

The Use of FM Technology for Infants and Young Children

Sandra Abbott Gabbard

Introduction

The successful trend of identifying hearing loss in the first few weeks of life has resulted in many new challenges for audiologists. For the approximately 2 of every 1000 infants born who are identified with bilateral hearing loss (Mehl and Thomson, 1998), the use of amplification is commonly the first step in the intervention process for the family. The use of hearing aids, combined with early intervention, has been shown to significantly improve the speech and language skills of young children with hearing loss (Yoshinaga-Itano, 2000). Therefore the goal of amplifying infants with congenital hearing loss optimally begins immediately after identification. The process includes selection, fitting, verification and validation for a population with its own unique issues and needs.

Audiologists working with young infants play an import role in the lives of families including information sharing, counseling, and case management. It is important that parents understand the relationship between hearing and communication. The goal of amplification for infants focuses around the emerging development of language, speech perception and speech production. Reaching decisions about the amplification for an infant includes examining available technology features with the parents and empowering them with the knowledge to choose the best option for their child given all of the available information and circumstances. Technology choices include the use of an FM system with the personal hearing aids with the goal of optimizing residual hearing in less than optimal environments and listening contexts.

Address correspondence to: Sandra Abbott Gabbard, Ph.D., University of Colorado, Health Services, 4200 E. 9th Ave, Box B210, Denver, CO 80262, USA.

Information for Parents Following Early Diagnosis

There is compelling evidence that children born with hearing loss who have been identified and begun intervention by 6 months of age will have significantly better language development than their late identified peers (Downs and Yoshinaga-Itano, 1999; Yoshinaga-Itano et al., 1998). Recent advances in audiologic assessment technology gives audiologists the opportunity to focus on the results of electrophysiologic tests including click and frequency specific auditory brainstem response (ABR), Auditory Steady State Responses (ASSR), otoacoustic emissions (OAEs), and acoustic immittance measures (Gabbard et al. 1998). There is consensus that the diagnosis of congenital hearing loss should be completed in the first three months of life and should be followed immediately with the consideration of amplification use (Joint Commission on Infant Hearing, 2000).

Issues with this population often arise which may challenge the transition from identification to early amplification and intervention. These include young infants limited behavioral response to sound, the potential for complicating middle ear fluid, parental uncertainties, possible existence of additional handicaps, and often limited resources to support and pay for technology. In spite of these potential hurdles, the initiation of early intervention should not be delayed. The audiologist's role in providing information to the family is a continuous one; however the quality of the information given to parents in the first few weeks of the diagnosis can effect their ability to make informed choices about the intervention the child receives. The parents need to be given information about the importance of ongoing early intervention and need to

be connected to a system. This is also an optimal time to establish parent-to-parent support for families and to connect them to resource and funding information.

The first step in the intervention process is often exploring the amplification options. It is the role of the pediatric audiologist to share information about hearing loss and available technology with the parents as well as their medical and support team. With the expansive growth in amplification technology in the past few years, audiologists face constant challenges in keeping up-to-date with the available technology and the research to support specific strategies in signal processing. Parents should receive information about available hearing aid types, styles, processing strategies, and features so they can play an active role in the technology selection.

The possible use of FM technology with the infant's personal hearing aids should be included in the comprehensive discussion of amplification options. Families of infants who are only a few weeks of age should be encouraged to consider the current or future addition of FM to supplement the benefits of the hearing aids. This accessibility will be especially important when the child becomes older and mobile. FM compatibility of the hearing aids should be discussed as a consideration that may influence the family's hearing aid choice. For example, a family's interest in using FM technology may lead to a decision to select hearing aids that are compatible with direct audio input and/or a multi-memory option that can incorporate a hearing aid/FM setting. These early choices made regarding the selection of hearing aids have consequences for the child for years to come while they are using the selected hearing aids.

Benefits of FM

As amplification choices are being explored for infants, it is important to remember that it has been demonstrated that children with all degrees of hearing loss often require a signal-to-noise ratio (SNR) advantage to preserve optimal speech perception in noise (Killion, 1997; Finitzo-Hieber and Tillman 1978; Gengel 1971; Ross and Giolas 1971; Crandell 1993). In order to obtain a consistent SNR ratio advantage, assistive listening technology may be necessary. The signal from a remote microphone can be sent directly into the ear of a listener by using FM system technology and a variety of transmitters and receivers. This direct transmission from a remote microphone has

been widely studied and is commonly used in a classroom situation to reduce the interference between a child and the teacher (Johnson et al., 1997; Crandell & Smaldino, 2000). FM is used in educational settings for children with and without hearing loss as an effective strategy to improve the listening environment and reduce the problems associated with speaker-to-listener distance, poor SNR, and room reverberation (Crandell, 1993).

