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Effects of Early Identification and Intervention on Language Development in Japanese Children With Prelingual Severe to Profound Hearing Impairment

Norio Kasai, MD, PhD; Kunihiro Fukushima, MD, PhD; Kana Omori; Akiko Sugaya, MD; Toshiyuki Ojima, MD, PhD

Objectives: Early identification and intervention for prelingual bilateral severe to profound hearing loss is supposed to reduce the delay in language development. Many countries have implemented early detection and hearing intervention and conducted regional universal newborn hearing screening (UNHS). However, the benefits of UNHS in later childhood have not yet been confirmed, although language development at school age has a lifelong impact on children's future. Our Research on Sensory and Communicative Disorders project attempted to reveal the effects of UNHS and those of early intervention on the development of verbal communication in Japanese children.

Methods: In this study, 319 children with prelingual bilateral severe to profound hearing loss, 4 to 10 years of age, were evaluated with the Test of Question-Answer Interaction Development used as an objective variable. Participation in UNHS and early intervention were used as explanatory variables. The adjusted odds ratio (AOR) was calculated after adjusting several confounding factors with use of logistic regression analysis. In addition, caregivers' answers were obtained by a questionnaire, and the process of diagnosis with and without UNHS was analyzed retrospectively.

Results: Early intervention was significantly associated with better language development (AOR, 3.23; $p < 0.01$). Participation in UNHS may contribute to better language development to some extent (AOR, 1.32), but not one that was statistically significant ($p = 0.37$). However, UNHS was significantly associated with early intervention (AOR, 20.21; $p < 0.001$). The questionnaire results indicated a lag in treatment after UNHS in more than 40% of screened cases.

Conclusions: Early intervention strongly influenced language development. It is necessary to ensure that early identification leads directly to early intervention.

Key Words: early identification, early intervention, hearing loss, language development, newborn hearing screening.

INTRODUCTION

To identify prelingual bilateral severe to profound hearing loss, universal newborn hearing screening (UNHS) was implemented from the year 2000 in some areas of Japan[1]; it has now been extended to 60% of all newborns in the country (Aso and Fukushima, personal communication, 2010). The short-term goal of UNHS is to achieve early intervention, and the long-term goal should include language development, as first reported by Yoshinaga-Itano et al.[2-4] Because the first generation of Japanese children to receive UNHS is now going to be 10 years old, it is appropriate to evaluate the effect of early identification or early intervention on their language development. Other factors, including hearing level,[5] hearing devices,[6] additional handicaps,[7,8] and familial support,[9,10] may individually or collectively affect language development. In this study, the association of early identification and intervention with language development was evaluated, with these known variables taken into consideration.

METHODS

Design and Participants. We used original data from 638 subjects (4 to 12 years of age), collected as part of our Research on Sensory and Communicative Disorders (RSCD) project. This population-based case-control study targeted children who fulfilled the following criteria: prelingual and severe to profound hearing impairment (more than 70 dB on average); age between 4 and 12 years, ranging from 2 years before entering school (grade −2) to grade 6,

From the Department of Otolaryngology–Head and Neck Surgery, Okayama University Postgraduate School of Medicine, Dentistry, and Pharmaceutical Science, Okayama (Kasai, Fukushima, Omori, Sugaya); the Association for Technical Aids, Tokyo (Kasai, Omori); and the Department of Community Health and Preventive Medicine, Hamamatsu University School of Medicine, Hamamatsu (Ojima); Japan. This work was a part of the Research on Sensory and Communicative Disorders project, which is supported by a grant from the Ministry of Health, Labor, and Welfare of Japan.

Correspondence: Kunihiro Fukushima, MD, PhD, Dept of Otolaryngology–Head and Neck Surgery, Okayama University Postgraduate School of Medicine, Dentistry, and Pharmaceutical Science, 2-5-1 Shikata-cho, Kita-ku, Okayama 700-8558, Japan.

during the period from April 2009 to March 2010; and participation in several tests to evaluate Japanese language development. From these data, children from 4 to 10 years of age (or from grade −2 to grade 3) were selected for this study.

Children who were studying at or consulting with the cooperating institutions were considered to be potential candidates for the study. The institutions included a deaf school, a school for special educational support, a training center for hearing-impaired children, and a hospital training room, as described elsewhere in this publication (pp 3-15). Written informed consent was obtained, language tests were performed, and inquiries of the children's caregivers were made. The study design was approved by the central and local ethics review boards.

Procedures. The participants were tested during face-to-face interviews in a quiet room with the assessment of language development for Japanese children (ALADJIN; this publication, pp 3-15) while wearing their usual hearing devices. They were first assessed with Raven's Coloured Progressive Matrices (RCPM)[11] and the Screening Test of Reading and Writing for Japanese Primary School Children (STRAW)[12,13] to exclude the presence of intellectual developmental problems or dyslexia. The Test of Question-Answer Interaction Development (TQAID)[14,15] was then conducted, and the children were divided into high- and low-score groups by the median values in each age bracket.

Furthermore, questionnaires were distributed to caregivers; these included questions about the following: birth date, birth weight, sex, age at identification of deafness, exposure to UNHS, date of commencement of hearing aid use, hearing devices, mode of communication, family structure, annual family income, and academic qualifications of caregivers. In addition, familial involvement, including communication between the participants and parents or other family members (intrafamilial communication) and caregivers' interest in the child's education (commitment to education), was evaluated with a questionnaire designed by the Benesse Educational Research and Development Center.[16] Another screening test, the PARS (Pervasive Developmental Disorders [PDD] Autism Society of Japan [ASJ] Rating Scale),[17] was also administered to caregivers to screen for pervasive developmental disorders or autistic tendencies. Similar questionnaires were distributed to the teachers and speech-language hearing therapists who were routinely involved in treatment of the targeted children in order to cross-check the caregivers' responses. Moreover, the progression of hearing impairment was assessed.

The following criteria were used to rule out additional handicaps that could hamper language development: low birth weight (less than 2,000 g, suggesting severe complications that might delay intervention); a low RCPM score (less than or equal to −2 SD for their grade, suggesting the presence of nonverbal intellectual delay); a high PARS score (greater than 11, suggesting the presence of pervasive developmental disorder–like behavioral characteristics); and a low STRAW score (less than or equal to −1.5 SD for their grade, suggesting the presence of dyslexia).

Variables and Measures. The results of the TQAID were set as objective variables. UNHS and early intervention were used as explanatory variables. Wearing a hearing aid before or at 6 months of age was defined as early intervention, in accordance with the Joint Committee on Infant Hearing[18] and Yoshinaga-Itano et al.[19] As confounding variables, unaided hearing level, intrafamilial communication, commitment to education, annual income, family size, and sex were included and adjusted for.

For unaided hearing level, the pure tone average was applied. To measure intrafamilial communication, 5 questions were asked: "Do you talk to your child about his/her friends or teachers?" "Do you talk to your child about studying or school records?" "Do you talk to your child about the future?" "Do you talk to your child about social concerns?" and "Do you talk to your child about daily happenings?" To measure commitment to education, 5 questions were asked: "Do you go to school visitations or athletic meets?" "Do you participate in PTA activities?" "Do you concern yourself with your child's education or share discipline with your spouse or family?" "Do you pay money for your child's education willingly?" and "Are you trying to follow the trends of your child's peers in education?" Caregivers were asked to select 1 of 4 scores for each question: almost always (score 1), sometimes (score 2), rarely (score 3), or almost never (score 4). To identify annual income, the questionnaire asked caregivers to choose one of the following to indicate total household income: less than 3 million yen, 3 to 5 million yen, 5 to 7.5 million yen, 7.5 to 10 million yen, 10 to 15 million yen, or more than 15 million yen.

Statistical Analysis. The results of the TQAID were divided into 2 groups for each grade: the high-score group (score greater than or equal to the median value for the same grade) and the low-score group (score less than the median value for the same grade). These scores represented objective variables. The explanatory variables, ie, participation in UNHS and early intervention, were also divid-

TABLE 1. DETAILS OF STUDIED CHILDREN

Grade	Age (mo)*	Sex: M	Sex: F	Sex: NA	UNHS Participation: Yes	UNHS Participation: No	UNHS Participation: NA	Early Intervention: Yes	Early Intervention: No	Early Intervention: NA	Total
–2	52-69	52 (54.2%)	43 (44.8%)	1 (1.0%)	59 (61.5%)	36 (37.5%)	1 (1.0%)	32 (33.3%)	64 (66.7%)	0 (0.0%)	96 (30.1%)
–1	62-83	32 (47.1%)	36 (52.9%)	0 (0.0%)	29 (42.6%)	32 (47.1%)	7 (10.3%)	22 (32.4%)	46 (67.6%)	0 (0.0%)	68 (21.3%)
1	72-95	37 (50.0%)	36 (48.6%)	1 (1.4%)	33 (44.6%)	39 (52.7%)	2 (2.7%)	19 (25.7%)	54 (73.0%)	1 (1.4%)	74 (23.2%)
2	88-104	19 (44.2%)	24 (55.8%)	0 (0.0%)	11 (25.6%)	31 (72.1%)	1 (2.3%)	11 (25.6%)	32 (74.4%)	0 (0.0%)	43 (13.5%)
3	100-115	22 (57.9%)	16 (42.1%)	0 (0.0%)	7 (18.4%)	28 (73.7%)	3 (7.9%)	9 (23.7%)	28 (73.7%)	1 (2.6%)	38 (11.9%)
Total	52-115	162 (50.8%)	155 (48.6%)	2 (0.6%)	139 (43.6%)	166 (52.0%)	14 (4.4%)	93 (29.2%)	224 (70.2%)	2 (0.6%)	319

Children were grouped according to school age (ie, grade). Grade –2 — preschoolers 2 years before entering school; grade –1 — preschoolers 1 year before entering school.

