Treacher Collins Syndrome: Otologic and Auditory Management

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Abstract

Treacher Collins syndrome (TCS) is an autosomal dominant genetic disorder, the phenotypic expression of which is seen in the head and neck area. The syndrome has full penetrance but variable expressivity even among family members, and recent investigation has reported gene site on chromosome 5q. TCS has a reported prevalence of 1 in 50,000 live births with about 40 percent of new occurrences resulting from a positive family history and a 60 percent new mutation rate. The clinical features of TCS involve bilateral abnormalities of the pinnae, external auditory canal, tympanic membrane, and middle ear space. Microtia has been reported to be as high as 85 percent, with one third of patients presenting with stenosis or complete atresia. Treacher Collins patients present with maximum conductive hearing loss often compounded by a high-frequency sensory component. This article describes the otologic and audiologic diagnosis and management of TCS.

Key Words: Aural atresia, bone-conduction amplification, conductive hearing loss, mandibulofacial dysostosis, microtia, Treacher Collins syndrome

Infants and children with craniofacial anomalies are at risk for otologic and auditory deficits. The Joint Committee on Infant Hearing (American Academy of Pediatrics, 1982; American Academy of Audiology, 1991) has long recognized congenital abnormalities associated with defects of the ears, nose, or throat as a high-risk factor for hearing impairment. Craniofacial anomalies represent between 2 and 5 percent of all risk factors on the high-risk register (Stein et al, 1983; Jacobson and Morehouse, 1984; Jacobson et al, 1990; Smith et al, 1992). Whereas the overall incidence of congenital abnormalities is small compared to other high-risk items, it is most often associated with hearing screening failure (Smith et al, 1992) and subsequent diagnosed hearing impairment (Alberti et al, 1985; Halpern et al, 1987). For example, in a group of 1240 graduates of an intensive care nursery, Smith and colleagues found that head and neck deformities were one of four risk factors (gestational age ≤ 36 weeks, meningitis, and ototoxic medications) that represented in excess of 90 percent of all hearing screening auditory brainstem response (ABR) failures. Further, Halpern et al (1987) reported that in a group of 820 high-risk infants, craniofacial anomalies were one of two high-risk items (TORCH complex was the other) that predicted hearing loss with 98 percent sensitivity. Whereas craniofacial anomalies represent a small proportion of infants at risk for hearing loss, when identified, this category yields a high percentage of hearing loss.

The prevalence of aural atresia has been reported to be about 1 in 10,000 live births and is frequently observed in craniofacial and skeletal anomalies such as Treacher Collins syndrome (TCS) (Jahrsdoerfer et al, 1991). Whereas the majority of Treacher Collins patients present with conductive pathology, sensory hearing impairment has been reported. Thus, early diagnosis and otologic and audiologic management of hearing loss are essential in the rehabilitation of infants and children diagnosed with craniofacial anomalies.
Genetic syndromes that include congenital aural malformations of the external and middle ear involve the embryologic development of the first and second branchial arch. Unilateral defects of the first and second branchial arch are best described as hemifacial microsomia. Over the past 20 years, we have evaluated over 1200 patients with a congenital ear malformation, including 57 patients with TCS. This manuscript addresses the otologic and audiologic conditions and problems associated with Treacher Collins syndrome.

**TREACHER COLLINS SYNDROME**

Treacher Collins syndrome was first reported around the turn of the century and has since been considered a mandibulofacial dysostosis (Franceschetti and Klein, 1949) having a genetic basis occurring during the early embryonic development from the first and second branchial arches (Gorlin et al, 1976). The pathogenesis leading to this syndrome has been attributed to abnormal neural crest cell migration (Poswillo, 1975) or possible mutation in extracellular development (Herring et al, 1979). TCS has a reported prevalence of 1 in 50,000 live births (Rovin et al, 1964; Frazen et al, 1967). Connor and Ferguson-Smith (1988) have reported that about 40 percent of new occurrences have a positive family history and a 60 percent new mutation rate (Gorlin et al, 1990). The syndrome becomes progressively more severe in succeeding generations and may become lethal (Duke-Elder, 1952; Gorlin et al, 1990).

Treacher Collins syndrome is an autosomal dominant genetic disorder, the phenotypic expression of which is seen in the head and neck area. Spontaneous mutation has also been reported (Pruzansky, 1973). The syndrome has full penetrance but variable expressivity even among family members (Poswillo, 1976; Murty et al, 1988). TCS is an expression in its most severe form. Molecular genetic research has resulted in two recent publications in which the site of the gene for TCS has been confirmed on chromosome 5q (Dixon et al, 1991; Jabs et al, 1991).