Like older children, infants and toddlers face challenges of poor acoustic environmental conditions. Young children however are unique in their dependence on good speech perception abilities for the development of auditory skills and speech and language acquisition. The use of FM technology is not commonly used with this population and there are very few studies that examine this application. Benoit (1989) investigated home use of FM with toddlers. The FM systems used in this evaluation were body worn which challenged the acceptance of the technology by several families. Six of ten families adjusted well to the technology. The parents reported that the FM transmitter microphone had a benefit of encouraging their children to imitate their parent's speech and also resulted in parents talking more to their children.

Moeller and her colleagues (1996) used formal language measures to compare two groups of two to four year old children. One group was encouraged to use FM as much as possible at home and the other group used hearing aids alone. While the language measures did not result in significant differences between the groups, some subjects had increased rates of language acquisition that suggested they received benefit from the use of FM. The authors reported several technology challenges including interference with single-channel transmitters and body worn receivers with multiple components. Parents in this study did report that FM usage in noisy situation was beneficial.

Implementing FM Use

While the information about FM systems may affect the hearing aid choices made, it may be several months before the family is ready to implement a plan for the addition of FM to the child's listening options. As infants become toddlers, the distance between their ear and the mouth of their parent or caretaker begins to increase which may compromise

audibility. Much of a young infant's awake and listening time is spent in close proximity to their parent. When the child begins to spend more and more time several feet away from their parent, often not attending directly to the parent's language model, it is appropriate to consider adding the use of FM. Distance however is only one issue that may influence a family's decision to choose FM. Others include the degree of the child's hearing loss, the amount of competing background noise in the child's environment, the child's ability to tolerate the full time use of hearing aids, and the parents' willingness and ability to manage the technology.

The use of FM with young children may be beneficial to improve audibility for children with severe-profound hearing loss (Madell, 1992, Moeller et al, 1996). The use of FM can increase the input intensity to the hearing instrument from the remote microphone, increasing audibility of that signal. Both personal hearing aids and FM systems can benefit children with all degrees of hearing loss, however the functional benefits are often most obvious with more significant losses.

Parent training and support are integral components to the implementation of FM use. The parent's willingness to handle the devices is a critical variable in the success with the instruments. Demonstration and practice with devices in the clinical setting will increase the parent's comfort in utilizing the technology. The use of ear level receivers minimizes the number of components needed. Body worn units have been traditionally used with young children; however, completely at-the-ear components are universally preferred by parents interested in FM systems through the Colorado FM loaner bank. It is important to train the parents to perform regular listening checks of the hearing aid alone and when connected to the FM system. Parents usually welcome the use of a family friendly hearing aid stethoscope that can be used for regular listening checks of the equipment.

It may be helpful to the parents to add the use of FM technology after they have mastered the care and use of the personal hearing aids. Many parents are overwhelmed with the unexpected demands of hearing use and often are better prepared to accept and appreciate the challenges and benefits of FM technology when the child is a few months of age and is readily accepting the use of the hearing aids. Additionally, it may be useful to create a list of possible environmental applications for the FM. A discussion of the

family's life style may result in a list which includes use in stores, museums, parks and while the child is in a car seat, stroller, backpack, bike seat and just running around. The list should only be used as a general guideline as parents often add to or modify the list over time.

Very young children are dependent on a variety of listening environments for exposure to opportunities for communication and language modeling. They are not only dependent on the quality one-on-one time that often occurs with their parents, but they are also dependent on exposure to incidental listening that comes from their environment. Their own speech, as well as speech and environmental sounds in their environment, needs to be audible for the emergence of auditory skills, speech and oral language. For these reasons, it is important that amplified speech from the FM transmitter have the same high quality processing as amplified speech from the hearing aid microphone. This consistency in sound quality is important as infants attach meaning to environmental sounds and speech. Using an FM receiver that is either built into the hearing aid or attached to the hearing aid will allow for this consistency. In addition, the hearing aid and FM microphone should both be sending audible signals to the child's ear whenever possible. For this to occur, the hearing aid used by the child needs to allow for simultaneous hearing aid and FM input.

