

# Chapter 8

## Hearing and Ear Abnormalities in Fanconi Anemia

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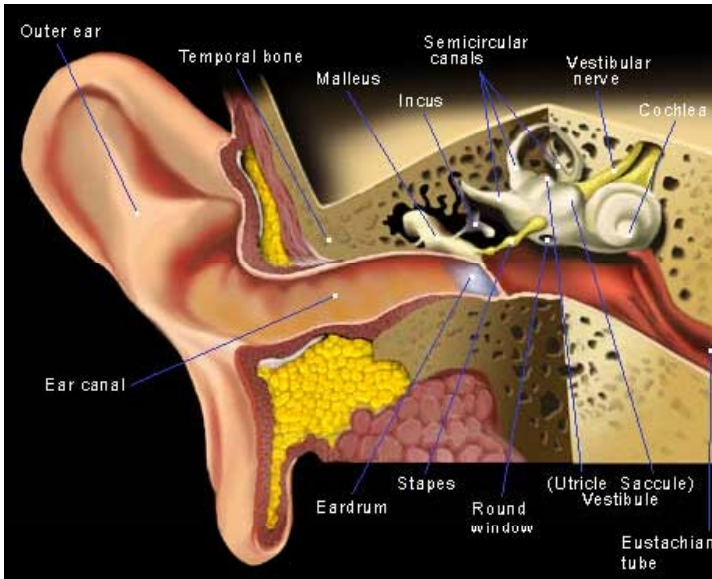
### Introduction

In 1927, Guido Fanconi, MD, noticed an association between ear anomalies and FA. In a 1993 review of 370 patients with FA, hearing loss was documented in 11.3% of cases and ear malformations in 14.9%.<sup>1</sup> However, detailed ear manifestations in FA have not been well described in the literature. This chapter will describe normal anatomy and function of the ear, types and degree of hearing loss, the common physical and audiologic findings among the patients with FA, and potential rehabilitation and treatment options for their hearing loss.

### Anatomy and Function of the Ear

The ear is made up of three main sections: the outer, the middle, and the inner ear (Figure 1). The two main portions of the outer ear are the pinna and the ear canal. The middle ear consists of the eardrum (tympanic membrane) and three tiny bones called ossicles: malleus (hammer), incus (anvil) and stapes (stirrup). The malleus bone attaches to the eardrum and bridges the gap between the eardrum, the other two ossicles, and the inner ear. The hearing part of the inner ear consists of a snail shell-like cochlea and is filled with several canals of fluids.

**Figure 1: Anatomy of Ear**



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Sound waves enter the ear canal and vibrate the eardrum like a real drum. These vibrations reach the three tiny ossicles and amplify the sound. Once the sound waves reach the inner ear, the fluid within the cochlea moves and stimulates thousands of tiny hair cells. These hair cells then transform the sound vibrations into electrical impulses, which travel along the auditory nerve from the cochlea to the brain. The brain then translates these signals and allows us to comprehend speech and surrounding sounds.

## **Types and Degree of Hearing Loss**

In general, there are three main types of hearing loss: conductive, sensorineural, and mixed (combined conductive and sensorineural). Conductive hearing loss (CHL) is commonly caused by problems in the outer and/or middle ear, which prevent the sounds from

reaching the inner ear. This is most often due to a middle ear infection, excessive wax accumulation, and/or a hole in the eardrum. Uncommonly, this can also happen if the middle ear tiny bones are malformed or if their movements are restricted from abnormal scar tissue formation.

Sensorineural hearing loss (SNHL) occurs when the hair cells in the inner ear are damaged and unable to transform sound waves into the electrical signals. This type of hearing loss is commonly caused by the aging process, excessive loud noise exposure, and certain drugs, such as particular chemotherapy agents or intravenous antibiotics. If the auditory nerve from the inner ear becomes damaged or is absent, this can prevent sound signals from reaching the brain.

