CI Stimulation Parameters Play a Key Role in Reducing Facial Nerve Stimulation

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Introduction

The proportion of CI users affected by unwanted facial nerve stimulation (FNS) is estimated to be >5%. For some sufferers, the effort to control this problem involves changing stimulation parameters, thereby reducing CI performance. For others, using their CI becomes impossible.

A growing body of case studies suggests that unwanted FNS can be treated by re-implantation with an Oticon Medical (OM) Neuro-Zti implant [1][2][3][4]. But why? Does the benefit arise from surgical adjustments—e.g., different array geometries and positioning—or from different stimulation parameters and/or grounding [5]? Indeed, the OM device has both: (1) unconventional stimulation parameters, including anodic leading pulses and loudness controlled by pulse duration instead of amplitude—leading to pulses with generally lower current amplitudes and (2) unconventional grounding, utilizing a distributed grounding scheme—one that is neither monopolar nor bipolar/tripolar—and passive (capacitive) discharge that affects the pulse shape. Case studies alone cannot disentangle surgical factors from these implant-related factors.
Here we present a follow-up study involving two CI subjects who previously suffered from FNS prior to re-implantation with Neuro-Zti implants [1]. For the first time we show that stimulation parameters play a key role in reducing FNS.

Materials and Methods

We previously reported on two subjects (involving three ears) where re-implantation using a Cochlear Implant (CI) by Oticon Medical provided relief from Facial Nerve Stimulation (FNS) [1] (see Fig. 1). This significantly improved speech comprehension as the comfort levels (C-levels) were able to be increased to appropriately loud volumes without any side effects.

- CASE 1: The patient was previously equipped with Advanced Bionics HiRes Ultra 3D and a Mid-Scala electrode on both sides.
- CASE 2: The patient was initially equipped with a Medel Synchrony with a FLEX28 electrode.

It was under debate whether the FNS issues were caused by the stimulation parameters or if the re-implantation surgery itself mitigated the FNS. The pulse shapes and stimulation modes employed in the clinical software of various CI manufacturers are depicted in Table 1 and Figures 2 and 3.

During follow-up visits with the patients from [1], we conducted measurements with the Oticon Medical Research Platform (OMRP) [7], using different stimulation types (as shown in Fig. 3). All tests were carried out using the Oticon Medical Neuro Zti implant. This approach enabled a direct comparison of the stimulation patterns used by different manufacturers using the same implant hardware in the same subject without changing the implant.

We identified candidate electrodes from regions where each subject had previously reported strong FNS responses prior to re-implantation. We then stimulated these electrodes using stimulus parameters designed to mimic their original CI stimulation paradigms.

Intensity was increasing until either a too strong non-auditory sensation was reported by the subject, or the loudness became too intense. We were not able to reproduce FNS responses for all candidate electrodes and selected the one with the largest response to continue to test. The chosen electrode was stimulated using parameters shown in Fig. 3 while the intensity was gradually increased. At each charge level, subjects were asked to: (1) rate the loudness on a scale from 0 (inaudible) to 10 (very loud), (2) report qualitatively on any non-auditory sensations, and (3) indicate if they wished to continue.

References

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Stimulus parameter	Advanced Bionics	Cochlear	Medel	Oticon Medical	OMRP
Pulse shape	See Fig. 3A	See Fig. 3A	See Fig. 3A, & Triphasic	See Fig. 3B	See Fig. 3A-D
Stimulation mode	See Fig. 2A	See Fig. 2A, & Common Ground & Bipolar	See Fig. 2A	See Fig. 2B	See Fig. 2A-B

Table 1. Stimulus parameters *pulse shape* and *stimulation mode, which are* currently used by different manufacturers. With OMRP, parameters, which are usually not available within the clinical software of a certain implant type, can be elicited and compared in the same subject.

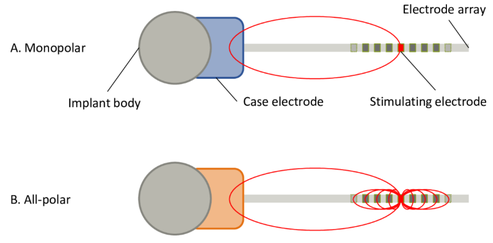

Fig. 2. Different stimulation modes. Stimulating intracochlear electrode is depicted in red. The spread of the electrical field is illustrated by red ellipses.

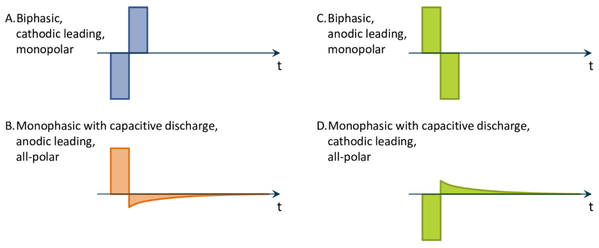

Fig 3. Different pulse shapes and stimulation modes under investigation with OMRP. A. biphasic, cathodic leading (pulse shape used with previously implanted CI); B. monophasic with passive discharge ("pseudomonophasic"), anodic leading (current standard in Oticon Medical); C. like A, but polarity reversed; D. like B, but polarity reversed. Loudness was varied in A and C by current or pulse duration, in B and D by pulse duration.

