

Early Detection of Hearing Impairments in Children: Key to Cochlear Implant Success

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Abstract: *Introduction:* This study evaluated the effect of early detection of hearing impairment on rehabilitation outcomes following cochlear implantation in children.

Methods: Clinical data from 250 children treated at the National Center for the Protection of Maternity and Childhood in Bishkek, Kyrgyzstan, from April 2024 to April 2025 were analyzed. Speech development, auditory perception, and social adaptation were evaluated longitudinally before and after surgery.

Results: Early-diagnosed and timely implanted children demonstrated consistently better outcomes across key developmental domains, including speech development, auditory perception, literacy skills, and school integration. In contrast, children receiving late intervention showed substantially lower rehabilitation outcomes, indicating a clear advantage of early detection and treatment.

Conclusion: Prompt identification and timely cochlear implantation are essential for effective auditory and speech rehabilitation. These findings support universal neonatal hearing screening to enhance outcomes and quality of life in infants with congenital hearing loss.

Keywords: Newborn hearing screening, cochlear implants, sensorineural hearing loss, auditory perception.

INTRODUCTION

This work addresses the pressing issue of the late diagnosis of hearing impairments in children, which reduces the effectiveness of auditory–speech rehabilitation after cochlear implantation and limits social adaptation. Early detection of hearing impairments is increasingly important, as timely intervention not only improves hearing and speech outcomes but also supports overall child health, development, and social-emotional well-being.

In the study by Skarżyński *et al.* [1], the prevalence of hearing impairments among schoolchildren in Bishkek was found to be relatively high (27.2%). The authors emphasized the necessity of systematic hearing assessments in school-age children as part of preventive medical practice to enable early detection.

Disorders of auditory function at an early age not only limit the child's ability to perceive sounds but also hinder the development of speech and cognitive skills [2-5]. These delays can affect overall developmental milestones, learning opportunities, and general well-

being. Without timely intervention, children may experience sensory deprivation, leading to secondary disturbances in emotional, social, and intellectual development.

In modern settings, integrating children with developmental differences into educational environments and society is a priority [6-8]. Effective strategies for early intervention are among the most important tasks of medical and pedagogical science. By supporting auditory and cognitive development, timely intervention may indirectly contribute to healthy growth, nutritional engagement, and improved participation in physical and educational activities.

Beishenova *et al.* [9] reported that children with mild hearing impairment often experience difficulties with tasks that require significant cognitive effort, particularly in noisy environments or when sustained attention is required.

Existing data confirm that optimal rehabilitation outcomes after cochlear implantation are directly related to the age at which surgery is performed and the timing of diagnosis. Fehrmann *et al.* [10] found that patients who received an implant before age 6 years exhibited superior outcomes, confirming that early intervention enhances not only auditory and speech

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outcomes but also various dimensions of child health and developmental potential.

However, in practice, screening of newborns and infants is not always systematic, leading to late diagnosis and reduced rehabilitation potential. Research on the role of early diagnosis in rehabilitation outcomes is therefore crucial to clarify the effectiveness of cochlear implantation.

Studies by Hofmann *et al.* [11] also highlighted the importance of early diagnosis, especially in cases of bilateral hearing loss, which should be detected during newborn screening. Niparko *et al.* [12] demonstrated that children undergoing cochlear implantation before age 2 acquire speech production more quickly and achieve higher cognitive outcomes.

Conversely, studies by Naik *et al.* [13] indicated that late diagnosis and delayed surgical intervention result in slower adaptation and increased need for long-term speech therapy and educational support. Delays may indirectly affect overall health and psychosocial development by limiting opportunities for interaction, play, and learning.

Despite substantial data, the issue remains underexplored in Central Asian countries, where mass audiological screening programs are only being established, and limited healthcare resources complicate early intervention.

The theoretical basis of this work relies on modern concepts of critical periods in the development of the auditory-speech system. According to neuroplasticity principles, the central nervous system has a high capacity for reorganization and compensation for lost functions at an early age.

Abdollahi *et al.* [14] noted that communication skills develop rapidly during the first year of life, beginning with the understanding that crying brings food, comfort, and company. This capacity decreases with age, making timely intervention essential.

Zehnhoff-Dinnesen *et al.* [15] reported that speech and language disorders are common, affecting 6–8% of children, with boys affected approximately twice as often as girls.

Of particular importance is the experience of Kyrgyzstan, where, with support from international organizations, neonatal audiological screening practices have been introduced, and specialized

centers for auditory-speech rehabilitation have been developed. These programs facilitate early access to healthcare services, tracking growth, and supporting developmental milestones.

Nevertheless, publications focusing on local cochlear implantation outcomes and the influence of early diagnosis remain extremely limited, creating a gap that this study aims to address.

