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Bimodal stimulation in children with inner ear malformation: One side cochlear implant and contralateral auditory brainstem implant

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Abstract

Objective: To determine audiological outcomes of children who use a cochlear implant (CI) in one ear and an auditory brainstem implant (ABI) in the contralateral ear.

Design: Retrospective case review.

Setting: Tertiary referral hospital.

Participants: Twelve children followed with CI and contralateral auditory brainstem implant (ABI) by Hacettepe University Department of Otorhinolaryngology and Audiology in Turkey. All children were diagnosed with different inner ear malformations with cochlear nerve aplasia/hypoplasia. CI was planned in the ear with better sound detection during behavioural testing with inserted ear phones and with better CN as seen on MRI. Due to the limited auditory and speech progress with the cochlear implant, ABI was performed on the contralateral ear in all subjects.

Main outcome measures: Audiological performance and auditory perception skills of children with cochlear nerve deficiency (CND) who use bimodal electrical stimulation with CI and contralateral ABI.

Results: Mean age of the subjects was 84.00 ± 33.94 months. Age at CI surgery and ABI surgery was 25.00 ± 10.98 months and 41.50 ± 16.14 months, respectively. However, hearing thresholds only with CI and only with ABI did not reveal significant difference, and auditory perception scores improved with bimodal stimulation. The MAIS scores were significantly improved from unilateral CI to bimodal stimulation (P = .002). Pattern perception and word recognition scores were significantly higher with the bimodal condition when compared to CI only and ABI only conditions.

Conclusion: Children with CND showed better performance with CI and contralateral ABI combined. Depending on the audiological and radiological results, bimodal stimulation should be advised for children with CND.

1 | INTRODUCTION

Cochlear implantation (CI) is the most frequent surgical method used with an electronic device for individuals with severe to profound sensorineural hearing loss (SNHL).[1] Approximately 20% of patients with congenital SNHL are diagnosed with radiologically detectable inner ear malformations (IEM).[2] Previously, inner ear malformations were considered a contraindication for CI. After publication of reports showing the benefits of CI in IEM, CI became an accepted procedure in this patient population.[3] However, when the IEM are severe and occur with cochlear nerve (CN) or cochleovestibular nerve (CVN) deficiency or hypoplasia, the clinicians are faced with the dilemma of deciding between CI and an auditory brainstem implantation (ABI).

Paediatric ABI indications were clearly defined in two groups in the first ABI consensus meeting. The first group was definite congenital indications, including complete labyrinthine aplasia (Michel aplasia), cochlear aplasia, CN aplasia and cochlear aperture aplasia. The second group was possible congenital indications, including hypoplastic cochlea with cochlear aperture hypoplasia, common cavity and incomplete partition type I cases with or without CN, the presence of a common CVN and the presence of hypoplastic CN.[4]

Patients with hypoplastic CNs or thin, unbranched CVNs constitute the most controversial group in the CI and ABI decision.[5] Even in patients with confirmed CN hypoplasia or aplasia on magnetic resonance imaging (MRI), some auditory responses could be observed on certain frequencies during audiological evaluation in one or both ears, which is compatible with severe hearing loss.[5,6] Cochlear implant users with hypoplastic CN or CVN have only a limited benefit and lag behind the cochlear implant users with normal CN or CVN.[5,7] Another amplification option for these types of patients is the ABI, which improves environmental sound awareness, speech detection and language skills.[5,8] Thus, for cases with limited benefit from CI, the application of contralateral ABI can be considered.

The first report of CI with a contralateral ABI was presented by Peng et al[9] with nine adult NF-2 patients. The results of paediatric bimodal stimulation with CI and the ABI in four children were reported by Friedman et al in 2018.[10] With this understanding of the benefits of bimodal stimulation, the first child at our clinic was implanted with a contralateral ABI in 2013. To date, 25 paediatric patients with various inner ear malformations have been implanted with a cochlear implant in one ear and an ABI in the other ear in our clinic. In the current paper, we report the audiological findings of 12 paediatric bimodal implant users with both cochlear implants and auditory brainstem implants.