**Dysmorphology**

The fully expressed phenotype will manifest itself as characteristic dysmorphic features involving the face, eyes, mandible, and ears (Jarsdoerfer et al, 1989; Kay and Kay, 1989). As illustrated in Figure 1, the dysmorphology in the face area appears symmetrical and includes downward sloping ( antimongolid) palpebral fissures, colobomata of the lower eyelids, a depressed malar region, retrognathia, and usually malformed pinnae (Gorlin et al, 1990). Additionally, there may be cleft palate, scalp hair extending to the cheek, and a paucity of eye lashes medial to the lower lid notching.

While the soft tissue facial features of TCS are bilaterally symmetrical, the bony facial skeleton may be asymmetrical. Right-left asymmetry is common and the most consistent skeletal aplasia involves the zygomatic process of the temporal bone (Marsh et al, 1986).

**Figure 1** Characteristic dysmorphic features seen in Treacher Collins syndrome. See text for a detailed description of typical phenotype.
Clinical Features

Ears

The clinical features of TCS involve bilateral abnormalities of the pinna, external auditory canal, tympanic membrane, and middle ear space (Jahrsdoerfer et al, 1989). The external ears are malformed bilaterally, and the degree of microtia is often equal. Microtia has been reported to be as high as 85 percent, with one third of patients presenting with stenosis or complete atresia (Stovin et al, 1960). Most patients have grade III microtia (an amorphous mound of skin and cartilage on the lateral face) with complete atresia (Fig. 2). A few patients will have grade II microtia (the external ear is smaller than normal — about half or two thirds normal size — but has fairly good form) with an epithelial meatal pit or, less commonly, stenosis of the external ear canal. A smaller number yet will have a very mild expression of the phenotype in which the external ear canal is almost normal. In this later group, one may find a patent external ear canal and an identifiable ear drum on otoscopy (see case study in this article). The middle ear structures often reveal a fused malleus/incus remnant (90%) and an abnormal stapes (73%) (Jahrsdoerfer et al, 1989).

Otologic Examination

Fifty-seven patients with TCS were evaluated over a 20-year period. Thirty-six patients were seen subsequent to 1982 when we began the routine use of high-resolution computed tomography (CT) scanning to assess the temporal bones.

Scanning was performed with a GE 9800 scanner in the 30-degree axial and 105-degree coronal planes. Contiguous 1.5-mm slices at 1.0-mm intervals were taken with a 0.5-mm overlap to better detail minute structures within the temporal bone. Images were reconstructed from the raw data with a standard GE bone algorithm program and were displayed and photographed with an extended window. Life-size images were produced by use of the 512 matrix, a display field of view of 12.8, the specific x and y coordinates, the multiple display photographic format, and a large image size on the filming device. It is important to emphasize that simple magnification techniques may not be used, as detail will be lost.

Thirty-two of 36 patients had temporal bone CT imaging. As previously reported (Jahrsdoerfer et al, 1989), there were three unique radiographic findings noted in this patient population: (1) the mastoid bone was never pneumatized; (2) there was ossicular dysjunction; and (3) a bony cleft was found on the lateral aspect of the temporal bone.

If the temporal bone was pneumatized on tomography, it was usually at the level of the middle ear. Occasionally, pneumatization extended to the aditus, rarer yet to the antrum, but the mastoid was never aerated. Instead, there was only bone marrow. The clinical significance of this finding was readily seen in those patients who had surgery. There were no landmarks to follow in the surgical dissection, and the bone marrow tended to bleed throughout the operation.

Ossicular dysjunction, in which the primitive and fused incus/malleus remnant was found 3 to 4 mm distal to the stapes and oval window, created a challenge to the successful reconstruction of the ossicular chain. The distance was often too great to interpose a strut, and a rudimentary incus/malleus complex would not accommodate a stapes prosthesis.

The bony cleft in the lateral aspect of the temporal bone presented a particularly dangerous situation. The facial nerve often exited the temporal bone through this cleft, where it was
enshrouded in soft tissue. In this location, it was vulnerable to injury from surgical dissection.

High-resolution CT imaging of patients with TCS will typically show that the malformation is limited to the middle ear and external ear canal, with normal inner ear architecture (Jahrdoerfer et al, 1985). Thus, CT correlates well with the audiologic evaluation, which classically shows a conductive hearing loss. This is not always the case, however. In the severe expression of the syndrome, inner ear abnormalities may be found. We have seen this in one patient in whom the vestibule was saccular and the horizontal semicircular canal widened. This patient had anotia, severe hypoplasia of the temporal bones, and other stigmata of the syndrome to include a small oral cavity and a cleft palate. The patient required a tracheostomy at birth for upper airway obstruction.