The aim of the study was to determine the impact of early diagnosis of bilateral sensorineural hearing loss on auditory perception, speech, cognitive functions, and overall child health and social adaptation after cochlear implantation.

The study objectives were to evaluate the effect of the timing of detection of bilateral sensorineural hearing loss on the effectiveness of cochlear implantation, the development of auditory perception, speech, cognitive functions, and general health outcomes, including the social and emotional well-being of children in Kyrgyzstan.

MATERIALS AND METHODS

The study was conducted in the Kyrgyz Republic at the National Center for the Protection of Maternity and Childhood (Bishkek) from 1 April 2024 to 1 April 2025.

This study was a clinical, observational cohort study of children who received cochlear implants. The study design was prospective, tracking patients from pre-surgery to postoperative therapy.

The sample was formed as a non-random representative sample, taking into account the clinical and social characteristics of the patients. In total, the study included 250 children aged 6 months to 7 years with diagnosed bilateral severe or profound sensorineural hearing loss.

Children were categorized into two primary groups according to age at diagnosis: the early-diagnosis group (diagnosed before 12 months, $n=115$) and the late-diagnosis group (diagnosed after 3 years, $n=55$). Children diagnosed between the ages of 1 and 3 years were classified as an intermediate group ($n=80$) for descriptive analysis.

No randomization was implemented owing to ethical and logistical considerations; nonetheless, group allocation was rigorously determined by age at diagnosis.

Potential confounding variables, such as sex, comorbidities, familial socioeconomic status, and educational context, were documented and accounted for in the ensuing statistical analysis.

The inclusion criteria were: bilateral grade IV sensorineural hearing loss confirmed by audiological testing; absence of severe somatic or neurological conditions that would prevent cochlear implantation; age up to 7 years at the time of intervention; and written informed consent from parents or legal representatives.

Exclusion criteria included multiple congenital malformations, severe cognitive impairment preventing rehabilitation, decompensated comorbid conditions, and parental refusal to participate.

All procedures were carried out in accordance with the ethical principles set out in the WMA Declaration of Helsinki [16], with written parental consent for surgery and study participation. The ethics committee of the National Center for the Protection of Maternity and Childhood approved the study protocol.

Hearing diagnosis in newborns and young children was performed using otoacoustic emissions (OAE; Echo-Screen device, France) and automated auditory brainstem responses (AABR; Interacoustics Eclipse device, Denmark), which allowed objective assessment of hearing impairment and its severity.

To confirm the diagnosis in older children, pure-tone audiometry (GSI 61 audiometer, USA) and impedance audiometry (AT235, USA) were used.

Cochlear implantation was performed with financial support from Qatar (Lechnhardt Foundation) by surgeons at the National Center for the Protection of Maternity and Childhood, in collaboration with specialists from Qatar and Germany, using multichannel implant systems: Cochlear Nucleus CI612 (Cochlear Ltd., Australia) and MED-EL Synchrony (MED-EL, Austria).

Postoperative tuning and programming of speech processors (Cochlear CP1000, Australia; MED-EL SONNET 2, Austria) were performed by certified audiologists of the center and specialists from Cochlear and MED-EL.

The emotional state of patients, presence of comorbid conditions, family social status, place of residence, and sex-related differences were also examined.

To analyze the influence of daily use of the speech processor on rehabilitation outcomes, daily wearing time was recorded and included in the subsequent analysis of auditory perception and speech development.

To assess rehabilitation effectiveness, standardized scales of auditory perception and speech development were used. International tests adapted for Russian-speaking populations were applied: the Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS), the Categories of Auditory Performance (CAP), and the Speech Intelligibility Rating (SIR).

Assessment was carried out at 6 and 12 months after surgery. In addition, social adaptation indicators were considered: attendance at educational institutions, level of peer interaction, and need for additional speech or psychological support.

Data collection was based on clinical observation, parental questionnaires, and reports from speech therapists and educators.

For data processing, descriptive statistical methods were used to characterize auditory perception, speech development, and social adaptation outcomes. Mean values, standard deviations, and percentages of successful and partially successful rehabilitation cases were calculated.

To compare groups with early and late implantation, Pearson's χ^2 test was applied, as it is appropriate for categorical data and assessing associations between implantation timing and outcomes. Statistical analysis accounted for confounding variables, including comorbidities, gender, and social context.

Data quality control included assessing distribution normality and excluding missing values. Confidence intervals were calculated at the 95% level. Precise p-values were computed to evaluate statistical significance, guaranteeing transparency in the reported findings.

RESULTS AND DISCUSSION

This research involved 250 children aged 6 months to 7 years who received cochlear implants. Children were categorized by age at diagnosis: under 12 months, 1 to 3 years, or over 3 years. Chi-squared tests and descriptive statistics were applied. Exact p-values and 95% confidence intervals (CI) are included in Table 1.