Sounds can be characterized as loud or soft, and high-pitched or low-pitched. Subsequently, hearing loss can be described in terms of the loss of auditory perception in variable degrees of intensity and ranges of pitches. An audiologist performs a hearing test to determine the degree, type and pattern of hearing loss. There are several types of measurement methods, including behavior audiologic tests, otoacoustic emission tests, and brainstem-evoked auditory response tests (BAER). The age and ability of a patient to cooperate will determine which methods are appropriate. In very young children, several tests are often required to characterize clearly their hearing loss.

Hearing loss is classified according to severity in terms of *decibels hearing level* (dB HL; measuring unit for sound intensity): mild hearing loss (> 25-40 dB HL); moderate hearing loss (> 40-70 dB HL); severe hearing loss (> 70-90 dB HL); and profound hearing loss (> 90 dB HL). When there is a mild to moderate hearing

loss, it is difficult to understand normal daily speech conversation, especially in the presence of background noise. When there is a moderate to severe hearing loss, speech must be very loud to be understood. For those with profound hearing loss, communication is very difficult, even with hearing aid amplification.

## **Ear and Hearing Presentations in Fanconi Anemia**

Only a few scattered case reports describing ear manifestations are currently found in the medical literature on Fanconi anemia. In order to systematically examine and define the ear manifestations in FA, a prospective study of twenty FA patients was conducted at the National Institutes of Health, Bethesda, MD, as part of a prospective inherited bone marrow failure syndrome study.<sup>2</sup> Patient ages ranged from 5 to 41 years. Four patients were excluded because either their audiogram and/or temporal bones computerized tomography were not available. Out of the remaining 32 ears in 16 patients, five ears in four FA patients were excluded from the data analysis because of surgical alteration of the congenital status of the ear. Thus, the results reflect the data obtained from 27 ears (16 patients). All patients underwent comprehensive audiologic and otolaryngologic evaluation, including microscopic ear examination.

Microscopic examination of the 27 eardrums revealed abnormally formed eardrums in 17 cases (63%), and one case of an undeveloped, absent ear canal (aural atresia). The abnormal eardrum findings include a smaller eardrum, shorter and abnormally placed malleus within the eardrum, and the presence of abnormal bony islands under the eardrum (Figure 2). Hearing loss was detected in 14 of 27 ears (53%) while normal hearing

was documented in the remaining 13 ears. The majority of hearing loss was mild, and the most common types of hearing losses were conductive hearing loss (9 cases, 65%), followed by sensorineural hearing loss (3 cases, 21%) and mixed hearing loss (2 cases, 14%). These findings suggest that over half of individuals with FA have a mild conductive hearing loss, probably due to an abnormally developed eardrum and/or ossicles in the middle ear space.

**Figure 2:**

***Normal eardrum***



***Abnormal eardrum in FA patient***



In summary, hearing loss, mostly conductive, is present in greater than 50% of our FA cohort ears. Congenital abnormalities in the tympanic membrane and middle ear ossicles were found in 67%. This incidence of hearing loss and congenital ear malformation is much higher than previously reported. This study suggests that these features characteristic of FA can occur even when hearing is normal or slightly reduced.

## **Consequences of Hearing Loss**

Children use their hearing to develop speech, language, communication skills, and to facilitate learning. Children with a mild hearing loss (25-40 dB HL) have difficulty hearing faint and distant speech. Vowel sounds can be heard clearly, but voiceless consonants (e.g., “s,” “f,” and “th”) can be difficult to hear. School-age students with mild hearing loss have difficulty when functioning in a regular classroom with normally present background noises.<sup>3</sup> Children with moderate hearing loss (41-55 dB HL) miss much of normal conversation. These children may have difficulty learning vocabulary, grammar, and other aspects of verbal communication. Even children with unilateral hearing loss (one ear with normal hearing and other other with at least a mild permanent hearing loss) can be affected. If listening takes place in a consistently noisy environment, their academic potential and social interaction can be compromised.

## **Early Identification and Intervention for Hearing-Impaired Children**

Once hearing loss is identified or suspected, the child should undergo comprehensive medical ear and audiologic evaluation. The earlier the hearing loss is identified and intervention initiated, the less serious the

permanent effects. Often hearing-impaired children require some form of special education or services including:

- 1) Favorable seating in the class;
- 2) Amplification systems;
- 3) Possible surgical intervention to improve hearing deficits;
- 4) Regular speech and language therapy from a specialist.