NA — not available; UNHS — universal newborn hearing screening.

*Age range during which participants underwent tests.

ed into 2 groups, indicated by the responses "yes" (the child received UNHS or early intervention) and "no" (the child did not receive UNHS or early intervention). Forced-entry logistic regression analysis was performed with IBM SPSS version 19 software (IBM Corp, Armonk, New York). A significance (p) level of 0.05 was used, and 95% confidence intervals (CIs) were calculated.

RESULTS

After exclusion of children over 10 years of age and/or those who were additionally handicapped, as described above, a sample of 319 subjects was obtained (Table 1). Among them, 139 (43.6%) underwent UNHS, 80 (57.6% of UNHS cases) of whom then received early intervention (≤6 months, Table 2). The average and median ages for initiation of intervention were 15.3 and 12.0 months, respectively. There were 146 (45.8%) cochlear implant users.

The results of the logistic regression analysis are shown in Table 3. After adjustment for confounding factors, the adjusted odds ratios (AORs) of the explanatory variables were 1.32 for UNHS (95% CI, 0.72 to 2.44) and 3.23 for early intervention (95% CI, 1.56 to 6.67). For the confounding factors, intrafamilial communication demonstrated significant AORs (0.85 and 0.81 for UNHS and early intervention, respectively). The unadjusted odds ratio for UNHS was 1.25 (95% CI, 0.76 to 2.06), and that for early intervention was 1.84 (95% CI, 1.07 to 3.18). The AOR of UNHS and early intervention was 20.21 (95% CI, 8.30 to 49.23; Table 4), indicating the apparent influence of UNHS on early intervention.

TABLE 2. RELATIONSHIP BETWEEN UNHS PARTICIPATION AND EARLY INTERVENTION

UNHS Participation	Early Intervention: Yes	Early Intervention: No	Early Intervention: NA	Total
Yes	80 (57.6%)	59 (42.4%)	0 (0.0%)	139
No	12 (7.2%)	154 (82.8%)	0 (0.0%)	166
NA	1 (7.1%)	11 (78.6%)	2 (14.3%)	14
Total	93 (29.2%)	224 (70.2%)	2 (0.6%)	319

UNHS — universal newborn hearing screening; NA — not available.

As shown in the Figure, 59 cases (42.4%) experienced no early intervention after UNHS (n = 139). Of these, 29 cases (20.9% of all UNHS cases) had an apparent history of progressive or late-onset hearing loss. In the other 30 (21.6% of all UNHS cases), intervention commenced between 7 and 12 months of age in 18 cases, and intervention was initiated after 13 months in 12 cases. The suspected reasons for delayed intervention included severe complications, denial, and inadequate support or information after UNHS in 12 cases.

By contrast, early intervention was performed for 12 patients who did not receive UNHS (Table 2).

TABLE 3. RESULTS OF LOGISTIC REGRESSION ANALYSIS FOR TQAID AS OBJECTIVE VARIABLE (N = 319)

Explanatory Variables	Confounding Factors	Odds Ratio	95% CI	p
UNHS participation		1.32	0.72 to 2.44	0.372
	Unaided hearing level	0.99	0.97 to 1.01	0.415
	Intrafamilial communication	0.85	0.75 to 0.96	0.009
	Commitment to education	0.89	0.74 to 1.07	0.203
	Annual income	1.14	0.82 to 1.57	0.436
	Family size	0.74	0.55 to 1.01	0.059
	Sex	1.33	0.71 to 2.47	0.375
Early intervention		3.23	1.56 to 6.67	0.002
	Unaided hearing level	0.99	0.97 to 1.02	0.609
	Intrafamilial communication	0.81	0.71 to 0.92	0.001
	Commitment to education	0.96	0.80 to 1.15	0.622
	Annual income	1.09	0.78 to 1.51	0.629
	Family size	0.71	0.52 to 0.98	0.036
	Sex	1.38	0.74 to 2.59	0.310

TQAID — Test of Question-Answer Interaction Development.

TABLE 4. RESULTS OF LOGISTIC REGRESSION ANALYSIS FOR EARLY INTERVENTION AS OBJECTIVE VARIABLE (N = 319)

Explanatory Variable	*Confounding Factors*	*Odds Ratio*	*95% CI*	*p*
UNHS participation		20.21	8.30 to 49.23	<0.001
	Unaided hearing level	0.99	0.97 to 1.02	0.631
	Intrafamilial communication	1.15	1.00 to 1.33	0.050
	Commitment to education	0.76	0.60 to 0.96	0.020
	Annual income	1.14	0.78 to 1.66	0.504
	Family size	1.044	0.71 to 1.54	0.827
	Sex	0.75	0.36 to 1.57	0.444

Among these cases, the mothers of 3 children suspected hearing loss during their children's neonatal period or in early infancy, and 4 children were considered at high risk for hearing impairment because of the presence of hearing-impaired siblings (n = 3) or an external ear anomaly (n = 1).

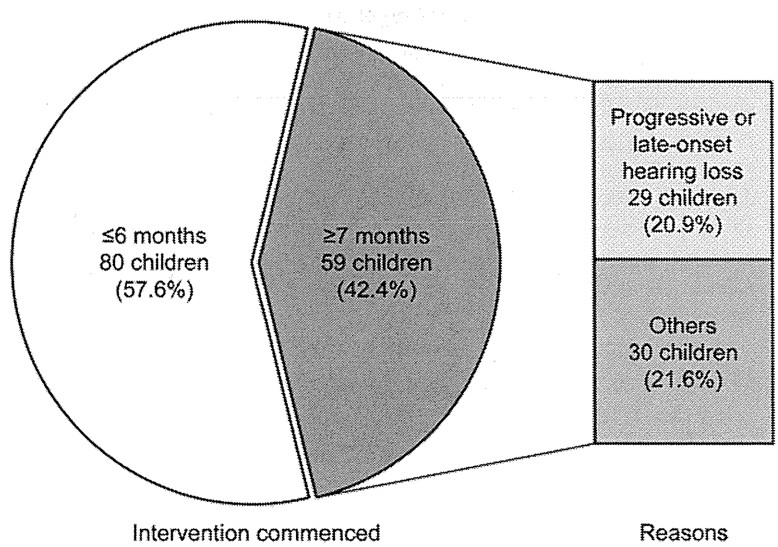
DISCUSSION

In this study of the effects of UNHS and early intervention in 319 cases, initiation of intervention by 6 months of age significantly influenced language development for children with hearing impairment of 70 dB or worse. However, participation in UNHS alone demonstrated no significant results. Because a tendency toward better language development was observed in cases with participation in UNHS (AOR, 1.32), and the number of screened children (139) was smaller than the number of unscreened children (166), significant results might be obtained with a greater number of screened children.

The fact that the influence of UNHS on language development was less than that of early intervention suggests that participation in UNHS does not always ensure an improvement in language development, at least not without early intervention. Factors that may inhibit early intervention include the presence of progressive or late-onset hearing loss; dropout after UNHS; delay of referral to a specialist because of other severe complications during infancy; and false-negative cases, including auditory neuropathy spectrum disorder.[20] In this study, nearly half of the cases in which early intervention failed to commence after UNHS (29 of 59) were suspected to be cases of progressive or late-onset hearing loss. Watkin and Baldwin[20] reported in their large cohort study that 1.51 in 1,000 children showed moderate hearing loss or worse, but only 0.9 in 1,000 with this degree of hearing impairment had been identified by UNHS, 0.11 in 1,000 of whom were missed by screening, probably because of auditory neuropathy spectrum disorder, and 0.25 in 1,000 of whom were considered to have late-onset hearing loss. The number of progressive and late-onset hearing loss and false-negative cases can be significant; about 25% of hearing-impaired children in the United Kingdom (21%, in our study) were not identified by UNHS. The difference between the UK statistic and ours is partly explained by the fact that the UNHS equipment used in Japan combines the automated auditory brain stem response with otoacoustic emissions (Aso and Fukushima, personal communication).

Despite its limited effect on language development, as indicated in this study, UNHS plays a very important role in early identification of and intervention for hearing-impaired children, because its contribution to early intervention is highly significant. Participation in UNHS is currently the only way to achieve early intervention. Fitzpatrick et al[21] studied 65 children with mild to profound hearing impairment under 5 years of age and reported that

Details of 139 children who underwent universal newborn hearing screening.



UNHS results in earlier identification and intervention for children with permanent hearing loss. Wolff et al[22] reviewed 17 studies and concluded that early identification and treatment of children with hearing impairments may be associated with advantages in terms of language development. Our results fully support those of their reports.

