Received: 18 April 2019 | Revised: 4 August 2019 | Accepted: 30 August 2019

DOI: 10.1111/coa.13427

WILEY

ORIGINAL ARTICLE

Feasibility of early activation after cochlear implantation

Chuan-Hung Sun[1,2] | Chan-Jung Chang[1] | Chuan-Jen Hsu[1,2] | Hung-Pin Wu[1,2]

[1]Department of Otolaryngology, Taichung Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, Taichung, Taiwan

[2]School of Medicine, Tzu Chi University, Hualien, Taiwan

Correspondence
Hung-Pin Wu, Department of Otolaryngology, Taichung Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, No.66, Sec. 1, Fongsing Rd., Tanzih Township, Taichung 427, Taiwan.
Email: hungpin_wu@yahoo.com.tw

Abstract

Objectives: The purpose of the study is to investigate feasibility of early activation after cochlear implantation by evaluating long-term impedance change and speech perception.

Design: Case-control study

Setting: Between July 2015 and December 2016, we prospectively enrolled 20 subjects for early activation (within 24 hours after cochlear implantation). On the other hand, from November 2013 to July 2015, 20 age- and sex-matched control subjects from the database of cochlear implantees treated with conventional activation schedule (4 weeks after surgery) were retrospectively enrolled.

Participant: Forty patients who underwent cochlear implantation surgeries.

Main outcome measures: The series impedance and speech perception score of both groups were compared.

Results: No statistical difference in long-term follow-up between the two groups was found using GEEs and multivariate analysis. In the early activation group, impedance reached a steady level by the 2nd postoperative week, and the hearing perception ability significantly improved by the 4th postoperative week.

Conclusion: This comparative study illustrated sequential impedance data during early activation (24 hours) and conventional activation (4 weeks) after CI surgery. There were no major complications in either group, and the safety of early activation with respect to impedance changes, postoperative residual hearing preservation and speech perception scores were non-inferior to that of the conventional group. Therefore, in this study, we established the feasibility of early activation 24 hours after cochlear implantation.

1 | INTRODUCTION

Cochlear implants (CIs) are currently the most promising device to restore hearing in both adults and children affected by severe to profound deafness. After CI surgery, the initial activation and electrode mapping define the next phase of hearing rehabilitation. Audiologists will adjust the current of each electrode according to the patient's maximum comfortable level (MCL) and threshold level (THR).

Impedance provides information about the status of the electrode-tissue interface, including whether the stimulator is operating within its compliance voltage.[1] At present, the switch-on of the external processor is routinely programmed 4 to 6 weeks after surgery.[2,3] However, there is no scientific data that illustrates the best timing for initial activation. The reasons to wait at least 1 month before initial activation may include concerns about the wound-healing process, the possible migration of implant package, the possible damage induced by electrical stimulation and the instability of the array impedance. An increased impedance due to subcutaneous oedema/haematoma following the surgery could hamper the communication between the receiver and electrodes of the CI apparatus. Air bubbles, blood clots and bone dust that possibly went in the cochlea because of the traditional cochleostomy might lead to

worse condition of impedance. Fortunately, current incision wounds of CI surgery have been minimised from 11 ~ 12 cm to 2.2 ~ 2.5 cm, and the traditional cochleostomy approach has been replaced by soft surgery techniques. A soft surgery technique that carefully preserves the endosteum during the drilling process, after which the electrode is advanced into the scala tympani, may cause fewer traumas. The improvements in surgical techniques and CI devices make early activation possible. An increasing number of surgeons shorten the waiting period, but there is still no consensus regarding the best timing for initial activation. Chen et al 2013[4] first observed 54 patients who underwent early activation within 24 hours after cochlear implantation. Impedance was found to be significantly lower when measured within 24 hours postoperatively than when measured intraoperatively (P = .001). No major complications were reported. However, there was no strong evidence to support early activation as a safe or a beneficial procedure.

