

Changes in Voice, Articulation, and Language Following Meningitis: A Case Study

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Every year, 40 children per 100,000 under the age of 4 contract bacterial meningitis. Over half of the survivors of this infection suffer a profound bilateral sensori-neural hearing loss. The effects on speech and language have been reported in the literature; however, most of these reports are anecdotal. This case study documents the speech and language status of a child before and after profound bilateral sensori-neural hearing loss resulting from bacterial meningitis at age 2 years, 9 months. Speech and language samples at one month before and one year after onset of hearing loss indicated deterioration of articulation, decrease in intelligibility, and lack of language development. Spectral analysis of selected parameters of voice in the pre- and post-meningitic conditions indicated changes in quality, pitch, and timing. Suggestions for rehabilitation include development of age-appropriate expressive language structures, establishment of alternative input modes, and conservation of segmental aspects of speech.

Each year 40 out of every 100,000 children in the United States under the age of 4 years will contract bacterial meningitis. Over one-half of the survivors of this infection of the central nervous system will have long-term neurological problems varying in degree and severity, including hearing loss (Vaughn, McCay, & Nelson, 1975). Although antibiotic treatment for bacterial meningitis has improved the chances of survival of its victims, prevalence of this disease has not decreased (Feign & Dodge, 1976). There has also been an increase in children affected with clinically significant hearing loss caused by bacterial meningitis or as a result of the antibiotics administered during treatment (Katz, 1978). Recently a vaccine has been developed and approved by the Food and Drug Administration which physicians hope will reduce the incidence of this disease. Nevertheless, we are faced with the habilitation of those children and adults whose hearing has been impaired as a result of bacterial meningitis.

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Deterioration of articulation and voice quality are among the most often cited effects of sudden profound bilateral sensori-neural hearing loss resulting from bacterial meningitis. Binnie, Daniloff, and Buckingham (1982) evaluated the speech of a 5-year-old patient deafened by meningitis. Their report noted slightly slower speech rate, elevated fundamental frequency, and increase in loudness of the voice. Plant (1984) evaluated the effects of meningitis in an 11-year-old at onset of hearing loss and at 2 and 30 months after meningitis. Speech intelligibility and quality deteriorated as indicated by phonetic errors in read and spontaneous speech and changes in vowel formant frequencies. Seidemann and Holbrook (1984) tracked the speech and voice quality of a 14-year-old male at intervals from one day to one year after meningitis. They observed a consistent decrease in the range of the fundamental frequency, flattening of intonation contours of the voice, lowering of the fundamental frequency, increased speaking rate, decreased phonation and pause times, and reduced precision in articulatory movements.

In most investigations of the changes following sudden onset of hearing loss, speech and voice samples have been gathered after onset, in the absence of data on speech and language status prior to the hearing loss. It is rare that speech and language samples prior to bacterial meningitis are available for comparison.

The following is a case study of a child who contracted bacterial meningitis at age 2 years, 9 months. His mother had recorded his speech and language for relatives shortly before his illness. Although the quality of these recordings is admittedly poor, this report will chronicle the apparent effects of hearing loss on voice, articulation, and language. The purposes of this case study are (a) to corroborate the changes in voice, articulation, and language reported by previous researchers, (b) to chronicle the breadth and rate of deterioration, and (c) to suggest strategies for rehabilitation based on the effects of such hearing loss.

PRE-MENINGITIS STATUS

History

J. T. was born following an uneventful pregnancy. His postnatal medical history was unremarkable with the exception of frequent earaches and colds. Pressure-equalizing tubes were inserted bilaterally when J. T. was 2 years, 5 months old. The developmental history reported by the mother at the initial audiologic evaluation suggested that J. T.'s speech, language, cognition, and motor skills were at or above norms for his age and sex prior to his illness. An audiotape recording was made of J. T. one month prior to the onset of his illness. This tape provided the sample from which the following results were obtained (see Table 1).

Table 1
Language, Articulation, and Voice Evaluation: Pre-Meningitis

Expressive Language	
MLU	3.9
Distribution of word type	
proper nouns	28%
common nouns	22%
verbs	12%
pronouns	0%
prepositions	14%
articles	14%
adverbs	2%
adjectives	5%
negatives	3%
conjunctions	0%
wh- questions	0%
Articulation	
Distribution by error type	
substitutions	100%
omissions	0%
distortions	0%
Distribution by manner	
within manner	30%
between manner	70%
Distribution by phoneme type	
fricative	50%
plosive	20%
affricate	10%
glide	10%
lateral	10%
nasal	0%
Voice	
F ₀ (average)	259 Hz
F ₁ (range)	370-1000 Hz
F ₂ (range)	1500-2500 Hz

Note. CA = 2 yrs, 7 mos.

