Electrode Impedance among Children Using the Combi-40+ Medel Cochlear Implant

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ABSTRACT

Objectives: To evaluate electrode impedance changes over time among children using the combi-40+ Medel cochlear implant system.

Method: A retrospective medical record review of electrode impedance values for 24 patients from gender aged between 3 and 8 years and received Combi-40+ Medel cochlear implant was used to gather data for the present study. Electrode impedances were measured at seven time intervals: intra operatively, and post operatively with intervals of one month, 3 months, 9 months, 1 years, 2 years and 3 years.

Results: Significant increase in electrode impedance values from intra operatively to one month and 3 months visit for all electrodes and cochlear segment (apical, medial and basal) was noticed. At, one year visit a decrease in electrode impedance values for the apical and medial cochlear segment was noticed and thereafter a stabilization of values was evident, but for the basal segment an increase in the impedance values was evident and stabilization was noticed after 1 year visit.

Conclusion: Significant changes in electrode impedance values were noticed during the first 3 months of implant use. Given the importance of the impedance role in the transmission of optimal speech perception, impedance measurements are very essential throughout the use of implant before any programming sessions.

Key words: Electorde Impedances, Combi-40+ Medel Cochlear Implant, Pre-linguinal deaf children.

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Introduction

In cochlear implant patients success or failure largely depends on the transfer of stimulating signals from the electrode toward the auditory nerve fibers. An important aspect of the electrode design is electrical impedance which depends on electrode surface area, morphological processes and electromechanical processes initiated by electrical stimulation.[1]

Electrode impedance is a measure of the resistance to current flow through the lead wires, intra - and extra- cochlear electrodes and biologic tissues. It is calculated by dividing the voltage at the electrode by the current flow through the electrode. Measurement of electrode impedance provides an indication of electrode integrity, such as short or open circuits. It also provides an indication of the status of electrode-tissue interface.[2]

The electrode impedances determine how easy the current flow from the cochlear implant into the cochlea is; as the electrode impedances are higher, more current is necessary for a proper stimulation of the cochlea.

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Table I. The means and standard deviations of electrode impedances over time for 24 patients

Time intervals		Electrode											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Intra op	Mean	5.73	5.61	5.86	5.15	5.51	5.89	5.93	5.54	5.41	5.51	5.94	6.67
	SD	1.39	1.16	1.22	0.93	0.91	1.25	1.07	0.99	1.21	2.04	4.02	5.05
1 Month	Mean	7.23	6.97	6.84	6.47	6.75	6.45	6.19	6.51	5.86	7.09	7.57	8.82
	SD	1.02	1.29	0.96	1.22	1.71	1.26	1.15	1.37	1.04	0.95	3.29	4.15
3 Months	Mean	7.25	7.02	6.72	6.22	6.43	6.36	6.22	6.62	5.74	6.93	7.00	9.11
	SD	1.13	1.36	0.98	1.18	1.53	1.27	1.00	1.05	1.26	1.61	3.55	4.55
9 Months	Mean	6.51	6.46	5.86	5.78	5.86	5.58	5.59	5.50	5.63	7.15	7.30	9.95
	SD	0.90	1.40	1.25	1.38	1.43	1.35	1.24	1.25	1.31	1.92	3.54	5.95
1 Year	Mean	5.96	6.19	5.64	5.39	5.92	5.48	5.67	5.33	5.78	7.36	13.62	11.63
	SD	0.90	1.26	1.23	1.22	1.77	1.48	1.37	1.19	2.18	1.97	20.22	5.10
2 Years	Mean	5.79	5.83	5.67	5.32	5.47	5.47	5.33	5.56	5.67	8.12	8.46	11.85
	SD	0.82	1.01	1.17	1.02	1.48	1.26	1.13	1.27	1.93	4.28	3.33	5.11
3 Years	Mean	5.66	5.72	5.57	5.32	5.45	5.42	5.41	5.54	5.72	7.32	8.12	12.00
	SD	0.76	1.06	1.22	1.00	1.51	1.35	1.08	1.31	2.26	1.66	3.54	4.96
Total	Mean	6.30	6.26	6.02	5.66	5.91	5.81	5.76	5.80	5.69	7.07	8.29	10.00
	SD	1.17	1.30	1.22	1.20	1.52	1.33	1.16	1.27	1.61	2.31	8.34	5.16