Keypoints

- CN hypoplasia presents a challenge in the decision-making process concerning the choice of CI, ABI, or CI and ABI together.
- Depending on the audiological and radiological results, bilateral stimulation should be advised for children with IEM and CN hypoplasia.
- In cases of hardly visible cochlear nerve, we have observed that children implanted with CI and contralateral ABI showed better performance when compared to either device alone.
- Depending on our clinical experience contralateral ABI should be done within 12-18 months after CI.

2 | MATERIALS AND METHODS

2.1 | Ethical considerations

The study was authorised by the Hacettepe University Non-Interventional Clinical Research Ethics Board (GO 18/437).

2.2 | Participants

Twenty-five children with bilateral prelingual profound SNHL were implanted with a cochlear implant on one side and an ABI on the other side at the Hacettepe University Department of Otorhinolaryngology. Six subjects were implanted with a cochlear implant and an ABI simultaneously. One subject was implanted with an ABI initially and with a cochlear implant at a later date due to a reimbursement issue. The remaining 18 subjects were implanted with a cochlear implant initially and later with an ABI. Six out of the eighteen were excluded, one due to postoperative neurological problems and the remaining five due to their limited experience with ABIs. The remaining 12 children with severe IEM and bilateral profound hearing loss were included in this study. Simultaneous CI and ABI results have been submitted separately as another paper.

All subjects completed medical, audiological, and speech and language assessments, as well as temporal bone imaging preoperatively. The preoperative audiological evaluation was composed of auditory brainstem responses (ABR) and behavioural testing with and without hearing aids. The hearing thresholds were assessed preoperatively using inserted earphones and hearing aids in free field with age-appropriate behavioural methods, such as visual reinforcement audiometry or play audiometry. The CI side was determined according to the results of behavioural responses and the status of the CN on magnetic resonance imaging (MRI). CI was planned in the ear with better sound detection during behavioural testing with inserted ear phones and with better CN as seen on MRI. Clinical features of the subjects are given in Table 1.

All 12 subjects (five male and seven female) were initially implanted with a cochlear implant and then subsequently implanted with an ABI between January 2013 and November 2016 due to their limited progress in auditory perception skills. The preoperative audiological test results were not reported in the current study, and only audiological performance with the CI and the ABI was retrospectively reviewed in this study. The data presented in this study were collected between January 2013 and July 2018.

2.3 | Intraoperative and postoperative audiological measurements

No major intraoperative complications were encountered during both CI and ABI surgeries. Initial activation of the cochlear implant was

TABLE 1 Clinical features of the subjects

Subject	Gender	Age (mo)	CT		MRI		CI		ABI		Duration between CI and ABI	Additional disability
			R	L	R	L	Age at surgery (mo)	Ear	Age at surgery (mo)	Ear		
S1	F	108	CH-III	CH-III	CN aplasia	CN hypoplasia	22	L	47	R	25	No
S2	M	107	CH-I	CH-III	CN aplasia	CN hypoplasia	23	L	40	R	17	ADHD
S3	M	85	CA	CA	CN hypoplasia	CN aplasia	18	R	36	L	18	No
S4	F	105	CH-I	CH-I	CN hypoplasia	CN aplasia	40	R	53	L	28	No
S5	F	89	CAS	CAS	CN aplasia	CN hypoplasia	21	L	41	R	20	No
S6	M	110	CC	CC	Common CVN	Common CVN	37	R	55	L	8	No
S7	F	73	CH-II	Michel	CN hypoplasia	CN aplasia	21	R	33	L	12	No
S8	M	74	CC	CADV	Common CVN	CN aplasia	14	R	30	L	16	No
S9	F	114	IP-I	IP-I	CN Normal	CN hypoplasia	49	R	80	L	31	No
S10	F	47	Normal	CH-II	CN Normal	CN aplasia	17	R	22	L	5	No
S11	F	49	CH-III	CH-III	CN hipoplasia	CN Normal	15	L	21	R	6	Down syndrome
S12	M	60	CAS	CAA	CN hipoplasia	CN aplasia	23	R	40	L	17	No