Results I (Case Reports from [1])

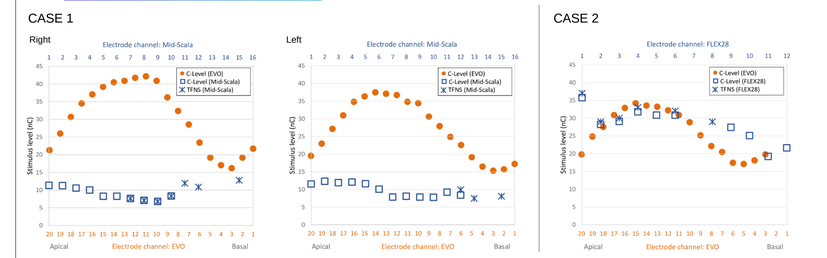

Fig. 1. Results from case reports presented in [1]. C-level before and about half a year after re-implantation with Oticon Medical Neuro Zti EVO. Asterisks refer to the facial nerve stimulation thresholds (TFNS) with the previously implanted electrode. The upper x-axis refers to the channel number of the previously implanted electrode, the lower x-axis refers to those of the EVO electrode.

Results II (Follow-up)

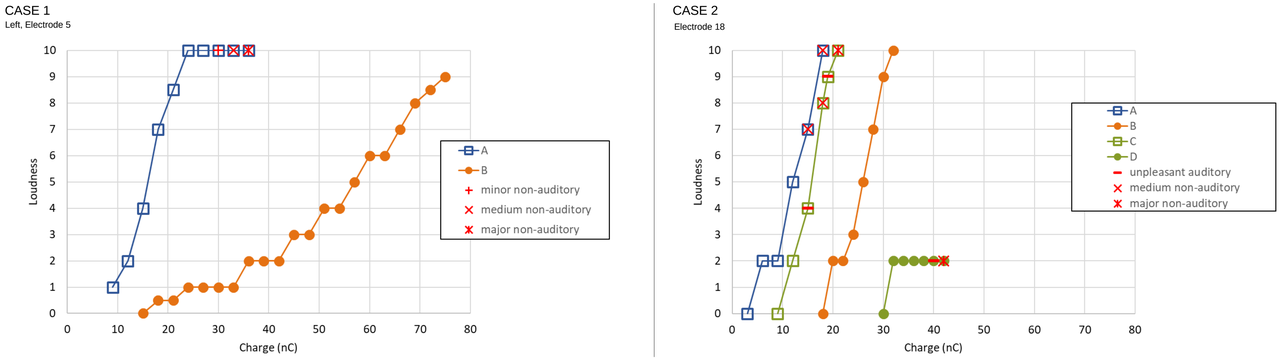

Fig. 4. Results from measurements with OMRP during a follow-up after re-implantation. Case 1: Measurements of the left CI by using parameters according to Fig. 3 A&B. Case 2: All four different types of stimuli according to Fig. 3 A-D were under investigation.

Side	Electrode	Charge (nC)	Loudness	Observation
R	3	36	10	vibration in outer ear
R	7	27	10	vibration in outer ear
R	11	33	10	no non-audiotory sensation
L	7	27	10	no non-audiotory sensation
L	16	33	10	no non-audiotory sensation

Table 2. Measurements of other electrodes at C-level using traditional stimulation for Case 1. These did not evoke FNS side-effects but some did evoke non-auditory sensations. Note: In Case 2 we only tested one electrode to allow time for polarity investigations. L = left; R = right.

Discussion and Summary

Facial Nerve Stimulation:
- FNS was elicited when using symmetric *biphasic* pulses (monopolar stimulation mode).
- FNS was elicited by both *cathodic* and *anodic* leading *biphasic* pulses.
- No FNS was elicited by *pseudo-monophasic anodic* leading pulses (all-polar stimulation mode).
- FNS was also elicited by non-standard *pseudo-monophasic cathodic* leading pulses.

Polarity:
- Cathodic pulses are likely more effective in eliciting FNS.
- Anodic pulses are likely more effective in eliciting auditory perception.
- Inverting polarity of pseudo-monophasic pulses (from anodic to cathodic leading) had a dramatic impact on loudness growth (Fig. 4, Case 2).

Loudness Growth:
- was more gradual with pseudo-monophasic pulses compared to symmetric bipolar pulses in one case.

Surgery Factors:
- Although contributing surgical factors cannot be ruled out, they are probably not key. For example, the relative proximity of an electrode to the auditory nerve fibres and facial nerve is an obvious and easy to understand factor on its own, but since the OM device is a lateral-wall array (which should be worse in this regard) this was not shown to be a major factor here. All regions which had FNS before re-implantation showed less FNS afterwards even with the same stimulation parameters (see Table 2) so some contribution of electrode placement or size and impedance are likely playing a role.

Manufacturers:
- should add more grounding/pulse-shape options to clinical fitting software to cope with FNS.