. Hemm S, Mennessier G, Vayssiere N, Cif L, El Fertit H, Coubes P. J Neurosurg. 2005;103(6):949–955.