Abbreviations: ADHD, Attention Deficit/Hyperactivity disorders; CA, cochlear aplasia; CAA, cochlear aperture aplasia; CADV, cochlear aplasia with vestibular dilatation; CAS, cochlear aperture stenosis; CC, common cavity; CH, cochlear hypoplasia; CN, cochlear nerve; CVN, cochleovestibular nerve; F, female; M, male; mo, month; L, left; R, right.

performed 2-4 weeks after CI surgery in all subjects. The programming parameters were selected as default at initial fitting, and the minimum duration levels and pulse width values were increased during the follow-up visits due to hypoplastic CN. After CI, all subjects were followed by the same audiologists. Due to the limited auditory and speech progress with the cochlear implant, ABI was performed on the contralateral ear in all subjects. The limited progress with cochlear implants was evaluated by the experienced auditory implant team during the follow-up visits through auditory performance and improvement in auditory perception skills. The electrical ABR was used intraoperatively during the ABI surgery to evaluate the placement of the ABI electrode. The initial activation of the ABI was executed four weeks after surgery with monitoring of the vital functions. Electrical impedances were measured in every programming session. Programming parameters of the ABI side and auditory/non-auditory sensations were recorded during each session. The follow-up programming visits were planned every two to three months in the first two years and every three months after the second year.

2.4 | Evaluation of the auditory perception skills

Auditory perception tests used during the follow-up period contained the following test battery: Meaningful Auditory Integration Scale (MAIS), pattern perception test, word recognition test, Speech Intelligence Rating (SIR) and Category of Auditory Performance (CAP) scale. The MAIS is a parent-reported questionnaire that assesses the listening skills in children with hearing loss. Each item was rated together with parents and scored from 0 to 4 (0 = never, 1 = rarely, 2 = occasionally, 3 = frequently and 4 = always), with a total score of 0 to 40.[11] The CAP is a rating scale from 0 (no awareness of sound) to 7 (the use of telephone with a familiar speaker) in order to evaluate the hearing outcomes.[12] The SIR measures the speech intelligibility and shows the overall progress in speech over time with a rating of 1 (unintelligible speech with a manual primary mode of communication) to 5 (understandable speech to all listeners).[13] The pattern perception and word recognition tests were applied from the Children's Auditory Perception Skills Test in Turkish (CIAT) test battery.[8] The pattern perception and word recognition tests were applied verbally in three different conditions: ABI only, CI only and bimodal condition. All auditory perception tests were administered by the same experienced audiologist with a live voice during the follow-up visits.

3 | RESULTS

3.1 | Demographics

Mean age of the subjects was 84.00 ± 33.94 months (range 60-108 months). Age at CI surgery was 25 ± 10.98 months (range 14-49 months), and age at ABI surgery was 41.50 ± 16.14 months (range 21-80 months). Mean duration between CI and implantation of the ABI was 16.91 ± 8.32 months (range 5-31 months).

Two of the subjects were reimplanted due to facial nerve stimulation (FNS) (Subject #6) or device failure (Subject #3) in the CI side. One subject (Subject #8) was reimplanted with another implant from a different company at the request of the family due to insufficient performance with the previous implant in the ABI side.

Except for one subject, all subjects used both CI and ABI sound processors regularly. Subject #6 refused to use the CI processor after ABI surgery, complaining of not hearing with CI as well as ABI.