We have developed a grading scheme for the surgical selection of patients with congenital aural atresia based on a top score of 10 points (Jahrdoerfer et al, 1992). Most patients with isolated microtia/atresia who are candidates for surgery grade out to be 7/10 or 8/10. This translates to a 70 to 80 percent chance of achieving normal or near normal hearing (15-25 dB pure-tone average and/or speech thresholds) through surgery. Only about 50 percent of patients with nonsyndromic microtia/atresia become candidates for surgery. In TCS, however, the percentage is much less, about 20 to 25 percent. The reason for this is poor middle ear development. The size of the middle ear space is small, often being represented by little more than a bony slit in the temporal bone. Moreover, the dominant middle ear malformation characteristically involves the stapes/facial nerve axis. It is not uncommon for the facial nerve to be bare and displaced over the oval window. The net result of these findings as determined by the preoperative CT scan is a low numerical grade, often 5/10 or less. The patient is therefore judged not to be a candidate for surgery. While one can always perform a surgical exploration, the risk of operating outweighs the potential benefit to the patient. For this reason, we advocate that if atresia is complete, the ear should not be opened for hearing purposes.

**Auditory Deficits**

Although sensory hearing loss has been reported in TCS (Hutchinson et al, 1977), conductive hearing loss is most frequently observed secondary to bilateral atresia. A review of our clinical population found that about 17 percent display a moderate degree of mixed hearing loss, defined by either a three-frequency bone-conduction (BC) pure-tone average greater than 20 dB, or BC ABRs in excess of 30 dB nHL. The range of hearing loss may vary greatly based on the degree of otologic abnormality. Further, age of the patient, audiologic experience with congenital ear malformations, and available electrophysiologic measures likely contribute to the uncertainty of auditory sensitivity, particularly in the infant.

**Audiologic Evaluation**

The Treacher Collins patient presents a unique opportunity for the audiologist. Generally, most patients with TCS demonstrate a maximum conductive hearing loss with a rising (low to high frequency) air-conduction (AC) pure-tone threshold configuration. Figure 3 illustrates a typical pure-tone audiogram from a 13-year-old female TCS patient with bilateral atresia. As noted, a symmetrical rising configuration is most prevalent but often accompanied by a decrease in hearing sensitivity in the 4000- to 8000-Hz range. AC speech recognition scores vary depending on the degree of pathology and ultimate stimulus presentation level. BC speech threshold scores are usually consistent with three-frequency BC pure-tone averages (albeit, the better cochlea contribution). Pure-tone AC and BC threshold measurement remains the audiologic foundation of the hearing evaluation.

Because the majority of Treacher Collins patients exhibit maximum bilateral conductive hearing losses, the masking dilemma (Jerger and Wertz, 1959) is a major audiologic challenge. In cases of unilateral atresia, this is of lesser concern; however, it is critical to accurately demonstrate normal cochlear function in the nonatretic ear for surgical consideration and ultimate rehabilitative strategies. The audiologic protocol used in the evaluation of TCS with bilateral atresia is straightforward. Pure-tone and speech threshold values are supplemented by sensorineural acuity level (Jerger and Jerger, 1965) scores. On occasion, differences between AC and BC speech recognition scores are observed. In the presence of maximum conductive pathology, it may not be possible to present AC speech stimuli at a PB maximum level, resulting in less than optimum recognition scores. An accurate deter-
ministration of speech intelligibility is critical, as this weighs heavily in the decision to operate and also to measure postoperative success. Thus, BC speech recognition scores are an important component when surgery is a future consideration.

**Electrophysiologic Measures**

Because of the significant dysmorphic features present at birth, most newborns with TCS are readily identified. Since bilateral atresia is usually accompanied by a 45- to 65-dB conductive hearing loss, it is essential to identify the degree of conductive component and to determine residual cochlear function. In both unilateral and bilateral atresia, the establishment of auditory sensitivity is critical for rehabilitative measures, including appropriate need and dispensing of amplification.

To date, the best method to measure hearing sensitivity in infants and children, particularly under the age of 3 years, is the use of the ABR. In our technique, both AC and BC stimuli are used in a multichannel recording protocol to measure auditory threshold function and integrity. The following is a summary of electrophysiologic parameters used at our facility to objectively evaluate Treacher Collins patients.

