IMPACT OF EARLY INTERVENTION ON EXPRESSIVE AND RECEPTIVE LANGUAGE DEVELOPMENT AMONG YOUNG CHILDREN WITH PERMANENT HEARING LOSS

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LONG WITH EARLY DETECTION, early intervention (EI) is critical for children identified with hearing loss. Evidence indicates that many children with sensorineural hearing loss experience improved language abilities if EI services were initiated at an “early” age. The present study’s objectives were to determine the impact of a state EI program on language over time of children with permanent hearing loss and evaluate the association of EI enrollment by age 6 months with early language skill development. Young children in a state EI program were included in this longitudinal study. Results indicate that children enrolled prior to age 6 months were more likely to have age-appropriate language skills at baseline than children enrolled at or after 6 months, and maintained age-appropriate skills over time. Children enrolled at or after 6 months had lower baseline skills but made significant language progress, irrespective of hearing loss severity.

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Background

Moderate to profound permanent bilateral hearing loss is identified in 2–3 infants per 1,000 live births (Centers for Disease Control and Prevention [CDC], 2003; Finitzo, Albright, & O’Neal, 1998; Van Naarden, Decoufle, & Caldwell, 1999). Studies have shown the benefits of early intervention (EI) to early language and vocabulary development (Mayne, 1998a, 1998b; Moeller, 2000; Robinshaw, 1995; Strong, Clark, & Walden, 1994; Vohr et al., 2008; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). Furthermore, early identification of hearing loss in the first 6 months of life has positive effects on language and vocabulary development (Mayne, 1998a, 1998b; Yoshinaga-Itano & Apuzzo, 1998; Yoshinaga-Itano et al., 1998).

The primary focus in the implementation of EI services is on the potential to reduce negative effects of a condition or risk factor and thus promote optimal development over time. Combined with early detection, EI is critical for children identified with hearing loss. Evidence indicates that many children with sensorineural hearing loss have improvement in their language abilities if EI services were initiated at an “early” age (Bubbico, Di Castelbianco, Tangucci, & Salvinelli, 2007; Calderon, 1998; Moeller, 2000; Strong et al., 1994; Watkin et al., 2007; S. J.

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White & R. E. White, 1987). Children entering an EI program as early as 11 months of age have been shown to have higher language levels compared to children enrolled at later ages (Moeller, 2000). Universal newborn hearing screening (UNHS) allows for identification of hearing loss to occur at much earlier ages. Early ages of EI enrollment must be regarded as significant to a child’s overall development.

Much of the evidence is related to services for children with moderate to profound hearing loss; little has been reported on the effects of EI on children with unilateral or mild bilateral hearing loss. Yet without any form of intervention, any degree of permanent hearing loss may have a substantial impact on language, with the potential over time to widen the gap between language skill age and chronological age (Davis, Shepard, Stelmachowicz, & Gorga, 1981). The advantage of early identification for language development is evident across varying degrees of hearing loss (Ramkalawan & Davis, 1992; Yoshinaga-Itano et al., 1998).

Within the field of EI, evidence-based programs are highly encouraged, (American Speech-Language-Hearing Association [ASHA], 2004), though few programs or curricula have been systematically studied. The objectives of the present study were (a) to determine the impact of one state’s EI program on language over time for children with permanent hearing loss and (b) to evaluate the association of EI enrollment by age 6 months with early language skill development.

Methods

Early Intervention Program

Ohio had a regionalized approach to hearing screening even prior to the implementation of UNHS in July 2004. Ten regional programs supply tracking and follow-up for UNHS and provide EI services to children from birth to age 36 months with permanent hearing loss. Services are primarily home based and include direct parent mentoring, parent educational forums, a deaf mentor program, a loaner hearing aid bank, and a lending library. The EI providers have training at the bachelor’s degree level or above in deaf education, language development, or early childhood. Providers are required to have a minimum of 3 years’ experience working with infants, toddlers, or preschoolers who are deaf or hard of hearing. The SKIHI Curriculum (Watkins, 1979) is followed, and information regarding communication choices is provided in an unbiased manner while families are supported in developing their child’s communication skills.

