Clinical application of an automatic system to record and analyze electrically evoked compound action potentials in cochlear implant patients

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Introduction

Meanwhile all major manufacturers of cochlear implants offer the possibility to measure electrically evoked action potentials (ECAPs) by means of the inserted electrode. Cochlear Corp. realized a system to automatically record and analyze the ECAP in its Nucleus RE24 "Freedom" implants (Patrick et al. 2006), including the estimation of the ECAP threshold. It is desirable to find a correlation between these measurement outcomes and programming parameters of the patient map to facilitate the fitting procedure.

Materials and Methods

The study group consisted of 16 adults all implanted with a Nucleus RE-24CA „Freedom"cochlear implant. The average age was 53.8 years. Demographics and etiological data are shown in Table 1. During the first week of initial fitting 8 subjects (s1 ... s8) were fitted based fully or partly based on measurements of the threshold NRT (TNRT) value while the other 8 subjects (d1 ... d8) were fitted behaviourally. At the end of the first week of initial fitting NRT measurements were performed postoperatively in each subject on each of 22 electrodes. Intraoperative measurements were done on 14 electrodes in order to not prolongate surgery time.

NRT measurements were done with the Freedom speech processor connected via the pod interface to an IBM compatible personal computer using the CustomSoundEP software in AutoNRT mode. Default settings were used. The indifferent electrode during stimulation was the ball electrode (MP1). The indifferent electrode during recording was the case electrode (MP2). Intraoperative TNRT measurements were done at stimulation rate of 250Hz without prior conditioning of the electrodes. Postoperative TNRT measurements were done at 80Hz. In addition the automatically performed recordings were analyzed by an experienced audiologist to verify the operational reliability of the AutoNRT algorithm which is described in detail by Botros et al. (2006).

ID	Gender	Status of deafness	Etiology	Age at implantation in years	Side of implantation	bilaterally provided	Deaf (implanted side) in years
s1	f	postlingual	unknown	66.8	right	no	0.1
s2	f	prälingual	unknown	24.0	right	no	24.0
s3	m	postlingual	sudden hearing loss	76.5	right	no	0.1
s4	f	postlingual	unknown	18.7	right	no	0.3
s5	m	postlingual	Meningitis	60.4	left	yes: Clarion C1	9.5
s6	m	postlingual	unknown	66.9	left	no	1.6
s7	m	postlingual	unknown	66.2	right	no	15.2
s8	f	postlingual	sudden hearing loss	70.8	right	no	0.0
d1	f	postlingual	Fechtner syndrome	53.0	left	yes: Nucleus M24	8.7
d2	m	postlingual	unknown	71.9	right	no	5.0
d3	f	postlingual	unknown	63.2	right	no	5.0
d4	m	postlingual	sudden hearing loss	49.1	left	no	0.8
d5	f	postlingual	unknown	50.7	left	no	0.0
d6	f	postlingual	unknown	18.6	left	no	0.1
d7	f	postlingual	unknown	46.0	right	no	0.0
d8	m	postlingual	unknown	58.3	right	yes: Nucleus R24CS	6.2
Mean				**53.8**			**4.8**

Table 1. Demographics and etiological data of the subjects

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Results

The total amount of postoperatively measured electrodes was 325. AutoNRT found TNRT values in 96.3% while the audiologist was successful in 95.1%. On average the TNRT values found by AutoNRT were 0.95 CL higher than those found by the audiologist. TNRT values calculated by AutoNRT and by the audiologist were highly correlated (correlation coefficient r=0.985, p<0.01).

Intraoperative TNRT measurements were done on 143 electrodes. On average intraoperative TNRT values were 25CL higher compared to the postoperative responses. Figure 1 and 2 show all postoperative and intraoperative TNRT measurements as well as the C and T levels of the patients map at the end of the week of initial fitting for the whole study group.

