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Speech perception outcomes after cochlear implantation in prelingually deaf infants: The Western Sicily experience

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ABSTRACT

Objectives: To describe audiometric characteristics and speech perception performances of prelingually deaf Sicilian children after cochlear implantation; to identify the influence of cochlear implant (CI) user and family's characteristics on speech recognition and intelligibility outcomes.

Methods: Twenty-eight infants with a congenital or acquired hearing impairment and implanted before the 3rd year of life were studied; all children suffered from bilateral sensorineural hearing loss (SNHL) with evidence of lack of hearing aids benefit and no evidence of intellectual disability. The study of the main characteristics associated with CI user and family's profile was performed with a clinical assessment including pre-implant and post-implant (1, 3, 6, 12 and 18 months) behavioural audiometry (evaluating average threshold for the frequencies 0.5, 1, 2 and 4 KHz) and speech recognition tests (IT-MAIS, MUSS, CAP and SIR).

Results: Our cohort was characterized by an early diagnosis of SNHL (5.77 and 12.17 months for congenital and acquired HL respectively), a short length of deafness (average = 6.78 months) and an implantation before the 3rd year of life (mean = 24.25 months; range from 10 to 36). Analysis of audiometric threshold revealed a significantly improved capacity to detect sounds within the conversational speech spectrum after 12 months from implantation ($r = 0.99$; $p < 0.001$). The main speech recognition test evidenced speech perception and speech intelligibility performances (CAP median value of 3; SIR category = 3 in 46.42%) equal to those children with same characteristics reported by literature. With the exception of 'daily CI use' ($p < 0.001$), none of the variables associated with CI user and family's profile resulted significant predictor of speech perception improvement.

Conclusions: This work demonstrates that all children of our cohort, with an early diagnosis of SNHL and a CI surgery performed before the 3rd year of life, presented a progressive audiometric and speech improvement through the first 12–18 months after cochlear implantation. The study also highlights that, differently from the others variables studied, a continuous CI use influences significantly speech perception and recognition outcomes.

1. Introduction

World literature have demonstrated improved auditory speech recognition and speech production ability in prelingual profound sensorineural hearing loss (SNHL) children after cochlear implantation [1–8]. The amount of benefit in speech recognition, however, varies among children and appears to depend on several factors. These factors include demographic and hearing characteristics of the child, as well as features of the implant device [3,4,7] In particular most studies have primarily investigated the characteristics of the cochlear implant (CI) user, the role of age of implantation, amount of residual hearing, mode of communication in education, family support and the educational setting [9–13]. Of the features related to the device, the majority of the research focused on the implant and on the effects of speech coding strategy within the implanted device and on the daily CI use. Geers et al. suggested that children with the highest non-verbal intelligence, newest technology, oral communication, and situated in ordinary educational settings had the best speech recognition skills [9]. Connor et al. found that the effect of total communication versus the effect of oral communication on speech recognition was minimal [10]. So it is possible that new technology, early

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implantation, and simultaneous activation of all electrodes play a major role than mode of communication.

Moreover some studies find that characteristics of the CI user account for a large part of the variability, and age at implantation seems to be together with daily CI use the most important factors [1–8,11–16].

All works cited above have explored speech performances of English, French, Belgian and Dutch children with CI; in Italy and specifically in Sicily, similar investigations were rarely performed with a consequent lack of knowledge and poorer data regarding our region.

From previous reports SNHL incidence in Western Sicily resulted 2.95/1000 on well babies, increasing 50-fold on infants at risk [17–19]; considering the high percentage of profound HL (44.68%) discovered, mainly related to genetic causes, it is clear that many children are potential candidates to CI [17–20]. Because of the expectations (in terms of intelligibility and speech development) of the families who choose to submit their child to CI surgery, there is a compelling need to investigate the main audiometric and speech outcomes in a defined group of SNHL infants after cochlear implantation. Results from this study, useful to reply to critics and counsel parents, could be generalized to other children who need of CI and used to monitor the development of speech perception and intelligibility as well as to establish appropriate parental expectations.