Expressive Language

J. T. was at Brown's (1973) Stage IV of language development as indicated by an MLU of 3.9. The majority of his utterances were S-V-O. All verbs were in the third-person present tense. J. T. was using prepositional phrases, but no pronouns.

Articulation

Articulation errors were all substitutions; most were made with a different manner of production than the correct phoneme. The majority of errors were

on fricatives and plosives. According to Prather, Hedrick, and Kern (1975) these articulation errors are typical for a child this age.

Voice

The speech sample was played into a Kay Elemetrics Sonograph (7029A) using a Wollensak 2570 cassette tape recorder. Spectograms showed vowel length, fundamental frequency, and range of the first and second formants to be within limits defined as normal (Peterson & Barney, 1954).

STATUS IMMEDIATELY FOLLOWING MENINGITIS

Hearing

J. T.'s hearing was evaluated by auditory brainstem response audiometry one month after the onset of meningitis. Results indicated a severe bilateral sensori-neural hearing loss. Acoustic impedance measurements revealed normal middle ear function bilaterally. Two weeks after the initial auditory testing, J. T. was fitted with binaural, high-gain ear-level hearing aids.

Communication

Two months after meningitis (at age 2 years, 11 months), J. T.'s communication skills were assessed by parent report and observation by a teacher of the deaf in the family's local school district using the Stage 0 Profile (Texas Education Association, 1980) and the SKI-HI Language Development Scale (Watkins, 1979). Results, displayed in Table 2, indicated that J. T.'s receptive and expressive language were above norms for his age, although auditory skills were reported to be below age level or absent.

The Zimmerman Preschool Language Scale (Zimmerman, Steiner, &

Table 2
Language Evaluation: Immediately After Meningitis

Receptive Language	
Stage 0	3 yrs, 0 mos ^a
SKI-HI	5 yrs, 0 mos
Zimmerman Preschool Language Scale	
Auditory Comprehension Age	2 yrs, 9 mos
Verbal Ability Age	2 yrs, 0 mos
Language Age	2 yrs, 4 mos
Auditory Comprehension Quotient	94
Verbal Ability Quotient	69
Language Quotient	82

Note. CA = 2 yrs, 11 mos.

^aAge limits of test.

Evatt, 1969) was also administered by the teacher of the deaf. The results showed that J. T.'s language skills were below age level in all areas measured. These results were not surprising, however, due to the emphasis of the test on auditory and verbal language skills and the lack of an effective mode of communication for the examiner to use in administering the scale to J. T. As this test was the last to be given in the battery, scores may have also been influenced by fatigue and J. T.'s attention span.

Cognitive Skills

The Kaufman ABC Test (Kaufman & Kaufman, 1983) was administered by the teacher of the deaf to assess intellectual functioning. J. T.'s cognitive skills were in the above average range. Adaptive and emotional behavior were within normal limits for his age. The examiner concluded that the following cognitive strengths were present: (a) visual short-term memory for sequence of hand movements, (b) ability to determine the whole when the parts are viewed separately, (c) rich experiential background, and (d) above average intellectual ability. Weaknesses identified were receptive and expressive language.

Motor Skills

J. T.'s motor skills were evaluated by the teacher of the deaf using the perceptual motor subtests on the Stage 0 Profile (Texas Education Association, 1980). Prehension, fine motor skills, and visual discrimination were within normal limits for J. T.'s age. On the locomotion subtest, J. T. scored 2 years, 4 months; 8 months below his chronological age.

EDUCATION AND HABILITATION

Five months after the onset of meningitis, J. T. was seen by a speech-language pathologist and audiologist, trained and experienced in working with preschool deaf children. Nine sessions of diagnostic speech-language therapy were conducted to determine effective strategies in communicating with J. T. and to enable J. T. to communicate more effectively with others. During that time, very little response to sound was noted even with amplification. It was thus determined that a visual means of communication would provide J. T. with the greatest amount of information for communication purposes. It was recommended that cued speech be tried as the communication mode for J. T. because of his high level of language development at the time of his illness.