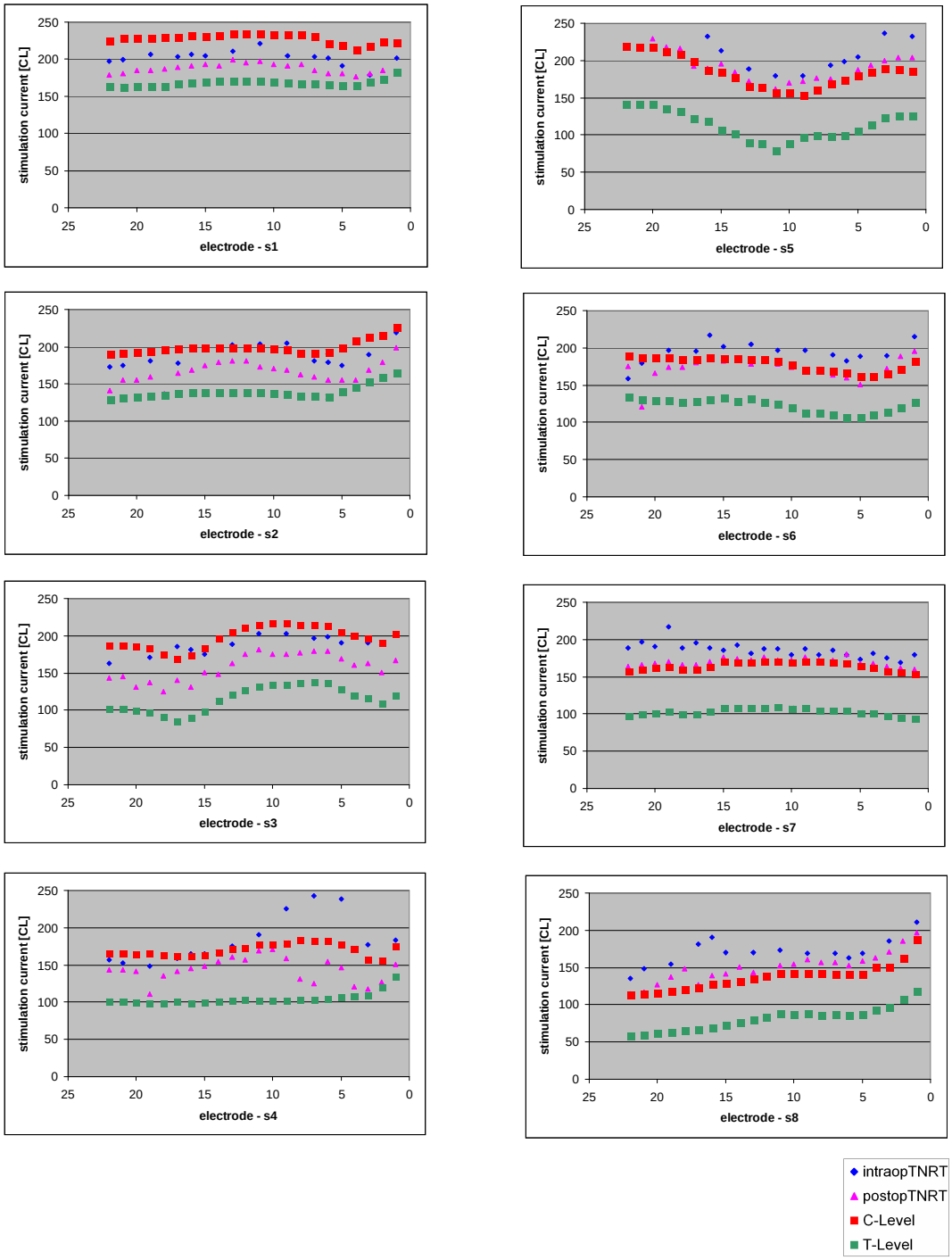

Figure 1. Intraoperative (dark blue) and postoperative (purple) TNRT values as calculated by AutoNRT are shown together with the threshold (T) (green) and comfortable (C) (red) levels for subjects s1 to s8.

