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Research Article

Prevalence of Auditory Problems in Children With Feeding and Swallowing Disorders

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Purpose: Although an interdisciplinary approach is recommended for assessment and management of feeding or swallowing difficulties, audiologists are not always included in the interdisciplinary team. The purpose of this study is to report the prevalence of middle ear and hearing problems in children with feeding and swallowing disorders and to compare this prevalence with that in typical children.
Method: A total of 103 children were included in the study: 44 children with feeding and swallowing disorders and 59 children without any such disorders. Audiological examinations included case-history information, visualization of the ear canals through otoscopy, middle ear evaluation through tympanometry, and hearing screenings using an audiometer.
Results: The odds of excessive cerumen (p = .0000, small effect size), middle ear dysfunction (p = .0148, small effect size), and hearing screening failure (p = .0000, large effect size) were 22.14%, 2.97%, and 13.5% higher, respectively, in children with feeding and swallowing disorders compared with typically developing children.
Conclusion: The significantly higher prevalence of hearing problems in children with feeding and swallowing disorders compared with typically developing children suggests that inclusion of an audiologist on the interdisciplinary team is likely to improve overall interventional outcomes for children with feeding and swallowing disorders.

Feeding and swallowing disorders include problems in gathering, preparation, intake, swallowing, and/or digestion of food. Feeding problems can include 23 different types of behaviors (Matson & Kuhn, 2001), such as food rejection, disruptive mealtime conduct, pica, rumination, rigid food preferences, and failure to master self-feeding skills at an expected developmental level. Feeding and/or swallowing difficulties can be caused by behavioral problems, neuromotor deficits, or related structural abnormalities, with frequent overlap between these categories (Bernard-Bonnin, 2006). Up to 86% of patients with feeding disorders being treated in tertiary care institutions may have an associated medical disorder (Rommel, De Meyer, Feenstra, & Veereman-Wauters, 2003).

The number of people with feeding and swallowing disorders is growing because of the increasing rate of survival of premature and low-birth-weight infants. The estimated prevalence of feeding problems ranges from 25% in typically developing children to 80% in children with developmental delays (Manikam & Perman, 2000). Feeding problems and retarded growth are common in children with deafness and blindness (Thommessen, Heiberg, Kase, Larsen, & Riis, 1991), cerebral palsy, mental retardation, and congenital heart disease. Among children with cerebral palsy, 37% to 86% of the children can suffer from feeding and/or swallowing disorders, depending on the extent of the palsy (Stallings, Charney, Davies, & Cronk, 1993a, 1993b). A review of research studies suggests that up to 42% of individuals with intellectual disabilities have feeding disorders (Gravestock, 2000), and the problems appear to be more frequent in those with severe or profound intellectual disabilities (Matson, Gardner, Coe, & Sovner, 1991). Parental reports suggest feeding problems in up to 60% of the children with severe developmental disabilities (Dahl, Thommessen, Rasmussen, & Selberg, 1996; Reilly, Skuse, & Poblete, 1996). Among children with congenital heart disease, 48% may refuse to eat or suffer from poor appetite (Thommessen, Heiberg, & Kase, 1992).

Gastrointestinal function, the immune system, and respiratory health can be affected by feeding and swallowing disorders. Failure to coordinate swallowing and breathing can result in aspiration, which over time can lead to bronchiectasis. Rumination can also lead to aspiration, which can be fatal. Without proper intervention, feeding and swallowing

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disorders can have a negative impact on the development, growth, nutrition, and cognitive function of the child. Chronic malnutrition is one of the most important risk factors for growth failure (Rempel, Colwell, & Nelson, 1988). Among children with disabilities, 43% may suffer from undernutrition (Dahl et al., 1996), and 5% to 30% of the children with diplegic or hemiplegic cerebral palsy may be undernourished (Stallings et al., 1993b). The prevalence of undernutrition may increase with age, lower cognition, and severity of neurological impairment (Sánchez-Lastres, Eirís-Puñal, Otero-Cepeda, Pavón-Belinchón, & Castro-Gago, 2003).

Nutrient deficiencies can be further exacerbated by interactions between medications and feeding difficulties. Anticonvulsant medications such as valproic acid or carbamazepine may decrease bone mineral density (Babayigit, Dirik, Bober, & Cakmakcı, 2006). Among children who have refractory epilepsy, 40% are malnourished and 24% are emaciated because of feeding difficulties and chronic use of anticonvulsants, which can affect both food intake and energy metabolism (Bertoli et al., 2006).

Feeding and swallowing difficulties can put an extraordinary burden on a child's family. Parents may have to spend extra emotional and physical energy and extra hours preparing special food and cleaning children with feeding problems (Tudor, 1976). Parents may perceive feedings as being more prolonged and stressful (Craig, Scambler, & Spitz, 2003). For 65% of parents who have children with congenital heart disease, feeding involves anxiety and additional time expenditure (Thommessen et al., 1992). The extra attention required by the child with feeding difficulties can reduce the interaction with other family members and increase the stress in the family (Thommessen et al., 1991). Dysfunctional mother–child feeding interactions are associated with malnutrition (Ammaniti, Ambruzzi, Lucarelli, Cimino, & D'Olimpio, 2004). Difficulties with socialization can also occur due to messy drooling. Learning to handle solid foods (Morris, 1977) or use of special techniques (Lancioni et al., 2008) can minimize problems related to drooling in some children.