We hypothesise that the shorter the waiting period before the initial activation, the better the outcomes are for the following reasons. For pre-lingual deafness patients, the age of initiation of hearing influences the possibility of physiological maturation of nerve structures. For post-lingual deafness patients, a longer duration of auditory deprivation has a negative influence on brain plasticity, which that allows for adaptation to the CI.[5] The potential advantages of early activation include a shortened waiting period for CI users and a minimisation of the "mute interval" (without hearing aids or CIs). The aim of this study was to evaluate whether early initial activation promotes safe and improved management by analysing long-term electrode impedance data and hearing perception ability.

Key points

- The aim of the study is to investigate feasibility of early activation after cochlear implantation by evaluating impedance change and speech perception.
- The impedance reached a steady level as early as 2nd postoperative, and the hearing perception ability significantly improved by the 4th postoperative week.
- There were no major complications in either group, and the safety of early activation with respect to impedance changes, postoperative residual hearing preservation and speech perception scores were non-inferior to that of the conventional group.

2 | MATERIALS AND METHODS

2.1 | Ethical consideration

This study was commenced after obtaining ethical approval from the research ethics committee of our facility (REC 105-02). The authors adhered to the guidelines of the Helsinki declaration of the World Medical Association at all times. Written informed consent was obtained from all prospectively enrolled patients (or their parents) with a protocol approved by the Research Ethics Committee of Taichung Tzu Chi Hospital.

2.2 | Experimental design

This study was a case-controlled study. Overall, 40 patients were enrolled from a single tertiary referral centre who underwent cochlear implantation surgeries using devices from MED-EL Co., Innsbruck, Austria. Between July 2015 and December 2016, we prospectively enrolled subjects for early activation (within 24 hours after cochlear implantation). To avoid selection bias, simple sampling was used to recruit cases. All CI candidates were evaluated with inclusion and exclusion criteria. Meanwhile, these patients were interviewed to confirm their willingness to participate in the programme. The recruitment was terminated while the first 20 subjects who satisfied the inclusion criteria were enrolled consecutively. On the other hand, from November 2013 to July 2015, 20 age- and sex-matched control subjects from the database of cochlear implantees treated on the regular activation schedule (4 weeks after cochlear implantation) were retrospectively enrolled.

2.2.1 | The enrolled subjects met the following inclusion criteria

Preoperative pure-tone average (PTA) at 500, 1000 and 2000 Hz being greater than 90 dB or meeting other CI indications; Receiving MED-EL Co. Sonata with Standard® or FLEX soft® electrode (31.5 mm); Full insertion with cochleostomy or round window approach; A type A tympanogram. Indications for cochlear implant in Taiwan also include patients with bilateral hearing loss who have used appropriate binaural hearing aids over 3 months show limited benefit. Limited benefit is defined as lack of progress in the development of simple auditory skills in younger children and measured by the Meaningful Auditory Integration Scale or the Early Speech Perception test. For older children, limited benefit is defined as 0% ~ 12% on the open-set Phonetically Balanced Word Test in the quite environment or ≤30% correct on the open-set Phonetically Balanced Word Test in the noise environment. For adults, limited benefit is defined as the test scores of open-set Phonetically Balanced Word Test is 30% correct or less on the ear to be implanted (60% or less in the best-aided listening condition) on tape-recorded tests of open-set sentence recognition.

The exclusion criteria include the following: Subjects with congenital cochlear malformation; otitis media; previous or present meningitis; otosclerosis; connective tissue diseases; other neurological disorders; recent use of ototoxic medications in 6 months; liver or renal dysfunction.

For all enrolled subjects, a neuro-otological battery of tests, laboratory studies and image studies, including temporal bone computer tomography (CT) and magnetic resonance imaging (MRI), were performed.

TABLE 1 Demographic information for the control and the early activation groups

	Control (n = 20)	Early activation (n = 20)	*P* value
Gender, male:female	11:9	11:9	1.000
Age (y)	10.78 ± 17.59	11.09 ± 16.64	.556
Range (y)	1-65	1-51	
Cochleostomy:round window	7:13	5:15	.490
Electrode, Standard:FLEX soft	7:13	5:15	.490
Lateralisation, left:right	9:11	10:10	.752
EVAS	6	7	.736
Diabetes	1	2	.548
CRP (mg/dL)	0.20 ± 0.20	0.27 ± 0.23	.873
ESR (mm/hr)	3.25 ± 1.80	3.00 ± 2.40	.419

Note: Values are presented as mean ± standard deviation.
Abbreviations: CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; EVAS, enlarged vestibular aqueduct syndrome.