Ohio’s internationally renowned EI curriculum is a comprehensive family-centered program for infants and young children with hearing loss (ages birth to 5 years). It was designed to help service providers offer support and resources to families in natural environments. The curriculum covers the basics of EI, including parent advising, cultivating family-centered partnerships, parent support, the first home visits, and assessment. Services are provided to children on either weekly or bireweekly schedules, depending on the needs of the child, and last a minimum of 1 hour. There were no changes to the EI program in the state after UNHS implementation.

Study Sample

The present study was retrospective, with the sample consisting of children who were involved in longitudinal monitoring of their language development as part of Ohio’s EI program. Children with permanent hearing loss, enrolled in Ohio’s EI program between 2004 and 2007, were included. Excluded from the analysis were children with complex medical conditions or with missing or incomplete data. Complex medical conditions were defined, per a data collection protocol, as syndromes or continuing illness or disease in addition to hearing loss. Children considered to be medically involved, with the need for home nursing care, or who had a tracheostomy tube, were classified as medically complex.

Information available for the present study included type and severity of hearing loss (better ear), amplification/device use, complex medical conditions, communication strategies, and the date EI services were initiated. Hearing loss was categorized as either mild (26–40 dB), moderate (41–70 dB), severe (71–90 dB) or profound (> 90 dB), as determined by the state’s data-tracking system. Level of hearing loss was not recorded in cases of unilateral hearing loss.

Language Measure

Per state protocol, the children were assessed with the SKIHI Language Development Scale (Tonelson & Watkins, 1979). The LDS is a parent-report observation scale listing receptive and expressive skills of children with normal hearing ages birth to 5 years. The LDS was developed and validated for children who are deaf or hard of hearing and has been shown to be highly correlated with the Bzoch-League Receptive-Expressive Emergent Language Scale. High degrees of interexaminer agreement, test-retest reliability, internal consistency, and reproducibility have been shown on the receptive and expressive scales of the LDS (Tonelson & Watkins, 1979). Performance can be scored for signed or spoken English-language skills. Scores are generated from a list of developmentally based language skills that are matched for developmental age in months. The LDS is divided into age-appropriate...
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units: 2-month intervals for children birth to 2 years and 4-month intervals for children ages 2–4 years. For the purpose of the present study, each age-appropriate unit was normalized for chronological age by dividing the actual score (unit completed) with the unit that signified the appropriate language skills for the child’s age at the time of testing, and multiplying by 100. Language quotients (LQs) close to 100 indicate that a child’s language level is age appropriate. The baseline language assessments occurred at EI enrollment. Although the protocol directs that the LDS be administered to all children at 6-month intervals, children may be assessed earlier if concerns or questions about language development are broached.

Statistical Analyses
Continuous variables were reported as means with standard deviations or medians with ranges. Categorical variables were reported as proportions. For the purposes of the main study objectives, the age at EI enrollment was categorized as either less than age 6 months (early entry group) or age 6 months or later (late entry group).

Differences between EI groups and continuous variables were tested by means of Student’s t test or the Wilcoxon rank sum test, as appropriate. Differences between group and categorical variables were tested using chi-square or Fisher’s exact test, as appropriate. The relationship between enrollment age (< 6 months vs. ≥ 6 months) and mean baseline language skills, after adjusting for age of identification and severity of hearing loss, was investigated using generalized linear models. Least mean squares were used to report the adjusted means with 95% confidence intervals. We constructed repeated measures regression models using generalized estimating equations to investigate language development over time (duration in EI) for each level of hearing loss while controlling for potential confounders. Results were reported as beta coefficients with standard errors. Beta coefficients were interpreted as follows: For every 1 month spent in EI, the LQ is estimated to change by the amount expressed by the beta coefficient. Estimated language trajectories were graphically illustrated. Potential confounders tested in the models included age of identification, use of amplification, primary communication modality, and region (for any site variability). Variables were included in the regression models if they were statistically significant (p ≤ .05), or were thought to confound the relationship between the outcome and the main effect. Age of identification of hearing loss always remained in the regression models, as it has been shown to be related to language outcomes as well as age of enrollment. For regression analysis purposes, children with mild and moderate hearing loss were combined into one model, and children with severe and profound hearing loss were combined into another.

To better understand the language trajectories among children with severe to profound hearing loss, we stratified the repeated measures analysis on the basis of whether or not the subjects had received a cochlear implant. Eight children with cochlear implants had received their implants at an age that occurred after their last available language assessment (two who entered at or after age 6 months and six who entered before age 6 months). Therefore, these children only contributed to preimplant models. Because a cochlear implant has great potential to influence oral language, differences in language development were noted during the periods prior to implantation compared to periods after implantation. Language development was determined to be curvilinear for the group with severe to profound hearing loss. Thus, a quadratic term for time (EI duration) was tested in all models.