Now that more than 60% of newborn infants currently receive UNHS in Japan, the establishment of a robust system for the post–hearing screening period is required. This system must include further examination and/or early intervention for all referred cases, and a follow-up system for children who "pass" initial screening to test for progressive or late-onset hearing loss and auditory neuropathy spectrum disorder. One possible way to achieve this goal in Japan is to enhance the existing health checkup system for 18-month-old infants and 36-month-old toddlers. To make the most of UNHS, it is necessary to work toward social acceptance to ensure that early identification leads directly to early intervention.

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Language Ability in the Intermediate-Scoring Group of Hearing-Impaired Children

Akiko Sugaya, MD; Kunihiro Fukushima, MD, PhD; Norio Kasai, MD, PhD; Akie Fujiyoshi; Tomoko Taguchi; Kana Omori; Toshiyuki Ojima, MD, PhD; Kazunori Nishizaki, MD, PhD

Objectives: Language development is a key issue in hearing-impaired children. However, interpersonal differences complicate our understanding of the situation. The bimodal or trimodal distribution of language scores in our other reports in this publication imply the presence of fundamental differences among these groups. The characteristic aspects of each group were profiled according to language data.

Methods: We divided 268 children with prelingual severe to profound hearing impairment into 3 groups according to their trimodal distribution observed on histogram-based analysis of their responses to the Test of Question-Answer Interaction Development. Test results in several language domains, including productive and comprehensive vocabulary, productive and comprehensive syntax, and academic achievement, were profiled and compared among these 3 groups.

Results: Significant differences were observed in the results of the Word Fluency Test, the Picture Vocabulary Test–Revised, and the Syntax Test of Aphasia among the 3 groups. No significant difference was observed between groups who were lower-scoring and intermediate-scoring on the academic achievement tests referred to as Criterion Referenced Test–II and the Standardized Comprehension Test for Abstract Words. Only the higher-scoring group showed excellent results. The demographic factors were not significantly different among the 3 groups.

Conclusions: Relatively poor academic achievement despite fair language production was the dominant feature of the intermediate-scoring group. This profile might correlate with academic failure in school.

Key Words: academic achievement, hearing impairment, interpersonal communication, language development.

INTRODUCTION

Many new technologies, including newborn hearing screening and cochlear implants, have improved the auditory experience of hearing-impaired children in the past 20 years. Despite these advances, a wide variety of developmental differences in terms of language can still be observed among hearing-impaired children. These differences may be caused by many different variables[1-5] (eg, family involvement, behavioral issues, consistency of amplification, noise levels in day-care settings, additional disabilities, quality of intervention, and cochlear implants) and can affect the children's quality of life. Thus, understanding these differences is important for specialists working with hearing-impaired children.

As detailed elsewhere in this publication, considerable research has been performed on differences in language development in both hearing-impaired and normal-hearing children. According to a histogram of results of the Test of Question-Answer Interaction Development (TQAID),[6] which is accepted as an index test of children's communication abilities, language development in hearing-impaired children shows a consistent trimodal distribution throughout the grades. The higher-scoring group seems to demonstrate language development comparable to or even superior to that of their normal-hearing peers. The language development of the intermediate-scoring group is on the average for hearing-impaired children, although slower than that of normal-hearing children.

The intermediate-scoring group, in which the majority of hearing-impaired children fall, is not well characterized. The aim of this study was to investi-

From the Department of Otolaryngology–Head and Neck Surgery, Okayama University Postgraduate School of Medicine, Dentistry, and Pharmaceutical Science (Sugaya, Fukushima, Kasai, Fujiyoshi, Taguchi, Omori, Nishizaki), and the General Rehabilitation Center, Okayama University Hospital (Fujiyoshi, Taguchi), Okayama; the Association for Technical Aids, Tokyo (Kasai, Omori); and the Department of Community Health and Preventive Medicine, Hamamatsu University School of Medicine, Hamamatsu (Ojima); Japan.
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Correspondence: Kunihiro Fukushima, MD, PhD, Dept of Otolaryngology–Head and Neck Surgery, Okayama University Postgraduate School of Medicine, Dentistry, and Pharmaceutical Science, 2-5-1 Shikata-cho, Kita-ku, Okayama 700-8558, Japan.

gate the features of the intermediate-scoring group. We analyzed the epidemiology of this population of hearing-impaired children, and created detailed profiles of several language domains in the intermediate-scoring group.

METHODS

DESIGN AND PARTICIPANTS

This study involved hearing-impaired children who were part of the Research on Sensory and Communicative Disorders (RSCD) project, a multicenter study involving children studying or consulting in cooperative institutions across Japan, including deaf schools, a self-contained classroom for hearing-impaired children, training centers, and hospital training rooms. The participants met the following inclusion criteria: age 4 to 12 years during the research period (April 2009 to March 2010); prelingual and severe-to-profound hearing impairment (greater than 70 dB on average); and ability to complete several language tests. Children with additional disabilities were excluded as follows.

The following criteria ruled out handicaps other than hearing loss that hamper language development: low birth weight (<1,830 g, suggesting severe complications that might delay intervention); a low Raven's Coloured Progressive Matrices (RCPM)[7] score (greater than −2 SD for children in the same grade, suggesting nonverbal intellectual delay); a high score on the PARS (Pervasive Developmental Disorders [PDD] Autism Society of Japan [ASJ] Rating Scale)[8] (greater than 11, suggesting pervasive developmental disorder–like behavior characteristics); and a low score on the Screening Test of Reading and Writing for Japanese Primary School Children (STRAW; greater than −1.5 SD for children in the same grade, suggesting the presence of dyslexia).[9,10]

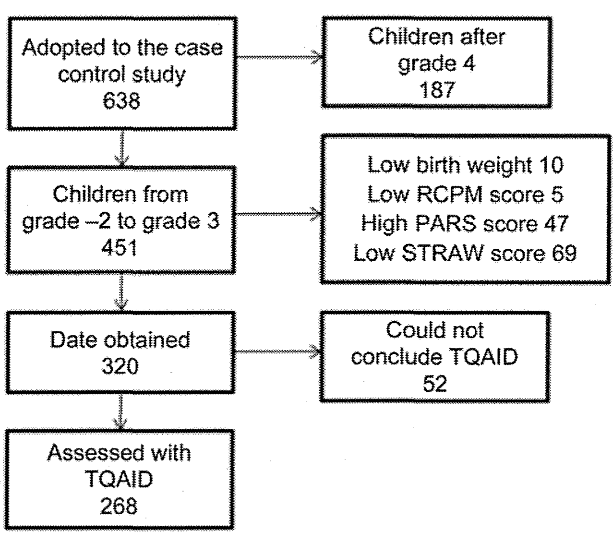

Fig 1. Participant flowchart for hearing-impaired children. Grade −2 stands for preschoolers 2 years before entering school, and grade −1 for preschoolers 1 year before entering school. See text for abbreviations of test names.

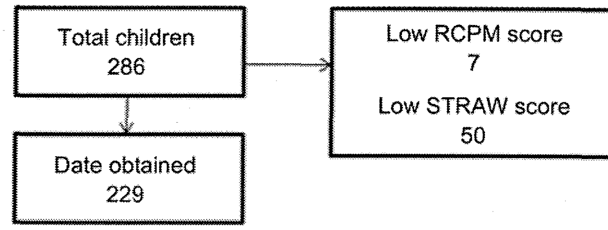

Fig 2. Participant flowchart for normal-hearing children.

In total, 638 children (4 to 12 years of age) were enrolled in the case-control study. Because the results of the TQAID showed ceiling effects, the data from children in grades higher than 4th grade were excluded. Thus, data were available for 451 children. After exclusion of those with additional handicaps (10 children with a low birth weight, 5 with a low RCPM score, 47 with a high PARS score, and 69 with a low STRAW score), data for 320 hearing-impaired children (grade −2 to grade 3) were used in the analysis. The TQAID was completed by 268 children whose data were used in the analysis (Fig 1). In addition, 286 normal-hearing peers were tested. Those with low RCPM scores (n = 7) and low STRAW scores (n = 50) were excluded. Finally, data from 229 normal-hearing children were obtained (Fig 2).

Language tests and questionnaires were distributed to the children's caregivers, teachers, and speech-language-hearing therapists after written informed consent had been obtained. The study design was approved by the central and local Institutional Review Boards.