Assessing FM Function and Benefit

The FM systems used with young children are commonly connected directly to their personal hearing aids. All hearing aids should be optimally adjusted to meet targets using a prescriptive method designed to measure or estimate the audibility of amplified speech. Both the Desired Sensation Method (Seewald et al, 1999) and the NAL-NL1 (Byrne et al., 2001) procedures have methods that can be applied to evaluate audibility. It can be valuable to evaluate the hearing aids while the FM is activated to validate that the input from the transmitter meets the prescribed targets. It may be helpful to also assess the increased audibility from the FM transmitter.

Performing informal functional listening checks with the child in HA only and HA/FM settings in a noisy environment is a valuable way to demonstrate benefit for the child. Often the demonstration will reveal an obvious improvement in the parent's ability

to get their child's attention and in the child's ability to attend to the parent's speech. This FM advantage can also be demonstrated in the sound room using a speech-in-noise stimulus, however until the child is able to perform a speech perception task, it may be difficult to quantify this improvement.

The **FM Listening Evaluation for Children** (Appendix A) was created by Cheryl Johnson as a tool to evaluate use and benefit of hearing aids and FM systems for young children. This questionnaire includes a scoring system and an opportunity for situational analysis. Each listening situation requires a subjective score based on the child's response. It can be completed by a parent or professional working with the child. This tool can be used to assess counseling and technical support needs of the family, as well as provide outcome measures of FM benefit.

The Colorado Loaner FM Project

Colorado has had a loaner FM bank administered by the University of Colorado Hospital since 1998. The need was first identified by parents who were very interested in accessing the technology but had been recently challenged to find the resources to support their child's personal hearing aids. The lack of documented benefit of FM use with infants often makes it nearly impossible to persuade third party funding sources to pay for the technology. The first generation receivers in the bank included a mix of ear-level and body worn devices. Currently all loaner systems include two ear level receivers and one transmitter. Some preliminary information collected from parents and interventionists of young children participating in this program is presented below.

Parent and Professional Perspectives of Early FM Use

The use of the **FM Listening Evaluation for Children** (Appendix A) is routinely used in the Colorado Loaner FM Program as a tool to better understand the use and benefit from the hearing aids and FM system used by the child. Both parents and early intervention providers are asked to return the questionnaires following at least 3–6 months of FM use and then quarterly thereafter. The results are primarily used to counsel and give technical assistance and training when appropriate for families and pro-

viders. The initial survey results from nine infants and toddlers are presented in tables 1 and 2.

Table 1. Description of participants

Number	9
Age range	15–30 months
Average age of confirmed HL	3 months
Average age of HA fitting	4.5 months
Average age intervention start	6 months
Average age of FM fitting	17 months
Degree of hearing loss	mild-profound
HA use in hours/day	10 (range 4–12)
FM use in hours/day	4 (range 2–12)
FM technology	6 ear level, 3 body worn

Table 2. Results of FM Listening Evaluation for Children (scores based on 1-seldom, 3-sometimes, 5-usually)

	HA	FM
Technology easy to operate	4.0	3.88
Technology remained in good working order	4.0	5.0
Technology judged as comfortable for children to use	4.28	4.6

The subjects included nine children between the ages of 15 and 30 months of age. Hearing aid and FM systems were all judged as easy to operate, remained in good working order and were comfortable for children to wear. The perceived benefit in listening performance between the hearing aids and the FM systems were identical. The greatest benefits from the FM systems were described in the parent's comments. They reported the benefits of FM systems included, "being mobile while continuing to hear", "consistent sound whether noisy or not", provides the best amplification to help auditory skills", "gives extra boost to hearing aids", "keeps him focused on the speaker", and "improves attention in noise".

Discussion

The choice of using an FM system for a young child clearly requires family commitment and supportive professionals. In the past, FM use has been limited to school children who have had to access the FM signal separate from their personal hearing aids.

With the technology available today, ear level receivers allow the FM system to be coupled to the child's hearing aids without the use of cords and body worn devices. This not only facilitates a consistent signal to the child's ear from either the hearing aid and/or FM microphone, it also results in an easier system to manage from the parent's perspective.