2.3 | Data collection and analysis

Demographic information, including age, sex, laterality, electrode type, current medical status and laboratory data, was obtained preoperatively. Preoperative hearing and postoperative hearing (3 months after the surgery) without CI aided audiogram were collected. PTA was defined as the average threshold at 500, 1000 and 2000 Hz.

The initial activation was performed in the typical manner. The ground impedance of all electrodes was measured before mapping. A short circuit of any electrode was to be marked as device failure. Then, MCL and THR were measured for all electrodes and were determined from the subjective responses to a series of stimuli at different levels. The impedance of all electrodes was measured intraoperatively and at 24 hours, 1 week, 2 weeks, 1 month, 3 months and 6 months after implantation in the early activation group. For the control group receiving the conventional activation protocol, impedance was measured intraoperatively and at 1 month, 3 months and 6 months after implantation. For the nested database, multiple measured impedances were analysed by generalised estimating equations (GEEs), SPSS Ver. 20.0 (IBM Corp), and multivariate analysis was performed to elucidate possible factors affecting the measured impedance. The criterion for statistical significance was $P < .05$.

The residual hearing of the operated ear was measured before and 3 months after surgery. For post-lingual deafness patients, the variables analysed were the pure-tone audiometry thresholds of residual hearing at octave frequencies of 250-8000 Hz; for pre-lingual deafness patients, the variables analysed were the ASSR of residual hearing at octave frequencies of 250-8000 Hz. Residual hearing preservation was defined as the formula established by the HEARRING Network[6]:

$$HP = \{1 - [(PTA_{post} - PTA_{pre})/(PTA_{max} - PTA_{pre})]\} \times 100\%$$

HP: hearing preservation
PTApost: average PTA threshold at 3 months postoperatively
PTApre: average PTA threshold preoperatively
PTAmax: maximal sound intensity generated by a standard audiometer. In our institution, it was set at 110 dB hearing level. Results were categorised into 3 groups, namely: complete (>75%), partial (26%-75%) and minimal (0%-25%) hearing preservation. The difference in the rate of hearing preservation rate was measured with chi-square estimation.

In this study, chronological changes of hearing ability in both groups were also evaluated. All post-lingual deafness patients (n = 24) were enrolled in subgroup analysis. Hearing ability was measured with modified Mandarin speech perception (MSP) originated from Dr Qian-Jie Fu.[7] The Mandarin speech perception sentence materials consist of three lists of 25 sentences each. All sentences met the following criteria: the sentences should all be familiar and widely used in daily life; each of the sentence lists should be phonetically balanced; the targeted number of vowels, consonants and tones within each list was first computed according to the statistical distribution across 3500 commonly used Mandarin Chinese words. The sentence perception score was obtained as follows:

1. Three versions of sentence perception lists are chosen randomly.
2. There are 25 sentences in each list.
3. Each sentence contains 2-7 key words.
4. The total score for version 1 is 102%.
   The total score for version 2 is 104%.
   The total score for version 3 is 102%.
5. A total of 1% is awarded for each correct key word.
6. A monitored live voice (speech balanced at 0 dB on the volume unit) is used without lip reading.
7. An open-set format (no options were given to patients) is applied, and patients must repeat after each sentence is finished.

For the early activation group, the sentence perception score was measured preoperatively and postoperatively at 1 month and 3 months. For the control group receiving the conventional activation protocol, the sentence perception score was measured preoperatively and