LANGUAGE ASSESSMENTS

The participants were tested by an experienced speech-language-hearing therapist face-to-face in a sound-attenuated chamber, wearing their usual hearing devices (ie, hearing aids or cochlear implants). They underwent a series of tests from the Assessment Package for Language Development in Japanese Hearing-Impaired Children (ALADJIN; this publication, pp 3-15), which includes the following: the TQAID, the Japanese-language Criterion Referenced Test–II (CRT-II)[11] for measuring academic achievement in Japanese and mathematics, the Picture Vocabulary Test–Revised (PVT-R),[12] the Standardized Comprehension Test of Abstract Words (SCTAW),[13] both parts of the Syntactic Processing Test for Aphasia (STA),[14] and the Word Fluency Test (WFT).[15-17] The SCTAW and the CRT-II were

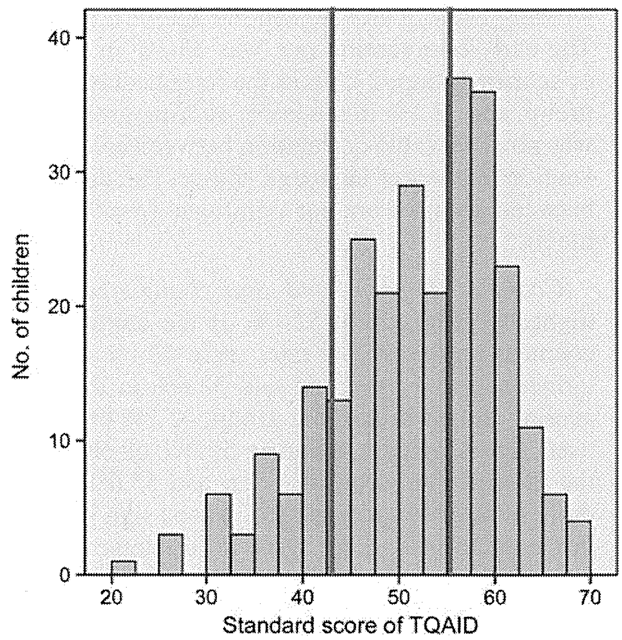

Fig 3. Histogram on which horizontal axis stands for standard score of Test of Question-Answer Interaction Development (TQAID), and vertical axis for number of children from grades –2 to 3.

used with school-age children only.

Questionnaires were also distributed to caregivers, soliciting the following information about the participants: birth date, birth weight, sex, age at identification of deafness, participation in universal newborn hearing screening (UNHS), age at commencement of hearing aid use, type of hearing device, mode of communication, family structure, annual income, and academic qualifications of caregivers. In order to double-check the answers from caregivers, we also distributed similar questionnaires to the teachers and speech-language-hearing therapists who routinely saw the targeted children. The language tests except for the PARS were also performed on normal-hearing children.

STATISTICAL ANALYSIS

The TQAID scores for the normal-hearing children and the hearing-impaired children in the higher-scoring group were compared by a 2-sample *t*-test. Pearson's χ^2 test was used to assess differences in gender, participation in UNHS, age of intervention, use of sign language or cochlear implants, annual family income, and family size among the 3 groups. The scores on the ALADJIN were converted to standard scores, that is, the number of standard deviations by which the scores differed from the mean scores (50 + 10 × "standard score") in each grade. We performed a post hoc test (Tukey's honestly significant difference or Dunnett's C) when the language test scores among the 3 groups were significantly different by an analysis of variance. The significance (p) level was set at 0.05, and the 95% confidence interval was also calculated. The statistics were computed with IBM SPSS version 19 (IBM Corp, Armonk, New York).

TABLE 1. POSITION OF DIPS OBSERVED IN HISTOGRAM OF FIGURE 3

Grade	*First Dip*	*Standard Score (Raw Data)*	*Second Dip*	*Standard Score (Raw Data)*
–2	175	57.2 (173.1)	75	42.2 (75.8)
–1	200	56.3 (200)	125	45.7 (128.5)
1	225	53.8 (223.8)	125	40.2 (125.4)
2	250	54.7 (250)	163	41.0 (164)
3	250	52.8 (249.7)	213	45.6 (213)
Mean	274.8	54.96	214.7	42.94

Higher score is shown in first dip, and lower score in second dip. Standard score from raw data of Test of Question-Answer Interaction Development (TQAID) of each grade was calculated, and average scores are shown in Table.

RESULTS

HISTOGRAM-BASED ANALYSIS OF TQAID

Figure 3 represents the results of the TQAID in our sample from grade –2 to grade 3. The details of the distribution of the TQAID are described in another article in this publication (pp 3-15). There were 2 dips and 3 peaks in the histogram. We calculated the standard scores of the results of the TQAID and matched them with the raw scores (Table 1). According to the data, the first dip occurred at 55 and the other at 43 (rounded to the closest whole number). Thus, we divided the children into 3 groups according to standard score. The children whose standard scores were at least 55 were defined as the higher-scoring group (n = 117; 43.7%), the children whose standard scores were between 43 and 55 were the intermediate-scoring group (n = 123; 45.9%), and the children whose standard scores were 43 or less made up the lower-scoring group (n = 28; 10.4%).

T-TEST ANALYSIS OF HIGHER-SCORING AND NORMAL-HEARING GROUPS

We performed a 2-sample *t*-test comparing the scores of the TQAID between the normal-hearing group and the higher-scoring group in each grade. The scores were not significantly different among the children in grades –1 to 3 (Table 2).

PEARSON'S CHI-SQUARE TEST OF DEMOGRAPHIC FACTORS

Gender. Overall, there were 138 boys (51.5%), 125 girls (46.6%), and 5 participants of unspecified gender (1.9%) in this study. The male-to-female ratio in the higher-scoring and intermediate-scoring groups was almost equal, but in the lower-scoring

TABLE 2. TWO-SAMPLE *T*-TEST OF TQAID FROM GRADES –1 TO 3

Grade	Number NH	Number HI	Mean NH	Mean HI	p
–1	99	25	230.1	227.9	0.737
1	60	34	255.6	258.8	0.480
2	32	15	269.1	269.9	0.855
3	38	18	273.2	280.7	0.074

Scores of normal-hearing (NH) children and higher-scoring group of hearing-impaired (HI) children are compared.

group, there were 20 boys (71.4%), 7 girls (25.0%), and 1 participant of unspecified gender (3.6%). In that group, the number of boys was 3 times more than the number of girls, but there was no statistically significant difference between the numbers of boys and girls among the 3 groups as a whole (p = 0.058; Table 3).

UNHS Participation and Age of Intervention. In total, 116 hearing-impaired children (43.3%) had undergone UNHS, 139 (51.9%) had not been screened, and for 13 (4.8%), it was unknown whether they had undergone screening. Among the 3 groups, the UNHS participation rates were as follows: higher-scoring group, 46.2%; intermediate-scoring group, 39.8%; and lower-scoring group, 46.4%. No fixed patterns were evident, and the difference was not significant (p = 0.418; Table 3).

The age at which intervention was commenced was also analyzed. We defined early intervention as wearing hearing aids before the age of 6 months.[18] The early-intervention rate was 33.3% in the higher-scoring group, 27.6% in the intermediate-scoring group, and 32.1% in the lower-scoring group. There was no observable correlation between earlier intervention and better language ability. The differences between groups were not significant (p = 0.630; Table 3).

Cochlear Implant and Sign Language. In the higher-scoring group, 52.1% of the children wore cochlear implants. The rates were 43.1% in the intermediate-scoring group and 53.6% in the lower-scoring group. In the first group, 42.7% of children used sign language, whereas 55.3% of children in the intermediate-scoring group and 53.6% of children in the lower-scoring group used sign language. For both factors, there were no obvious trends or significant differences between groups (p = 0.311 and p = 0.110, respectively; Table 3).

Annual Family Income and Family Size. In the higher-scoring group, 49.6% of children came from families with an annual income of at least ¥5,000,000. The percentages were 37.4% in the intermediate-scoring group and 28.6% in the lower-scoring group. The highest income was observed in the higher-scoring group, but the differences were not significant among the 3 groups (p = 0.111; Table 3).

We also compared the 3 groups in terms of family

TABLE 3. DEMOGRAPHIC FACTORS OF THREE GROUPS

		Higher-Scoring (n = 117)	*Intermediate-Scoring (n = 123)*	*Lower-Scoring (n = 28)*	*p**
Sex	Male	56 (47.9%)	62 (50.4%)	20 (71.4%)	0.058
	Female	58 (49.6%)	60 (48.8%)	7 (25.0%)	
	Unknown	3 (2.5%)	1 (0.8%)	1 (3.6%)	
Universal newborn hearing screening	Received	54 (46.2%)	49 (39.8%)	13 (46.4%)	0.418
	Not received	57 (48.7%)	70 (56.9%)	12 (42.9%)	
	Unknown	6 (5.1%)	4 (3.3%)	3 (10.7%)	
Use of hearing aids	≤6 mo	39 (33.3%)	34 (27.6%)	9 (32.1%)	0.630
	>6 mo	78 (66.7%)	88 (71.5%)	18 (64.3%)	
	Unknown	0 (0.0%)	1 (0.8%)	1 (3.6%)	
Use of cochlear implant	Yes	61 (52.1%)	53 (43.1%)	15 (53.6%)	0.311
	Now	56 (47.9%)	70 (56.9%)	13 (46.4%)	
Use of sign language	Yes	50 (42.7%)	68 (55.3%)	15 (53.6%)	0.110
	Now	67 (57.3%)	54 (43.9%)	12 (42.9%)	
	Unknown	0 (0.0%)	1 (0.8%)	1 (3.5%)	
Annual income	≥¥5,000,000	58 (49.6%)	46 (37.4%)	8 (28.6%)	0.111
	<¥5,000,000	46 (39.3%)	56 (45.5%)	15 (53.6%)	
	Unknown	13 (11.1%)	21 (17.1%)	5 (17.8%)	
Family size	≥4 persons	94 (80.3%)	105 (85.4%)	23 (82.1%)	0.395
	≤3 persons	23 (19.7%)	16 (13.0%)	4 (14.3%)	
	Unknown	0 (0.0%)	2 (1.6%)	1 (3.6%)	

*Pearson's χ^2 test.