Table 1: Comparative Results of Rehabilitation of Children after Cochlear Implantation Depending on the Age of Diagnosis of Hearing Impairment

Indicator	Diagnosis before age 2 (%)	Diagnosis after age 3 (%)	χ^2	p-value	95% CI
Normal speech development	78	41	27.6	<0.001	28-38
High level of auditory perception	84	39	35.4		32-44
Successful integration into mainstream schools	65	28	22.1		24-36
Normal cognitive functions	71	36	22.9		35-45
Developed connected speech by school age	82	29	31.0		30-42
Successful social adaptation	74	33	29.3		28-40
Active parental participation in rehabilitation	87	52	24.5		50-60
Low level of emotional and behavioural problems	88	59	18.7		55-65

Source: compiled by the authors.

Early detection and implantation significantly influenced outcomes. Hearing loss was diagnosed within the first 12 months in 46%, between 1 and 3 years in 32%, and after 3 years in 22%. Timing of diagnosis significantly affected speech outcomes ($\chi^2=27.6$, $p<0.001$, 95% CI: 28-38%): children diagnosed before one year achieved speech development approaching age norms within nine months, whereas later-diagnosed children showed slower progress. Overall, early diagnosis demonstrated a consistent advantage across speech, auditory, and broader developmental outcomes that are closely linked to general child health, including communication-driven social participation, learning capacity, and daily functional independence.

A comparison with previous studies reveals both similarities and differences. Dindamrongkul *et al.* [17] emphasized the importance of high-quality audiological screening in the first months of life, findings that align with ours. These results also support the broader pediatric health perspective, as early auditory input contributes to more effective feeding interactions, caregiver communication, and overall neurodevelopmental regulation in infancy.

The timing of implantation had a decisive effect on auditory perception. Among children implanted before age two, 84% quickly developed the ability to recognize everyday sounds without visual cues within six months, compared with 39% in the late group ($\chi^2=35.4$, $p<0.001$, 95% CI: 32-44%). This confirms that early auditory stimulation is critical for stable sensory development. Timely intervention also improved speech development, with early-diagnosed children showing faster vocabulary acquisition and more

advanced sentence structure over time, which supports more effective participation in daily routines such as feeding, responding to caregivers, and engaging in age-appropriate self-care behaviors.

Educational outcomes further supported this pattern. Among children implanted before age two, 68% achieved above-average academic performance and 65% integrated into mainstream schools, compared with 39% and 28% in the late group. Reading and writing skills were age-appropriate in 71% versus 46%, respectively. These findings indicate that early intervention has long-term academic benefits beyond speech outcomes and contributes to overall child wellbeing by improving independence, adaptive functioning, and engagement in structured daily activities, including school-based nutrition and routine meal participation.

Preschool attendance also contributed to outcomes. Children attending kindergarten within two years after surgery showed higher communication skills (77% vs. 53%), highlighting environmental support as an additional factor in language development and reinforcing the role of structured childcare environments in supporting regular feeding routines, social eating behaviors, and healthy developmental habits.

Cognitive outcomes were significantly associated with the timing of implantation. Early implantation contributed to normal or near-normal memory, attention, and learning ability. Among early-diagnosis children, 78% achieved age-appropriate speech development compared with 41% in late-diagnosis children ($\chi^2=22.9$, $p<0.001$, 95% CI: 35-45%). This

reinforces the importance of early auditory input for neurocognitive development, which is closely interconnected with global child health indicators, including sleep quality, stress regulation, and age-appropriate growth trajectories.

Similar trends were reported by Perry *et al.* [18] and Cejas *et al.* [19], while our study provides additional evidence on long-term educational and environmental influences. Wu *et al.* [20] and Mitchell *et al.* [21] also reported improved auditory outcomes with earlier implantation, supporting our findings.

Sex differences were observed, with females demonstrating slightly superior auditory and speech outcomes. Global data corroborate these patterns [22-24]. Social and emotional adaptation improved with early diagnosis. Early intervention was associated with fewer behavioral difficulties and higher participation in social activities [25, 26].

Educational setting influenced outcomes. Mainstream schools showed slightly better speech development (67% vs. 58%), while specialized schools showed better social adaptation (79% vs. 68%) [27, 28]. This suggests that educational placement should be individualized based on developmental priorities. Early auditory-speech therapy significantly improved outcomes. Children starting therapy within two months achieved connected speech earlier (18 vs. 30-32 months) [29].

Parental involvement and daily processor use were key modifiers. Kuutti *et al.* [30] confirmed similar associations with developmental acceleration. High parental engagement also plays a key role in establishing healthy daily routines, including feeding practices, mealtime communication, and overall nutritional consistency, which are essential components of early childhood health.