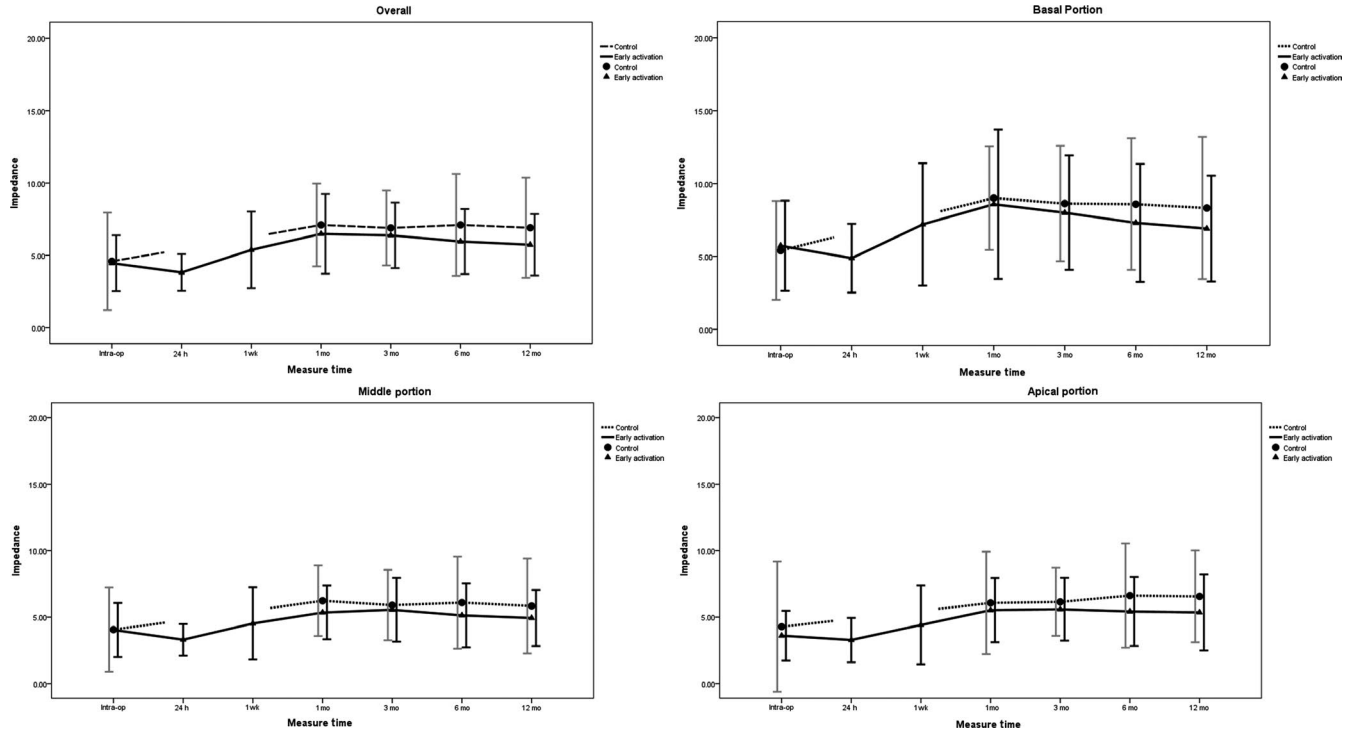

FIGURE 1 Impedance measured in early activation and control groups. Mean impedance of all electrodes, electrodes at basal, middle and apical portion were illustrated. No significant difference was achieved between two groups according to electrode position. The *P* value between two groups according to all electrodes, electrodes at basal, middle and apical portion were .478, .558, .533 and .084, respectively

3 months after implantation. Hearing perception ability was analysed with a paired *t* test.

3 | RESULTS

3.1 | Demographic features of the two groups

Total 29 cases were screened, and 20 subjects were included in the study and received an early activation protocol. Among the 9 cases excluded from the study, two cases refused to participate the study, four cases were cochlear anomalies, and other 3 cases receive cochlear implant other than MED-EL Sonata Standard® or FLEX soft® electrode. Twenty sex- and age-matched subjects were retrospectively enrolled as a control group and received the conventional regular activation protocol. The demographic features, including sex, age, route of electrode insertion, two types of electrodes, lateralisation of implantation, and underlying disease, including diabetes, enlarged vestibular aqueduct syndrome (EVAS), C-reactive protein (CRP) and ESR levels, are shown in Table 1. No significant difference was observed between the two groups on each characteristic. Prevalence of EVAS in sensorineural hearing loss in Taiwan was reported around 15%-40%, where isolated EVAS presented 15%.[8] In our study, a higher proportion of isolated EVAS was found in both groups. This could be due to limited sample size. However, as a pioneer study, it's our liability to reveal our result authentically.