3.2 | Intraoperative testing and audiological performance

Electrical ABR was performed intraoperatively during ABI surgery in all subjects. The eABR results and programming parameters of the subjects are given in Table 2. Programming parameters were selected as default for strategy, rate and pulse width/duration at the initial fitting session of the ABI. For Cochlear™ ABI systems, the initial stimulation was performed in bipolar mode in order to avoid possible non-auditory stimulation. During follow-up, stimulation mode was changed to monopolar mode. The values of the pulse width/duration/amplitude were not given in this paper due to the heterogeneity of the subjects. In case there was any non-auditory stimulation, these values were widened to avoid stimulation of any other cranial nerves.

Hearing thresholds with CI only and ABI only are given in Table 3. Thresholds with CI only were not assessed for Subject #6 due to the subject not using the CI processor and were reported as "not applicable" (NA) in Table 3. Subject #11 was diagnosed with Down syndrome, and since it was not possible to evaluate thresholds with CI and all thresholds with ABI due to her additional disability, this is reported as NA in Table 3.

3.3 | Non-auditory sensations in ABI side

The mean number of active electrodes was found 67.62 ± 17.49% (between 33.33% and 93.33%). The three causes of electrode deactivation were defined as non-auditory sensations, inadequate auditory stimulation and impedance/voltage problems. Non-auditory sensations were not observed in 1 (Subject #8) out of 12 children. The observed non-auditory sensations were FNS (58.3%), balance problems (8.3%), gag reflex (8.3%), and shoulder (25%) or neck pain (8.3%) in the remaining subjects. In 2 out of 12 children, more than 1 non-auditory sensation was observed, and the electrode was deactivated.

3.4 | Auditory perception skills before and after ABI

The MAIS scores were significantly improved from unilateral CI to bimodal stimulation ($P = .002$). Although all patients improved to ≤3 in CAP scores after CI, their CAP scores increased to ≥4

TABLE 2 Programming parameters and intraoperative eABR responses during ABI surgery in all subjects

	CI				ABI				
Subject	Company	Type of implant	Type of SP	NoAE	Company	Type of implant	Type of SP	NoAE	Intraoperative eABR
S1	Cochlear	CI512	CP910	20/22	Cochlear	ABI24M	CP910	14/22	+; single peak
S2	Cochlear	CI512	CP910	22/22	Cochlear	ABI24M	CP910	15/22	+; single peak
S3	Medel	Sonata	Opus 2	10/12	Oticon	Digisonic SP	Saphyr SP	13/15	NR
S4	Medel	Sonata	Opus 2	8/12	Oticon	Digisonic SP	Saphyr SP	8/15	NR
S5	Cochlear	CI24RE	CP810	18/22	Oticon	Digisonic SP	Saphyr SP	12/15	NR
S6	Medel	Pulsar	Opus 2	12/12	Medel	Concerto	Opus 2	8/12	+; single peak
S7	Medel	Sonata	Opus 2	8/12	Oticon	Digisonic SP	Saphyr SP	10/15	+; single peak
S8	Cochlear	CI422	CP910	19/22	Cochlear	ABI541	CP1000	17/22	+; single peak
S9	Medel	Sonata	Opus 2	12/12	Oticon	Digisonic SP	Saphyr SP	5/15	NR
S10	Oticon	Digisonic SP EVO	Saphyr SP	15/15	Oticon	Digisonic SP	Saphyr SP	7/15	NR
S11	Oticon	Digisonic SP	Saphyr SP	10/15	Oticon	Digisonic SP	Saphyr SP	10/15	NR
S12	Oticon	Digisonic SP	Saphyr SP	15/15	Oticon	Digisonic SP	Saphyr SP	14/15	NR