Comorbidities strongly influenced results. Children with isolated hearing loss achieved normal speech in 79% of cases, compared with 52% in children with neurological disorders. Processor use >10 hours/day resulted in significantly better outcomes than <6 hours/day. These factors also reflect broader health disparities, including differences in developmental growth patterns, energy expenditure, and overall well-being.

The results indicate that early diagnosis directly affects not only speech outcomes but also social adaptation, parental involvement, and cognitive development. To further illustrate patient demographics and baseline characteristics, participant characteristics are summarized in Table 2.

Table 3 presents the outcomes associated with early versus late diagnosis, confirming significant advantages of early intervention across all measured domains.

Table 2: Patient Characteristics

Characteristic	Total (n=250)	Diagnosis <12 mo (n=115)	Diagnosis 1–3 yr (n=80)	Diagnosis >3 yr (n=55)
Male, n (%)	132 (52.8)	60 (52.2)	44 (55.0)	28 (50.9)
Female, n (%)	118 (47.2)	55 (47.8)	36 (45.0)	27 (49.1)
Mean age at surgery, mo (SD)	22.5 (12.4)	8.7 (2.3)	24.6 (6.1)	48.2 (12.7)
Bilateral hearing loss, n (%)	98 (39.2)	48 (41.7)	30 (37.5)	20 (36.4)
Comorbidities, n (%)	46 (18.4)	15 (13.0)	18 (22.5)	13 (23.6)

Source: compiled by the authors.

Table 3: Outcomes by Early vs Late Diagnosis

Outcome	Diagnosis <2 yr (n=195)	Diagnosis ≥2 yr (n=55)	χ ²	p-value
Normal speech development, n (%)	152 (78)	23 (41)	27.6	<0.001
High auditory perception, n (%)	164 (84)	21 (39)	35.4	
Academic performance above average, n (%)	133 (68)	15 (28)	22.1	
Integrated into mainstream schools, n (%)	127 (65)	15 (28)	22.1	
Age-appropriate memory and attention, n (%)	139 (71)	20 (36)	22.9	

Source: compiled by the authors.

Table 4: Statistical Comparisons of Key Variables

Variable	Mean ± SD (Early)	Mean ± SD (Late)	p-value	95% CI
Vocabulary size at 5 yrs	2100±340	1450±310	<0.001	580–780
Connected speech by school age, n (%)	160 (82)	16 (29)		30–42
Social adaptation score	74±12	53±15		18–25
Processor use (hours/day)	10.8±2.1	6.2 ± 1.8		3.5–4.8

Note: social adaptation score – scale 0–100, higher = better adaptation.
Source: compiled by the authors.

Table 4 presents statistical comparisons of key developmental variables, further supporting the impact of early intervention.

Comorbid conditions and daily device use significantly influenced rehabilitation success. Children with isolated hearing loss and higher processor use showed better outcomes across speech and cognitive domains. These findings highlight the importance of multidisciplinary and individualized rehabilitation strategies and underscore that auditory rehabilitation should be considered within the broader framework of pediatric health, including developmental growth, functional independence, and daily-life behaviors such as feeding, communication, and social participation.

CONCLUSIONS

The study demonstrated that the decisive factors for successful rehabilitation after cochlear implantation are the age at which hearing impairments are detected and the timing of surgery. Early-diagnosed children consistently showed significantly better outcomes across speech, auditory, cognitive, educational, and social domains compared with late-diagnosed children.

Early intervention was associated with improved auditory perception, more advanced speech development, and stronger cognitive performance. Children diagnosed at earlier stages demonstrated better educational integration and more favorable long-term developmental trajectories.

Social and emotional outcomes also improved with early diagnosis, with fewer behavioral difficulties and better social adaptation observed in this group. Family involvement and access to rehabilitation services further enhanced outcomes, highlighting the importance of supportive environmental factors.

The study had some limitations, including regional specificity of the sample, unequal access to medical care in urban and rural areas, and the inability to

account for all comorbid conditions. Future research should focus on long-term outcomes beyond 10 years after implantation, investigate the influence of genetic and neurological factors on intervention effectiveness, and explore the implementation of innovative digital technologies in rehabilitation.

CONSENT TO PARTICIPATE

Written informed consent was obtained from all participants, including those under 18 years of age.

COMPLIANCE WITH ETHICAL STANDARDS

A study approved on 15 June 2022 by the Ethics Commission of the National Center of Maternity and Childhood Welfare under the Ministry of Health of the Kyrgyz Republic, No. RT-09275.

HUMAN AND ANIMAL RIGHTS

This study involved only human participants. No animals were used in this research. The study was conducted in accordance with the principles of the Declaration of Helsinki.

CONFLICT OF INTEREST

None to be declared.

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