3.2 | Comparison of impedance outcomes in both groups

Differences in multiple measured impedances were analysed with GEEs. The mean impedance of all electrodes measured intraoperatively and was compared at 24 hours, 1 week, 2 weeks, 3 weeks, 1 month, 3 months and 6 months after implantation. No significant difference was revealed between the two groups ($P = .478$). In addition, when the impedance data of different electrodes were subdivided into basal, middle and apical portions, no significant difference was found ($P = .558$, .533 and .084, respectively; Figure 1).

3.3 | Possible factors that affect impedance

Multivariate analysis was performed to evaluate the factors that might affect impedance (Table 2), indicating that only the timing of measurement affects impedance ($P < .001$).

3.4 | Time to achieve stationary impedance in each group

Subgroup analysis according to the timing of measurement was performed to clarify the difference between each measurement time point and to find out the possible best timing for activation. In the early activation group, impedance was higher when measured 2 weeks after implantation than when measured intraoperatively,

TABLE 2 Multivariate analysis for factors affects impedance

	OR	95% CI	*P* value
Group	0.374	−0.560 ~ 1.308	.478
Age	−0.034	−0.084 ~ 0.017	.191
Gender	0.391	−0.307 ~ 1.090	.273
Electrode	1.182	−0.613 ~ 2.977	.197
Lateralisation	0.369	−0.828 ~ 1.566	.546
EVAS	0.290	−0.584 ~ 1.163	.516
Diabetes	1.479	−0.547 ~ 3.505	.152
Route	1.182	−0.613 ~ 2.977	.197
ESR	−0.172	−0.389 ~ 0.044	.118
CRP	2.017	−0.494 ~ 4.529	.115
Timing of measurement	0.204	0.116 ~ 0.292	<.001

Abbreviations: CI, confidence interval; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; EVAS, enlarged vestibular aqueduct syndrome; OR, odds ratio.

24 hours and 1 week after implantation ($P < .05$). The impedance was stable, in other words, there was no significant change from 2 weeks after implantation (Figure 2). Stable impedance was not observed until 1 month after implantation in the control group, which received the conventional activation protocol (Figure 2).

3.5 | Hearing preservation rate in both groups

Total 12 patients (60%) achieved complete preservation in control group, and 15 patients (75%) achieved complete preservation in early activation group. Eight patients (40%) achieved partial preservation in control group, and 5 patients (25%) achieved partial preservation in early activation group. No minimal hearing preservation after cochlear implant was found in either groups. No difference was observed in the rate of complete and partial hearing preservation between the two groups ($P = .324$).

3.6 | Hearing perception outcomes

In subjects with language development, hearing perception ability was further determined via sentence perception scores. In early activation group, 12 post-lingual deafness patients were recruited and 12 post-lingual patients were collected in control group retrospectively. Before implantation, the score was 16.8 ± 13.08 in the control group and 12.8 ± 13.08 in the subjects who received the early activation protocol. No significant difference was found between the two groups ($P = .642$). At 3 months after implantation, the score was 74.0 ± 10.58 in the control group and 80.8 ± 7.69 in the subjects who received the early activation protocol. (Figure 3) Although significant improvement was observed in both groups, no significant difference was found between the two groups ($P = .327$). The range of improvement in hearing perception was similar in the two groups ($P = .172$). In addition, significant improvement could be observed as early as 1 month after implantation in the early activation group ($P = .001$; Figure 4).

4 | DISCUSSION

4.1 | Safety of early activation

In our study, we first examined the safety of early activation. All patients received a standard protocol of wound care and analgesics according to their age and body weight. During the 1-year follow-up period, no patient developed surgical site infection, oedema, seroma or haematoma. Other complications such as receiver-stimulator instability, electrode extrusion or implant migration also did not occur. Three patients in the control group and four younger children in the early activation group had ecchymosis around the surgical site that spontaneously resolved after application of ice packing for a few days. This did not delay the activation schedules of the patients nor necessitate additional doses of pain medications. None of the patients developed meningitis or CNS infection in this study. The