Children with multiple disabilities often have feeding and swallowing difficulties (Trier & Thomas, 1998) and hearing loss. For example, 50% of the children with oculoauriculovertebral spectrum disorders (a type of brachial arch disorder) have feeding difficulties, and 83% have conductive, mixed, or sensorineural hearing loss (Strömland et al., 2007). Oral cavity and oropharyngeal lesions such as those apparent in children with cleft palate can interfere with sucking and deglutition, leading to either airway obstruction by food during inspiration or reflux of food in the nasopharynx or nasal passages. Children with cleft palate can also have middle ear problems (Paradise, Bluestone, & Felder, 1969) that can result in transient or in some cases permanent hearing loss.

Behavior disorders associated with feeding often involve complex interactions among the biological, interpersonal, intrapsychic, and social domains (Needlman, Adair, & Bresnahan, 1998). Existence of a transient or permanent untreated hearing loss can further affect these domains. Psychotherapeutic approaches play a significant role in treating the biological, interpersonal, intrapsychic, and social domains of feeding disorders. Often a combination of oral motor and behavioral interventions is used (Clawson, Palinski, & Elliott, 2006). Some problems with a physical basis can also be treated with behavior modification programs (Ball, Hendricksen, & Clayton, 1974). Behavior modification approaches include successive approximation, reinforcement (e.g., cheer, social praise, or social interaction) of desired eating behaviors, and extinction or ignoring (leaving the room or a brief time-out or physically turning away from the child) of undesirable behaviors (Johnston, 1976; Patel et al., 2006; Riordan, Iwata, Wohl, & Finney, 1980; Schädler, Süss-Burghart, Toschke, Von Voss, & Von Kries, 2007).

Such approaches are successful when the desired behavior is elicited from the patient by modeling and prompting through physical guidance or verbal direction and praise. Verbal communication has an important role in behavior modification. However, in young children even mild hearing loss can compromise verbal communication, and hearing loss may not be obvious to all caregivers, especially in the presence of other visible disabilities. Poor verbal communication due to a transient or permanent hearing loss can reduce the effectiveness of psychotherapeutic approaches unless adequate steps are taken to ensure sufficient audibility of verbal stimuli through hearing aids or other assistive listening devices.

An interdisciplinary approach is recommended for the general management of children with feeding or swallowing difficulties. Published reports suggest that the professionals on the feeding and swallowing teams generally include physiotherapists, speech-language pathologists, social workers, pediatricians, dietitians, nutritionists, gastroenterologists, nurses, radiologists, psychologists, and occupational therapists (Arvedson, 2006; O'Brien, Repp, Williams, & Christophersen, 1991; Trier & Thomas, 1998; Walter, 1994; Williams, Witherspoon, Kavsak, Patterson, & McBlain, 2006). An otolaryngologist occasionally may be involved, mainly for physical examination of the upper aerodigestive tract and detailed airway assessment and treatment (Arvedson, 2006). This review of research suggests that inclusion of an audiologist on the feeding and swallowing interdisciplinary team may be beneficial in the overall treatment and management of feeding and swallowing disorders. However, to justify the inclusion of an audiologist on a regular or as-needed basis, the prevalence of hearing disorders among children with feeding and swallowing disorders must be determined.

I am unaware of any previous reports related to the prevalence of hearing disorders among children with feeding and swallowing disorders. Thus, the purpose of this study was to report the prevalence of audiological and middle ear problems in children who were referred to a community-based interdisciplinary feeding and swallowing clinic and to compare the prevalence of these problems with that in a group of typical children.

Method

Participants

Of the 103 children included in the study, 44 had feeding and swallowing disorders and 59 had no such disorders. Children with feeding and swallowing disorders received audiological screenings as part of an interdisciplinary evaluation of children referred to a feeding and swallowing clinic. The feeding and swallowing clinic is held once per week. The children come from within the state and from surrounding states. Between August 2005 and May 2007, all parents of children referred to the clinic were asked whether they would like to have an audiological screening as part of the team evaluation. Forty-three parents or caregivers from a group of 68 referrals were interested in having the audiological screenings. One of these parents had twins with autism; thus, the author (an audiologist) worked with 44 children with feeding and/or swallowing disorders. The children (13 girls and 31 boys) ranged in age from 3 months to 11 years (M = 4.57 years). One child was 3 months old, two children were between 6 and 12 months of age, and all other children were older than 15 months. They had a variety of medical conditions or diagnoses (see Table 1). Three of the children were not diagnosed with any syndromes; however, syndromes were suspected based on detailed case studies and audiological evaluations (see Table 2). These children were referred for genetic workups. Many of the 44 children were taking a variety of medications (see Table 3).

Fifty-nine children who received hearing screenings between August 2005 and May 2007 were included in the typically developing group. These children attended preschools in the same area and were 3 to 6 years of age (M = 3.94 years). These children received audiological screenings as part of annual hearing screenings that are provided in preschools.

Procedure

Screenings consisted of a case history obtained from the caregiver, a visual examination of the ear canal using an

Table 1. Medical conditions or diagnoses noted at birth or later in the children included in the current study.

