



Review

Speech and language outcomes of very preterm infants



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S U M M A R Y

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Speech and language impairments of both simple and complex language functions are common among former preterm infants. Risk factors include lower gestational age and increasing illness severity including severe brain injury. Even in the absence of brain injury, however, altered brain maturation and vulnerability imposed by premature entrance to the extrauterine environment is associated with brain structural and microstructural changes. These alterations are associated with language impairments with lasting effects in childhood and adolescence and increased needs for speech therapy and education supports. Studies are needed to investigate language interventions which begin in the neonatal intensive care unit.

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1. Introduction

Speech and language impairments are common in preterm infants with delays in the acquisition of expressive language, receptive language processing, and articulation, and deficits in phonological short-term memory [1–6]. Factors which may be associated include low gestational age, increased illness severity, neonatal morbidities including brain injury, duration of hospitalization, hearing status, gender, age of assessment, socio-economic risk factors and environment [7–10]. Language delay may be associated with additional neurodevelopmental and neurosensory morbidities, particularly hearing loss and cerebral palsy. Proficient language skills are critical for the development of appropriate communication, joint attention, and social interactions [11]. This review explores possible mechanisms that contribute to language delays and impairments and reports on outcomes of contemporary populations.

2. Origins of language and the language environment

Auditory input is critical for the development of speech and the auditory cortex [12]. The maturational progression of the auditory system occurs in utero with the perception, reaction, and storing of auditory information including maternal physiologic sounds and voice at approximately 26 weeks of gestation.

Exposure of preterm infants to maternal sounds in a neonatal intensive care unit (NICU) compared to routine nursery sounds has been shown to be associated with reduced frequency of apnea and bradycardia [13]. Both term and preterm infants respond preferentially to their mother's voice, [14–16] the preference being demonstrated within hours of birth [15]. So what is the extra-uterine learning environment in a busy NICU for the infant who is delivered at 26 weeks, intubated, and placed on a ventilator? There is an immediate change in the sound environment with loss of the intrauterine controlled sound environment to the noise of the delivery room and NICU. Several studies [12,13,16] have shown that exposure to maternal sounds and voice are significantly reduced in the NICU. Deprivation of maternal sounds in the NICU during this important period of auditory system development has been shown to impact both auditory brain maturation and subsequent speech and language [17,18]. Caskey et al. [16] reported that very preterm infants begin to make vocalizations in the NICU at 32 weeks and increase their vocalizations between 32 and 36 weeks. Median percent exposure times to sounds captured in 16 h recordings were 1% and 5% for total language, 19% and 36% for electronic sounds including monitors, 39% and 27% for silence, and 25% and 29% for noise at 32 and 36 weeks, respectively. Adult word counts and mother–infant conversation turns were significantly higher when parents were visiting compared to nurses caring for the infant. There were also a higher number of conversational turns (parent and child vocalization within 5 s) at 32 weeks when a parent was giving the feeding compared with a staff nurse. This is highly suggestive that parent interactions with their infants in the NICU play an important role in early language stimulation. Currently, however, there is limited information about the effects of the language environment in the NICU on language outcomes.

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3. The immature brain versus the injured brain

Preterm infants have reductions in cerebral tissue volume at term equivalent compared to term infants [19,20]. Neonatal risk factors associated with this decrease in cerebral tissue volume include gestational age, dexamethasone therapy, brain injury, intrauterine growth restriction, and bronchopulmonary dysplasia – all risk factors associated with adverse outcomes [21–24].

The language centres of the brain are located predominantly in Broca's area and Wernicke's area of the left hemisphere [25]. Brain injury in these areas is a strong predictor of subsequent cognitive and language impairments [26–28]. Children born preterm also have increased working memory deficits which have been linked to language delays [29]. Working memory deficits at 2 years were associated with smaller hippocampal brain volumes at term equivalent in preterm infants <1250 g and persisted after adjusting for perinatal risk, socio-economic status, and developmental factors [30]. At 12 years both memory scores and cortical volumes subserving language and memory were reduced on magnetic resonance imaging (MRI) in a second cohort [31]. Peterson et al. [32] reported decreased cortical sensorimotor, premotor, mid-temporal, parietal, occipital, and subgenual regions in preterm compared to term controls at school age. Larger sensorimotor areas and mid-temporal cortices were associated with higher full-scale, verbal and performance IQ.

Cortical development of the temporal lobe is differentially vulnerable in preterm infants. Preterm children have significantly greater bilateral temporal lobe gyrification compared to term controls [33]. Higher left temporal gyrification index has been correlated with lower reading recognition scores, a marker for language skills at 8 years of age. Since gyrification begins during the third trimester, the extrauterine environment may impact on this developmental process.