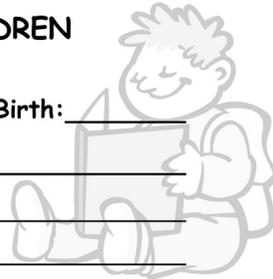
Our positive experiences with families accessing technology from the Colorado Loaner FM program have led us to the conclusions that many families can easily use and maintain the equipment with on-going information and support. While the use of an FM system is not chosen by all families, many families value the contribution they have on the child's ability to communicate in difficult listening situations. Clearly more research on the benefits of FM use in young children is needed, however assessing outcomes of FM cannot be completely separated from the benefits of the personal hearing aids and the early intervention services. It is easy to value a system that has the ability to provide an improved listening environment for young children during their critical years of auditory skill and speech and language development.

References

- Benoit, R. Home use of amplification systems during the preschool years. *Hearing Instruments*. 1989, 40, 8–12.
- Brackett D. Effects of early FM use on speech perception. In M Ross (ed) FM auditory training systems: characteristics, selection and use. 1992. Timonium, MD: York Press.
- Byrne D, Dillon H, Ching TYC. The NAL-NL1 procedure for fitting non-linear hearing aids: characteristics and comparisons with other procedures. *JAAA* 2001. 12:37–51.
- Crandell C. Noise effects on children with minimal sensorineural hearing loss. *Ear and Hearing* 1993; 14:210–217.
- Finitzo-Hieber T, Tillman T. Room acoustics effects on monosyllabic word discrimination ability for normal and hearing-impaired children. *Journal of Speech and Hearing Research* 1978;21:440–458.
- Crandell, C, Smaldino, J. When hearing aids are not enough: assistive technologies for the hearing impaired. In R. Sandlin, rd. Handbook of Amplification. San Diego: Singular Press; 2000.
- Gabbard SA, Thomson V, Brown AS. Considerations for universal hearing screening, audiologic assessment and intervention. *Audiology Today*, Special Issue: Hearing In Infants 1998;12: 8–10
- Gengel R. Room acoustics effects on monosyllabic word discrimination ability for normal and hearing-impaired children. *Journal of Auditory Research* 1971;11:219–222.
- Joint Commission on Infant Hearing: Year 2000 position statement: principles and guidelines for early hearing detection and intervention. *American Journal of Audiology* 2000;9:9–29.
- Killion M. Hearing aids: past, present, future: moving toward normal conversation in noise. *British Journal of Audiology* 1997;31:141–148.
- Madell J., FM systems a primary amplification for children with profound hearing loss. *Ear and Hearing* 1992, 13, 102–107.
- Mehl AL, Thomson V. Newborn hearing screening: the great omission. *Pediatrics* 998;101(1):4.
- Moeller, MP, Donaghy, KF, Beauchaine, KL, Lewis, DE, Stelmachowicz, PG. Longitudinal study of FM system use in nonacademic settings: effects on language development. *Ear and Hearing* 1996, 17, 28–41.
- Ross M, Giolas T. Three classroom listening conditions on speech intelligibility. *American Annals of the Deaf* 1971;116:580–584.
- Seewald R, Moodie KS, Sinclair S, Scollie S. Predictive validity of a procedure for pediatric hearing instrument fitting. *American Journal of Audiology* 1999;8(5):1–10.
- Yoshinaga-Itano C. Successful outcomes for deaf and hard-of-hearing children. *Seminars in Hearing* 2000;21(4):309–326.
- Yoshanaga-Itano C, Sedey A, Coulter D, Mehl A. Language of early and later identified children with hearing loss. *Pediatrics* 1998;102 (5):1161–1171.

Appendix 1

FM LISTENING EVALUATION FOR CHILDREN



Name: _____ Date of Birth: _____

Completed by: _____ Date: _____

___parent ___audiologist ___teacher other-specify _____

Length of hearing aid usage: _____ HA brand/model: _____

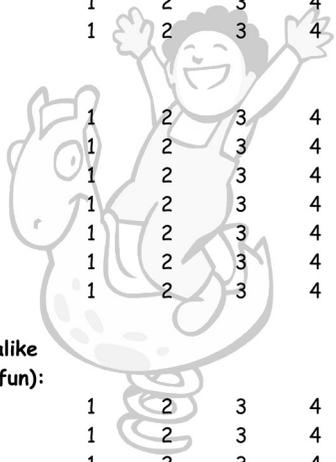
Length of FM usage: _____ FM brand/model: _____