Beginning at 5 months after meningitis, J. T. was enrolled in the same Montessori school he had attended before his illness. In addition, he was seen by a teacher of the deaf for individual speech and language tutoring 2½ hours per week. One Montessori teacher, both of J. T.'s parents, and the teacher of the deaf were fluent in and used cued speech to accompany all of their spoken

language interactions with J. T. The goals of the speech and language tutoring program included (a) auditory training — sound awareness and localization, (b) speech training — phonologic development and conservation, (c) expressive language and vocabulary development, and (d) receptive language improvement to increase J. T.'s use of cued speech as a receptive mode of communication.

Table 3
Language, Articulation, and Voice Evaluation: 9 to 12 Months After Meningitis

Receptive Language	
PPVT - Form L (cued)	2 yrs, 5 mos
PPVT - Form M (no cues)	2 yrs, 1 mo
Expressive Language	
Spontaneous Sample	
MLU	3.3
Distribution of word type	
proper nouns	10%
common nouns	23%
verbs	21%
pronouns	15%
prepositions	5%
articles	5%
adverbs	4%
adjectives	12%
negatives	1%
conjunctions	3%
wh- questions	1%
Articulation Errors	
Distribution by error type	
substitutions	50%
omissions	50%
distortions	0%
Distribution by manner	
within manner	36%
between manner	64%
Distribution by phoneme type	
fricative	21%
plosive	36%
affricate	11%
glide	14%
lateral	4%
nasal	14%
Voice	
F ₀ (average)	220 Hz
F ₁ (range)	260-960 Hz
F ₂ (range)	1400-1700 Hz

Note. CA = 3 yrs, 6 mos.

STATUS 9-12 MONTHS AFTER MENINGITIS

Nearly one year after his illness, J. T.'s communication abilities were re-evaluated. Evaluation sessions were kept short, but even with this modification results were influenced by a shortened attention span. Despite their questionable reliability, the following findings can serve as an approximate index of J. T.'s performance levels.

Hearing

Nine months after the onset of meningitis, aided binaural thresholds were 95 dB HL at 250 Hz and 85 dB HL at 500 Hz, with no response above 500 Hz to warbled pure tones. Speech awareness threshold was 95 dB HL.

Receptive Language

J. T. seemed to have "broken the code" of cued speech according to his pre-school teacher. His visual attention span when speech was accompanied by cuing was adequate. The Peabody Picture Vocabulary Test (PPVT), Forms L and M (Dunn & Dunn, 1981), were administered by the speech-language pathologist to assess receptive vocabulary (a) using cues and spoken language simultaneously and (b) using spoken language without cues, to quantify the effectiveness of cued speech. Results, shown in Table 3, indicated essentially no difference between presentation modes, though skill level may have been higher than observed during this test. A comparison with Table 2 indicates that receptive language skill had not returned to pre-illness levels.

Expressive Language

Audiotape recordings were made of J. T.'s spontaneous language in a semi-structured activity with his teacher and in an unstructured situation with his mother. Most of the utterances would have been unintelligible out of context or without watching J. T. as he spoke. The middle 50 utterances of this sample were analyzed in the same manner as the tape made before the onset of hearing loss.

The MLU was 3.3 (Brown's Stage IV), indicating no significant growth or decrement in sentence length. The majority of utterances were S-V-O with limited use of prepositional phrases. J. T. was beginning to use pronouns (a goal of formal language training), "I", "my", and "me". All verbs were expressed in the third-person present tense. J. T. was using more adjectives and conjunctions than before his illness and was beginning to use wh- questions. He understood and used some pragmatic features such as turn-taking, opening, and topic introduction in his spontaneous language.

Articulation

Articulation errors increased overall. Compared to the prior speech sample, there was an increase in the percentage of speech sound omissions. With

the exception of fricatives and laterals, errors in all other speech sound categories increased over those noted in the pre-meningitic sample. Phonemes that were produced correctly before the onset of hearing loss were produced incorrectly, especially in the plosive and nasal categories. The frequency of between- and within-manner errors was similar to what occurred in the pre-meningitic sample, but there were many errors in which voiced and voiceless cognates were confused.