Medical condition or diagnosis	Number of children
Airway abnormalities	
Obstruction	1
Respiratory infection	1
Sinusitis	1
Tracheomalacia	2
Cardiac abnormalities	
Atrial septal defect	1
Cardiomyopathy of the left ventricle	1
Complex cardiac disease	1
Coronary artery abnormality	1
Heart murmur	1
Patent ductus arteriosus	1
Ventricular septal defect	1
Hormonal disorders	
Growth hormone deficiency	1
Thyroid problems	1
Hypothyroidism	2
Nervous system abnormalities	
Cerebral palsy	4
Hydrocephaly with shunt placement	1
Leukoencephalopathy	1
Microcephaly	2
Right hemiplegia due to lobectomy	1
Seizures	7
Traumatic brain injury with near drowning	1
Traumatic brain injury due to accident	1
Oral structure abnormalities	
Defective palate	1
High palate	2
Cleft lip	1
Submucous cleft	1
Tied tongue	1
Arched palate	1
Hypotonia	4
Hypertension	1
Esophagitis	1 mild, 1 possible
Reflux	7
Chronic urinary tract infection	1
Possible conditions (no definitive diagnoses or unknown history)	
Child abuse	1
Fetal alcohol syndrome	1
Shaken baby syndrome	1
Atypical Rett syndrome	1
Syndromes	
Down	1
Di George	1
VATER	1
Mitochondrial disorder	1
Mitochondrial disorder of the respiratory chain (III and V)	1
Myotonic muscular dystrophy	1
Visual impairments (significant)	
Blindness	1
Possible blindness	1
Cortical visual impairment	2
Ocular abnormalities	1
Postsurgical complication of middle ear surgery	1
Autism	3
Possible autism	3
Autism or bipolar disorder	1
Developmental delays	7
Coprophagia and pica	1
Feeding aversion	1
Failure to thrive	2
Hypersensitivity	1
Iron anemia	1
Other birth defects	
Clenched fist	1
Hip dysplasia	1
Intrauterine growth restriction	1
Locked finger	1
Stapes fixation	1
Webbed neck	1
Rash on cheek	1
Contractures of fingers and legs	1

Table 2. Suspected syndromes following case history and/or evaluation by the audiologist.

Suspected syndrome	Relevant history/conditions
Alstrom	Father: diabetic, seizures, pacemaker since the age of 18 years, hearing status unknown. Child: prediabetic, seizures, visual difficulties, mild hearing loss.
Spondyloepiphyseal dysplasia congenita	Family: history on the father's side unknown, mother had two previous miscarriages. Child: hearing loss, webbed neck, locked finger, hip dysplasia at birth.
Trisomy 18	Family: miscarriages on both paternal and maternal side, cleft lip. Child: microcephaly, cleft lip, clenched fist, congenital heart defects (atrial septal defect, ventricular septal defect, patent ductus arteriosus), failure to respond to sounds.

otoscope, tympanometry using a portable middle ear screener, and audiometric screening using a portable audiometer.

Otoscopy

Ear canals were examined using a hand-held otoscope. Results indicating moderate or excessive cerumen or the presence of pressure equalization (PE) tubes were noted. Criteria for describing cerumen were based on the Scale of Cerumen Accumulation (Sullivan, 1997). Moderate cerumen was defined as nonocclusive, allowing partial visualization of the tympanic membrane. Excessive cerumen was defined as occlusive, completely obstructing any view of the tympanic membrane.

Table 3. Medical diagnoses and medications for a 3-year-old boy in the study.

Medical diagnosis	Medication
Mitochondrial disorder	Levocarnitine
Cerebral palsy	
Cardiomyopathy of the left ventricle	
Seizure disorder	Clonazepam, phenobarbital, Topamax, Keppra
Hypothyroidism	Synthroid
Arched palate	
Tied tongue	
Contractures of fingers and legs	
Reflux and reduced gastric motility	Erythromycin, Zantac
Apneic episodes	
G tube	
Hypertension	Captopril, carvedilol
Asthma	Pulmocort, Xopenex, diuretic (furosemide)

Middle Ear Screening

The portable middle ear screener (GSI 38 Autotymp, Grason-Stadler, Inc. Milford, New Hampshire) used to evaluate middle ear function was calibrated on a daily basis using cavities of sizes 0.2 to 5 cc. The screener incorporated a 226-Hz probe tone for tympanometry. For infants younger than 6 months, a 1000-Hz probe tone is necessary (American Academy of Pediatrics, Joint Committee on Infant Hearing, 2007). However, only one child in the study was younger than 6 months (3 months old).

The following criteria were used for determining abnormality of tympanograms (American Speech-Language-Hearing Association, 1997): (a) infants ages 6 months to 1 year: compensated static admittance less that 0.2 mmho or tympanometric width greater than 235 daPa; (b) infants and children older than 1 year: compensated static admittance less than 0.3 mmho or tympanometric width greater than 200 daPa.

Flat tympanograms with no peaks and large ear canal volumes of 1 to 5.5 cm^3 suggest the presence of eardrum perforations or patent PE tubes. In such cases, the data from otoscopic examinations were used to differentiate between eardrum perforations and patent PE tubes. Middle ear dysfunction was recorded when abnormal findings were found in one or both ears.