The aim of this work was to analyze audiometric characteristics and speech perception performances of the CI users over a 12–18 months follow-up period; studying family and CI user's profile, to identify the main predictors of speech intelligibility and recognition improvement.

2. Materials and methods

2.1. CI users and families' profile

This study was carried out by the Department of Audiology, University of Palermo, and investigated 28 children who were congenitally deaf or deafened before the age of 2 years and implanted before the 3rd year of life. Additionally, all infants studied had a bilateral SNHL with evidence of lack of hearing aids benefit and no evidence of intellectual disability.

Following ethical Committee approval, the study protocol was fully explained to parents, and written consent was obtained for each child.

The diagnosis of SNHL was performed by experienced audiologist and otorhinolaryngologist and consisted of ABR (AMPLAID mk22 auditory evoked potentials system); click stimuli were presented starting at a level of 100 dB HL. With step sizes of 10 dB the level was decreased until no response was found. The response threshold was estimated by the lowest level at which a response was found. TEOAE (Otodynamics ILO 288 USB II system with standard setting) and tympanometry (Interacoustics AT 235H system) measurement were used to confirm the diagnosis. The morphologies of middle and inner ear were evaluated with high resolution computer tomography (HRCT) and all showed no pathological CT findings.

Each child was also assessed by a neuro-paediatrician to exclude the presence of any additional confounding non-auditory handicaps which would affect their performance on any of the test measures.

The CI user and family's characteristics investigated were the following: age and gender of the infant, number of family's members (3 or less; 4–5; 6 or more), educational status of the parents (primary; high school; university), economic status (low; medium; high), mother's work status (housewife; working), kind of support service (public or private speech therapy) and the expectations of the family (F.E.1 – Implant will not provide normal hearing; child will probably function like a child with a severe hearing loss; the process will take time. F.E.2 – Implant will allow child to function as a child with a moderate hearing loss and reduce the need for educational support services. F.E.3 – Implant will provide normal hearing). Deafness onset time (congenital/acquired), age of hearing loss first diagnosis, length of deafness, ABR threshold V wave, use of hearing aids (NO; YES bilateral; YES unilateral) and age at implant were also studied. Finally specific data about the CI device (length of CI use, implant type, speech coding strategy, stimulation rate, number of channel and number of active electrodes) were collected.

2.2. Audiometric test

Audiometric test was performed routinely in free field using standard age-appropriate paediatric test battery; even if the practice of the our centre was to provide children the option of using bimodal stimulation (cochlear implant and hearing aid), all postoperative audiometric measures were not performed in the bimodal condition; therefore all results extracted for this study were obtained in a unilateral cochlear implant mode. The audiometric threshold of the ear implanted was evaluated calculating the pure-tones average for the frequencies 500, 1000, 2000 and 4000 Hz.

2.3. Questionnaires

The clinical assessment protocol for the CI users included pre-implant and post-implant (1, 3, 6, 12 and 18 months) speech recognition testing to determine candidacy and to establish baseline functioning. A composite questionnaire was constructed and included questions from the meaningful auditory integration scale (MAIS), meaningful use of speech scale (MUSS), categories of auditory performance (CAP), and speech intelligibility rating (SIR) [21–24].

The IT-MAIS (Infant Toddler-MAIS) questionnaire includes 10 questions posed to the parents in an interview schedule regarding their child's spontaneous listening behaviours in everyday situations. The questions reflect three different areas of auditory skills development: changes in vocalization associated with device use, alertness to sounds in everyday environments and derivation of meaning from sound. The MUSS assesses the child's ability to use speech and language meaningfully. It also consists of 10 questions related to the development of the child's speech and language, including an evaluation of the vocalization efforts, communicative interactions and the use of oral language. Scores for each question range from 0 (''never demonstrates the behaviour'') to 4 (''always demonstrates the behaviour''). The maximum score for IT-MAIS and MUSS is 40.

CAP comprises a non-linear and hierarchical scale of auditory receptive abilities, the lowest level describing no awareness of environmental sounds, with the highest level being represented by the ability to use a telephone with a known speaker. CAP is not a closed-set laboratory type test but a measure of everyday auditory performance and thus reflects the ''real life'' progress of children in the developing use of audition. Furthermore, the inter-observer reliability of this scale has been formally confirmed [25].

