In CV stimulation, the actual current (I) delivered to brain tissue may vary by -1.1% ± 9.8 (range -27 + 28) for 6-12 months of follow-up.

Changes of CD and impedance between visits, and compared to baseline (first study visit) were calculated in each patient.

**Methods**

A retrospective chart review (1/2010 – 4/2014) identified Parkinson’s disease patients with Activa DBS pulse generators (PC, SC) and 3387 electrodes programmed in CV mode, with documented therapy impedance over at least 3 consecutive visits after the last DBS-related surgery (initial implant, battery exchange).

Exclusion criteria:

- Change in electrode polarity
- Abnormal impedance (therapy or electrode) reading consistent with possible open or short circuit
- All impedance values were documented at the beginning of each study visit before making any changes in DBS parameters.

The magnitude of stimulation was calculated as Charge Density (CD):

\[ \text{CD} = V / R \]

where \( V \) is voltage and \( R \) is the resistance in ohms.

The extent and clinical significance of impedance changes in vivo over long-term DBS treatment are not well characterized.

Objectives:

1. To follow therapy impedance changes over time in patients with CV DBS;
2. To determine if a correlation exists between changes in therapy impedance and changes in DBS parameters.

**Results**

**Table 1. Patient and DBS Characteristics**

<table>
<thead>
<tr>
<th>Patient/electrodes, N</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male (n=6), Female (n=4)</td>
</tr>
<tr>
<td>DBS device</td>
<td>Activa PC (n=10)</td>
</tr>
<tr>
<td>Target</td>
<td>b/l STN (N=4), b/l GPi (N=6)</td>
</tr>
<tr>
<td>Mean time to 1st visit with impedance check (days)</td>
<td>158.8 ± 4.233 (all initial DBS implants)</td>
</tr>
<tr>
<td>Mean # follow-up visits/electrode</td>
<td>6.55 ± 4.2</td>
</tr>
<tr>
<td>Mean duration of follow-up/electrode</td>
<td>467.5 ± 156.2</td>
</tr>
<tr>
<td>Electrode configuration</td>
<td>Bipolar (n=4), double monopolar (n=1), and monopolar (n=15)</td>
</tr>
</tbody>
</table>

**Table 2. Impedance change from baseline vs. change between visits**

| Mean change impedance from baseline in all electrodes over all visits | -11.04 ± 19.37 |
| Mean change impedance between visits | -3.5 ± 10.7 |
| 0-180days | -6.8 ± 16.7 |
| 181-360days | -1.1 ± 9.8 |
| >360days | -2.6 ± 5.8 |

Despite large changes in CD, impedance fluctuations between visits or last visit vs. baseline were relatively small.

**Discussion**

Stimulation current influences Volume of Tissue Activated (VTA) - activated neuronal elements around active contact(s) producing clinical benefits and adverse effects of DBS treatment.

In CV stimulation, the actual current (I) delivered to brain tissue may vary if there are significant fluctuations of impedance (R) based on the formula: \( I = V / R \) (V = voltage). In CC stimulation, current does not change but the voltage varies in order to maintain the same current in response to impedance fluctuations.

A previous study of 63 patients with older Medtonic DBS devices (Kinera and Soletra) did not identify any significant intra-patient impedance fluctuation over 2 visits with unchanged DBS parameters with CC stimulation devices [2].

On the other hand, impedance can change significantly during first 3 months after electrode implant due to tissue healing [3]. This observation could theoretically justify the advantages of CC over CV stimulation during the early post-implantation period.

We analyzed serial impedance readings in response to real-world clinical application of DBS (in the absence of changes in polarity) up to 1504 days after electrode implantation.

Our findings suggest the following about the degree and nature of impedance changes in chronic DBS therapy:

- Impedance measurements are generally reduced over time, while CC increases with chronic stimulation.
- Impedance fluctuations are small relative to changes in CD at any stage of DBS treatment, and vary inversely.
- Impedance fluctuations are greatest in the initial post-implantation period (6-12 months): -8.6 ± 10.7% (range -44 – 16).
- In the chronic phase of DBS therapy, impedance fluctuations are relatively small, though they may still occur: -1.1% ± 9.8% (range -27 ± 28) for 5-12 months, -2.6 ± 5.8% (range -22 to +11) for >12 months.

**Conclusions**

Impedance fluctuations in chronic DBS therapy delivered in CV stimulation mode are minimal over time, and generally decrease, in a real world clinical setting.

In CV mode, impedance appears to decrease proportionally to increases in CD, as can be expected according to \( V = IR \).

The results of our study do not support the use of CC DBS delivery over CV in order to accommodate for fluctuating impedance in chronic DBS therapy.

**References**