The present study was approved by the institutional review boards of the Ohio Department of Health and Cincinnati Children’s Hospital Medical Center. Because this was a retrospective study with deidentified data, informed consent was waived.

Results
Between January 2004 and July 2007, 640 infants and toddlers were enrolled in EI services in Ohio; 328 subjects were included in the analyses. Of the 312 children who were excluded, 213 had complex medical conditions, 89 had no available baseline testing data, and 10 had missing data on hearing loss severity or an incorrect date of birth and/or enrollment. One reason for the nonavailability of data on baseline testing was that the child was early in the enrollment process and had not yet received a baseline language assessment (n = 44); another reason was that the child had exited the EI system prior to receiving an assessment (n = 26). For 19 children, there was no documented reason. Among the 328 included subjects, 270 (82%) had bilateral hearing loss. The median age of identification for the entire population was 3.4 months (range 0.0–34.2). The median age of EI enrollment was 6.5 months (range 0.0–34.4). The age of identification and EI enrollment decreased postscreening for subjects with bilateral hearing loss. Seventy-five percent of subjects (n = 246) were enrolled after UNHS screening was implemented; 49% of subjects (n = 160) entered the EI system before age 6 months. Characteristic differences between EI groups are shown in Table 1.
Table 1
Characteristics of Children in Early Intervention Program, by Enrollment (N = 328)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>EI &lt; 6 months of age (n = 160)</th>
<th>EI ≥ 6 months of age (n = 168)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of identification, in months</td>
<td>2.0 (0.0–5.9)</td>
<td>9.1 (0.0–34.2)</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Born after UNHS implementation</td>
<td>137 (85.6%)</td>
<td>109 (64.9%)</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Age at enrollment, in months</td>
<td>3.2 (0.6–5.9)</td>
<td>15.4 (6.0–34.4)</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Type of hearing loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensorineural</td>
<td>131 (81.9%)</td>
<td>144 (85.7%)</td>
<td>.41</td>
</tr>
<tr>
<td>Conductive</td>
<td>14 (8.8%)</td>
<td>8 (4.8%)</td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>8 (5.0%)</td>
<td>6 (3.6%)</td>
<td></td>
</tr>
<tr>
<td>Auditory neuropathy</td>
<td>7 (4.4%)</td>
<td>10 (6.0%)</td>
<td></td>
</tr>
<tr>
<td>Severity of hearing loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>27 (16.9%)</td>
<td>37 (22.0%)</td>
<td>.03</td>
</tr>
<tr>
<td>Moderate</td>
<td>43 (26.9%)</td>
<td>58 (34.5%)</td>
<td></td>
</tr>
<tr>
<td>Severe to profound</td>
<td>52 (32.5%)</td>
<td>53 (31.5%)</td>
<td></td>
</tr>
<tr>
<td>Unilateral</td>
<td>38 (23.8%)</td>
<td>20 (11.9%)</td>
<td></td>
</tr>
<tr>
<td>Received amplification</td>
<td>117 (73.1%)</td>
<td>131 (78.0%)</td>
<td>.31</td>
</tr>
<tr>
<td>Received cochlear implant</td>
<td>29 (18.1%)</td>
<td>27 (16.1%)</td>
<td>.62</td>
</tr>
<tr>
<td>Age at amplification, in months</td>
<td>4.1 (1.2–21.5)</td>
<td>15.0 (2.9–36.0)</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Age at cochlear implant, in months</td>
<td>14.9 (9.1–36.0)</td>
<td>19.5 (13.8–36.0)</td>
<td>.009</td>
</tr>
<tr>
<td>Primary communication mode</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral</td>
<td>93 (58.1%)</td>
<td>101 (60.1%)</td>
<td></td>
</tr>
<tr>
<td>ASL/bilingual-bicultural</td>
<td>5 (3.1%)</td>
<td>6 (3.6%)</td>
<td>.24</td>
</tr>
<tr>
<td>Total Communication</td>
<td>49 (30.6%)</td>
<td>56 (33.3%)</td>
<td></td>
</tr>
<tr>
<td>Other/undecided</td>
<td>13 (8.1%)</td>
<td>5 (3.0%)</td>
<td></td>
</tr>
</tbody>
</table>

Notes. ASL, American Sign Language. EI, early intervention. UNHS, universal newborn hearing screening.
* Medians with ranges or frequencies with percentages reported.
* Includes one child with moderate hearing loss.