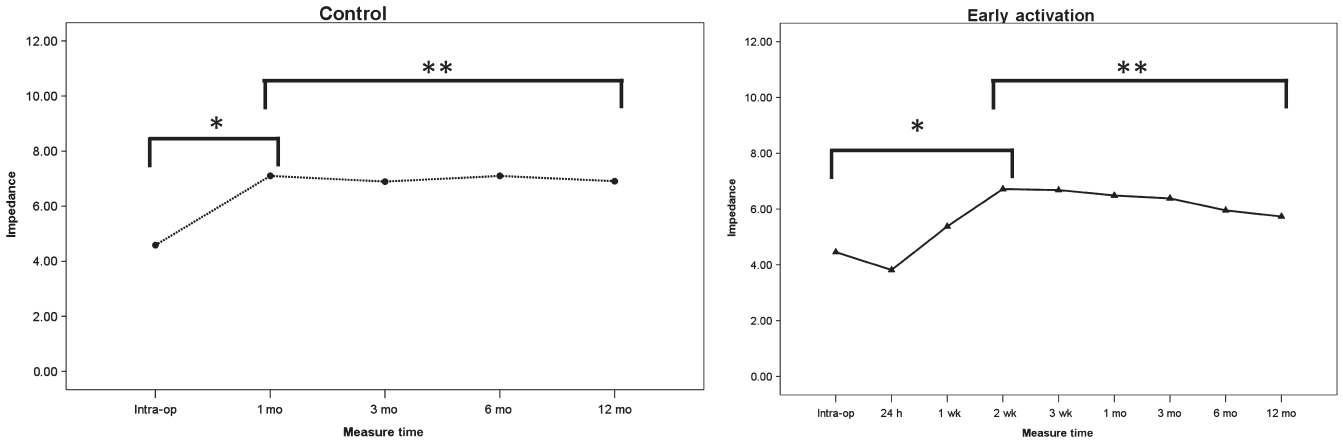

FIGURE 2 Subgroup analysis according to the timing of measurement. In early activation group, impedance was higher when measured 2 wk after implantation than when measured intraoperatively, 24 h and 1 wk after implantation ($P < .05$). The impedance was stable since 2 wk after implantation. Stable impedance was not observed until 1 mo after implantation in the control group, which received the conventional activation protocol. Significant difference was labelled as * while difference did not achieve statistical significance was labelled as **

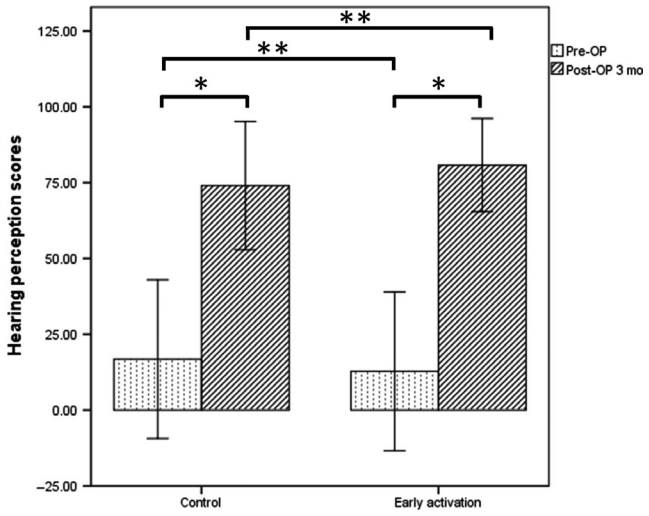

FIGURE 3 Hearing perception ability in subjects with language development determined via sentence perception scores. Before implantation, no significant difference was found between the two groups. Significant improvement was observed in both groups. No significant difference was found between the two groups at three months after implantation. The range of improvement in hearing perception was similar in the two groups. Significant difference was labelled as * while difference did not achieve statistical significance was labelled as **