In addition to volumetric differences, there is increasing evidence of altered microstructure and connectivity in the brains of preterm infants. At 8 years of age preterm subjects in the Indomethacin Trial had impaired performance on semantic test tasks, and used different pathways than term children [34]. Alterations in functional connectivity for language tasks were identified in subsets of the population [35]. It was speculated that plasticity of network connections provides the opportunity for improving basic language skills with increasing age among preterm children.

There are direct associations between specific areas of brain microstructure and developmental functions. Counsell et al. [36] performed diffusion tensor imaging studies and developmental assessments at 2 years of age in preterm children without any focal abnormality on conventional MRI and reported that developmental impairments were associated with specific brain microstructural abnormalities, namely lower fractional anisotropy (FA). FA is a summary measure of microstructure as it assesses water diffusivity in tissue which can reflect cell, axonal and myelination integrity. Microstructure abnormalities were also identified in a cohort of preterm children at 12 years of age with no major neonatal brain injury and no ventriculomegaly [37]. Diffusion tensor imaging identified decreased FA in fibre tracts of regions subserving language. Values in the left anterior uncinata correlated with verbal IQ, full-scale IQ and Peabody Picture Vocabulary test (PPVT) scores for preterm boys. Preterm boys had the lowest FA values in the right anterior uncinata fasciculus. FA values in this region also correlated with verbal IQ and PPVT for preterm boys. These fibres contribute to the temporal stem. Other reports have shown reorganization of pathways subserving lexical semantic processing [38], language processing [39], phonological tasks [40], auditory language tasks [41], and auditory sentence comprehension [42] in preterm adolescents. These studies indicate that preterm birth places the infant

brain at increased risk of gray and white matter injury, and that, even in the absence of injury, brain development is altered with significant structural and microstructural changes which are associated with the neurodevelopmental impairments. The temporal lobe and adjacent regions, which are centers for language development, are particularly vulnerable.

4. Assessment of speech and language

Traditionally, there are two methods of language assessment: simple, which includes vocabulary words and short phrases, and complex, which includes an expanded spectrum of language components including wording, and meaning of concepts, use of verbs and relational terms, and complex sentences. Early pre-vocalizations heard in preterm infants are a form of simple language. Language also has subcategories of semantics (meaning), grammar (language structure), phonological awareness (understanding of sounds), discourse (integrating information in conversations), and pragmatics (use of language appropriate to context).

5. Language outcomes

A representative sample of language outcome studies of preterm infants published since 2000 are shown in Table 1. Publication of the Bayley III with a separation of cognitive and language composite scores resulted in a series of studies reporting early language skills in preterm infants. A National Institutes of Child Health and Human Development (NICHD) Neonatal Research Network study [43] reported Bayley III language scores [44] of extremely preterm infants of 401–1000 g who also had a gestational age <27 weeks. The mean language composite score of infants evaluated at 18–22 months of corrected age (CA) was 83 ± 18 , and 20% had a language composite score <70. This rate of language impairment is consistent with prior reports of preterm toddlers [3,45]. Duncan et al. [46] examined effects of race and ethnicity on Bayley III language scores of preterm infants <28 weeks. Children who were black and Hispanic had similar cognitive scores but lower language scores than white children. The authors note that the Bayley III has no standardized Spanish version and therefore may provide a bias against non-English speaking children. The findings indicate, however, that minority status suggests vulnerability for language delay. Lowe et al. [47] explored language and ethnicity further by comparing the language outcomes of preterm children whose primary language was Spanish compared to those whose primary language was English. Although cognitive scores were similar for the two groups, Bayley III language scores were significantly lower for children whose primary language was Spanish. A third study examined oromotor control in infants ≤ 26 weeks [48]. Dysfunctional feeding at 18 months CA was defined as any of the following: physician order of no oral feeds, gastrostomy feeds, cough/gag/choking during oral feeds, aspiration, excessive drooling during feeds, or difficulty swallowing. Children with dysfunctional feeding had significantly lower cognitive and language scores compared to those with normal feeding.

These early language delays indicate a need for support services. Hintz et al. [49] reported that 33.7% of extremely preterm infants at 18–22 months CA received speech therapy and 55.8% received early intervention (EI). Rates of receiving speech therapy services ranged from 41.2% for infants born ≤ 24 weeks to 25.6% for infants born at 27 weeks.

Meta-analyses consistently report speech and language delays of preterm children compared to term children [1,6]. A meta-analysis of preterm children aged 3–12 years [6] identified that preterm children scored significantly lower than term children on both simple and complex language function tests and that preterm

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