All Treacher Collins patients undergo ABR evaluation on their initial visit. In TCS patients with aural atresia, conventional TDH-39/49 earphones are used for AC click stimulation. For BC click stimulus, we use a standard calibrated bone vibrator (Radioear B-70A). It must be noted that bone vibrator output decreases in the high-frequency region, and as such, the relationship between BC and AC click stimulus are not identical. Further, there is a substantial loss of energy with bone-conducted signals, usually about 40 dB, limiting the maximum hearing level output to 50 to 55 dB nHL, depending on the evoked potential system and its output. The result is an elevated threshold level compared to AC click stimuli. The BC vibrator is typically calibrated using a group of normal hearing young adults, establishing an average threshold for the BC click stimulus and noting correction threshold differences. A major caveat is the area of testing and the effects of ambient noise on stimulus calibration and ABR testing. Significant differences in threshold levels are possible if environmental noise is not taken into consideration. Finally, similar BC problems (placement, skull pressure and impedance, stimulus distortion, intersubject threshold variability, high-pass filter cut-off settings, masking dilemma, etc.) found in conventional behavioral testing remain a consideration in the successful recording of ABR BC thresholds. There are several excellent BC ABR reviews in the literature, and the reader is referred to Hall (1992) and Stapells and Ruben (1989).

Both AC and BC threshold sensitivity are estimated as the lowest replicable wave peak.
component, usually wave V. Masking is not possible in bilateral aural atresia. However, in unilateral atresia, masking is used in the non-atretic (contralateral) ear for those cases having normal anatomical ear landmarks on otopscopy and those with partial and/or stenotic ear canals where insert transducers can be used. To assure ear specificity, we have adopted a method of clinical ABR analysis advocated by Hall et al (1984). This process evaluates simultaneously recorded ipsilateral and contralateral ABR measures. Briefly, the presence of a replicable ipsilateral wave I response (electrode ipsilateral to stimulation) in the absence of a corresponding wave I peak component recorded from the contralateral (nonstimulated) ear ensures an ear-specific ABR threshold. An example of this technique is demonstrated in Figure 4, where simultaneous (ipsilateral/contralateral) ABR BC recordings from a 2-year-old patient with congenital unilateral aural atresia are illustrated. ABR findings play an important role in the audiologic and surgical management of TCS patients, and, as a result, complete intensity-latency functions are essential.

**Auditory (Re)habilitation**

For the audiologist working closely with the otologist, the rehabilitation component of TCS patients presents another intriguing evaluative approach. Generally, the attending audiologist must assume responsibility for the diagnostic evaluation (previously described). However, because the majority of TCS patients evaluated travel from outside our geographic area, our position has been that the selection of amplification is a mutually inclusive decision on the part of the physician, the diagnostic audiologist, and the ultimate dispensing audiologist. Because the patient must receive routine audiologic evaluation and hearing aid management on a local (i.e., close to home) basis, it is in the best interest of the patient that a second audiologist assume primary rehabilitative responsibility. Further, speech and language programs are best accomplished under the guidance of local professionals. Most importantly, open lines of communication must be maintained between the diagnostic and dispensing/rehabilitation audiologist in order to closely follow patient progress.

**Amplification**

Our experience has been that TCS infants with bilateral atresia receive maximum benefit through the use of BC amplification. Alternatively, Dunham and Friedman (1990) have reported on the use of BC implantable hearing devices in four patients with bilateral atresia, including one patient with TCS. Pre- and postoperative comparative AC scores improved between 40 and 60 dB. They noted stable hearing improvements after implantation with respectable patient acceptance. In contrast, Yellin et al (1991) reported that in a group of 21 patients implanted with a BC device, only 7 indicated benefit, 12 were nonusers, and 1 patient complained of persistent pain. One patient was lost to follow-up. Further, Abramson et al (1989) have shown that the percutaneous bone-anchored hearing aid offered no better threshold sensitivity than conventional BC hearing aids. Conventional BC amplification has greater...
available gain and wider frequency spectrum. Our personal experience with the implantable BC device suggests that the careful selection of surgery candidates yields better hearing results. Regardless of the type of amplification, the earlier the detection and eventual hearing aid dispensing, the better the opportunities for normal speech and language development.

Follow-up Services

In cases of aural atresia with accompanying grade III microtia, consultation should be sought with either a plastic surgeon or a facial plastic surgeon to plan auricular reconstruction around 6 years of age. At about the same time, the child should undergo definitive behavioral audiometric study and repeated ABR measures if required. High-resolution CT scans of the temporal bones should be ordered. This latter study is the single most important study obtained for surgery and will determine if the child is a candidate to have his or her ear opened for hearing purposes. It should be remembered that the information gathered from the CT scan concerns primarily bone structures (ossicles, labyrinthine windows, inner ear anatomy, facial canal, etc.) and also some soft tissue (facial nerve). Moreover, the course of the facial nerve can be accurately plotted with CT.