Alterations in the impedances usually require re-fitting of the implant processor to adapt the programming parameters to the new electrical conditions of the cochlea to achieve optimal perception from the cochlear implant.[3]

Gijs *et al* 2009 assessed the electrode position in cochlear implant patients and evaluated the extent to which the electrode position is determinative in the electrophysiological functioning of the cochlear implant system; they concluded that the electrode modiolus distance is of importance to the stimulation of the auditory nerve fibers.[1]

There have been few reports of electrode impedance changes over time after implantation, these reports were limited to only Nucleus and Clarion types of cochlear implant systems, no reports were reported of electrode changes for the Medel type over a long interval of time. The objective of the present study is to evaluate the electrode impedance changes over time for the Combi-40+ Medel type which has been launched at King Hussein Medical Center since 2004 and 2007.

Method

A retrospective medical record review of electrode impedance values was used to gather data for the present study. Electrode impedance was measured at intervals: intra operatively, and post operatively at intervals of one month, 3 months, 9 months, 1 year, 2 years and 3 years.

Subjects

Twenty-four pre-lingual children, who received the Combi-40+ Medel cochlear implant system at King Hussein Medical Centre between 2004 and 2007, and used the implant for minimal period of 3 years, were included in the study. All patients had full insertion of their electrode array without any surgical complications.

Electrode impedance

Electrode impedance measurements were performed using the diagnostic and programming system diagnostic interface box (DIB). The standard clinical method for recording impedances using the telemetry system for the Medel Combi 40 + was used. In the present study the extra-cochlear and intra-cochlear electrodes were used for the analysis. Stimuli were charged balance bi-phasic current pulses presented at 250 pulses per second at a current level of 100 clinical units. The impedances were measured at the end of the bi-phasic pulse.

Results

Table I shows the means and standard deviations of electrode impedances over different interval of time for the 24 patients.

Table I shows also that there was an increase in the means of electrode impedances between one month and 3 months post operatively compared to the intra operative means for all electrodes. After one year the means of electrode impedances decreased for all

Table II. The means and Standard deviations of Cochlear segments

Cochlear segment	Mean	SD
Apical	24.25	4.38
Medial	23.28	4.23
Basal	31.04	12.33

electrodes and stabilized thereafter for the apical and medial segment except the mean of the basal segment which increased after one year and 3 years.

Data analysis

One-way ANOVA and multiple comparisons analysis of variance for repeated measures with seven levels of time intervals (Intra –operatively, 1month, 3months, 9 months, 1 year, 2years and 3 years post operatively) was performed for electrode impedance changes and cochlear segment (apical, medial, and basal). Alpha error level was $P < 0.05$.

Significant differences in electrode impedance were found among different time intervals; overall there were significant differences in the first 4 electrodes which represent the apical segment of cochlea, and the electrodes from 5 to 9 which represent the medial segment of the cochlea: differences were from the intra operative and at one and 3 months visit. The means of the electrode impedances in the first visit and 3 months visit after implantation were significantly higher than the intra operative. At one year interval there was a decrease in the means of the electrode impedances and thereafter a stabilization of impedances was evident.

For the basal segment of the cochlea represented by electrodes from 9 to 12 electrodes a significant increase in electrode impedance values from intra operative to one month and 3 months visit was evident. Similarly at 1 year post operatively an increase in the impedance values was evident and stabilization thereafter was found.

The results of the present study showed that there were significant differences among the cochlear segments over time with additional differences between the (apical, medial) and basal segments; the impedance values for the basal segments was higher than that for the apical and medial segments; however, no significant differences between apical and medial segments were found as shown in Table II.

Discussion

The results of the present study indicated that electrode impedance changed significantly during the first 3 months after surgery and after one year of insertion stabilization was evident for the apical and medial segment of the cochlea, in contrast stabilization for the basal was evident after 1 year. The increase in the first 3 months of cochlear implant use compared to the intra operative measurements may reflect the anatomical and physiological status of the cochlea. This increase in impedances values may be explained by the presence of intra cochlear fibrous tissue and new bone growth in the cochlea.