TABLE 4. MULTIPLE COMPARISONS OF ALADJIN SCORES OF THREE GROUPS

Language Test	*Scoring Group*	*No. of Pts*	*Average*	*p Value (Tukey HSD) or 95% Confidence Interval (Dunnett C)*		
WFT	High	91	56.21	<0.001*		
	Intermediate	111	49.98	<0.001*	<0.001*	
	Low	25	41.77			
PVT-R	High	99	57.07	−10.685 to −5.132*		
	Intermediate	116	49.16	2.844 to 8.833*		10.401 to 17.092*
	Low	26	43.33			
SCTAW	High	44	56.13	0.001*		
	Intermediate	54	49.23	0.748	0.015*	
	Low	9	46.91			
STA production	High	94	56.70	−9.747 to −4.378*		
	Intermediate	112	49.64	3.981 to 11.188*		11.045 to 18.248*
	Low	26	42.05			
STA comprehension	High	95	57.55	<0.001*		
	Intermediate	112	49.16	0.002*	<0.001*	
	Low	24	42.71			
CRT Japanese	High	48	56.77	0.001*		
	Intermediate	47	51.63	0.783	0.014*	
	Low	9	50.06			
CRT mathematics	High	48	56.48	−7.422 to −1.811*		
	Intermediate	47	51.86	−8.707 to 8.602		−3.798 to 12.927
	Low	9	51.92			

See text for abbreviations of test names.
*Significant difference.

size. In the higher-scoring group, 19.7% of households had no more than 3 family members living together. In the intermediate-scoring group, this percentage was 13.0%, and in the lower-scoring group it was 14.3%. In the higher-, intermediate-, and lower-scoring groups, 80.3%, 85.4%, and 82.1% of households, respectively, had 4 or more family members living together. There were no significant differences among the 3 groups ($p = 0.395$; Table 3).

COMPARISON OF ALADJIN SCORES

There were significant differences in standard scores in the higher-, intermediate-, and lower-scoring groups for the PVT-R, the STA, and the WFT. On the other hand, the standard scores of the SCTAW and the CRT-II in the intermediate-scoring group were significantly different from those in the higher-scoring group, but there was no difference from the lower-scoring group. The results are shown in Table 4.

DISCUSSION

According to the language scores in the 3 groups as defined by the results of the TQAID, there was no significant difference between the intermediate- and lower-scoring groups in the scores on the SCTAW and the CRT-II. Both tests reflect or directly indicate academic achievement, mainly in an educational environment. On the other hand, the scores of the intermediate-scoring group on the other language tests, which indicate ability in the areas of productive vocabulary (WFT), perceptive vocabulary (PVT-R), and productive and comprehensive syntax (STA), were between those of the higher- and lower-scoring groups.

The association between the TQAID and the other language domains was confirmed in both normal-hearing and hearing-impaired children (this publication, pp 3-15 and 35-39). We initially assumed consistent differences throughout all language domains in this study. However, it is interesting that only academic achievement in the intermediate-scoring group was indistinguishable from that of the lower-scoring group. This finding implies that the members of the intermediate-scoring group can hear and speak well, or at least better than children in the lower-scoring group, although they might still have difficulty with academic achievement. Detailed language analysis is required to reveal the presence of this intermediate-scoring group.

To identify the prevailing cause of the results, we also analyzed the backgrounds of the children in the intermediate-scoring group, but found no significant differences for them. Early identification of and intervention for hearing impairment[19] (also this publication, pp 16-20), gender,[20] family income,[21] and the use of cochlear implants[22] were considered to be the possible causes of the difference in language development, but the distribution of these factors was not significantly different among the groups. There is still the possibility that with a larger sample, significant differences might exist. However, these findings suggest the importance of identifying the intermediate-scoring group through domain-based analysis such as the ALADJIN.

Language domain–based analysis with the ALADJIN facilitates early diagnosis of children in the intermediate-scoring group. In addition, such an analysis makes appropriate intervention possible for the improvement of language development. As the vocabulary and syntax abilities of the intermediate-scoring group lie in the middle position, appropriate intervention may ultimately make this group comparable to the higher-scoring group in these abilities. Their academic achievement could ultimately be equivalent to that of the higher-scoring group, as a consequence. Further study of RSCD results is necessary for evaluating the long-term outcome.

There are some limitations to this study. First, because the results of the TQAID showed a ceiling effect, those for children in grade 4 and above were not considered in this study. Second, to draw definite conclusions about possible problems in children who fall into the intermediate-scoring group, multivariate and carefully executed longitudinal studies on large groups of children are needed to understand individual differences and guide intervention practices. Even with these limitations, the current study provides important insights about hearing-impaired children.

Finally, because there were no confirmed Japanese language assessment tools with which to examine these children in the past, there is a possibility that the children in the intermediate-scoring group were simply left untreated. These children would be able to speak relatively fluently, and might be judged to have satisfactory development; however, they might also have inapparent problems in school. It is important to identify these children and start to plan appropriate interventions. Domain-based language evaluation using the ALADJIN is needed to detect these problems in hearing-impaired children who are Japanese language users.

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Syntactic Development in Japanese Hearing-Impaired Children

Akie Fujiyoshi; Kunihiro Fukushima, MD, PhD; Tomoko Taguchi; Kana Omori; Norio Kasai, MD, PhD; Shinya Nishio, PhD; Akiko Sugaya, MD; Rie Nagayasu; Takayuki Konishi; Syuuhei Sugishita; Jyunpei Fujita; Kazunori Nishizaki, MD, PhD; Masae Shiroma, PhD

Objectives: This study examined syntactic development of auditory comprehension of sentences in Japanese-speaking school-age children with and without hearing impairment.

Methods: In total, 592 preschool and school-age children (421 normal-hearing and 171 hearing-impaired) were included in this cross-sectional observation study conducted using the Syntactic Processing Test for Aphasia for Japanese language users. Linear regression analysis was used to determine the estimated age at which each syntactic structure was acquired.

Results: Acquisition of syntactic structures was observed in hearing-impaired and normal-hearing children. Basic word order sentences of agent-object-verb and the goal benefactive construction were acquired at preschool age (earlier group), whereas reverse word order sentences of object-agent-verb, source benefactive construction, passive voice, and relative clauses were acquired at school age (later group). The results showed that many hearing-impaired children may not acquire Japanese grammatical structures until the age of 12 years.

Conclusions: Adequate screening for language development for school-age hearing-impaired children is required for an effective intervention.

Key Words: cochlear implant, hearing impairment, language development, syntactic development.

INTRODUCTION

Comprehension of sentence structure is a key component of syntax, which is the grammatical arrangement of words in spoken utterances or sentences.[1] Because adequate assessment of syntactic and vocabulary development is important for planning effective intervention programs for educating hearing-impaired children (this publication, pp 3-15 and 21-27), many different tests, such as the Test for Reception of Grammar 2 (TROG-2)[2] or the Test for Auditory Comprehension of Language 3,[3] are available for English-speaking populations. The Syntactic Processing Test for Aphasia (STA) is the first established TROG-like comprehension test for Japanese sentence structures.[4] This test was originally developed for evaluating auditory and reading comprehension, as well as production of syntactic structures, for patients with aphasia. Currently, the test is also used for school-age children.[4]

A few notes should be made about understanding Japanese syntax in comparison to that of Indo-European languages. The standard Japanese word order has a subject-object-verb (SOV) or agent-object-verb (AOV) pattern, unlike many Indo-European languages, which tend to have a subject-verb-object (SVO) order, and the word order in Japanese is not as strict as that in Indo-European languages. The only strict rule of word order is that the verb should be placed at the end of a sentence; other elements such as subjects or objects in the sentence can be placed in various orders or even omitted when they are identified by the context. Instead, postpositional particles such as "*ga*," "*wo*," "*ni*," and "*kara*" play an important role in identification of semantic features of sentences. In this study, we examined the timing of syntactic processing, age, and sequence of

From the Department of Otolaryngology–Head and Neck Surgery, Okayama University Postgraduate School of Medicine, Dentistry, and Pharmaceutical Science (Fujiyoshi, Fukushima, Taguchi, Omori, Kasai, Sugaya, Nagayasu, Nishizaki), and the General Rehabilitation Center, Okayama University Hospital (Fujiyoshi, Taguchi, Konishi, Fujita), Okayama; the Association for Technical Aids, Tokyo (Omori, Kasai); the Department of Otolaryngology, Shinshu University, Matsumoto (Nishio); the Department of Rehabilitation, Takasago Municipal Hospital, Takasago (Sugishita); and the Department of Speech and Hearing Science, School of Health Science, International University of Health and Welfare, Ohtawara (Shiroma); Japan. This work was a part of the Research on Sensory and Communicative Disorders project, which is supported by a grant from the Ministry of Health, Labor, and Welfare of Japan.