The speech intelligibility rating (SIR), developed in 1989, was used as a framework to rank the child's spontaneous speech into one of five hierarchic categories [23,24]. SIR is not a performance test and like MAIS and MUSS designed as a time-effective global outcome measure of speech production in real-life situations.

2.4. Statistical analysis

Statistical analysis was performed with Matlab® computer program; χ^2 test, Fisher's Exact Test, linear regression (r value) and

Table 1
Patients' profile and CI characteristics.

Gender	*n* (%)	Pre-implant use of hearing aids	
Male	18/28 (64.28%)	Yes	17/28 (57.15%)
Female	10/28 (35.72%)	No	11/28 (42.85%)
Deafness onset	*n* (%)	Age at implantation	(Months)
Congenital	22/28 (78.57%)	Mean ± S.D.	24.25 m ± 8.28
Acquired	6/28 (21.43%)	Range	10 m–36 m
		Median	24.5 m
Age at diagnosis	(Months)	Time between diagnosis and CI surgery	(Months)
Mean ± S.D.	7.14 m ± 4.46	Mean ± S.D.	17.10 m ± 7.77
Congenital	5.77 m ± 3.32	Range	3 m–31 m
Acquired	12.17 m ± 4.75	Median	18 m
Range	2 m–18 m	Use of CI	
Median	6 m	Daily	24/28 (85.71%)
Congenital	5.5 m	Discontinuous	4/28 (14.29%)
Acquired	10.5 m	Bimodal stimulation	
Length of deafness	(Months)	Yes	5/28 (17.86%)
Mean ± S.D.	6.78 m ± 4.20	No	23/28 (82.14%)
Congenital	5.77 m ± 3.32	Length of CI use	(Months)
Acquired	10.5 m ± 5.28	Mean ± S.D.	20.14 m ± 10.28
Range	2 m–17 m	Range	12 m–51 m
Median	6 m	Median	16 m
Congenital	5.5 m		
Acquired	8.5 m		
ABR threshold	(dB HL)		
Mean	>100		
Min–max	90–>100		
Median	100		

ANOVA test were used, following usual conditions of application. Significance was set at 0.05.

3. Result

3.1. CI users' profile

Twenty-two children suffered from congenital hearing loss and six lost their hearing before the 16th week of life (deafness' onset mean value = 6.66 weeks ± 4.84) (Table 1). All children, 18 males and 10 females (male: female ratio = 1.8) presented bilateral hearing loss with an hearing threshold mean value > 100 dB HL. The age at first diagnosis of hearing impairment ranged from 2 to 18 months with a mean of 7.14 months ± 4.46 (5.77 months ± 3.32 for congenital HL and 12.17 months ± 4.75 for acquired HL) while the length of deafness ranged from 2 to 17 months (mean value of 6.78 ± 4.20 months). All children were enrolled in an intensive auditory-verbal therapy programme for the deaf; in particular 15 cases (53.57%) benefited of private speech therapy while the others (46.43%) of the public one. In 11 cases (42.85%), hearing aids use was discontinuous while in 57.15% it resulted daily and continuous. In the 75% of subjects (9/12) who have benefited of public speech therapy, the hearing aids use was discontinuous, while the 75% of infants, who underwent private speech therapy, used hearing aids daily (p = 0.009).

The mean age of cochlear implantation was 24.25 months ± 8.28 (min = 10; max = 36), with a mean interval between the diagnosis of HL and the age of implantation of 17.10 months ± 7.77 (min = 3; max = 31); moreover the pre-implant hearing aid experience ranged from 3 months to 2.7 years with a mean value of 8.33 months ± 4.68 and 19.5 months ± 6.67 for congenital and acquired HL infants respectively.

3.2. Families' profile

As showed in Table 2, the economic status resulted of low type in 21.44%, medium in 39.28% and high in 39.28%; the correlation between economic status and F.E. score (100% of the families with low economic status had a F.E.1 score and the 54.55% of the families with high economic status had a F.E.3 score) evidenced a significant statistical difference among the groups (χ^2 = 21.7, f.d. = 4, $p < 0.0001$). However, no relationship between economic status and speech perception performance was found (p = 0.12).