Baseline Language Quotients
The overall mean receptive and expressive LQs at baseline (EI enrollment) for the entire cohort were 85.7 (SD = 28.0) and 83.7 (SD = 33.0), respectively. Subjects with bilateral hearing loss had slightly lower mean receptive and expressive LQs ($M = 83.5, SD = 28; M = 82.7, SD = 34$, respectively) compared to subjects with unilateral hearing loss ($M = 96.1, SD = 29; M = 88.7, SD = 29$, respectively).

Children who entered EI early (< 6 months of age) had significantly higher ($p < .001$) adjusted mean receptive and expressive LQs than children who entered late ($≥ 6$ months; see Figure 1). This finding was fairly consistent across different levels of hearing loss severity. Children with mild or unilateral hearing loss showed a similar trend, with higher expressive skills among children entering the EI system early. Although the mean expressive LQs appeared higher for children with severe to profound hearing loss who entered early, they were not significantly different from the baseline quotients among children with mild or moderate bilateral hearing loss ($p ≥ .20$).

Regression Analyses
Repeated measures models using generalized estimating equations were constructed by degree of hearing loss to evaluate the rate of change in LQs over time. Because we were interested in the direct comparison between children enrolled in EI early and children enrolled late regarding language development, models were stratified accordingly. Due to possible practice variability across the different EI sites, region of intervention was tested in all models. The variable for region was not significant in any of the models, and goodness-of-fit tests indicated that region added no additional information to the regression results. Thus, it was not included in the final models reported in the present study.

Mild, Moderate, and Unilateral Hearing Loss
Among children with mild or moderate hearing loss (n = 165), both EI groups
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Figure 1
Mean Baseline (at EI Enrollment) Language Quotients for Expressive (Figure 1a) and Receptive (Figure 1b) LQs, by Level of Hearing Loss

![Figure 1](image)

Notes: Language quotients have been adjusted for age of hearing loss diagnosis. Numbers above each comparison are p values for statistical comparisons made between early intervention (EI) groups regarding baseline language skills. MLD, mild; MOD, moderate; SEV-PROF, severe-profound; UNI, unilateral.

(<6 months and ≥6 months) had significant increases in receptive LQs over time (see Figure 2a). Children who entered EI before age 6 months had, on average, age-appropriate expressive language skills at baseline and appeared to have maintained these skills over time, though no significant increase in LQs was noted (β = 0.17, p = .45; Figure 2b). By contrast, children who entered EI at or after age 6 months had significant increases in LQs over time (β = 1.13, p < .0001), indicating a potential for a “catch-up” period for language skills.

Children with unilateral hearing loss had similar findings (see Figure 3). Children who entered EI early (n = 38) had a significant increase in receptive LQs, and appeared to maintain age-appropriate expressive LQs while in EI. Children with unilateral hearing loss who entered EI at or after age 6 months (n = 20) made significant progress over time in receptive (β = 1.10, p = .006) and expressive (β = 1.16, p = .04) LQs.

**Severe to Profound Hearing Loss**

The relationship between language and EI duration appeared to be modified by cochlear implant use among children with severe to profound hearing loss. Twenty-nine (57%) of the 51 children who were enrolled in EI earlier than age 6 months and 27 (50%) of the 54 children who were enrolled at or after age 6 months had received a cochlear implant at the time of the present study. Among all children with severe to profound hearing loss, no significant differences regarding median age of identification (3.0 months [range 0.2–32.0] vs. 3.2 [0.1–30.0], p = .60) or age at enrollment (5.9 [0.6–33.0] vs. 7.2 [0.9–34.0], p = .30) were seen between children who had received a cochlear implant and those who had not. The median age of implantation was significantly lower (p = .01) among children who were enrolled early compared to those enrolled later (see Table 2). The median time spent in EI prior to an implant was significantly longer among children enrolled by age 6 months compared to children enrolled at or after 6 months (12.6 vs. 7.5 months, p < .0001).
**Figure 2**
Estimated Receptive (Figure 2a) and Expressive (Figure 2b) Language Skill Trajectories for Children With Mild and Moderate Hearing Loss, by Age of Early Intervention Enrollment