Hearing Screening

A portable audiometer (MAICO MA 39 MAICO Diagnostic, Eden Prairie, Minnesota) was used for hearing screenings. The audiometer is calibrated every year to check (and if necessary reset) the accuracy of all parameters, including frequency and intensity. Biologic checks were performed each day. The children in the experimental group were screened in a quiet room. Children in the control group were screened in a relatively quiet area within their preschools.

Pure or warbled tones were used for the screening under headphones. The passing criterion was set at 20 dB HL at 1000, 2000, and 4000 Hz (American Speech-Language-Hearing Association, 1997) and 25 dB HL at 500 Hz. The frequency of 500 Hz was included because the test environment was relatively quiet, and inclusion of this frequency is recommended in some guidelines (Johnson, 2002) because it provides information about the ability of the child to respond to low-pitch sounds. In a few cases, narrow band noises centered at the test frequency were used as test stimuli to restore any habituated responses. Lack of responses at any one frequency in any of the ears was confirmed after repeating instructions when possible and repeated testing after cycling through different frequencies and different types of stimuli (warbled tones, narrow band noise, pulsed tones, etc.). Hearing screening failure was noted when a child failed to respond to any of the frequencies directed to one or both ears.

Emphasis was placed on traditional behavioral techniques because these procedures provide information about

how the child responds to auditory stimuli such as verbal prompts or verbal praise that are used in behavioral treatment approaches for treating children with feeding disorders. Behavioral tests are considered the true tests of hearing by some pediatric audiologists (Madell, 2008). The specific behavioral technique differed depending on the developmental age of the children.

Children With Developmental Ages Below 6 Months

One child in the experimental group had a developmental age of less than 6 months. For this child, behavioral observation procedures included observation of a response (e.g., sucking, cessation of activity, or eye turns) immediately following a stimulus. The child was resting comfortably in a stroller before presentation of stimuli. Several no-stimulus intervals were introduced to watch for and minimize any false responses.

Children With Developmental Ages Between 6 Months and 2.5 Years

Fourteen children in the experimental group had a developmental age of 6 months to 2.5 years; their actual ages ranged from 6 months to 2.42 years. For these children, visual reinforcement test procedures were used that included reinforcement of correct responses by visual stimuli. Children in this age range can be evaluated using visual reinforcement audiometry as noted by others (Madell, 2014). For example, Culpepper and Thompson (1994) evaluated infants 24 to 30 months of corrected age using visual reinforcement audiometry and noted that habituation in 2-year-olds can be decreased by limiting the exposure time to visual reinforcers, without compromising response consistency, false-positive rates, or interjudge reliability. In addition to limiting the exposure time to visual reinforcers, we used several other strategies, including use of the natural head turn response for initial trials and social reinforcement to reliably establish thresholds.

Each child was seated comfortably in a baby chair with some nonnoisy toys in front. The toys were selected to hold sufficient but not too much interest from the child. In most cases toys provided by parents were used. A testing assistant sat in front of the child with a few soft toys (e.g., puppets) hidden under a table. The examiner signaled a correct response immediately following a stimulus to the assistant, and the assistant briefly revealed and moved around one of the hidden toys in front of the child in a highly animated manner. This visual reinforcement was accompanied by verbal (good job! good listening!) or tactile (gentle tap on the hand or pat on the back) praise for most correct responses. Sufficient time was provided between stimuli to minimize false responses and to reduce habituation. In most cases, children stopped playing with the toys in front of them and turned their heads toward the stimulus ear or visually searched for the sound source following the auditory stimuli, signaling very clear responses to audible sounds. Blind children usually stopped any activity they were conducting following the stimulus and/or became alert to the sound.

Children With Developmental Ages Between 3 and 4 Years

Seven children with feeding and swallowing disorders and 51 children in the typical group had a developmental age of 3 to 4 years. Children within this age were screened using conditioned play audiometry. More specifically, children were trained to perform a definitive activity such as placing a peg in a board or placing a ring in a ring tower immediately following the stimulus. Verbal and/or tactile praise was provided for correct responses to maintain interest in the activities.

Children With Developmental Ages Greater Than 4.5 Years

Twenty-two children with feeding and swallowing disorders and eight children in the typical group had a developmental age of greater than 4.5 years. Children in this age range were screened using conventional test procedures by instructing the children to raise their hand every time they heard the stimulus. They were urged to pay close attention and respond to even "very tiny" sounds. Verbal and/or tactile praise was used to maintain motivation.

Results

Otoscopic Results

Five of the 44 children in the experimental group had a moderate amount of cerumen in one or both ears, and seven other children had excessive cerumen in both ears that needed medical attention. Nine of the 59 children in the typical group had a moderate amount of cerumen in one or both ears, and one child had excessive cerumen in one ear that needed medical attention. The chi-square test of association revealed that the rate of excessive cerumen was significantly higher in children with feeding disorders (14/88 ears, 15.91%) than in the typical group (1/118 ears, 0.85% ears), $\chi^2 = 16.9376$, $p = .0000$; small effect size: $r = 0.2867$, 95% CI [0.1533, 0.4099]. Thus, the odds of having excessive cerumen were about 22.14% higher (95% CI [2.85, 171.86]) in children with feeding and swallowing disorders than in typically developing children.