The study of educational status evidenced primary school in 28.58%, high school in 28.58% and University degree in 42.84%; an expectation of type 3 (F.E.3) was observed in the 0%, 25% and 50% of the families with a low, medium and high educational status respectively (χ^2 = 12.3, f.d. = 4, p = 0.015); furthermore, educational status did not result an important predictor of good speech improvement (p = 0.2).

Table 2
Study of families' profile and correlation with expectations and speech performance scores.

Family profile	*n* (%)	Expectations	Speech performances*
Economic status			
Low	6/28 (21.44%)	$p < 0.0001$	ns
Medium	11/28 (39.28%)		
High	11/28 (39.28%)		
No of members			
3 or less	12/28 (42.86%)	$p = 0.5$	ns
4–5	14/28 (50%)		
6 or more	2/28 (7.14%)		
Mother's work status			
Housewife	14/28 (50%)	$p = 0.007$	ns
Working	14/28 (50%)		
Education			
Primary school	8/28 (28.58%)	$p = 0.01$	ns
High school	8/28 (28.58%)		
University	12/28 (42.84%)		
Support service			
Public speech therapy	13/28 (46.43%)	$p = 0.008$	ns
Private speech therapy	15/28 (53.57%)		
Expectations			
F.E.1	9/28 (32.14%)	–	ns
F.E.2	11/28 (39.28%)		
F.E.3	8/28 (28.58%)		

* Statistical analysis for $p < 0.05$ relative to IT-MAIS, MUSS, CAP and SIR scores.

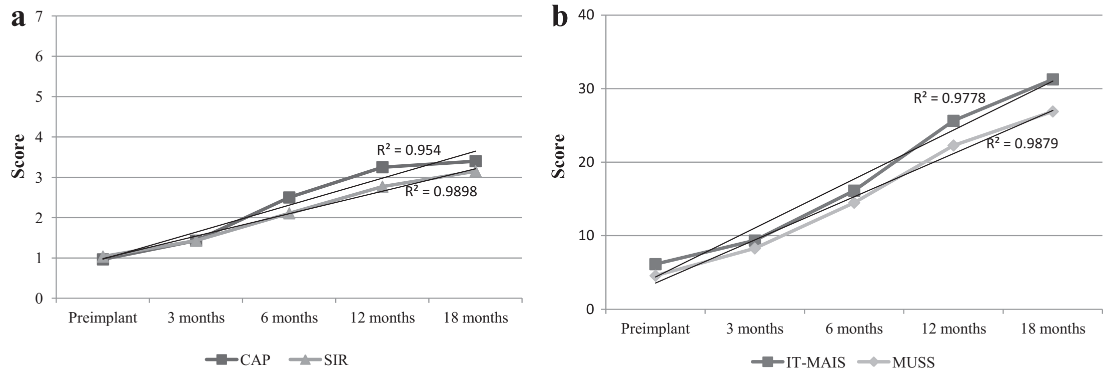

Fig. 1. (a) Study of evolution of Categories of Auditory Performance (CAP) and Speech Intelligibility Rating (SIR) scores over time; (b) study of evolution of meaningful auditory scale (IT-MAIS) and meaningful use of speech scale (MUSS) scores over time.

No statistical relationship between number of members and F.E. score was found ($p = 0.5$); the low percentage (12%) of F.E.3 among families in which the mother was housewife evidenced a relationship between mother's work and family expectations ($p = 0.007$).

In the 100% of cases of maximum expectations (F.E.3) a private speech therapy was done to support the C.I. user ($p = 0.008$) and no significant relationship between kind of support service and speech perception questionnaires results was found ($p = 0.225$).

Finally, concerning family's expectations, observed of low degree (F.E.1), medium degree (F.E.2) and high degree (F.E.3) in the 32.14, 39.28 and 28.58% of cases, no influence on speech perception performance was evidenced ($p = 0.18$).