**Notes.** Age of identification was included in the models as a potential confounder. EI, early intervention.

**Children Without Cochlear Implants**

Figure 4 illustrates the relationship between duration of time spent in EI and language development over time for children who did not receive a cochlear implant. Children who entered EI early (<6 months, n = 23) had significantly higher receptive and expressive skills at baseline and maintained skills with no significant change over time (p ≥ .50 for both receptive and expressive models). For children who entered late (≥ 6 months, n = 27), baseline language level was an important factor regarding changes in receptive LQs over time. Children with baseline LQs less than 80 (n = 18) had significant increases in their receptive LQs over time (β = 1.6, p = .0002). Children with LQs of 80 or higher had no significant change in LQ (p = .45). All models included age of hearing loss identification as a potential confounder. Primary mode of communication was tested, and was not found to be significant in any of the models described above.

**Children With Cochlear Implants**

EI durations pre- and post-cochlear implantation were analyzed separately. Four children in the late EI group did not enroll in EI until after they had received a cochlear implant. At the time of the present study, eight subjects (six in the early EI group and two in the late EI group) had not had postimplant EI language assessments. Prior to receiving a cochlear implant, children enrolled in EI prior to age 6 months had an initial significant decrease in receptive and expressive LQs, with a slight increase over time (see Figure 5). Although visually it appeared that LQs increased prior to implantation among children enrolled in EI at or after age 6 months, this increase was not statistically significant. Both groups seemed to make some postimplant language progress while in EI, though this finding was not quite statistically significant for children in the early EI group (see Figure 6). All models included age of identification. Postimplant models also included the preimplant EI duration and primary communication modality. Communication modality was not significant in the preimplant regression models.
**Impact of Early Intervention on Early Language**

**Figure 3**
Estimated Receptive (Figure 3a) and Expressive (Figure 3b) Language Skill Trajectories for Children With Unilateral Hearing Loss, by Age of Early Intervention Enrollment

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**Notes:** Models included age of identification and amplification (received, yes or no) as potential confounders. EI, early intervention.

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**Early Intervention Enrollment by Age Three Months**
To determine the language outcome benefits of EI enrollment by age 3 months (Vohr et al., 2008), the early EI enrollment group was further stratified into two groups: (a) EI enrollment at or before age 3 months ($n = 76$), hereafter the “≤ 3 group”; and (b) EI enrollment at later than 3 months up to 5.9 months ($n = 84$), hereafter the “> 3.0–5.9 group.” The median ages of EI enrollment for these two groups were 2.0 (range 0.6–2.9) and 4.1 months (range 3.0–5.9), respectively. The mean baseline LQs, adjusted for hearing loss severity and age of identification, were not significantly different when the ≤ 3 group was compared with the > 3.0–5.9 group. Adjusted mean receptive LQs for the two groups (with 95% confidence intervals in parentheses) were 99.4 (92.7, 106.0) and 99.9 (83.9, 96.0), $p = .08$. Adjusted mean (95% CI) expressive LQ for the ≤ 3 month group was 92.3 (89.8, 104.9) and for the > 3.0–5.9 month group was 96.2 (89.4, 103.0), $p = .97$. LQs for both groups were significantly different from those of children entering EI at or later than age 6 months.

To investigate the relationship between EI enrollment groups (i.e., ≤ 3 compared to > 3–5.9) with language over time, we constructed regression models. Among subjects with mild to moderate hearing loss, enrollment group was not statistically significant in either receptive ($p = .90$) or expressive models ($p = .80$). These findings were consistent for subjects with severe to profound hearing loss. Enrollment group (≤ 3 vs. > 3–5.9) was not significantly related to change in either receptive ($p = .50$) or expressive language ($p = .90$) over time.

**Discussion**
The findings of the present study signify the importance of EI enrollment to early language development. Children enrolled before age 6 months had initially higher language skills than children enrolled at or after age 6 months, and maintained age-appropriate skills over time. Although children enrolled at or after 6 months had a lower baseline skill set (lower LQ score), they appeared to have made significant language progress while in EI. This finding was consistent across different levels of hearing loss severity.