Voice

Analysis of voice quality was made from spectrograms of the recorded sample. The fundamental frequency of J. T.'s voice had lowered (this may have been due to change in age), and the range of both the first and second formants was narrowed. Rate was slower and vowels were prolonged, especially in multi-syllabic words and syllables with diphthongs. The overriding problems of prosody and rhythm, coupled with numerous articulation errors, prevented intelligibility out of context.

Summary of Results

Language, articulation, and voice evaluations indicated the following, one year after the onset of hearing loss caused by meningitis.

1. There was essentially no vocabulary growth.
2. Speech intelligibility decreased from approximately 90% to 10% as rated by three experienced listeners using the NTID Intelligibility Scale (Subtelny, Orlando, & Whitehead, 1979).
3. Rate was slower as evaluated by the NTID Intelligibility Scale.
4. MLU showed no growth in expressive language.
5. Use of prosodic features decreased.
6. There was an increase in consonant omissions.
7. Vowels were prolonged.
8. Fundamental frequency of the voice was lowered.
9. The second formant was flat.
10. Pharyngeal resonance increased as rated by the NTID Intelligibility Scale.

DISCUSSION AND IMPLICATIONS

With documentation of this child's preexisting status, the effect of hearing loss can be seen to be dramatic as well as pervasive, including deterioration of both nonsegmental and segmental features of speech, change in voice quality, and little if any growth in receptive or expressive language in a year's time, despite intervention. The lack of vocabulary and language growth were certainly related to the absence of an effective receptive mode for J. T. Even though his teacher stated that J. T. had "broken the code" of cued speech, the

PPVT indicated no difference between presentation with and without cues. J. T. may have relied on speechreading, rather than cues, but this mode of reception was not formally evaluated. J. T.'s use of a variety of new language forms — pronouns, wh- questions, adjectives, conjunctions, and adverbs — was probably the direct result of language therapy, as use of all of the above structures was a goal of intervention.

Articulation errors at a year after the onset of hearing loss, such as omission of final consonants, were characteristic of congenitally deaf speakers (Markides, 1970; Levitt & Stromberg, 1983; Levitt, 1971; Smith, 1975). Intelligibility decreased also to 20-30% as reported for congenitally deaf speakers (Markides, 1970; Smith, 1975). Deterioration on the segmental level was probably due to the removal of auditory feedback from a phonologic system that was neither stabilized nor complete. J. T. may have had some memory of sounds previously developed, but, without the auditory feedback, retained only their visible features. Plosive and nasal errors may have been associated with the increase in pharyngeal resonance which, in turn, may have been an attempt to increase tactile-kinesthetic feedback.

Changes in voice resulted in characteristics descriptive of deaf children (Levitt, 1971; Metz, Whitehead, & Mashie, 1982). J. T.'s voice quality may have reflected an attempt to monitor articulatory precision more carefully or compensatory adjustments to increase tactile-kinesthetic feedback. J. T. may also have been imitating the rate at which he was spoken to. Although his parents and teachers cued accurately, they did not cue at the rate of speech used in everyday conversation.

J. T. was 2 years, 9 months, old when he was deafened. Research has shown that articulation and language skills are not developed to adult level or stabilized at this age in normally-hearing children (Muma, 1978; Winitz, 1969). Thus, it must also be considered that the rapidity of deterioration was due to the instability of skill development prior to the loss of hearing. Communication intervention with children deafened before language and speech development is complete is a complex process of conservation, teaching a new receptive communication mode, and developing new language skills. J. T.'s rehabilitation attempted to establish an effective input mode and maintain articulatory accuracy and voice quality. It is in these two areas that the effects of sudden hearing loss were most evident. Alternatives to auditory input need to be presented, tried, and evaluated. Vibrotactile devices may be useful for input and feedback.

Although rehabilitative efforts with deafened children may become unnecessary with the development of a vaccine for meningitis, the challenges presented by this population remain. The changes in speech, voice, and language offer not only clues to the course of habilitation, but also information invaluable to educators of the deaf, speech-language pathologists, and audiologists, enabling them to better understand the effects of sudden hearing loss and develop more effective strategies for remediation.

ACKNOWLEDGEMENTS

The author wishes to thank the parents of this child for allowing the recordings to be analyzed. The author also is indebted to Mrs. Barbara Hoffman and Mrs. Dora Castillo for secretarial support in preparation of this manuscript.

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