Correspondence: Kunihiro Fukushima, MD, PhD, Dept of Otolaryngology–Head and Neck Surgery, Okayama University Postgraduate School of Medicine, Dentistry, and Pharmaceutical Science, 2-5-1 Shikata-cho, Kita-ku, Okayama City, Okayama 700-8558, Japan.

TABLE 1. AGE DISTRIBUTION OF HEARING-IMPAIRED AND NORMAL-HEARING CHILDREN

Age (y)	*Normal-Hearing*		*Hearing-Impaired*			
	Total	*Final**	*Total*	*Final**	*Cochlear Implant*	*Hearing Aids*
4			11	11	3	8
5	57	57	21	25	15	10
6	96	92	16	13	6	7
7	63	53	30	21	14	7
8	59	54	23	17	11	6
9	39	35	21	13	8	5
10	50	43	16	12	7	5
11	57	46	17	11	7	4
12			16	8	4	4
Total	421	380	171	131	75	56

*Not excluded by scores on Raven's Coloured Progressive Matrix Test or Standardized Comprehension Test of Abstract Words.

TABLE 2. AGE DISTRIBUTION OF ACQUISITION RATES OF VARIOUS SENTENCE STRUCTURES IN NORMAL-HEARING CHILDREN

Age (y)	*AOV*	*Benefactive Goal*	*Benefactive Source*	*Reverse Word Order*	*Passive Voice*	*Relative Clauses ORRC*	*Relative Clauses SRRC*
5	95.5	90.9	45.5	52.3	22.7	40.9	43.2
6	92.9	96.4	60.7	67.9	64.3	82.1	71.4
7	100.0	96.7	80.0	70.0	63.3	83.3	80.0
8	100.0	96.4	92.9	82.1	75.0	89.3	92.9
9	100.0	100.0	100.0	88.2	88.2	94.1	94.1
10	100.0	100.0	100.0	91.3	100.0	100.0	100.0
11	100.0	100.0	91.7	79.2	91.7	79.2	83.3

Data are percentages.

AOV — agent-object-verb sentences; ORRC — object-related relative clauses; SRRC — subject-related relative clauses.

acquisition for various sentence forms in hearing-impaired and normal-hearing children.

SUBJECTS AND METHODS

A total of 421 normal-hearing children living in 18 different districts in Japan were administered the STA. To avoid the effect of additional developmental problems, we administered the Standardized Comprehension Test of Abstract Words (SCTAW)[5] and Raven's Coloured Progressive Matrix Test (RCPM),[6] and 41 children were excluded because their SCTAW scores were less than 6 or their RCPM scores were less than −2 SD.

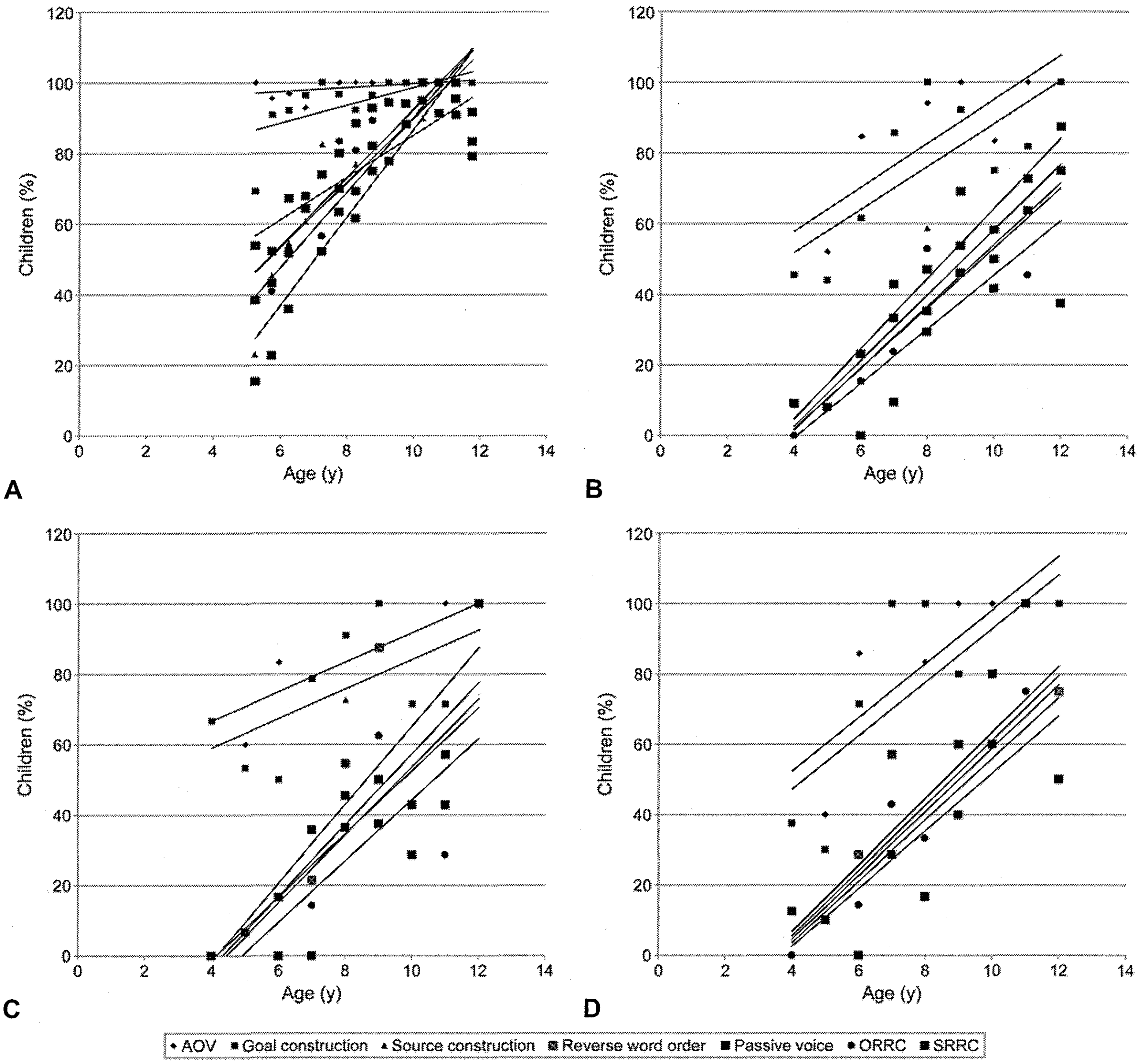
The age-specific distribution of the normal-hearing children included in the sample was as follows: 57 were 5 years of age, 92 were 6 years of age, 53 were 7 years of age, 54 were 8 years of age, 35 were 9 years of age, 43 were 10 years of age, and 46 were 11 years of age. In total, 380 normal-hearing children were included in the study.

A total of 171 hearing-impaired children from 11 districts in Japan were administered the STA. The same exclusion criteria were used as with the hearing children. Eleven children were 4 years of age, 25 were 5 years of age, 13 were 6 years of age, 21 were 7 years of age, 17 were 8 years of age, 13 were 9 years of age, 12 were 10 years of age, 11 were 11 years of age, and 8 were 12 years of age. Thus, a total of 131 hearing-impaired children were included in this study. Among them, 75 had cochlear implants and 56 had hearing aids. The detailed backgrounds of the children are summarized in Table 1. The study design was approved by our ethics committee. Written informed consent was obtained from the parents of all participants.

All participants were evaluated by trained speech-language-hearing therapists in noise-controlled rooms in a one-on-one setting. For the hearing-impaired children, individually optimized hearing devices, including hearing aids and/or cochlear implants, were activated before the test. The children were requested to point to 1 picture out of 4 after listening to each target sentence.

For this study, two approaches for determining the age acquisition of the syntactic processing were taken: one was analysis based on the acquisition of sentences, and the other was based on the hierarchy level shown in the STA manual. The acquisition of sentence structures was categorized as follows: a basic AOV structure (agent-object-verb); a benefactive construction of AOGV (agent-object-goal-verb), which is called goal construction; AOBV (agent–object–beneficiary source–verb), which is called source construction; a reverse word order sentence of OAV (object-agent-verb); a passive voice sentence; and relative clauses that are subject-related (SRRC) or object-related (ORRC). Four sentences were used for each structure; when a child comprehended 3 of 4 sentences of a given structure, the child was assumed to have acquired that structure.

According to the STA manual, there are 4 levels of hierarchy based on the strategies for auditory comprehension syntax processing, and each level consists of 8 sentences. In addition to those sentences, there are 8 relative clause sentences (4 SRRC and 4 ORRC). Level I is the easiest that is based on semantic strategy (AO or AOV structure), and one could understand such sentences using only one cue of the agent or the verb (eg, "a boy walks" or "a boy kicks the ball"). Level II is based on the basic word order strategy in which the agent appears at the beginning of sentences, such as "the mother pushes a boy" or "the mother gives a cake to a boy." Levels III and IV are based on the particle strategy; level



Linear regressions of syntax acquisition. **A)** In normal-hearing children. **B)** In hearing-impaired children. **C)** In cochlear implant users. **D)** In hearing aid users. AOV — agent-object-verb sentences; ORRC — object-related relative clauses; SRRC — subject-related relative clauses.