Early hearing detection and intervention is considered essential to age-appropriate language development for children with hearing loss. Although
Table 2
Characteristics of Children With Severe to Profound Hearing Loss

<table>
<thead>
<tr>
<th></th>
<th>EI &lt; 6 months, received CI n = 29*</th>
<th>EI ≥ 6 months, received CI n = 26*</th>
<th>EI &lt; 6 months, no CI n = 23*</th>
<th>EI ≥ 6 months, no CI n = 27*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of identification, in months</td>
<td>1.4 (0.2–4.5)</td>
<td>11.8 (1.5–32.2)</td>
<td>2.0 (0.8–5.9)</td>
<td>9.4 (0.1–30.4)</td>
</tr>
<tr>
<td>Age at enrollment, in months</td>
<td>2.2 (0.6–5.9)</td>
<td>14.4 (6.2–32.6)</td>
<td>3.0 (0.9–5.6)</td>
<td>15.3 (6.0–34.3)</td>
</tr>
<tr>
<td>Age at implantation, in months</td>
<td>15.0 (9.1–38.0)</td>
<td>19.4 (13.8–36.0)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Time in EI prior to implantation, in months</td>
<td>12.6 (7.4–35.0)</td>
<td>7.5 (2.3–15.1)b</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Time between CI and first post-CI language assessment, in months</td>
<td>1.9 (0.3–8.0)</td>
<td>4.3 (0.3–13.0)</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Primary communication mode

<table>
<thead>
<tr>
<th></th>
<th>EI &lt; 6 months, received CI n = 29*</th>
<th>EI ≥ 6 months, received CI n = 26*</th>
<th>EI &lt; 6 months, no CI n = 23*</th>
<th>EI ≥ 6 months, no CI n = 27*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral</td>
<td>13 (46%)</td>
<td>16 (59%)</td>
<td>9 (39%)</td>
<td>5 (18%)</td>
</tr>
<tr>
<td>ASL/bilingual-bicultural</td>
<td>1 (4%)</td>
<td>1 (4%)</td>
<td>1 (4%)</td>
<td>3 (11%)</td>
</tr>
<tr>
<td>Total Communication</td>
<td>14 (50%)</td>
<td>9 (33%)</td>
<td>8 (35%)</td>
<td>18 (67%)</td>
</tr>
<tr>
<td>Other/undecided</td>
<td>0</td>
<td>1 (4%)</td>
<td>5 (22%)</td>
<td>1 (4%)</td>
</tr>
</tbody>
</table>

Notes: ASL, American Sign Language. CI, cochlear implant. EI, early intervention.
* Medians with ranges or frequencies with percentages reported.
b Four children entered early intervention postimplant.

Figure 4
Estimated Receptive (Figure 4a) and Expressive (Figure 4b) Language Skills Trajectories by Age of Early Intervention Enrollment for Children With Severe to Profound Hearing Loss Who Did Not Receive Cochlear Implants

Notes. Estimated slopes from models overlay the individual language trajectories of each child. Baseline receptive skills were found to modify the regression slopes (or trajectories) for children enrolled at or after age 6 months. Slopes for receptive language quotient (LQ) were stratified by baseline LQ levels: > 80 (filled circles) and < 80 (hollow circles). Age of identification was included in the models as a potential confounder. EI, early intervention.

early detection and intervention programs have encouraged EI enrollment by age 6 months, the evidence has not been specific regarding the use of this cutoff point. Calderon (1998) studied 80 children with bilateral permanent hearing loss and concluded that children enrolled in EI by 24 months of age had improved language skills (on the LDS) after leaving EI compared to those enrolled after 24 months. No difference was seen between children entering before 12 months of age and those entering at 12–24 months, possibly because of the small number of children who actually enrolled by age 12 months. Bubico and colleagues (2007) stated that EI enrollment within the first 12 months of life may help children attain good receptive vocabulary at 5 years of age. Investigators studied 70 children, 17 (24%) of whom were enrolled by age 12 months. Moeller (2000) showed that 112 children enrolled in an EI program by age 11 months had improved language outcomes at age 5 years compared to children enrolled after 11 months.
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**Figure 5**
Estimated Receptive (Figure 5a) and Expressive (Figure 5b) Language Skills Trajectories by Age of Early Intervention Enrollment for Children With Severe to Profound Hearing Loss Who Received Cochlear Implants

Notes: Regression models focused only on the duration of early intervention (EI) prior to implantation (i.e., preimplant). Slopes, or estimated language trajectories, represented by the solid dots, were found to be curvilinear in regression models. \( \beta \) represents the coefficient for the first term (duration in EI), and \( \beta^2 \) represents the coefficient for the quadratic term (duration in EI x duration in EI). Dotted lines behind the slopes represent individual trajectories of each child for children enrolled prior to age 6 months (top panels) and children enrolled at or after age 6 months (bottom panels). Age of identification was included in the models as a potential confounder.