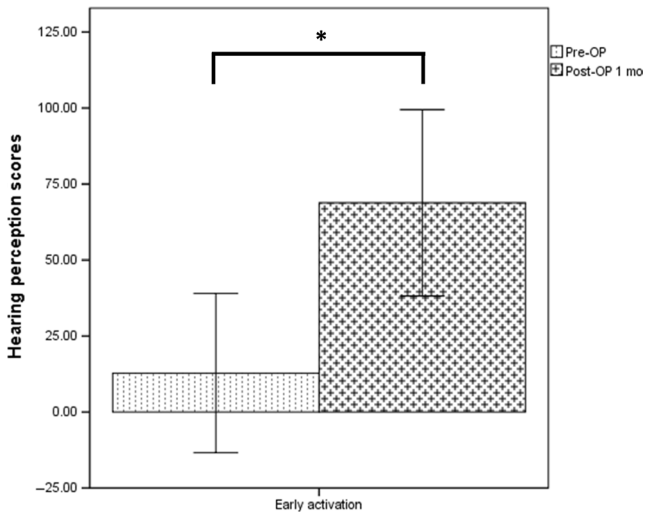

FIGURE 4 Significant improvement could be observed as early as 1 mo after implantation in the early activation group ($P = .001$). Significant difference was labelled as *

impedance, the impedance in all portions of the electrodes, and residual hearing preservation rate in both the early activation and control groups were not significantly different. Marsella et al[9] had a similar conclusion in their study, though the "early activation" was conducted 1 week after CI surgery. In their 9-month follow-up period, they also found that the early switch-on was well tolerated by patients and did not cause complications. The possible reasons to prevent early activation from damaging the microenvironment of the cochlea may be addressed by minimally invasive surgery, thus causing less damage.

4.2 | Oscillations of impedance

We found that the impedance became significantly lower 24 hours postoperatively as opposed to intraoperatively ($P < .001$) in the early activation group. A possible explanation for this "one-day drop" phenomenon in the early activation group was that electrical stimulation causes the rearrangement of the surrounding environment of the electrode array.[10] This phenomenon was thought to be related to the restoration of neuronal sensitivity to electrical stimulation and/or the interaction between the matrix enveloping the electrodes and the electrical stimulation of the initial switch-on. During the operation, tiny air bubbles generated by electrode insertion, specifically because of surface tension between endolymph and electrode-coating material, may have led to higher intraoperative impedance values, which then resolved quickly after implantation.[11] Within several hours after the electrode insertion, a cell cover composed of inflammatory cells, protein adsorption, macrophages and fibroblasts will form around the electrodes, which will lead to increased impedance. When early activation occurs 24 hours after surgery, electrical stimulation causes the formation of a hydride layer, which increases the array surface and triggers cell escape from the surface of the contacts,[12] thereby dramatically decreasing the impedance. In our study, impedance in the early activation group achieved steady level at 2 weeks after cochlear implantation. In the early activation group, the impedance increased gradually after reaching a nadir after activation. This process suggests that at 2 weeks after the surgery, impedance reaches a delicate balance between cell cover formation, a divergence effect with electrical stimulation, and pro- and anti-fibrotic cytokines.[13] Cell cover formation begins within hours after cochlear implantation, while fibrosis starts from 2 to 5 days after wounding, resulting in a gradual rise in impedance. Due to the longer waiting period in the conventional 4-week activation group, impedance may have already reached a steady level before our first postoperative evaluation. Although there was no measurement data during the first month after the implantation in the control group, this result suggested a shorter period to reach stable impedance level than the previous studies.[2,3,9,12] Dose the early electrical stimulation help to stabilise the surround environment of the electrode array is still unknown. Further study including the serial histology changes may provide stronger evidence.

4.3 | Hearing perception ability

Hearing ability was also evaluated to examine the objective benefit of early activation. Only post-lingual deafness implantees (n = 24) were evaluated. In the early activation group, the speech perception score revealed significant improvement 1 month postoperatively. However, the speech perception score 3 months postoperatively was not superior to that of the control group, meaning that early activation may have provided CI recipients with restored hearing

ability a few weeks earlier, but there was no benefit found at long-term follow-up.