After 3 months of cochlear use the impedance decreased and this decrease may be attributed to the notion that stimulation of electrodes results in the formation of a hybrid layer on the surface of the electrode, which creates a rougher, uneven surface resulting in lower electrode impedance.[4]

There were significant differences among the cochlear segments; the mean impedance values for the apical and medial segments were significantly lower than the basal segment and this may be due to the electrode distance.

The results of the present study are in contrast to the results of the study carried out by Saniz *et al*,[3] who reported that the impedances values are high during the first period after implantation, and during the first month there is a fast decrement in the impedances, the impedances reach stabilization after 4 or 5 months.

The results of the present study are in contrast to the results obtained by Aronson *et al* 2002.[5] He performed a longitudinal telemetric measurements in children implanted with the Combi 40+ systems from the first fitting and every three months up to 24 months of using the system. His data indicated an impedance decrease in the first 3 to 4 months after the switch on and then values remained stable.

Henkin *et al* 2005,[6] recorded changes in electrical stimulation levels and electrode impedance values in children using the MED-EL Combi 40+ cochlear implant during the first 12 months of implant use and he found decreased impedances values. Values decreased from initial stimulation to the 3 month time point and was, stable through the study follow up.

The differences between the results of the present study and the results obtained by previous studies may be attributed to the notion that stimulation of electrodes results in the formation of a hybrid layer on the surface of the electrode, which creates a rougher, uneven surface resulting in lower electrode impedance and may be due to the absence of intra cochlear fibrous tissue and new bone growth in the cochlea, and may be due to the inflammatory process which may result in increasing the impedances values.

In comparing these results of impedances changes for the Medel type with reported results of other previous studies carried out for other cochlear implant systems, we have found that there were differences in the impedances values between the Medel type and other cochlear system such as Nucleus and Clarion. For the Nucleus 24 M the impedance values decreased significantly from connection to the 1-month visit, thereafter a stabilization of values was evident.(7) For the Clarion cochlear implant system the impedances value decreased significantly from connection to the 3-month visit , thereafter a stabilization of values was evident.(8) The differences between the electrode impedance changes for the Medel type and other types may be due to the mode of stimulation used and number of electrodes stimulated; for the Medel type the number was 12 electrodes whereas for the Nucleus and Clarion types the number of electrodes was 22, in addition to that the differences may be due to the electrode surface area.(3)

Other factors which may explain the differences among the available cochlear implant devices is the electrode design for example, the number of electrodes and electrode configuration; which may be monopolar or bipolar; the Nucleus devices uses 22 electrodes spaced 0.75 mm apart. Electrodes that are 1.5 mm apart are used as bipolar pairs. The Clarion device provides both monopolar and bipolar configurations. Eight electrodes are used which are spaced 2 mm apart. The Mede-El device uses eight electrodes spaced 2.8 mm apart in monopolar configuration.(9)

The value of electrode impedance varied with time after surgery and these results are consistent with the hypothesis that a layer of fibrous tissue forms around the electrode within the cochlear canal resulting in a slow increase of access resistance, whereas a layer of proteins builds up on the surface of electrode in the early phase after implantation. Electrical stimulation appears to disperse this surface layer, thereby reducing both the polarization impedance and electrode impedance.(10)

The differences among the apical, medial and basal cochlear segments may be due to the distance between the basal electrodes and the auditory nerve fibers; the apical and medial electrodes are very close to the auditory nerve fibers whereas the basal segment is far away therefore, the resistivity of different cochlear structures such as the cochlear wall and the modiolus at several sites along the cochlea may have influences on the variation of electrode impedance values, in addition to that the effect of tissue hydration which changes the tissue sensitivity.(11)

Conclusion

We conclude that the impedance values may change over time and thus must be observed for many reasons such as the inflammatory process, changes in the biological tissues and the formation of new bone growth. In some cases which were excluded from the present study the reason behind increase of impedance was due to the impact on the electrodes due to trauma. Therefore it is very important to measure the electrode impedances, before any programming sessions as long as the cochlear implant is in use because alterations in the impedances usually require refitting of the implant processor to adapt the programming parameters to the new electrical conditions of the cochlea to achieve optimal perception from the cochlear implant.

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