The Individuals with Disabilities Education Act (IDEA) mandates that children who have hearing loss receive appropriate early intervention programs from birth to age three and throughout the school years (ages 3-21).<sup>4</sup> Hearing impairment is defined by IDEA as “an impairment in hearing, whether permanent or fluctuating, that adversely affects a child’s educational performance.” Early intervention services for children are often family-centered and involve multidisciplinary services.

## **Hearing Amplification**

### **Hearing aids**

An audiologist and early intervention team should evaluate the aural amplification needs of hearing-impaired children. Infants as young as four weeks old can be fitted with amplification such as hearing aids and assistive listening devices (ALD). Hearing aids can be beneficial for all types of hearing loss (conductive, sensorineural or mixed hearing loss).

Several types of hearing aids are available. Hearing aids differ in design (analog versus digital), size (smaller completely-in-the-ear canal versus larger behind-the-ear), the amount of amplification, and availability of special features. They also have common components that include:

- 1) A microphone to pick up sound;
- 2) A processor to make the sound louder;
- 3) A receiver to deliver the amplified sound into the ear.

The behind-the-ear (BTE) hearing aid is the type of hearing aid most commonly used in children. It can accommodate a wide variety of hearing losses and can be adjusted for different degrees of amplification. It is easier to handle and can be monitored by the child and caretakers. The ear mold, a plastic piece that fits the ear and holds the hearing aid on the ear, can be detached and easily remade as the child grows. The hearing aid is often equipped with a direct audio input capability that can be used with other listening devices.

### **Assistive listening devices**

An assistive listening device can provide excellent help to hearing impaired individuals to function better in daily communication situations. ALDs may be used alone or in combination with hearing aids. These devices provide extra help in specific listening situations, such as in noisy backgrounds (e.g., school classrooms, restaurants, movie theaters, conferences). The most commonly utilized ALDs are based on frequency modulation (FM) systems, like a radio. The personal FM system consists of a transmitter microphone used by the speaker and a receiver used by the listener. For example, this device allows the voice of a teacher, who is wearing a microphone, to be heard more clearly over the background noises of a classroom by a student with an FM receiver.

## **Surgical Management of Hearing Loss in FA**

### **Middle ear surgery**

When the middle ear bones are malformed and unable to vibrate normally, the sound wave cannot be amplified



and transferred to the cochlea; this leads to conductive hearing loss. In FA cases, several possible causes for the inefficient sound transmission through the ossicles include fusion of the malleus to the bony island under a bony eardrum, scarring around the stapes, or an absent ear canal. Sometimes, a portion of the ossicles may miss sound transmission to the inner ear. These causes of conductive hearing loss can sometimes be corrected surgically. Sensorineural hearing loss from the inner ear or auditory nerve damage cannot be restored by ear surgery.

During a middle ear bone surgery to restore normal sound transmission (also called ossicular chain reconstruction), the bony and fibrous tissue restricting ossicular movements is corrected or the immobile ossicle(s) replaced with a middle ear bone prosthesis. Prostheses are commonly composed of artificial bone (hydroxyapatite), titanium or other biocompatible composite materials. Middle ear bone surgery can be done using either local anesthesia sedation or general anesthesia and typically takes about one to three hours.

When thinking about a middle ear surgery, an ear specialist (also known as an otologist) and the patient and family must consider multiple factors and other treatment options, such as hearing aids. Individuals with serious medical conditions such as heart problems, bleeding tendencies, and high susceptibility for infection from significant bone marrow failure, are probably better candidates for hearing aid trials. Middle ear bone surgery is usually recommended after the age of seven when patients are less susceptible to frequent ear infections.