3.3. Characteristics of implant use

Twenty-four children underwent a 'Cochlear' type device while in 4 infants the 'Med-El' device was used; with the exception of one children, implanted with 'Cochlear' device and treated with the Spectral-PEAK speech coding strategy (SPEAK), for the other twenty-seven children the Advanced Combination Encoder (ACE) strategy was used. Only in one patient it was not possible to activate all electrodes (because of hemi facial spasm), while in the other cases all electrodes were activated post operation. The number of channels ranged from 8 to 12, while the pulse stimulation rate ranged from 900 pulses/s to 2400 pulses/s; particularly in 42.85% of cases the stimulation rate was 900 (12 subjects) and 1200 pulses/s (12 subjects) while in two cases, corresponding to 7.14%, the stimulation rate was higher (2400 pulse/s).

After implantation the children continued their specific auditory-verbal therapy programme setting with a bilingual approach using sign language and spoken language. No case was in a setting where spoken language was used alone or with single signs as support.

The length of CI use ranged from 12 months to 51 months with a mean value of 20.14 ± 10.28; in 4 cases (14.29%) CI use was discontinuous (short periods during the day), while in 85.71% the implant was used all day (Table 1). Even if it was recommended to wear a hearing aid in the contralateral ear, the bimodal stimulation was performed only in 5 children (17.85%).

3.4. Audiometric thresholds data over time

The study of mean threshold data (Fig. 2) gathered from population for both listening conditions with and without cochlear implant evidenced a significant improvement in hearing threshold across the frequencies, especially 12 months post switch-on. Particularly the mean hearing threshold improved from 96.96 to 47.14 dB HL ($p < 0.001$) for 500 Hz, from 101.6 to 48.21 dB HL ($p < 0.001$) for 1 KHz, from 107.14 to 49.82 dB HL ($p < 0.001$) for 2 KHz and from 115.71 to 72.14 dB HL ($p < 0.001$) for 4 KHz. Audiological data at 18 months post implant, available only for 11 children, evidenced an audiometric curve within the speech spectrum of conversational speech (mean hearing threshold = 34.54, 38.18, 38.18, and 43.18 dB HL respectively for 500 Hz, 1, 2, and 4 KHz). Linear regression analysis (Fig. 2f) confirmed a progressive improvement of hearing threshold over time ($r \geq 0.97$).

3.5. Results from the questionnaires and variables associated

Table 3 reports mean values, standard deviation, median and *t*-test for IT-MAIS, MUSS, CAP and SIR before cochlear implantation and 3, 6 and 12 months post switch-on respectively; it is clearly evidenced as speech perception and speech intelligibility performances improved progressively after implantation. Linear regression (Fig. 1), performed comparing the mean values for each speech test, resulted statistically significant (r values of 0.99, 0.98, 0.98 and 0.98 respectively for IT-MAIS, MUSS, CAP and SIR). Specifically the study of *t*-test evidenced the highest significant progression after 6 month ($p < 0.0001$), even if in the 17.86% of cases (corresponding to 5/28) the speech performances resulted poor.

Eleven cases were also examined at 18 months because the length of CI use was >12 months; it resulted an improvement of the median values respect to the previous examinations, with a continuous progression in speech perception and intelligibility capacities.

The relationship between speech performances of CI users and families' characteristics (economic status, educational status, family size, mothers work status and expectation) were analyzed, but none of these variables influenced significantly speech development ($p \geq 0.05$) (Table 2). Among CI users' characteristics instead, only daily CI use (85.71% of the cohort) resulted an important predictor of good speech improvement ($p < 0.0001$).

4. Discussion

Considering the high percentage (44.68%) of profound SNHL in Western Sicily, mainly related to genetic causes, it is clear that several children, who do not benefit from hearing aids, could be candidates to cochlear implantation [17–20].

Many studies have demonstrated that CI is a suitable method to manage profound SNHL in children; however, because of a high variability in speech performances among CI users, several studies

Table 3
Mean, standard deviation (S.D.), median and *t*-test ($p < 0.01$) for MAIS, MUSS, CAP and SIR at preimplant and postimplant evaluations.