Middle Ear Screening/Tympanometric Results

Twenty-three of the 44 children (52%) in the experimental group had a history of otitis media as reported by parents or caregivers. In 10 of the 44 children, tympanometry could not be performed because of lack of cooperation. Eleven of the 33 children tested had abnormal tympanometric findings suggesting middle ear dysfunction, and an additional seven children had flat tympanograms because of the presence of PE tubes, which were apparent during otoscopic examinations. The 3-month-old child had flat tympanograms with the 226-Hz probe tone, but the screening equipment did not have the 1000-Hz probe tone necessary for more accurate results in young infants. Thus, 18 of 33 children had definitive abnormal tympanometric results.

Fifteen of the 59 typical children had abnormal tympanometric results suggesting middle ear dysfunction. One

additional child had a PE tube in one ear, and another had PE tubes in both ears, which yielded flat tympanograms. Thus, 17 of these 59 children had abnormal tympanometric results.

The chi-square test of association revealed that the rate of middle ear dysfunction was significantly higher in children with feeding disorders (18/33, 54.55%) than in the typical group (17/59, 28.81%), $\chi^2 = 5.945$, $p = .0148$; small effect size: $r = 0.2542$, 95% CI [0.0509, 0.4372]. Thus, the odds of middle ear dysfunction were about 2.97% higher (95% CI [1.221, 7.1985]) in children with feeding and swallowing disorders than in typically developing children.

Hearing Screening Results

Hearing screenings were performed on all 44 children in the experimental group. Twenty-two of these 44 children (50%) failed hearing screenings at one or more of the test frequencies (500, 1000, 2000, and 4000 Hz) in one or both ears; two of these children had excessive cerumen in their ears. Five of the seven children with excessive cerumen passed the hearing screening.

Four of the 59 children in the typically developing group failed the hearing screening at one of more test frequencies in one or both ears. One of these children failed the hearing screening in one ear but also had a PE tube in the same ear. Another child who failed the screening in both ears also had abnormal tympanometric results for both ears suggesting middle ear dysfunction.

The chi-square test of association revealed that the rate of failure on hearing screening was significantly higher in children with feeding disorders (22/44, 50%) than in the typically developing group (4/59, 6.78%), $\chi^2 = 24.9491$, $p = .0000$; large effect size: $r = 0.4922$, 95% CI [0.3162, 0.6354]. Thus, the odds of failing hearing screenings were about 13.5% higher (95% CI [4.1698, 43.7168]) in children with feeding and swallowing disorders than in typically developing children.

Discussion

Results of this study suggest that the prevalence of hearing loss in children with feeding and swallowing disorders is significantly higher than that apparent in a control group of children; up to 50% of the tested children with feeding and swallowing disorders suffered from transient or permanent hearing loss. The prevalence of hearing loss in combination with various medical conditions noted in this group of children with feeding and swallowing disorders ranged from 2.9% to 100% (see Table 4). In the group of typically developing children, 6.78% failed the hearing screening. The reported prevalence of hearing loss among children in the general population differs based on the criteria used and the ages of the children. In a recent study, the prevalence of hearing loss was 2.2% among urban South African children 6 to 12 years of age (Mahomed-Asmail & Eikelboom, 2016). A population-based developmental disabilities surveillance program between 1991 and 2010 revealed a 0.14% prevalence of moderate to profound hearing loss among 8-year-old children in metropolitan Atlanta (Braun et al., 2015). In the current study, the prevalence of excessive ear canal cerumen and middle ear dysfunction was also higher in the children with feeding and swallowing disorders than in the typically developing children.

Connections Between Swallowing Difficulties, Middle Ear Dysfunction, and Hearing Difficulties

In the current study, 18 of the 33 children (55%) with feeding and swallowing disorders evaluated with tympanometry had abnormal findings consistent with middle ear dysfunction or had PE tubes, suggesting the possibility of a high prevalence of a transient conductive hearing loss. Pain is an integral part of frequent episodes of otitis media (Hayden & Schwartz, 1985). A child who suffers from earaches may also experience pain during swallowing. Thus, chronic otitis media is considered one of the causes of swallowing difficulty in children (Jolley, McClelland, & Mosesso-Rousseau, 1995). Children with ear infections also often have enlarged tonsils and adenoids, which have been associated with difficulty in progressing to solid foods (Arvedson, 2006). Chronic middle ear inflammation can also decrease the taste threshold for foods (Sano, Ito, Suzukawa, Kaga, & Yamasoba, 2007), thus potentially reducing the appetite further.

When a child does not swallow frequently enough, swallowing difficulties may minimize natural ventilation of the middle ear due to automatic opening of the Eustachian tube during swallowing. Such poor ventilation can increase the potential of fluid accumulation, leading to middle ear infections. For example, a lesion in the cerebral cortex or the brain center may lead to absence of pharyngeal swallowing, which can lead to poor ventilation of the middle ear. Lack of oral feeding in children with gastrostomies may similarly lead to poor ventilation of the middle ear. Ninety-five percent of patients with Down syndrome cannot reduce negative middle ear pressure by swallowing (White, Doyle, & Bluestone, 1984), thus increasing the potential for middle ear infections. Feeding difficulties can occur in up to 67% of children with cleft palate (de Vries et al., 2014), and all children with cleft palate have middle ear effusion (Paradise et al., 1969) with Eustachian tube dysfunction as the most probable cause (Bluestone, 1971).