Only 24 subjects (21%) were enrolled by 11 months of age, and there was a wide range of enrollment ages (up to 4.5 years). Watkin and colleagues (2007) focused on 120 children and compared those receiving some form of EI by age 9 months with those receiving it at later ages. Findings indicated that the earlier-managed group had higher expressive and receptive language skills than later-managed groups at entry, and maintained these skills over time.

To date, the present study has the largest cohort of any study considering the effectiveness of EI in advancing early language development among children with hearing loss. Nearly 50% of all children in Ohio were enrolled in the state’s EI system prior to age 6 months. Results from the longitudinal analyses provide striking evidence for significance of age at entry for maintaining age-appropriate language levels. Although children enrolled at or after age 6 months had lower mean baseline language skills compared to earlier-enrolled children, they showed significant improvements in both receptive and expressive language while in EI. The present study cannot address the question of whether these language skills were maintained beyond the years of EI, yet it addresses a fundamental question of whether EI is effective in improving the language skills of children while they are enrolled. Unfortunately, for many children who enter the EI system late, the time spent in EI may be too brief to provide adequate language “catch-up.”

A strength of the present study is the ability to report on children with unilateral hearing loss. Eighteen percent of the cohort (\( n = 58 \)) had unilateral hearing loss. Children with unilateral hearing loss who were enrolled in EI either maintained age-appropriate skills (if enrolled prior to age 6 months) or had a significant increase in skills (if enrolled at or after 6 months). To our knowledge, no peer-reviewed study has been published on infants and young children with unilateral hearing loss receiving EI. It is possible that children with unilateral hearing loss who receive EI services are different from those who do not. More developmental concerns may exist among this subgroup that drive a parent to seek EI. We did not have information on the number of children whose newborn hearing screening indicated the presence of a unilateral hearing loss, and therefore we could not determine what proportion of such children entered the EI system.

**Language Development in Children With Severe to Profound Hearing Loss**

The findings regarding children with severe to profound hearing loss were complex, due in part to some children’s use of cochlear implants. For children who did not receive an implant, early EI enrollment was key in maintaining age-appropriate language skills. Children who entered at or after age 6 months had a significant language increase, though this was modified by the language level at entry; children with lower language levels made the biggest leaps in language upon entry. Because receiving a cochlear implant may affect language
trajectory, it was important to investigate the effect of EI in preimplant periods separately from postimplant periods. Prior to receiving a cochlear implant, children who enrolled before age 6 months had age-appropriate language skills at entry and maintained these skills, even though they had a decrease in language scores. This decrease may be related to a decline in skills that either signaled the need for a cochlear implant or was part of the natural decline in language that may have taken place as a child was waiting to receive an implant. Children struggling with speech perception (and oral receptive language) may be more likely to receive a cochlear implant. Eight children had not had postimplant language assessments at the time of the study. Thus, our ability to detect a statistically significant increase in postimplant language for children who enrolled prior to age 6 months was hampered by a diminished sample size and subsequently diminished statistical power.

In addition, five children who had enrolled at or later than age 6 months enrolled only after cochlear implantation. The cochlear implant experience prior to the first postimplant EI assessment varied significantly between the early and late EI groups, a factor that could also play into the differences in estimated language skills between the groups. The median time between implant and first postimplant language assessment was only 2 months for the early EI subjects and 4 months for the late EI subjects. The latter group had more time to acclimate to the implant, which could have affected the appearance of language development.

Our results did not show a significant difference between infants who were enrolled by age 3 months and infants enrolled at or after age 3 months up to age 5.9 months, which has been suggested to be an important cutoff in terms of age of EI enrollment (Vohr et al., 2008). A reason for this finding could be related to the way our data were analyzed, comparing the group that enrolled at or before age 3 months with the group that enrolled after 3 months and up to 5.9 months. Children who entered the system at or after age 6 months were not included in this subanalysis. Including children who entered the system much later would have skewed the results toward those children enrolled significantly later who had lower language levels.