Speech perception and speech intelligibility test	Examination				
	Preimplant	3 Months	6 Months	12 Months	18 Months*
MAIS					
Mean ± S.D.	6.14 ± 3.17	9.36 ± 4.04	16.14 ± 6.03	25.64 ± 7.58	31.27 ± 5.88
Median	7	9	15	27	32
t-test	–	3.31	7.76	12.55	12.79
MUSS					
Mean ± S.D.	4.57 ± 3.39	8.28 ± 4.06	14.5 ± 5.85	25.64 ± 7.58	26.91 ± 6.34
Median	4	7	13	27	28
t-test	–	3.71	7.76	12.55	11.67
CAP					
Mean ± S.D.	0.96 ± 0.33	1.43 ± 0.79	2.5 ± 0.74	3.25 ± 1.00	3.40 ± 0.58
Median	1	1	2.5	3	4
t-test	–	2.86	9.96	11.43	11.7
SIR					
Mean ± S.D.	1.03 ± 0.19	1.42 ± 0.50	2.1 ± 0.574	2.775 ± 0.71	3.13 ± 0.59
Median	1	1	2	3	3
t-test	–	3.86	9.49	12.23	10.16

* Statistical analysis performed on 11 children.

were conducted to identify the main significant predictors of cochlear implantation outcomes [1,2,5,7,8,11–13,16,26–36].

Thus the purpose of our study was to describe the main outcomes obtained after cochlear implantation over a 12–18 months follow-up period and to correlate them with family and/or CI user profile.

Our cohort consisted of 28 children with congenital or acquired (before the 2nd year of life) bilateral SNHL with evidence of lack of hearing aids benefit and without intellectual disability; these characteristics, used as criteria of inclusion in the study, made our sample smaller but more homogeneous than those reported in literature (mean age of cochlear implantation 24.25 months ± 8.28; min = 10; max = 36), allowing us to reply to critics and counsel parents as well as to establish appropriate parental expectations.

Others authors, in fact, studied larger groups of children but implanted at different ages and followed in their speech improvements for a variable period of time. Calmels et al., in their study, examined 63 children from 1 to 10 years old, with a median age of 45 months at the time of implantation and a 3 years follow-up only in the 76% of their sample [37]. Wie, Taitelbaum-Swead and Manrique studied instead children with a maximum age at implantation of 15, 16, and 7 years respectively [12,38,39]. All these data, even if provide interesting information, are difficult to compare because of the heterogeneity of the cohorts studied.

The study of families' profile (Table 2), carried on with the purpose to evidence any correlation between family characteristics and the expectations score, showed a significant statistical differences for economic status (F.E.1 is strictly correlated with low economic status; $p < 0.0001$), educational status (primary school is strictly correlated with F.E.1; $p = 0.01$), mother's work status (in the 88% of family with F.E.1 the mothers are housewife; $p = 0.007$) and private support service (the 100% of the cases of private support service present the highest expectation scores; $p = 0.008$); therefore low economic and educational status, no mother's work and public support service could be considered as predictors factors for the lowest family expectation scores.

The analysis of audiometric thresholds over time (Fig. 2f) clearly reveals a significantly improved capacity to detect the presence of sounds with the cochlear implant in comparison to the preoperative unaided condition ($p < 0.001$). Particularly CI users easily detect sounds within the spectrum of conversational speech: at 12 months post switch-on for frequencies 500 Hz, 1 and 2 KHz (Fig. 2d) and at 18 months after implantation also for 4 KHz (Fig. 2e). These results confirm previous demonstration of improved auditory speech perception [1,2,5,7,12,30,37–39].

Speech perception tests evidenced a good improvement for all children, although in the 17.86% of cases (5/28), a lower progression in speech recognition was observed; additionally, the 80% of infants with poorer speech improvement had a discontinuous use of CI, with a significant difference respect to children with better speech perception scores ($p < 0.0001$). On the contrary, neither 'age at implant' ($p = 0.97$), nor the 'length of HL' ($p = 0.29$) and the 'interval between the diagnosis of HL and the CI' ($p = 0.26$) resulted predictor factors of speech recognition improvement. Even if in contrast with literature data [12,27,27,31,32,34], our findings could be explained because the homogeneity of our cohort, characterized by low mean age at implant (24.25 months ± 8.28; min = 10, max = 36), low mean value of length of HL (6.78 months ± 4.20; min = 2, max = 17), and low mean interval between the diagnosis of HL and the age of implantation (17.10 months ± 7.77; min = 3, max = 31). Instead, Robbins et al., who studied a cohort with similar characteristics (children implanted before the age of 2 years), obtained scores superimposable to our results from the IT-MAIS questionnaire [40]. This fact indirectly evidences how early diagnosis of congenital profound bilateral SNHL and young age at implantation (≤2 years of life) represent crucial variables for children's auditory speech perception and language ability.