Reflux appears to be the most frequent cause of dysphagia among patients who are referred to outpatient tertiary care swallowing centers (Hoy, Domer, Plowman, Loch, & Belafsky, 2013). Reflux of gastric content into the oropharynx and nasopharynx in the presence of gastroesophageal reflux disease can lead to chronic sore throat, sinusitis, and recurrent otitis media and/or otitis media with effusion. Antireflux therapy can improve the quality of life of children with otitis media and gastroesophageal reflux disease (McCoul et al., 2011).

Middle ear infections can lead to the feeling of being sick and can reduce the child's responses to sounds due to conductive hearing loss. Bilateral middle ear effusion has

Table 4. Reported incidence of hearing loss associated with the various medical conditions noted in the current study.

Medical condition or diagnosis	Reported incidence of hearing loss	Reference(s)
Autism	13% have mild to profound hearing loss, and 23.5% may suffer from serous otitis media.	Rosenhall, Nordin, Sandström, Ahlsén, & Gillberg, 1999
Rett syndrome	27%–35% of cases have middle ear dysfunction.	Pelson & Budden, 1987; Pillion, Rawool, & Naidu, 2000; Stach, Stoner, Smith, & Jerger, 1994
	18% of children have sensorineural hearing loss.	Pillion et al., 2000; Pillion, Rawool, Bibat, & Naidu, 2003
Fetal alcohol syndrome (FAS)	11.2% of children have hearing loss, and 14.7% have chronic otitis media.	Cohen-Kerem, Bar-Oz, Nulman, Papaioannou, & Koren, 2007
Cleft palate	100% of children have middle ear problems that can result in transient or permanent hearing loss.	Paradise et al., 1969
Submucous cleft	59% of children have hearing loss: 34% have conductive and 25% have sensorineural or mixed.	Bergstrom & Hemenway, 1971
Mitochondrial encephalopathy	42%	Zwirner & Wilichowski, 2001
Cerebral palsy	2.9%	Laisram, Srivastava, & Srivastava, 1992
Mental retardation	16%	Karjalainen, Kääriäinen, & Vohlonen, 1983
Down syndrome	78% of noninstitutionalized children have hearing loss: 54% conductive, 16% sensorineural, and 8% mixed.	Balkany, Downs, Jafek, & Krajicek, 1979
Drowning	31% of the children with injuries from near drowning can have abnormal auditory brainstem response.	Kaga, Ichimura, Kitazumi, Kodama, & Tamai, 1996
Serious congenital heart disease	44%	Arnold, Brown, & Finitzo, 1986
Hypothyroidism	74%	Khechinaschvili, Metreveli, Svanidze, Knothe, & Kevanishvili, 2007
Reflux	In up to 60% of patients with otitis media with effusion, reflux has been implicated in the pathogenesis.	Crapko, Kerschner, Syring, & Johnston, 2007
DiGeorge syndrome	60% of patients with clinical features of del22q11 have hearing loss (majority of cases of Di George syndromes are due to del22q11 [microdeletion 22q11]).	Digilio et al., 1999
Muscular dystrophy	60% of patients with facioscapulohumeral dystrophy have hearing loss; no hearing loss in other types of muscular dystrophy.	Voit, Lamprecht, Lenard, & Goebel, 1986

been associated with an average elevation of thresholds of 10 or 15 dB HL (Sabo, Paradise, Kurs-Lasky, & Smith, 2003). A mild hearing loss can muffle sounds and can have a significant impact on the child's ability to learn language (Skinner, 1978). Children with cleft palate who have an increased number of myringotomy tubes, middle ear surgery, and cholesteotoma are at risk for long-standing conductive hearing loss (Goudy, Lott, Canady, & Smith, 2006). One child in the current study had a long-standing conductive hearing loss from complications of middle ear surgery. Sensorineural hearing loss has been found in 1% of individuals with otitis media with effusion (Harada, Yamasoba, & Yagi, 1992).

Cycle of Feeding Problems, Malnutrition, and Ear Infection

Untreated feeding or swallowing disorders can lead to malnutrition, which can compromise the child's ability to resist infections. Infections can then increase a child's energy requirements and reduce the ability to successfully utilize nutrients, thus setting up a cycle of malnutrition and ear infections (Frank & Drotar, 1994).

Micronutrient Deficiencies and Auditory Response Behavior

Children with feeding or swallowing disorders can suffer from a variety of micronutrient deficiencies. For example, zinc and vitamin B6 deficiencies have been noted in children with feeding problems (Lindberg, Östberg, Isacson, & Dannaeus, 2006). Low bone mineral density (associated with significant fracture risk) has been reported in 77% of individuals with moderate to severe cerebral palsy, and feeding difficulty is considered one of the contributing factors (Henderson et al., 2002). One child in the current investigation was diagnosed with iron anemia, but the micronutrient status of the other children was unknown. Children who suffer from iron deficiency in early infancy can have delays in processing of auditory signals at 10 years of age (Yehuda & Yehuda, 2006). Red cell basic ferritin concentrations tend to be lower in individuals with sensorineural hearing loss than in healthy individuals (Sun et al., 1991). Because normal function of the cochlea and brain depends on delivery of sufficient oxygen and micronutrients, micronutrient deficiencies in children with feeding and swallowing disorders could have an adverse effect on the child's ability to respond to and benefit from auditory

stimuli. Lower composite language scores have been noted in children with abnormal feeding patterns and hearing impairment (Adams-Chapman, Bann, Vaucher, & Stoll, 2013).