We did not focus on degree of hearing loss as a predictor of language outcome. Rather, we stratified the analyses by degree of hearing loss to understand the effect EI may have on different groups of children with hearing loss. At EI enrollment, the receptive and expressive quotients were not significantly different among the different hearing loss groups (see Figure 1). This finding would be consistent with those of other investigators who have reported minor contributions of the severity of hearing loss to language outcomes (Moeller, 2000; Ramkalawan & Davis, 1992; Yoshinaga-Itano et al., 1998). It is possible that the severity of hearing loss would affect speech production, but the present study was not designed to address speech outcomes. With the widespread implementation of EI services for children with hearing loss, the relationship between degree of hearing loss and language outcomes may be shifting, as children are being
IDENTIFIED WITH HEARING LOSS AND INTERVENTIONS ARE BEING APPLIED AT EARLIER AGES. ALL FORMS OF HEARING LOSS APPEAR TO HAVE AN IMPACT ON LANGUAGE.

ALTHOUGH THE STATE OF OHIO HAS 10 DIFFERENT REGIONAL PROGRAMS THAT PROVIDE EI SERVICES FOR PERMANENT HEARING LOSS, NO DIFFERENCES IN OUTCOMES WERE SEEN ACROSS THE DIFFERENT REGIONS. THIS likely speaks to the effectiveness of the SKI*HI curriculum and the appropriateness of the training of the EI providers in the application of therapeutic strategies. Because existing statewide data were not collected specifically to address our hypothesis, we were limited to the language assessment tool of the program. Because the LDS does not provide standardized language scores, we used LQ scores as approximations of skill development. Both LQs and the LDS have been reported in studies of children with hearing loss (Yoshinagaitano et al., 1998, 2000). A limitation of any criteria-referenced tool is that it yields a greater amount of subjective data, whose content can be influenced by scoring differences among examiners. However, the LDS has been shown to have good interexaminer reliability and it has a high level of reproducibility. Advantages of the LDS include ease of testing in the clinical setting and the ability to document developmental changes across a wide age range.

The data we used was collected as part of a statewide program; thus, information on certain factors influencing outcomes (e.g., developmental disabilities, family interaction, prematurity) was not available. It is unknown whether corrected gestational age was used on the LDS for children born prematurely. Socioeconomic status (SES), an important predictor of language scores, is not obtained as part of the current statewide data collection system, and thus was not available for analysis. In general, it is not thought that the families that seek out EI in the state are either predominately of high or low SES. Children with complex medical conditions were excluded from analysis, but developmental assessments were not available for the remaining cohort. Missing data (for 89 subjects) could have biased our findings. No difference in the age of identification was seen between infants who were enrolled and those who had no baseline testing available (p = .40).

THE IMPORTANCE OF MEASURING LANGUAGE DEVELOPMENT

Perhaps one of the critical elements of EI programs is the ability to measure a child’s language development (regardless of communication mode). From a pragmatic perspective, the testing of children at regular intervals as they are enrolled in EI systems offers several benefits. From the individual child’s standpoint, systematic testing demonstrates how that child is developing and identifies whether or not the progress is appropriate and if additional interventions might be indicated. From the parent and EI provider perspectives, testing offers reassurance that the child is meeting language milestones or indicates the need for other interventions. From the statewide perspective, the systematic collection and tabulation of test scores allows for continuous performance improvement and quality assurance of the EI system across the state. These data displaying the efficacy of EI systems provide the necessary information that makes competition for limited resources more successful. Accordingly, identifying the proper metrics for assessing the impact of EI systems for hearing and capturing those measures in a systematic fashion are vital to the long-term efficacy and sustainability of hearing- and language-related EI systems.

CONCLUSION

Early enrollment in an appropriate intervention program for children who are deaf or hard of hearing is an effective strategy for the development of age-appropriate language in infants and toddlers. Although evidence supporting EI continues to accumulate for children with hearing loss, a need remains to identify the critical age by which children should be enrolled and receiving services. The present study supports the fundamental push toward enrolling children in EI systems before the age of 6 months. It also addresses the ability of a statewide program to be effective in pursuing the development of language in children with hearing loss.

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REFERENCES