Middle ear bone surgeries (not specific to FA) typically improve conductive hearing loss in 75% to 90% of the

surgeries.<sup>5</sup> The potential complications associated with ear surgeries are uncommon but include:

- 1) Further hearing loss or no hearing improvement (in <10% to 20% of surgeries). Total deafness is extremely uncommon;
- 2) Injury to the facial nerve that runs through the ear, which can cause facial paralysis. This is extremely uncommon, and a facial nerve monitor is typically used during ear surgery to minimize risk;
- 3) Altered taste on the side of the tongue, which can last for a couple months; and
- 4) Persistent post-operative dizziness or ringing in the ears, but both are quite uncommon.

### **Implantable BAHA hearing device**

Bone-anchored hearing aids (BAHA) are very useful for those with conductive hearing loss from ossicular chain problems or a congenitally undeveloped ear canal when conventional hearing aids cannot be used, or for those individuals who are not good candidates for traditional middle ear surgery.<sup>6</sup> BAHA works by transmitting sound vibration through the skull and the inner ear, bypassing the external auditory canal and middle ear. It has been used since 1977 in Europe and was approved in the United States in 1996 as a treatment for conductive and mixed hearing losses.

In the BAHA system, a titanium implant is placed during a short surgical procedure and allowed to integrate with the skull bone for three months. A sound processor attached to the titanium implant produces sound vibrations through the skull and inner ear that stimulate the inner ear nerve fibers.

## Hearing and Ear Screening for FA Family Members

When a patient is diagnosed with FA, his or her siblings must also be tested to rule out FA. More than 50% of the individuals with FA have hearing loss and abnormal eardrums and middle ear bones. If a sibling does not test positive for FA via a chromosomal breakage test but has classic FA-related ear and hearing findings, the hematologist may wish to rule out FA with further genetic tests, including a clastogen-induced chromosomal breakage test in skin fibroblasts. Approximately 10% to 20% of FA patients with somatic mosaicism may have normal peripheral blood chromosomal breakage tests.<sup>7</sup> In the absence of obvious clinical presentations like absent thumbs and aplastic anemia, a diagnosis of FA is often delayed. Early detection and diagnosis of FA means prompt early surveillance, appropriate timely treatment, and eventually improved overall prognosis.

## Regular Periodic Auditory Monitoring

FA patients are predisposed to recurrent infections from neutropenia, multiple blood transfusions for severe anemia, and solid organ and hematologic malignancies. Consequently, they are more likely to receive ototoxic intravenous antibiotics (e.g., aminoglycoside), iron-chelating agents (e.g., desferoxamine), and chemotherapy agents (e.g., cisplatin). While they are exposed to these ototoxic agents, their auditory function should be closely monitored with serial audiograms.

## Conclusions

- 1) Congenital hearing loss and eardrum and middle ear malformations are more commonly associated with FA than previously reported.

- 2) All patients with FA should undergo comprehensive ear examination and audiologic evaluation by an otolaryngologist and audiologist, respectively, who are familiar with FA.
- 3) FA-related hearing problems can often be successfully treated with either appropriate amplification and/or surgical correction.

## **Useful Resources for Hearing Impaired**

Alexander Graham Bell Association for the  
Deaf and Hard of Hearing  
3417 Volta Place, NW  
Washington, DC 20007  
202-337-5220; 202-337-5221 (TTY)  
info@agbell.org

American Academy of Audiology  
11730 Plaza America Drive, Suite 300  
Reston, VA 20190  
800-AAA-2336 (V)

American Academy of Otolaryngology-HNS  
One Prince Street  
Alexandria, VA 22314  
703-836-444 (V)  
www.entnet.org

American Speech-Language-Hearing Association  
10801 Rockville Pike  
Rockville, MD 20852  
301-897-5700 (V/TTY)  
800-638-8255 (V/TTY)

National Institute on Deafness and Other Communication Disorders Information Clearinghouse

1 Communication Avenue  
Bethesda, MD 20892-3456  
800-241-1044; 800-241-1055 (TTY)  
nidcdinfo@nidcd.nih.gov

Self Help for Hard of Hearing People (SHHH)

7910 Woodmont Avenue, Suite 1200  
Bethesda, MD 20814  
301-657-2248; 301-657-2249 (TTY)  
info@hearingloss.org

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