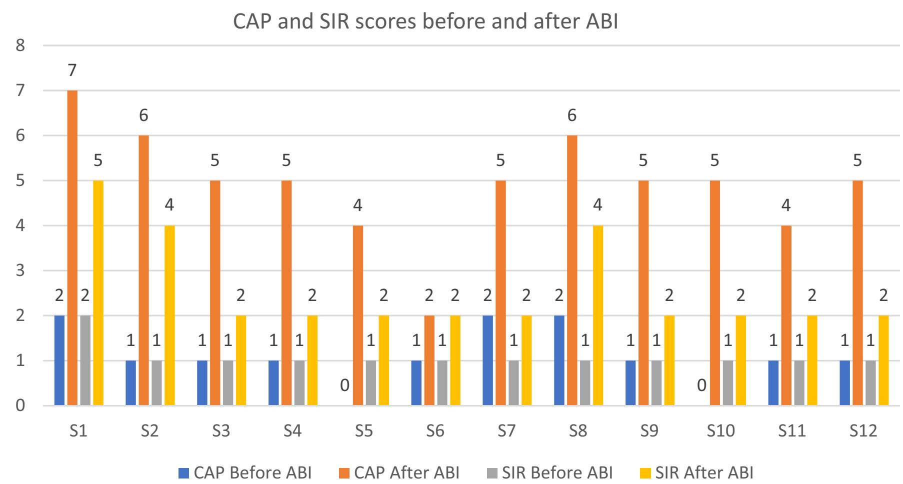
Abbreviations: ABI: auditory brainstem implant; CI: cochlear implant; eABR: electrically ABR; NoAE: number of active electrodes; NR: no response; SP: sound processor.

TABLE 3 Hearing thresholds with CI and with ABI

Test frequency	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Thresholds with CI												
500 Hz	30	50	40	40	50	NA	45	50	30	35	NA	40
1000 Hz	25	55	40	40	50	NA	45	60	30	35	NA	40
2000 Hz	25	55	35	45	60	NA	40	60	35	35	NA	50
4000 Hz	30	65	45	50	60	NA	40	55	40	40	NA	40
SAT	25	50	40	35	50	NA	40	35	35	35	NA	40
Thresholds with ABI												
500 Hz	40	35	30	40	55	35	35	50	30	45	NA	50
1000 Hz	35	30	40	35	55	35	35	55	30	50	60	55
2000 Hz	35	40	30	40	50	45	35	55	35	50	70	55
4000 Hz	40	40	40	50	50	45	45	50	40	50	NA	50
SAT	30	35	30	40	50	20	40	40	30	50	60	50

Abbreviations: ABI, auditory brainstem implant; CI, cochlear implant; NA, not available; SAT, speech awareness threshold.

FIGURE 1 Category of Auditory Performance and Speech Intelligibility Rating scores before and after ABI



after ABI (Figure 1). There was a statistical improvement in CAP scores with bimodal stimulation ($P = .002$). The speech intelligibility of all subjects advanced rapidly with the use of both CI and ABI ($P = .001$).

Pattern perception and word recognition scores were significantly higher with the bimodal condition when compared to CI only and ABI only conditions. Pattern perception scores with CI only, with ABI only and with bimodal conditions were 62.25 ± 39.21, 57.83 ± 39.59 and 84.91 ± 24.83, respectively. Word recognition scores with CI only, with ABI only and with bimodal conditions were 33.00 ± 14.14, 25.25 ± 18.38 and 53.16 ± 38.18, respectively. As seen in Table 4, pattern perception scores increased in the bimodal condition, even when the scores were significantly lower in both CI only ($P = .017$) and ABI only ($P = .018$) conditions. Word recognition scores were also significantly higher in the bimodal condition when compared to CI only ($P = .012$) and ABI only ($P = .008$) conditions. Despite pattern perception scores not being significantly different ($P = .680$), the word recognition scores were significantly higher ($P = .027$) in the CI only condition than in the ABI only condition.

3.5 | Factors influencing auditory performance with ABI

It was found that hearing performance with ABI was negatively correlated with chronological age ($P = .032$; $r = -.618$) and the age at ABI ($P = .039$; $r = -.601$). There was a positive correlation between hearing performance with ABI and bimodal pattern perception scores ($P = .056$; $r = -.564$). The postoperative MAIS scores were positively correlated with pattern perception and word recognition scores in all three conditions.

