The Effects of Multi-Mode Monophasic Stimulation with Capacitive Discharge on the Facial Nerve Stimulation Reduction in Young Children with Cochlear Implants: Intraoperative Recordings

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Introduction

Facial nerve stimulation (FNS) is a potential complication which may affect the auditory performance of children with cochlear implants (CIs). FNS incidence has been reported to range from 1.14% to 43% in children, with immediate or delayed onset. Although it is known that otosclerosis, meningitis, temporal bone fractures and congenital cochlear anomalies increase the risk of FNS, some patients experience it after cochlear implantation without any of these etiologies. FNS symptoms may range from mild facial movements to severe facial spasms, painful or debilitating, either visually detected or self-reported by the patient. In young children, FNS has been underestimated, as they may not accurately report its symptoms.

It is assumed that the electric current passing from the electrode to spiral ganglion cell can spread to the nearby facial nerve causing FNS, but the exact mechanism underlying the FNS remains unclear, as well as the relative contribution of factors to trigger the symptoms and the best treatment option to resolve it. Some strategies have been adopted to manage FNS symptoms, including maximum comfort levels (MCL) reduction, pulse wide widening, the use of triphasic pulses, electrode deactivation and cochlear re-implantation. Recently, the use of the multi-mode monophasic stimulation was proposed as a promising strategy to manage FNS. It is hypothesized that multi-mode monophasic stimulation decreases the spatial extent of electrical stimulation and reduces the amount of the current spread to the periphery structures, including the facial nerve, thereby reducing FNS.

Methodology

We carried out an exploratory prospective observational study to investigate the effects of the electrical stimulation pattern on FNS reduction in young children with CI.

- Ten ears from seven prelingually deafened children aged up to 6 years old who underwent either unilateral or bilateral CI surgeries in Brazil were included in this study.
- All subjects were implanted with the Neuro Zti Evo® device associated to the Neuro 2 sound processor (Oticon Medical, France).
- We recorded intraoperative EMG action potentials to investigate the use of the multi-mode monophasic stimulation in young children and the effects of this stimulation pattern on the FNS reduction in this population.
- Four electrodes were tested in each ear: one basal (E1), two medial (E8, E15) and one apical (E20).
- In order to investigate EMG responses using the two different CI stimulation patterns, the experimental protocol first employed monopolar biphasic stimulation (ST1) and then, multi-mode monophasic stimulation (ST2).
- We also used Nautilus (Oticon Medical, France) image analysis tool to estimate the CI intra-cochlear electrodes placement, as well as the distances between the basal turn of the cochlea and electrodes (based on their real intra-cochlear positioning) to the labyrinthine segment of the facial nerve, to investigate their influence on the EMG recordings.

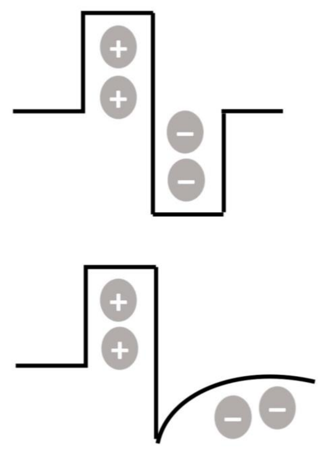
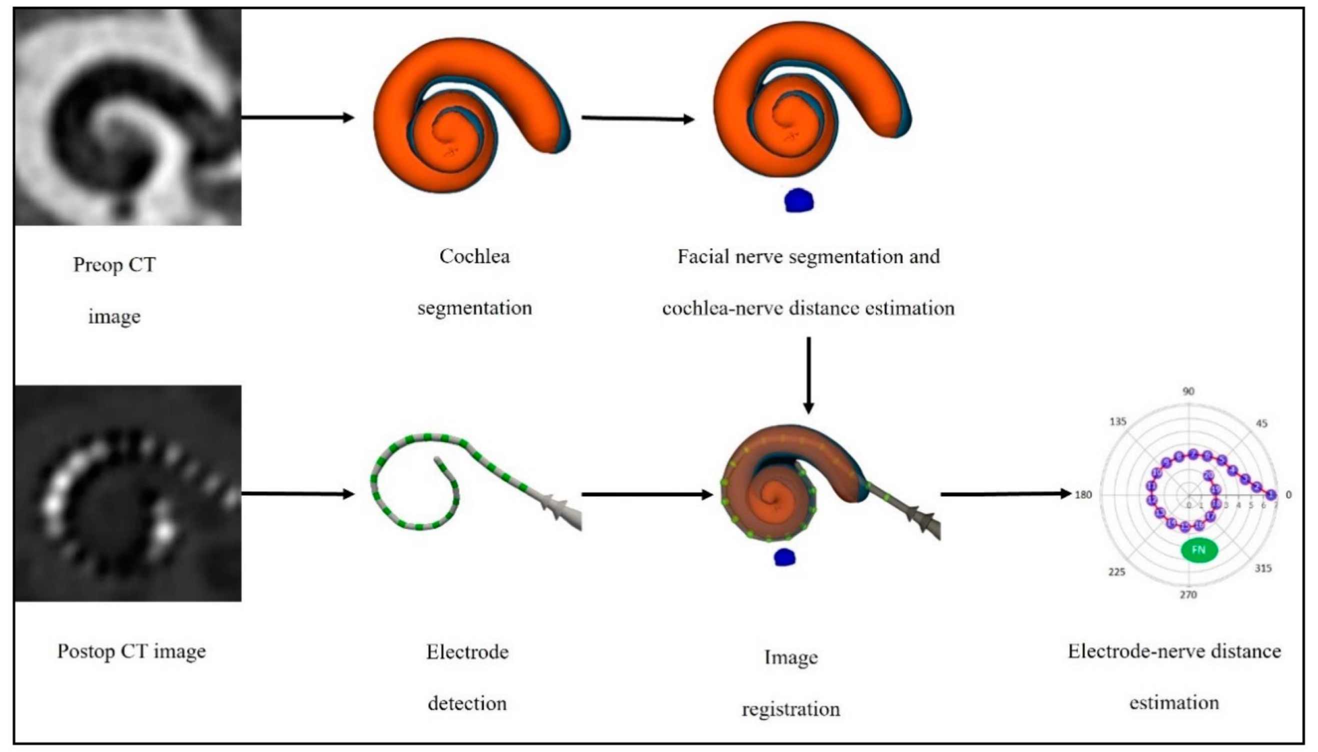