4.4 | Limitation

As a pioneer study discussing feasibility of early activation, the case number of this study was limited, especially in subgroup analysis. The subgroup analysis of hearing perception was only conducted on post-lingual deafness patients, and there were only 12 cases in each group. The possibility of type 2 error could not be excluded while comparing between the groups. In addition to safety concern of early activation, patients' quality of life during early activation period, such as wound pain, might also play an important role in this issue. The control group which retrospectively enrolled from database was short of this kind of information. Further randomised prospective study including larger case number and patient's subjective feeling should be conducted.

5 | CONCLUSION

This comparative study illustrated sequential impedance data during early activation (24 hours) and conventional activation (4 weeks) after CI surgery. There were no major complications in either group, and the safety of early activation with respect to impedance changes and postoperative residual hearing preservation was similar to that of the conventional group. In the early activation group, impedance reached a steady level by the 2nd postoperative week, and the hearing perception ability significantly improved by the 4th postoperative week. Therefore, in this study, we established the feasibility of early activation 24 hours after cochlear implantation.

CONFLICT OF INTEREST

There are no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data used to support the findings of this study are available from the corresponding author upon request.

ORCID


Hung-Pin Wu https://orcid.org/0000-0003-3336-6319

REFERENCES

1. Newbold C, Mergen S, Richardson R, et al. Impedance changes in chronically implanted and stimulated cochlear implant electrodes. *Cochlear Implants Int*. 2014;15:191-199.
2. Paasche G, Bockel F, Tasche C, Lesinski-Schiedat A, Lenarz T. Changes of postoperative impedances in cochlear implant patients: the short-term effects of modified electrode surfaces and intracochlear corticosteroids. *Otol Neurotol*. 2006;27:639-647.
3. Henkin Y, Kaplan-Neeman R, Muchnik C, Kronenberg J, Hildesheimer M. Changes over time in electrical stimulation levels and electrode impedance values in children using the nucleus 24M cochlear implant. *Int J Pediatr Otorhinolaryngol*. 2003;67:873-880.
4. Chen JK, Chuang AY, Sprinzl GM, Tung TH, Li LP. Impedance and electrically evoked compound action potential (ECAP) drop within 24 hours after cochlear implantation. *PLoS ONE*. 2013;8:e71929.
5. Lazard DS, Giraud AL, Gnansia D, Meyer B, Sterkers O. Understanding the deafened brain: implications for cochlear implant rehabilitation. *Eur Ann Otorhinolaryngol Head Neck Dis*. 2012;129:98-103.
6. Skarzynski H, van de Heyning P, Agrawal S, et al. Towards a consensus on a hearing preservation classification system. *Acta Otolaryngol Suppl*. 2013;3-13.
7. Fu QJ, Zhu M, Wang X. Development and validation of the Mandarin speech perception test. *J Acoust Soc Am*. 2011;129(6):EL267-EL273.
8. Wu CC, Chen YS, Chen PJ, Hsu CJ. Common clinical features of children with enlarged vestibular aqueduct and mondini dysplasia. *Laryngoscope*. 2005;115:132-137.
9. Marsella P, Scorpecci A, Pacifico C, et al. Safety and functional results of early cochlear implant switch-on in children. *Otol Neurotol*. 2014;35:277-282.
10. van Wermeskerken GK, van Olphen AF, Smoorenburg GF. Intra- and postoperative electrode impedance of the straight and contour arrays of the Nucleus 24 cochlear implant: relation to T and C levels. *Int J Audiol*. 2006;45:537-544.
11. Hu HC, Chen JK, Tsai CM, Chen HY, Tung TH, Li LP. Evolution of impedance field telemetry after one day of activation in cochlear implant recipients. *PLoS ONE*. 2017;12:e0173367.
12. Newbold C, Risi F, Hollow R, Yusof Y, Dowell R. Long-term electrode impedance changes and failure prevalence in cochlear implants. *Int J Audiol*. 2015;54:453-460.
13. Joseph J, Mohanty M, Mohanan PV. Role of immune cells and inflammatory cytokines in regulation of fibrosis around silicone expander implants. *J Mater Sci Mater Med*. 2010;21:1665-1676.

How to cite this article: Sun C-H, Chang C-J, Hsu C-J, Wu H-P. Feasibility of early activation after cochlear implantation. *Clin Otolaryngol*. 2019;00:1–7. https://doi.org/10.1111/coa.13427