4 | DISCUSSION

Cochlear hypoplasia with hypoplastic cochlear aperture, the presence of an unbranched CVN and hypoplastic CN constitute a dilemma for decision-making for CI and ABI selection.[4,5] Previous studies report poor outcomes for IEMs with CN deficiency with CI.[6,14-16] Despite the limited progress with CI in patients with hypoplastic CN, this was not considered as a contraindication for CI.[17]

TABLE 4 Auditory Perception Scores only with CI, only with ABI and bimodal conditions; MAIS scores before and after ABI; communication modes and educational placements after ABI

	Pattern perception scores			Word recognition scores			MAIS			
Subject	Only with CI (%)	Only with ABI (%)	Bimodal (%)	Only with CI (%)	Only with ABI (%)	Bimodal (%)	Before ABI	After ABI	Communication modes	Educational placements
S1	100	100	100	50	50	92	24	38	Oral and LR	Mainstream School
S2	100	100	100	52	52	88	20	35	Oral and LR	Mainstream School
S3	42	42	100	33	33	75	25	31	Oral and LR	Mainstream School
S4	58	0	83	40	0	75	15	31	Total	School for deaf
S5	0	25	42	0	0	0	12	35	Total	Mainstream School
S6	0	25	58	0	0	0	14	21	Total	Mainstream School
S7	42	42	100	62	42	75	25	35	Total	Mainstream Preschool
S8	100	100	100	56	45	72	24	38	Total	Mainstream Preschool
S9	75	50	100	33	25	75	22	38	Oral and LR	Mainstream School
S10	100	100	100	40	32	48	15	35	Total	Mainstream Preschool
S11	30	10	36	0	0	0	16	20	Total	Mainstream Preschool
S12	100	100	100	30	24	38	20	38	Total	Mainstream Preschool

Abbreviations: ABI, auditory brainstem implant; CI, cochlear implant; LR, lip reading; Total, Oral, LR and sign language.

On the other hand, ABI provides users with sound identification and development of open-set speech discrimination in patients with CN deficiency.[4] In accordance with the literature, 12 CI only users in our series showed some progress with CI, but after a while, they reached a plateau. This finding may be related to the fact that stimulation of CN fibres that cannot be revealed clearly on the MRI may have provided input to the auditory brainstem, but this input was not adequate for appropriate stimulation at higher levels of the auditory pathway. As a solution for this suboptimal progress of CI users with CN deficiency, contralateral ABI was considered as another option during the follow-up.

During the preoperative evaluation for decision-making between CI and ABI, we evaluated the audiological and radiological results together. In the preoperative audiological evaluation, it is important to perform subjective behavioural tests with inserted earphones. The behavioural tests provide us with the chance to see the auditory responses that we cannot get in objective tests such as ABR. The response of both ears can be assessed separately while using the inserted earphones, and it is then possible to determine which ear is better during the audiological evaluation. CI should be recommended for that better ear with the presence of a response during behavioural testing and the presence of a hypoplastic CN or CVN on MRI. ABI can be recommended for the worse ear when we cannot get any response in audiological tests and cannot see any CN or CVN on imaging.