III is sentences without a complement, such as "the boy is pushed by his mother," and level IV is sentences with a complement in passive voice such as "a pencil that belongs to the boy was taken away by his mother." In addition to those sentences, relative clauses that are subject-oriented or object-oriented are also included in the test.

The age-specific acquisition rate was calculated by dividing the number of children who had acquired the given structures by the number of children in a specific age group. Regression estimates of age at 60% of the acquisition rate were performed and defined as the acquisition age of each structure or level. All statistical values were calculated with IBM SPSS Statistics 19 software (IBM Corp, Armonk, New York).

RESULTS

Normal-Hearing Children. The acquisition rates for each structure for normal-hearing children are listed in Table 2. The basic word order was acquired with 95.5% accuracy (5 years and older). For benefactive construction, goal construction was acquired early (90.9% of 5-year-olds and 96.4% of 6-year-olds), but source construction was acquired slightly later (45.5% of 5-year-olds, 60.7% of 6-year-olds, and 92.9% of 8-year-olds). The reverse word order structure was acquired at almost the same time as

TABLE 3. STATISTICAL SIGNIFICANCE OF SYNTACTIC ACQUISITION AGE IN NORMAL-HEARING CHILDREN

		Benefactive Construction		*Reverse*		*Relative Clauses*	
	AOV	*Goal*	*Source*	*Word Order*	*Passive Voice*	*ORRC*	*SRRC*
AOV		0.6011	0.0027	0.0007	0.0002	0.0048	0.0008
Goal			0.0049	0.0010	0.0003	0.0087	0.0012
Source				0.7473	0.0715	0.6657	0.9370
Reverse word order					0.0281	0.4698	0.7509
Passive voice						0.2130	0.0461
ORRC							0.2899
SRRC							

Data are p values.

source construction; 52.3% of 5-year-olds, 67.9% of 6-year-olds, and 82.1% of 8-year-olds had acquired this structure at the time of testing. Passive voice was also acquired later; 22.7% of 5-year-olds, 64.3% of 6-year-olds, and 75.0% of 8-year-olds had acquired this structure at the time of testing. Relative clauses with the ORRC structure had been acquired by 40.9% of 5-year-olds, 82.1% of 6-year-olds, and 89.3% of 8-year-olds, whereas relative clauses with the SRRC structure had been acquired by 43.2% of 5-year-olds, 71.4% of 6-year-olds, and 92.9% of 8-year-olds.

Regression analysis revealed the age of acquisition of each syntactic structure. The Figure, A, illustrates the ages of acquisition for basic word order, goal construction, source construction, reverse word order, passive voice, and relative clauses (ORRC and SRRC). Significant differences were observed between structures acquired earlier and those acquired later (AOV sentences versus all later-acquired structures, $p = 0.002$ to $p = 0.0027$, and goal construction versus all later-acquired structures, $p = 0.0003$ to $p = 0.0049$; Table 3). Among the later-acquired structures, significant differences were observed only between reverse word order structure and passive voice ($p = 0.0281$).

The acquisition rates for each age group are summarized in Table 4 according to the categorization system of the original STA manual. Regression analysis of these data revealed the age of acquisition at each level. Levels I and II were achieved before 5 years of age, level III was achieved at 7 years 11 months, level IV at 9 years 8 months, and relative clauses at 7 years 9 months.

TABLE 4. LEVEL DISTRIBUTION OF SYNTACTIC COMPREHENSION IN NORMAL-HEARING CHILDREN

	Age 5 y	*Age 6 y*	*Age 7 y*	*Age 8 y*	*Age 9 y*	*Age 10 y*	*Age 11 y*
Level II	84.2	86.2	98.2	94.4	100.0	97.8	100.0
Level III	26.3	36.2	50.9	59.3	85.3	80.0	89.4
Level IV	5.3	13.8	23.6	33.3	67.6	57.8	76.6
Relative clauses	14.0	34.0	49.1	75.9	88.2	95.6	87.2

Data are percentages.

Hearing-Impaired Children. The acquisition rates for each structure for hearing-impaired children are listed in Table 5. The basic word order structure (AOV) was acquired relatively early; 52.0% of 5-year-olds, 84.6% of 6-year-olds, and 100% of 9-year-olds had acquired this structure at the time of testing. Goal construction was acquired at almost the same time as AOV; 44.0% of 5-year-olds and 61.5% of 6-year-olds had acquired this structure at the time of testing. Source construction was acquired slightly later; 8.0% of 5-year-olds, 15.4% of 6-year-olds, and 58.8% of 8-year-olds had acquired this structure at the time of testing. The reverse word order sentence structure (OAV) was also acquired later; 8.0% of 5-year-olds, 23.1% of 6-year-olds, and 47.1% of 8-year-olds had acquired this structure at the time of testing. Passive voice was acquired even later; 8.0% of 5-year-olds, 0% of 6-year-olds, 42.9% of 7-year-olds, 35.3% of 8-year-olds, 53.8% of 9-year-olds, 41.7% of 10-year-olds, 63.6% of 11-year-olds, and 75.0% of 12-year-olds had acquired this structure at the time of testing. Relative clauses with an ORRC structure had been acquired by 8.0% of 5-year-olds, 15.4% of 6-year-olds, and 52.9% of 8-year-olds,

TABLE 5. AGE DISTRIBUTION OF ACQUISITION RATE OF VARIOUS SENTENCE STRUCTURES IN HEARING-IMPAIRED CHILDREN

Age (y)	*AOV*	*Benefactive Goal*	*Benefactive Source*	*Reverse Word Order*	*Passive Voice*	*Relative Clauses ORRC*	*Relative Clauses SRRC*
4	45.5	45.5	0.0	9.1	9.1	0.0	9.1
5	52.0	44.0	8.0	8.0	8.0	8.0	8.0
6	84.6	61.5	15.4	23.1	0.0	15.4	0.0
7	85.7	85.7	33.3	33.3	42.9	23.8	9.5
8	94.1	100.0	58.8	47.1	35.3	52.9	29.4
9	100.0	92.3	53.8	69.2	53.8	53.8	46.2
10	83.3	75.0	50.0	50.0	41.7	50.0	58.3
11	100.0	81.8	63.6	72.7	63.6	45.5	72.7
12	100.0	100.0	75.0	87.5	75.0	75.0	37.5

Data are percentages.

TABLE 6. STATISTICAL SIGNIFICANCE OF SYNTACTIC ACQUISITION AGE IN HEARING-IMPAIRED CHILDREN

		Benefactive Construction		*Reverse*		*Relative Clauses*	
	AOV	*Goal*	*Source*	*Word Order*	*Passive Voice*	*ORRC*	*SRRC*
AOV		0.3275	0.0005	0.0003	0.0002	0.0001	<0.0001
Goal			0.0012	0.0009	0.0005	0.0003	0.0001
Source				0.5628	0.8477	0.7880	0.6782
Reverse word order					0.4223	0.3700	0.2776
Passive voice						0.9394	0.8818
ORRC							0.5576
SRRC							

Data are p values.

whereas relative clauses with an SRRC structure had been acquired by 8.0% of 5-year-olds, 0% of 6-year-olds, and 29.4% of 8-year-olds at the time of testing.

Regression analysis revealed the age of acquisition of each syntactic structure (see Figure, B). Significant differences were observed between the acquisition of AOV sentences and those of source construction ($p = 0.0005$), reverse word order ($p = 0.0003$), passive voice ($p = 0.0002$), relative clauses with an ORRC structure ($p = 0.0001$), and relative clauses with an SRRC structure ($p < 0.0001$). Furthermore, significant differences were observed between goal construction and source construction ($p = 0.0012$), reverse word order ($p = 0.0009$), passive voice ($p = 0.0005$), relative clauses with an ORRC structure ($p = 0.0003$), and relative clauses with an SRRC structure ($p = 0.0001$). Unlike in the normal-hearing children, significant differences between acquisitions of passive voice, reverse word order, and source construction were not observed in hearing-impaired children (Table 6).

The acquisition rates for each age group are summarized in Table 7 according to the categorization system of the original STA manual. Regression analysis of these data revealed the age of acquisition at each level. Level I was achieved before 4 years of age, level II was achieved by 7 years 2 months, and levels III and IV were not reached until 12 years in 60% of children at the time of testing.

Cochlear Implants and Hearing Aids. The acquisition rates and ages of the hearing aid and cochlear implant users are summarized in Tables 8 and 9 and the Figure, C,D. The acquisition ages of each structure for cochlear implant users were as follows: the AOV sentence structure was acquired before 4 years of age, goal construction at 4 years 2 months, source construction at 10 years 3 months, the reverse word order structure at 9 years 6 months, the passive voice at 10 years 8 months, relative clauses with an ORRC structure at 10 years 10 months, and relative clauses with an SRRC structure at 11 years 10 months. For hearing aid users, the acquisition ages are as follows: the AOV sentence structure was acquired at 5 years, goal construction at 5 years 9 months, source construction at 9 years 11 months, reverse word order at 9 years 8 months, passive voice at 11 years, relative clauses with an ORRC structure at 10 years 6 months, and relative clauses with an SRRC structure at 11 years.