___FM used daily Number of hours per day used _____

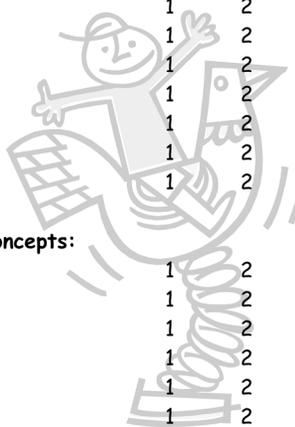
___FM used occasionally Number of hours per week used _____

Please rate the following skills based on the child's behavior or performance on typical days. Indicate if performance was obtained with FM or without FM (baseline). To score, subtract any NA (not applicable) items from the total, then determine percent for total performance and for each situation.

	SELDOM	SOMETIMES	USUALLY	
1. Child responds to his/her name when spoken to:				
a. In a quiet room, within 3 feet	1	2	3	4 5 NA
b. In a quiet room, at 10 feet	1	2	3	4 5 NA
c. In a noisy room, within 3 feet	1	2	3	4 5 NA
d. In a noisy room, at 10 feet	1	2	3	4 5 NA
e. Without visual cues	1	2	3	4 5 NA
f. From another room	1	2	3	4 5 NA
g. Outside/in the community	1	2	3	4 5 NA
2. Child attends to person speaking:				
a. In a quiet room, within 3 feet	1	2	3	4 5 NA
b. In a quiet room, at 10 feet	1	2	3	4 5 NA
c. In a noisy room, within 3 feet	1	2	3	4 5 NA
d. In a noisy room, at 10 feet	1	2	3	4 5 NA
e. Without visual cues	1	2	3	4 5 NA
f. From another room	1	2	3	4 5 NA
g. Outside/in the community	1	2	3	4 5 NA
3. Child distinguishes between words that sound alike (e.g., bay for day, sink for think, or sun for fun):				
a. In a quiet room, within 3 feet	1	2	3	4 5 NA
b. In a quiet room, at 10 feet	1	2	3	4 5 NA
c. In a noisy room, within 3 feet	1	2	3	4 5 NA
d. In a noisy room, at 10 feet	1	2	3	4 5 NA
e. Without visual cues	1	2	3	4 5 NA
f. From another room	1	2	3	4 5 NA
g. Outside/in the community	1	2	3	4 5 NA



	SELDOM	SOMETIMES	USUALLY		
4. Child responds accurately to spoken directions and/or questions:					
a. In a quiet room, within 3 feet	1	2	3	4	5 NA
b. In a quiet room, at 10 feet	1	2	3	4	5 NA
c. In a noisy room, within 3 feet	1	2	3	4	5 NA
d. In a noisy room, at 10 feet	1	2	3	4	5 NA
e. Without visual cues	1	2	3	4	5 NA
f. From another room	1	2	3	4	5 NA
g. Outside/in the community	1	2	3	4	5 NA
5. Child comprehends oral instruction & concepts:					
a. In a quiet room, within 3 feet	1	2	3	4	5 NA
b. In a quiet room, at 10 feet	1	2	3	4	5 NA
c. In a noisy room, within 3 feet	1	2	3	4	5 NA
d. In a noisy room, at 10 feet	1	2	3	4	5 NA
e. Without visual cues	1	2	3	4	5 NA
f. From another room	1	2	3	4	5 NA
g. Outside/in the community	1	2	3	4	5 NA



TOTAL SCORE: _____/(175) = % ___with FM ___without FM

Situational Analysis: Quiet (a,b) _____/(50) = % Noise (c,d,g) _____/(75) = %

Auditory only (e) _____/(25) = % Distance (b,d,f) _____/(75) = %

Information on FM Use:

HA/FM system is easy to operate:	1	2	3	4	5	NA
HA/FM system has remained in good working order:	1	2	3	4	5	NA
HA/FM system is comfortable for child to use:	1	2	3	4	5	NA
Child tries to turn HA/FM system off:	1	2	3	4	5	NA
Feedback (whistling noise) is present with HA/FM:	1	2	3	4	5	NA

Indicate types of activities the FM is used for?

- ___ snacks ___ play ___ story-time/reading ___ playground ___ walks
- ___ listening/language/speech therapy ___ shopping ___ car
- other (describe) _____

For which of the above activities do you think the FM was most beneficial?

What do you think is the greatest benefit(s) of the FM system?

What do you think is the greatest challenge(s) with the FM system?