The study of SIR up to 1 year after implantation evidenced, in the 46.42% of CI users, a SIR category = 3, considered by Flipsen as 'barely intelligible'. In contrast, Bakhshaee et al. reported, in the 91% of a group of 47 CI users (age at implantation ranging between 13 and 68 months), a SIR category of 3+; differently Calmels et al. found a SIR = 3+ only in the 17% of 63 children (mean age at implantation of 45 months). However, as suggested by Flipsen, a correct comparison between these findings is possible only after three years of daily CI use [37,41,42].

Concerning to Categories of Auditory Performance (CAP), it must be said that CAP is the only supraliminal auditory receptive outcome measure that is applicable to all children irrespective of their age and so the results of our study can be compared easily with those of literature. Specifically, with a CAP average score of 3.25 ± 1 and a median value of 3 at 12 months post implantation, our outcomes are in line with those of Govaerts et al.; in fact he found also that children implanted before the age of 2 years, compared with their normal hearing peers, showed similar CAP values just at three months post implantation [7].

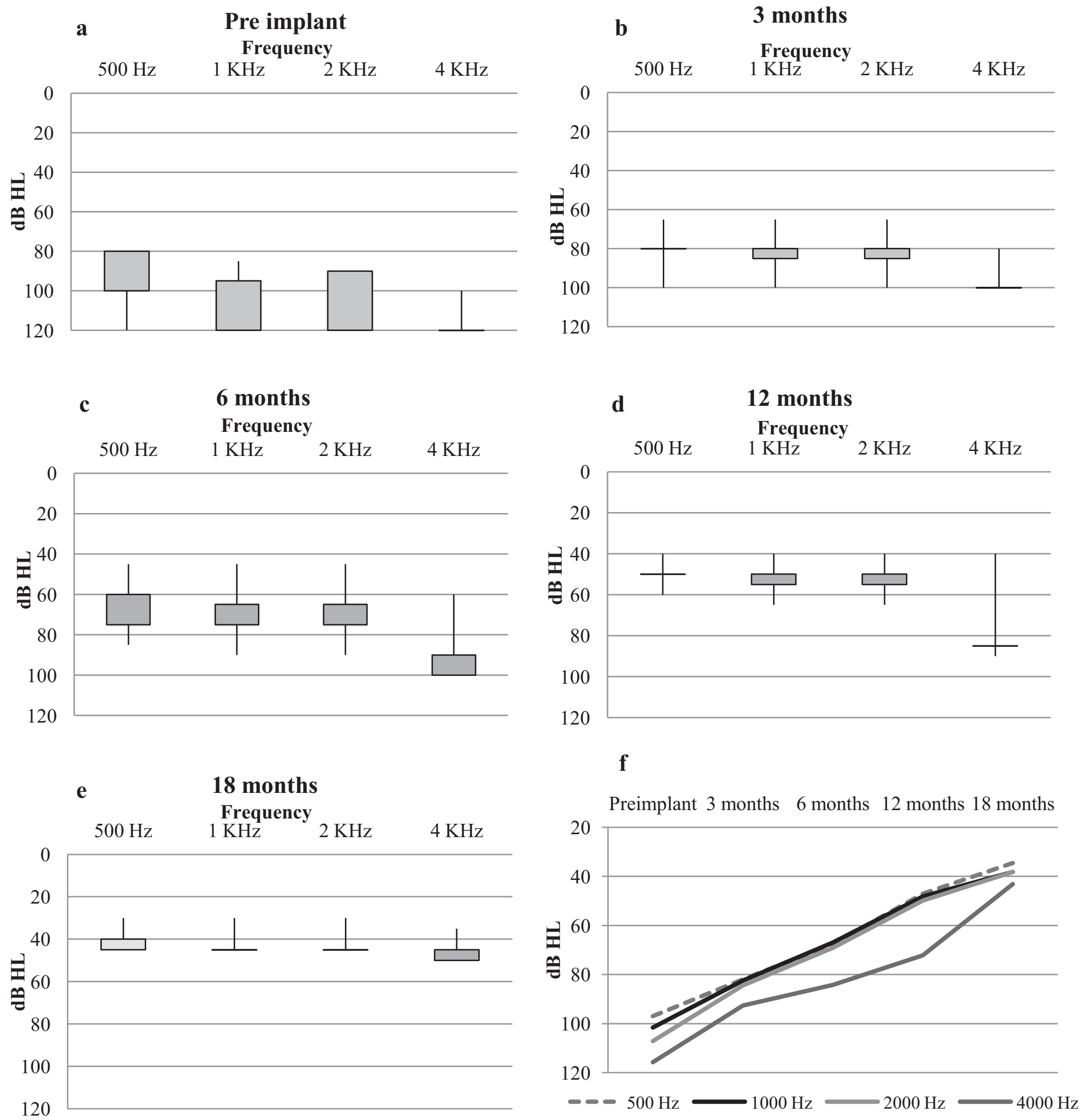

Fig. 2. Audiometric thresholds over time (ANOVA test). Mean value (dB HL) ± S.D., median (dB HL) and *t*-test for $p < 0.001$ relative to: (a) Preimplant – 5 KHz: 96.96 ± 11.41, 100; 1 KHz: 101.61 ± 10.97, 100; 2 KHz: 107.14 ± 12.72, 100; 4 KHz: 115.71 ± 7.66, 120; (b) 3 months – 0.5 KHz: 81.96 ± 7.86, 80, 5.73; 1 KHz: 82.5 ± 7.88, 80, 7.48; 2 KHz: 84.46 ± 8.96, 85, 7.71; 4 KHz: 92.68 ± 8.87, 100, 10.4; (c) 6 months – 0.5 KHz: 67.5 ± 10.14, 70, 10.21; 1 KHz: 66.96 ± 11, 65, 11.8; 2 KHz: 69.10 ± 11.06, 70, 11.94; 