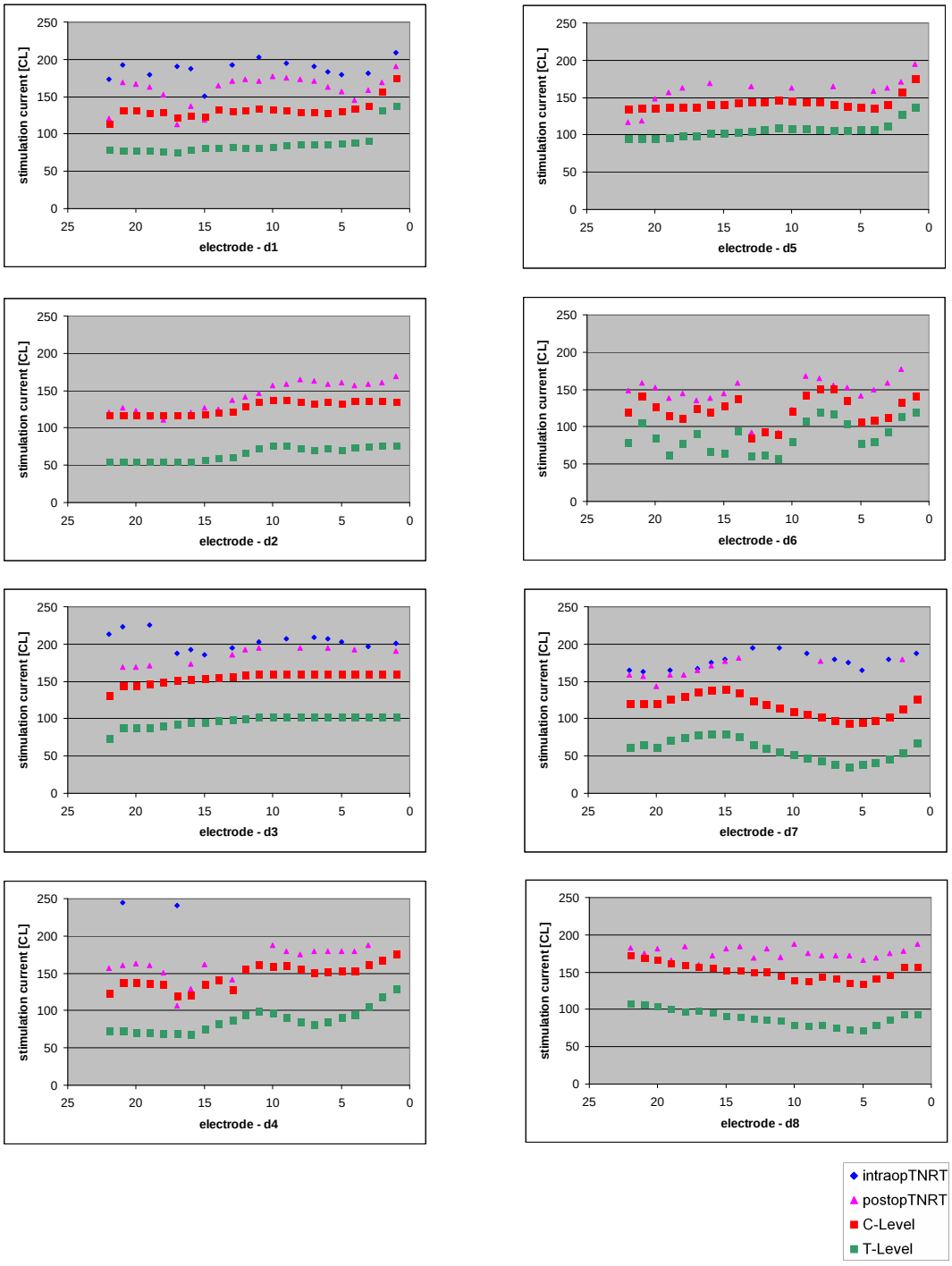

Figure 2. Intraoperative (dark blue) and postoperative (purple) TNRT values as calculated by AutoNRT are shown together with the threshold (T) (green) and comfortable (C) (red) levels for subjects d1 to d8.

	postop. TNRT			intraop. TNRT		
subjects	correlation coefficient versus C level	correlation coefficient versus T level	total amount of TNRT measurements	correlation coefficient versus C level	correlation coefficient versus T level	total amount of TNRT measurements
s1 ... s8	0.59**	0.61**	172	0.54**	0.49**	114
d1 ... d8	0.77**	0.55**	141	0.44**	0.36*	44
all	0.56**	0.55**	313	0.37**	0.36**	158

Table 2. Correlation coefficients of the correlation between intraoperative / postoperative TNRT values and C / T levels of all subjects and each subgroup s and d.

Correlation coefficients of all subjects and each subgroup "s" and "d" are shown in Table 2. All subjects were fitted with a consistent pulse width of 25µs. Out of them 13 subjects had the same stimulation rate (1200pps) and from this homogeneous group mean postoperative TNRT value was 163CL, while mean C level was153CL and mean T level was 96CL.

Discussion

The AutoNRT system met the requirements during clinical routine. In approximately 15 minutes TNRT values were found automatically on each of the 22 electrodes, which provide a basis to fit the speech processor. This is very important in the case of little children who are not able to give sufficient feedback about the loudness of single stimulation tones. It also accounts for adults who cannot judge loudness or feel uncertain in doing so. Measuring the TNRT profile and using it as a basis for fitting led to a very appreciable map.

Sometimes valleys in the TNRT profile are visible which do not match the C level or T level profile (example: subject s4, electrode 19). These valleys may be stable over time, but also could emerge as an interpretation error by the software. Further investigation will address the issue if T-tails could account for this phenomenon.

The big discrepancy between intraoperative and postoperative TNRT values may not only be explained by the differences in stimulation rate. Unconditioned electrodes exhibit usually a higher impedance which leads to an increased amount of voltage needed for the stimulus and subsequently to bigger artefacts. Also the noise level during recording is higher with increased impedance values.

It is astounding that the correlation coefficients of postoperative TNRT values versus C levels are better for the subgroup "d". One would argue that underlying TNRT measurements like in subgroup "s" would lead to better correlations. The fact that the correlation is even worse for the whole study group indicates that there is a great intraindividual variability.

It is also clear that measurements of TNRT values which reflect peripheral mechanisms could not hold for central processes.

Since TNRT values are on average 10CL above C level, one has to take care both when measuring TNRT values postoperatively and generating a map, because of possibly increased loudness perception.

Summary

NRT measurements at the end of the week of initial fitting could be carried out postoperatively in all cases. TNRT values evaluated by an audiologist and by the software showed very good accordance. Postop TNRT values show better correlation with C and T levels than intraop TNRT values. TNRT values measured intraoperatively are on average 25CL higher than those found postoperatively. Postop TNRT values are about 10CL above C levels. In some cases, valleys appear in the TNRT profile which does not match the behavioural profile.

References

Patrick et al. 2006

Patrick JF; Busby PA; Gibson PJ: The Development of the Nucleus® Freedom™ Cochlear Implant System. Trends Amplif 2006;10(4):175-200

Botros et al. 2006

Botros A, van Dijk B, Killian M: AutoNRT™: An automated system that measures ECAP thresholds with the Nucleus® Freedom™ cochlear implant via machine intelligence. Artif Intell Med 2006;40(1):15-28