Table 2. Stimulation parameters used to record EMG responses.

Stimulation Patten	Stimulation Mode	Waveform	Polarity	Pulse Train	Coding	Pulse Amplitude Min:Step:Max (µA)	Pulse Duration (µs)	Stimulation Rate (Hz)
1 Monopolar biphasic	MP	Biphasic active symmetrical	Anodic leading	Masker probe	Amplitude	444:110:1554	30	83
2 Multi-mode Monophasic with CD	MM	Monophasic capacitive discharge	Anodic leading	Continuous	Amplitude	444:110:1554	30	250

CD: capacitive discharge; MP: monopolar; MM: multi-mode grounding, min: minimum; max: maximum.

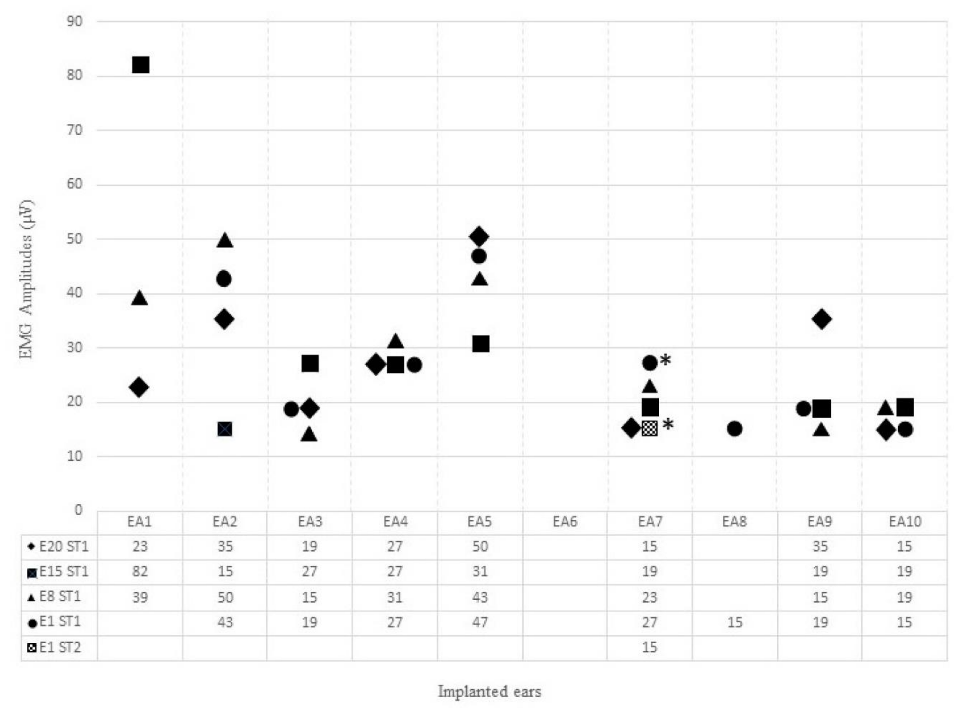
Results

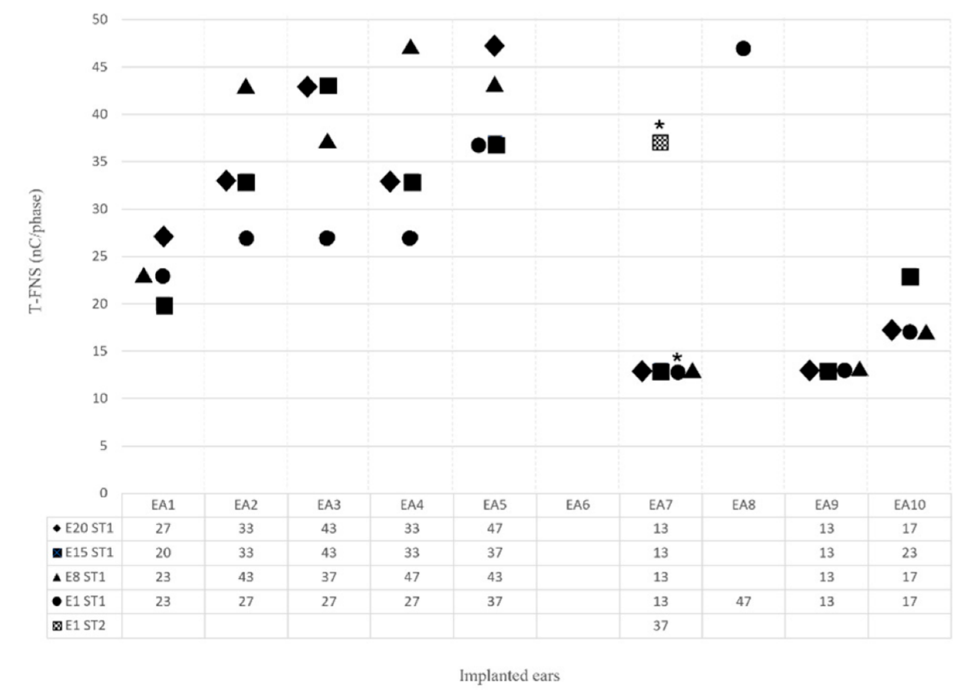


Intra-cochlear electrodes placement, cochlea-nerve and electrode-nerve distances estimation of the subjects.

Subject	Ear	Side	Extra-Cochlear Electrodes	Cochlear-Nerve Distance (mm)	Insertion Depth Angle (°)	Electrode Closest to the FN
S1	EA1	L	0	0.24	279	15
	EA2	R	2	0.20	281	18
S2	EA3	R	1	0.20	285	15
	EA4	L	1	0.40	290	15
S3	EA5	R	1	0.44	267	16
	EA6	L	2	1.00	270	16
S4	EA7	R	1	0.20	273	16
S5	EA8	L	0	0.32	279	14
S6	EA9	R	0	0.56	276	11
S70	EA10	L	0	0.64	250	10

S1–S7: subjects 1–7; EA1–EA10: implanted ears 1–10; L: left; R: right; cochlea-nerve distance: closest distance between basal turn of the cochlea and the labyrinthine segment of the facial nerve; mm: millimeters; Electrode closest to the facial nerve: Evo® electrode with closest electrode-nerve distance values; FN: facial nerve.





Proportion of intraoperative EMG responses recorded in each tested electrode using the stimulation patterns ST1 and ST2.

Electrode	ST1 N (%)	ST2 N (%)	*p*-Value
E1 (basal)	9 (90.0)	1 (10.0)	0.0143 *
E8 (medial)	8 (80.0)	0 (0.0)	0.0047 *
E15 (medial)	8 (80.0)	0 (0.0)	0.0047 *