Another remedy for these patients may be the bilateral application of CI. In fact, it was reported that bilateral CI provides more benefit for users with CN hypoplasia compared to unilateral CI in CVN deficiency.[18] Considering the limited benefit of CI alone for these patients, ABI could provide better outcomes. An option in this case may be the removal of the CI electrode and ABI application to the same side. Colletti et al (2013) presented outcomes of 21 children diagnosed with possible CN aplasia/hypoplasia and CAP scores of less than 2 who had a CI in another centre. Due to their suboptimal progress, ABI was planned on the same side with CI. During surgery, they observed that none of the children had a CN. After ABI, CAP scores of the users were reported to be significantly better. This procedure described by Colletti et al,[7] although successful, still provides unilateral stimulation. In our opinion, bilateral stimulation of the auditory pathways is the most important factor in a paediatric population with possible ABI indications. Therefore, in case of a confirmed hypoplastic CN or CVN on radiological imaging, keeping the CI in place and applying ABI to the other ear would be a better approach. In fact, patients reported in our work showed improvement in language and auditory perception skills after ABI surgery. For the greatest benefit, bimodal stimulation should be provided as soon as possible due to the brain plasticity. In our case series, the mean duration between CI and ABI surgeries was found as 16 months. Depending on our clinical experience, contralateral ABI should be done within 12-18 months after CI.

In fact, the importance of bilateral stimulation for paediatric patients with various inner ear malformations has been mentioned in the second consensus meeting of ABI in complex inner ear malformations.[19] Improvement in language skills after the application of ABI for CI users with inner ear malformations may be related to adequate stimulation of areas in higher auditory pathways, which were not optimally stimulated during CI usage. This improvement could be increased in time with regular use and result in more favourable outcomes for users. It was also mentioned in the second consensus meeting that hearing thresholds with ABI were between 30 and 60 dB in most patients with ABI.[19] In our case series, the hearing thresholds with ABI were found to be similar to the ABI consensus paper. In our paper presenting the long-term results of the ABI, it was found that better thresholds were associated with better CAP scores.[20] Similar to the children with unilateral ABI, better hearing performance with ABI resulted in higher bimodal pattern perception scores for children with CI and contralateral ABI. Another positive prognostic factor affecting the auditory performance with ABI was defined as chronological age and age at ABI surgery in the present study. Age at ABI activation was also found to be one of the most important prognostic factors in the same paper.[19]

In the study of Peng et al,[9] despite deteriorated auditory performance with CI within time, ABI was indicated as the primary method of hearing in nine NF-2 patients with CI and contralateral ABI. Similar to our study, Friedmann et al reported performance with ABI and contralateral CI in four paediatric patients and found that three out of four patients had better auditory perception performance in the bimodal condition. They concluded that bimodal stimulation contributes to the auditory performance of children with CN deficiency.[10]

The CI and contralateral ABI can be used together safely and synergistically. After ABI surgery, a relatively rare side effect was observed for Subject #2. Three days after the ABI surgery, when the patient activated his CI device for the first time since the ABI surgery, he had an excessive FNS on the CI side. This was remedied by decreasing the C-levels globally on the CI side. Later, after initial activation of the ABI, the same FNS was observed both with individual electrode stimulation and with live voice through CI. In order to remove this FNS on the CI side, the pulse width of the stimulation was increased from 50 to 88, and C-levels were decreased according to his responses. A possible reason for this problem may be the increased impedance values on the CI electrode after ABI surgery.

4.1 | Study limitations

Even though the present study is the first and therefore the largest study of children with IEM using CI and contralateral ABI, the study sample is still too small to conclusively show the effect of the bimodal stimulation with CI and ABI. The present study is also limited by the heterogeneity of the study population and reported test results. Only the auditory performance data from before ABI and the last follow-up visit were included in this study. In future studies, long-term results in large cohorts can be presented during the follow-up visits.

5 | CONCLUSION

CN hypoplasia presents a challenge in the decision-making process concerning the choice of CI, ABI, or CI and ABI together. In case of visible cochlear nerve with behavioural responses, CI should be tried first. In cases of hardly visible cochlear nerve, we have observed that children implanted with CI and contralateral ABI showed better performance when compared to either device alone. In some cases, contralateral procedure can be decided according to CI performance. If there is a definite indication on one side, both CI and ABI surgeries can be done simultaneously. Depending on the audiological and radiological results, bilateral stimulation should be advised for children with IEM and CN hypoplasia.

CONFLICT OF INTEREST

All authors declare that they have no conflict of interest.

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