Medications Used to Treat Middle Ear Infections and Feeding Difficulties

Many children in the current study were on antibiotics that are commonly used to treat middle ear infections. The antibiotic amoxicillin is frequently used to treat middle ear infections, but its side effects include mild nausea, vomiting, diarrhea, and abdominal pain. The amoxicillin-clavulanate combination can cause diarrhea. Erythromycin often causes upset stomach, which may lead to vomiting; it can also occasionally cause nausea and diarrhea. Sulfisoxazole can cause nausea and less frequently diarrhea or cramping. The combination of trimethoprim and sulfamethoxazole is sometimes used for treating ear infections and can cause nausea or upset stomach and occasionally lead to anorexia (Needlman, Adair, & Bresnahan, 1998).

When the gastrointestinal side effects of antibiotics prescribed for ear infections are not carefully monitored, the child may develop further aversion to foods. Anecdotal accounts from mothers suggest that an ear infection itself and diarrhea from antibiotics can lead to weight loss. After myringotomies, the growth of children with chronic otitis media tends to improve (Reifsnider, Allan, & Percy, 2000) and hearing thresholds within the speech frequency range can return to normal within 24 hours (Mair, Fjermedal, & Laukli, 1989).

Ototoxic Medications

In some cases of feeding and swallowing disorders, ototoxic medications may have an effect on the child's ability to respond to sounds. For example, two of the children in the current study were taking furosemide (Lasix), which is prescribed for the treatment of congestive heart failure or pulmonary edema or to reduce blood pressure and swelling of the body due to fluid buildup. This drug works on the kidneys to increase water excretion, can alter electrolyte balance, and can change cochlear function and cause a temporary hearing loss (Rybak, 1985). Therapeutic administration of furosemide causes hearing loss in neonates (Brown, Watchko, & Sabo, 1991). When the child is exposed to other ototoxic drugs such as aminoglycosides (e.g., gentamicin) that are used to treat infections in addition to furosemide, the combination can further alter the response of the cochlea (Mulheran & Harpur, 1998). Some children with feeding and swallowing disorders suffer from seizures and thus are prescribed antiseizure medications. Four of the children in the current study were taking phenobarbital, which can prolong latencies of the auditory brainstem response (Chan, Woo, & Yu, 1990; Pelson & Budden, 1987).

Syndromes Involving Both Feeding and Swallowing Difficulties and Hearing Loss

Some children in the current study were diagnosed with various syndromes, including VATER, DiGeorge, and Down syndromes, myotonic muscular dystrophy, and mitochondrial disorders. Based on a detailed case history, observations, and audiological evaluations, additional syndromes were suspected including Alstrom, spondyloepiphyseal dysplasia congenita, and trisomy 18 in three of the children (see Table 2). In all these syndromes, ear anomalies can exist along with hearing loss.

Because feeding and swallowing disorders and hearing loss can co-occur, involvement of an audiologist on the feeding and swallowing team appears to be important. The recognition of previously undiagnosed syndromes also can improve the overall outcomes for children. For example, a child with an undiagnosed but suspected spondyloepiphyseal dysplasia congenita (an inherited disorder of bone growth causing short stature or dwarfism and skeletal abnormalities with vision and hearing problems) was referred to the feeding clinic because of concerns with very limited food intake. Detection of hearing loss and proper recognition of the syndrome can allow accurate predictions about growth patterns and food intake typically seen in individuals with dwarfism.

Importance of the Knowledge of Hearing Status in Blind Children With Feeding Difficulties

In the current study, one child was blind, one child was suspected of being blind, and two children had cortical visual impairment. The parents of each child were unsure whether the child had typical hearing and thus restricted their auditory input; these parents were unsure about whether the child was able to hear them and whether the child benefited from any auditory input. This behavior was partially guided by the fact that all of these children were nonverbal. In such cases, when hearing was typical, the audiologist was able to demonstrate the child's responses (eye blinks, stopping sucking or vocalization, etc.) to auditory stimuli and was able to encourage the parents to provide plenty of verbal and tactile stimuli. Such parents can take advantage of the feeding time to provide verbal stimulation to promote language development. Verbal stimulation or reinforcement also can assist in reducing feeding difficulties.

Ensuring Sufficient Verbal Input to Maximize Efficacy of Behavioral Modification Approaches

Behavioral treatment approaches are often an important element of the treatment provided to children with feeding and swallowing disorders. Such approaches frequently include verbal instructions and reinforcements, and typical hearing is necessary for maximum benefit from such verbal input. In children with transient or permanent hearing loss, the audiologist can inform both parents and the

interdisciplinary team about the hearing loss and the procedures for maximizing the efficiency of verbal input.

Consistent use of known communication triggers is often recommended to promote feeding in different surroundings such as a school. A child who suffers from transient or permanent hearing loss may not benefit maximally from verbal communication triggers unless steps are taken to provide at least natural amplification (e.g., speaking closer to the child's ears, speaking closer to the normal ear in cases of unilateral hearing loss, or reducing background noise while speaking) or to provide amplification in the form of hearing aids at home and remote microphone (FM) devices in school settings. Several devices are available that are well suited for children with chronic otitis media and the resulting transient hearing loss. Parents or caregivers need to be trained to recognize the signs of transient hearing loss and to use assistive listening technologies.