DISCUSSION

This cross-sectional survey of syntactic development in normal-hearing and hearing-impaired children revealed differences in syntactic structure acquisition. Basic word order and goal construction were acquired at preschool age (earlier group), whereas reverse word order, source construction, passive voice, and relative clause structures were acquired during school age (later group). Statistically significant differences were observed between the two groups. Within-group comparison was not possible, except for a small difference in passive voice.

The results of this study indicated that nearly half of the hearing-impaired children who took part in the Research on Sensory and Communicative Disorders project may not properly acquire certain syntac-

TABLE 7. LEVEL DISTRIBUTION OF SYNTACTIC COMPREHENSION IN HEARING-IMPAIRED CHILDREN

	Age 4 y	*Age 5 y*	*Age 6 y*	*Age 7 y*	*Age 8 y*	*Age 9 y*	*Age 10 y*	*Age 11 y*	*Age 12 y*
Level I	63.6	68.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Level II	18.2	40.0	53.8	76.2	82.4	85.7	75.0	90.9	75.0
Level III	0	4	0	19.0	35.3	42.9	16.7	27.3	62.5
Level IV	0	0	0	4.8	11.8	14.3	0	9.1	37.5
Relative clauses	0	8	0	9.5	17.6	30.8	33.3	45.5	37.5

Data are percentages.

TABLE 8. STATISTICAL SIGNIFICANCE OF SYNTACTIC ACQUISITION AGE IN COCHLEAR IMPLANT USERS

		Benefactive Construction				*Relative Clauses*	
	AOV	*Goal*	*Source*	*Reverse Word Order*	*Passive Voice*	*ORRC*	*SRRC*
AOV		0.4188	0.0031	0.0021	0.0014	0.0004	0.0002
Goal			0.0066	0.0049	0.0032	0.0010	0.0004
Source				0.9851	0.9548	0.7194	0.6124
Reverse word order					0.9366	0.6889	0.5794
Passive voice						0.7530	0.6326
ORRC							0.7747
SRRC							

Data are p values.

tic structures until the age of 12 years. This statistic indicates the status of hearing-impaired children in Japan and emphasizes the necessity for intervention to prevent delay of their syntactic development during their elementary school years. Establishment of a screening system for early detection of such language delays will facilitate intervention strategies (this publication, pp 3-15 and 21-27).

Syntactic structures are acquired slightly earlier in cochlear implant users than in hearing aid users. The timing of syntactic structure acquisition in this group is similar to that of normal-hearing children. However, both hearing aid and cochlear implant users acquired certain structures at a later age. This fact again suggests the need for screening to detect language delay, regardless of the device, in school-age hearing-impaired children.

In terms of syntactic structure, differences between the "earlier" and "later" groups may be caused by differences in the grammatical subjects of the stimulation sentences. The later-acquired syntactic structures require conversion of grammatical and semantic subjects to comprehend the meaning of the sentences,[7] whereas the earlier-acquired syntactic structures do not.

In addition, minor difficulty in acquisition of the passive voice was observed in normal-hearing children. In the Japanese language, additional inflection is required to express passive voice. This difficulty may primarily be due to the need for conversion of cases and roles in this particular syntactic structure. Comprehension of inflection can present secondary problems. Thus, perhaps the training sequence for syntactic structures in developmental programs for hearing-impaired children should first include case-converting structures (ie, goal construction and source construction or reverse word order structures), later moving to structures that require converting inflection, because this follows the pattern of children's natural development.

Later-acquired structures are typically delayed in hearing-impaired children. Friedmann and Szterman[8] evaluated understanding and use of phrasal movement (relative clauses, topicalized sentences) in 20 Hebrew-speaking students with moderate to profound hearing impairment in comparison with those in their normal-hearing peers. The hearing-impaired children reportedly demonstrated deficits in comprehension and production of sentences requiring noun phrase movement. This case-conversion problem may be common among hearing-impaired children, regardless of language differences.

Interestingly, for normal-hearing children, the passive voice was the last sentence structure to be acquired among those examined with the STA, whereas in hearing-impaired children, relative clauses were last. This is the only difference between normal-hearing and hearing-impaired children in terms of the developmental sequence of syntax acquisition. Difficulties in acquisition of relative clauses have

TABLE 9. STATISTICAL SIGNIFICANCE OF SYNTACTIC ACQUISITION AGE IN HEARING AID USERS

		Benefactive Construction				*Relative Clauses*	
	AOV	*Goal*	*Source*	*Reverse Word Order*	*Passive Voice*	*ORRC*	*SRRC*
AOV		0.4449	0.0009	0.0006	0.0006	<0.0001	0.0001
Goal			0.0025	0.0019	0.0018	0.0002	0.0003
Source				0.9838	0.8932	0.6332	0.4871
Reverse order					0.9052	0.6381	0.4846
Passive voice						0.7426	0.5753
ORRC							0.7044
SRRC							

Data are p values.

been frequently noted in hearing-impaired children, as described by Davis and Blasdell.[9] Our study revealed that this is a unique characteristic in hearing-impaired children, in contrast to other syntactic structures and normal-hearing children. Several factors, including working memory[10] and other cognitive functions,[11] may influence the understanding of relative clauses. Several studies[12-14] have suggested that better working memory may play an important role in better sentence comprehension in hearing-impaired children. Further study is needed to clarify the cause of this characteristic deficit in syntax.

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Language Development, Interpersonal Communication, and Academic Achievement Among Japanese Children as Assessed by the ALADJIN

Syuuhei Sugishita; Kunihiro Fukushima, MD, PhD; Norio Kasai, MD, PhD; Takayuki Konishi; Kana Omori; Tomoko Taguchi; Akie Fujiyoshi; Toshiyuki Ojima, MD, PhD

Objectives: Japanese-speaking children in a standard sample were subjected to a test battery (ALADJIN: Assessment Package for Language Development in Japanese Hearing-Impaired Children) to evaluate the effect of language development on both interpersonal communication skills and academic achievement.

Methods: A total of 414 preschool and school-age children without hearing impairment were included in this study. The following tests make up the ALADJIN: the Test of Question-Answer Interaction Development (TQAID), the Japanese Language by Criterion Referenced Test–II (CRT-II) for measuring academic achievement, the Picture Vocabulary Test–Revised (PVT-R), the Standardized Comprehension Test of Abstract Words (SCTAW), both parts of the Syntactic Processing Test for Aphasia (STA), and the Word Fluency Test (WFT). Means and standard deviations at each academic grade level were calculated, and a multiple regression analysis was performed.

Results: A ceiling effect was observed for the TQAID and the STA in children in grade 3 of elementary school, and the scores for the PVT-R, SCTAW, and WFT increased incrementally according to grade level. Multiple regression analysis revealed that the PVT-R, WFT, and STA (production) have predictive power for the results of the TQAID ($R = 0.59$; $R^2 = 0.58$; $p < 0.0001$), whereas the SCTAW and STA (comprehension) have predictive power for the results of the CRT-II.

Conclusions: Both vocabulary and syntax are important in communication development among children. The results of our multiple regression analysis suggest that different language domains may play different roles in the development of interpersonal communication skills and in academic achievement. The development of interpersonal communication skills is largely based on productive vocabulary and syntax abilities, whereas academic achievement is largely based on comprehensive vocabulary and syntax abilities. Children who have difficulties in either area should be evaluated with detailed language assessment tools such as the ALADJIN in an effort to aid in the selection of appropriate intervention.

Key Words: academic achievement, interpersonal communication skills, language development.

INTRODUCTION

Knowing the processes of language development is an important step in understanding the degree of children's development.[1] The importance of language development increases during the school-age years, because language is crucial not only to interpersonal communication but also to academic achievement.[2] Language problems in this age group may lead to secondary learning problems that may ultimately limit occupational choice and social interaction.[3] Thus, monitoring language development in school-age children assists in identifying those who are at risk of language delay, including children with hearing impairment, autistic disorders, or intellectual problems.

Language development tests for at-risk children can aid in diagnosis, determination of the degree of delay, and intervention planning. The tests must be objective and easy to administer. The test results must be easily interpretable; ie, it should be clear how the results of a given language domain test may reflect academic achievement or interpersonal communication skills. Some information is difficult to obtain by inquiries of caregivers. Total

From the Department of Rehabilitation, Takasago Municipal Hospital, Takasago (Sugishita); the Department of Otolaryngology–Head and Neck Surgery, Okayama University Postgraduate School of Medicine, Dentistry, and Pharmaceutical Science (Fukushima, Kasai, Omori, Taguchi, Fujiyoshi), and the General Rehabilitation Center, Okayama University Hospital (Konishi, Taguchi, Fujiyoshi), Okayama; the Association for Technical Aids, Tokyo (Kasai, Omori); and the Department of Community Health and Preventive Medicine, Hamamatsu University School of Medicine, Hamamatsu (Ojima); Japan. This work was a part of the Research on Sensory and Communicative Disorders project, which is supported by a grant from the Ministry of Health, Labor, and Welfare of Japan.

Correspondence: Kunihiro Fukushima, MD, PhD, Dept of Otolaryngology–Head and Neck Surgery, Okayama University Postgraduate School of Medicine, Dentistry, and Pharmaceutical Science, 2-5-1 Shikata-cho, Kita-ku, Okayama 700-8558, Japan.