4 KHz: 84.28 ± 14, 90, 10.42; (d) 12 months – 0.5 KHz: 47.14 ± 6.44, 50, 20.11; 1 KHz: 48.21 ± 8.19, 50, 20.63; 2 KHz: 49.82 ± 7.99, 50, 20.19; 4 KHz: 72.14 ± 15.24, 75, 13.51; (e) 18 months (11 subjects) – 0.5 KHz: 34.54 ± 6.10, 30, 14.16; 1 KHz: 38.18 ± 5.6, 40, 15.33; 2 KHz: 38.18 ± 5.6, 40, 16.49; 4 KHz: 43.18 ± 5.6, 22.09; (f) linear regression (*r* index) of audiometric threshold; 0.5 KHz $r = 0.99$, 1 KHz $r = 0.99$, 2 KHz $r = 0.99$, 4 KHz $r = 0.97$.

5. Conclusion

The presence of a mandatory NHS programme in Sicily highlights the necessity to better understand the main outcomes in CI users. Through the study of families and CI users' profile it was possible to recognize only the continuous use of CI as significant predictor of speech recognition improvement ($p < 0.001$); all the other variables influence only the family's expectation ($p < 0.05$), but are irrelevant in the determination of CI user speech performances. So it is important to spur the child's parents on a continuous CI use, especially in case of families with low economic status and mother's education level associated with poorer expectations from implant use.

With an early diagnosis of SNHL (mean age of 7.14 months) and a C.I. surgery performed before the 3rd year of life (mean age = 24.25 months), all 28 infants presented speech perception and speech intelligibility performances comparable to those reported in literature. However a larger sample and a 3–5 years follow-up post implantation study are necessary to confirm our findings.

Financial disclosure and declaration of interest

The authors report no conflict of interest. The authors alone are responsible for the content and writing of the paper.

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