The course of long-term rehabilitative management is dictated by the surgical intervention. If a patient with bilateral atresia is not a surgical candidate, the continued use of BC hearing aids is advocated. However, if surgery is performed and is successful (postoperative AC pure-tone and speech scores less than 25 dB), several options become available to the patient and audiologist. Depending on the degree of successful auricle reconstruction, postauricular amplification and/or in-the-ear hearing aids may be considered.

When surgery for hearing purposes is contraindicated, a small ear canal opening may be created for the purpose of accommodating a high-gain AC hearing aid. Interestingly, we have observed children who have become so dependent on the quality of BC amplification that they use AC hearing aids only as a supplement while maintaining full use of their BC hearing aid. Others have not found the use of AC amplification adequate since middle ear function may not be optimized even after correctable surgery. These patients are inclined to maintain their use of BC amplification. Following surgery, periodic visits to an otologist are necessary to clean and remove accumulative epithelial debris from the reconstructed ear canal. Tenderness and infection frequently preclude the long-term use of AC hearing aids.

CASE STUDY

When first examined, EK was a 4-year-old girl displaying mild, dysmorphic TCS features. The left external ear was almost normal (grade I) in appearance with a visible tympanic membrane. Microscopic inspection showed a rudimentary malleus imprint in the ear drum that was probably free-floating and did not represent a malleus handle. There was a soft tissue structure adherent to the undersurface of the drum and crossing the middle ear, probably representing the chorda tympani nerve or a partial atretic plate.

The right ear canal narrowed to approximately 3 mm, making it difficult to see a smaller ear drum. No ossicular landmarks could be identified. The external ear on the right side was a grade II microtia and cup-shaped. Based on initial examination, a complete work-up including CT scan and audiometric and ABR evaluation was scheduled.

Audiometric evaluation of EK is presented in Figure 5. Test findings resulted in a bilateral conductive hearing loss with greater severity in the right ear. Speech recognition scores were within normal limits for both AC and BC speech stimuli. Because of the age and reliability of the patient, ABR measures were undertaken to confirm behavioral testing using standard AC and BC click protocol. ABR tracings are shown in Figure 6. ABR AC thresholds were observed at 35 dB in the right ear and 55 dB in the left. BC ABR traces are seen in Figure 7. Note the threshold level of 15 dB in the right ear and the ipsilateral/contralateral comparison at 25 dB nHL. The absence of wave I from the contralateral side in the presence of wave I from the stimulated side confirmed near normal cochlear function on the right.

The results of the CT scan disclosed that the facial nerve encroached upon the stapes, which, in turn, was not connected to the incus/malleus complex. To improve hearing, an attempt would have to be made to rebuild the ossicular chain, including a prosthesis from the stapes or stapes footplate to the ear drum. The constraining factor was the encroachment
of the facial nerve, which was malpositioned over the oval window. The risk of temporary or permanent facial paralysis from the nerve being deprived of its immediate blood supply was a major concern. A grade of 5/10 for the left ear and 3/10 for the right ear did not warrant surgery in view of the risks.

The child currently wears bilateral postauricular hearing aids and is doing well in school. This case study underscores the fact that in TCS there is no guarantee that middle ear structures have developed normally in the presence of only mild (grade I and II microtia) external ear and auditory canal pathology.

Figure 5   Audiometric evaluation of EK, a 4-year-old Treacher Collins patient with grade I microtia of the left ear and grade II microtia of the right ear. External ear canals were stenotic but patent bilateral.

Figure 6   Air-conduction ABR traces from the right and left ears of EK, a 4-year-old Treacher Collins patient. Thresholds were measured to 55 dB nHL in the right ear and 35 dB nHL in the left ear.

Figure 7   Bone-conduction ABR traces from the right ear of EK, a 4-year-old Treacher Collins patient. Thresholds were measured to 15 dB nHL. Note the ipsilateral/contralateral ABR comparison at 25 dB nHL. No wave I peak is evident from the contralateral side, assuring ear-specific responses.
SUMMARY

Treacher Collins Syndrome patients have severe middle ear malformations that make reconstructive surgery for hearing difficult, if not impossible. We now recommend that only those patients who manifest a mild phenotype of the syndrome be operated on. This excludes patients with aural atresia and limits surgery to those with external ear canal stenosis or those in whom the malformation is confined to the middle ear. Accurate auditory assessment is essential in this population and provides pertinent information in the overall care of Treacher Collins syndrome patients. Finally, a team approach is essential and in the best interest of the patient.

REFERENCES