E20 (apical)	8 (80.0)	0 (0.0)	0.0047 *

ST1: stimulation pattern 1 (monopolar biphasic stimulation); ST2: stimulation pattern 2 (multi-mode monophasic stimulation); N: number of EMG responses in each implanted ear. * Significant difference (McNemar's test, 5% of significance level).

Relationship between cochlear-nerve distances and EMG responses of the subjects.

Electrode	Spearman (rho)		*p*-Value	
	T-FNS (nC/Phase)	EMG Amplitude (µV)	T-FNS (nC/Phase)	EMG Amplitude (µV)
E20	−0.1975	0.1605	0.6391	0.7042
E15	−0.1975	0.0881	0.6391	0.8358
E8	−0.1605	−0.2332	0.7042	0.5784
E1	−0.1384	−0.2981	0.7439	0.4732

nC: Nanocoulomb; µV: microvolt; T-FNS: facial nerve stimulation thresholds; EMG Amplitude: peak-to-peak electromyographic amplitudes. Spearman's correlation test, at a significant level of 5%.

Conclusion

Our results suggest that CI electrical stimulation pattern may affect FNS in young children and multi-mode monophasic stimulation with capacitive discharge should far reduce FNS in young children with CIs. The adoption of this electrical stimulation pattern should be an effective option for patients with a higher risk of experiencing FNS after CI surgery, such as patients with otosclerosis, meningitis, temporal bone fractures and congenital cochlear anomalies, or those who have indication for cochlear re-implantation due to severe FNS. Contrarily from the CI electrical stimulation pattern, the cochlea-nerve and electrode-nerve distances seem to have limited effects on FNS reduction in this populations

Acknowledgments

The authors would like to thank Denny Marcos Garcia for the review of the statistical analysis.

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