Reducing Parental Stress

One of the biobehavioral constructs considered in the diagnosis of feeding disorders is caregiver competence (Kedesdy & Budd, 1998). When behavior modification through verbal reinforcements such as social praise is not achieved because of transient or permanent hearing loss, parental competence may be inappropriately questioned. Parenting stress tends to be higher in parents of children with feeding problems (Babbitt et al., 1994; Garro, Thurman, Kerwin, & Ducette, 2005). Although parents may perceive feeding time as stressful, they may also recognize it as a very special time they have with their child (Craig et al., 2003). Mealtimes can provide opportunities for shared communication, enjoyment, and nurturing, which are highly dependent on verbal communication and input. A child with undiagnosed and untreated hearing loss may draw minimal or no benefit from such opportunities. A child's limited response to verbal input due to hearing loss may reduce enjoyment for parents and can result in additional stress.

Some temperamental characteristics of children can complicate feeding and overwhelm parents' ability to cope (Pliner & Loewen, 1997). Parental stress and frustration related to difficulty in understanding the child due to speech and language disorders or delays have been noted in a few investigations related to feeding problems (Starke, Albertsson Wikland, & Möller, 2003). Hearing loss can also cause children to throw tantrums due to frustrations related to their inability to express themselves or to accurately understand parental expectations. Any undiagnosed hearing loss can exacerbate such difficulties because of the parental perception that the child is being inattentive, disobedient, or stubborn. The child can sense parental frustrations or anger during meals, thus further increasing the aversion to foods. Hearing loss is an invisible disability, and the significant impact of hearing loss may not be obvious to parents or other caregivers especially when the child has several other more visible disabilities. In some cases, parents may attribute the child's failure to respond to sounds to cognitive or neuromotor deficits. Appropriate detection and management of hearing loss in such children can help decrease behavioral problems at meals, decrease parent stress, and increase pleasurable parent–child interactions.

Improving Overall Treatment Effectiveness

In terms of overall treatment effectiveness, some investigators have reported that up to 75% of the goals set by a multidisciplinary team can be met (Williams et al., 2006). In other studies, success of behavioral intervention has been reported in about 62% of the children with feeding disorders (Schädler et al., 2007). The rate of success may improve when the auditory diagnostic and habilitation needs of the children are addressed.

In the current study, cerumen management was necessary in some children with feeding and swallowing disorders. Hearing loss had been previously diagnosed in six of the 22 children who did not pass the hearing screening test. However, even in these children, additional audiological services were necessary. One child with unilateral conductive hearing loss was having problems in classroom situations; these problems were resolved by use of an assistive listening (FM) device. Another child had a hereditary conductive hearing loss due to fixation of the stapes (one of the bones in the middle ear) and was fitted with hearing aids but did not wear them. He complained about discomfort from the earmolds, indicating the need for new earmolds.

One of the children had elevated auditory thresholds at 4 kHz in the left ear. He carried his favorite noisy toy with him everywhere, suggesting a noise-induced hearing loss. In this case, informational counseling was provided to the child and the mother. Two of the children had moderate to severe sensorineural hearing loss and were fitted with hearing aids but did not wear them on a regular basis. Parents of these children appeared to have forgotten the procedures for slowly increasing the use of the hearing aids and also were unsure about the benefit. One 18-month-old child with sensorineural hearing loss had a loose earmold, which resulted in whistling of one of the aids. The mother of this child had several questions related to a variety of topics, including the selection of a communication mode and cochlear implants. Extensive informational counseling was provided to the mother. The second child with sensorineural hearing loss did not appear to gain much benefit from hearing aids, probably because of insufficient amplification. Both children responded well to sounds when fitted with a trial FM device. With the FM device, the audiologist was able to demonstrate to the parents the kinds of responses that can be expected. Both parents reported that they were unaware of the ability of their children to respond to sounds. Parents of these children were advised to see their audiologists for refitting of earmolds and/or readjustment of amplification. One child with profound hearing loss had a cochlear implant and wore the implant on a regular basis. These parents appeared to be very knowledgeable about the care and use of cochlear implants, but the need for ongoing demonstrations and training in aural habilitation was clearly evident during the session.

Future Studies

This preliminary study was conducted to investigate the auditory response behavior of children through conventional behavioral techniques. However, future studies with other measures such as otoacoustic emissions and the auditory brainstem response may be useful for assessing cochlear and brainstem integrity. In the current study, only those children whose parents were interested in the audiological screenings were screened. In future studies, audiological screenings of all children referred for feeding and swallowing disorders may provide a more accurate estimate of the prevalence of hearing loss in such children. In the current study, a convenience sample of typically developing children was included for comparison. In future studies, the current results should be confirmed by including typically developing age-matched children.

Clinical Implications

The prevalence of hearing-related difficulties, including excessive cerumen, middle ear dysfunction, and hearing loss, is relatively high in children with feeding and swallowing disorders. Thus, the inclusion of an audiologist in the interdisciplinary team providing services to such children should improve the overall service delivery.

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