

RETHINKING PROGRESSIVE HEARING LOSS

Ear Foundation

Christine Yoshinaga-Itano, Ph.D.

Professor

University of Colorado, Boulder

Department of Speech, Language &
Hearing Sciences

Allison Sedey, Ph.D.

Rosalinda Baca, Ph.D.

Molly Dalpes, AuD 4th year

LEARNING OBJECTIVES

- ◉ At the conclusion of this presentation, the participant will be able to:
- ◉ 1. Identify the prevalence and etiologies of progressive hearing loss by age (from birth through 7 years) and hearing loss.
- ◉ 2. Identify the prevalence and etiologies of acquired hearing loss by age (from birth through 7 years) and hearing loss.
- ◉ 3. Identify the longitudinal language development of children with progressive hearing loss from birth through 7 years as compared to children with stable losses

CAUSES OF PROGRESSIVE HEARING LOSS

- Genetic
- Approximately 50% of prelingual childhood hearing loss have a genetic cause.
 - Of these 50%, approximately 70% are non-syndromic and 30% are syndromic.
- 15% of children with prelingual HL have syndromic genetic cause
- 35% of children with prelingual HL have non-syndromic genetic cause

GENETIC: SYNDROMIC

- The following syndromes have been associated with progressive hearing loss:
 - Waardenburg syndrome,
 - Brachio-Oto-Renal (BOR) syndrome,
 - CHARGE syndrome,
 - Stickler syndrome,
 - Neurofibromatosis Types I & II,
 - Usher syndrome,
 - Pendred's syndrome,
 - Jervell-Lange-Nielsen syndrome,
 - Cockayne syndrome, and
 - Alstrom syndrome.

GENETIC: NON-SYNDROMIC

- The following non-syndromic causes of hearing loss have been associated with progression:
 - 1) Connexin 26,
 - 2) Enlarged Vestibular Aqueduct Syndrome,
 - 3) X-linked (attributed to 2-3% of children with hearing loss), and specifically Alport syndrome.

CONGENITAL INFECTIONS

- ◉ Infectious causes of hearing loss are divided into congenital and acquired infection.
- ◉ Congenital infections most often reported as causing progressive hearing loss in pediatric patients are intrauterine infections.
- ◉ TORCH is an acronym for a group of diseases that cause congenital conditions if there is fetal exposure while in utero.
 - toxoplasmosis,
 - other (syphilis, mumps, HIV, parovirus B19),
 - rubella virus
 - cytomegalovirus (CMV), and
 - herpes simplex.

ACQUIRED INFECTIONS

- Acquired infections reported to cause hearing loss include:
 - bacterial meningitis,
 - human immunodeficiency virus 1 & 2,
 - herpes zoster virus, and
 - herpes simplex virus 1 & 2

NEURODEGENERATIVE DISORDERS

- ◉ Some neurodegenerative disorders have risk factors associated with delayed onset or progressive sensorineural hearing loss.
- ◉ Degenerative nerve diseases result with worsening of bodily functions including balance, movement, breathing and organ function.
- ◉ Some of the diseases are genetic, Hunter syndrome, Charcot-Marie-Tooth-syndrome, while others are caused by environmental factors such as chemicals, viruses and strokes.

AUTOIMMUNE INNER EAR DISEASE (AIED)

- ◉ Autoimmune inner ear disease (*AIED*) is described as a progressive hearing loss and can occur as a result of immune-mediated diseases found in Cogan's syndrome and other autoimmune pediatric disorders.
- ◉ AEID typically affects young children and
- ◉ is an uncommon symptom in childhood.
- ◉ Late-onset or progressive hearing loss can be due to factors such as noise exposure or teratogens. Ototoxic drugs may be used in the neonatal period to fight infections.

OTOTOXIC DRUGS

- Ototoxic drugs generally, but do not always cause permanent bilateral, symmetrical sensorineural hearing loss with varying degrees and configuration,
- however patients may also experience vertigo, nausea and gait instability.
- Some of the ototoxic treatments in children include :
 - the use of aminoglycoside antibiotics, such as kanamycin, neomycin, and gentamicin are commonly used antibiotics, however additional antibiotics such as vancomycin, amikacin, and tobramycine have also been noted to cause threshold shifts in hearing
 - With prolonged use of nonsteroidal analgesic anti-inflammatory drugs,
 - chemotherapeutic drugs, containing platinum, such as cisplatin and carboplatin are some of the known ototoxic causes of hearing loss
 - quinine and loop diuretics (Newton, 2001)

OTOTOXIC DRUGS

- ◉ Additionally mitochondrial mutations (e.g. 1555A) responsible for variations of ribosomal RNA sequences may result with some individuals being more susceptible to hearing loss due to hypersensitivity to aminoglycosides
- ◉ Aminoglycosides are the most common and widely used antibiotics as they are efficient antibiotics and are available at a low cost
Aminoglycosides are both ototoxic and nephrotoxic.

NOISE EXPOSURE

- The American Academy of Pediatrics note that infant's exposure to noise in the neonatal intensive care unit (NICU) may result in cochlea damage and may disrupt normal growth and development in premature children.
- It is important that care be taken to reduce the amount of noise exposure that infants and young children experience.
- Some evidence indicates that noise exposure and the use of ototoxic drugs such as Aminoglycosides are synergistic in producing auditory damage.

PERINATAL PROBLEMS

- ◉ There is evidence that supports the association of hearing loss with perinatal problems and problems around the time of birth.
- ◉ Such cases include hyperbilirubinemia,
- ◉ persistent pulmonary hypertension (PPHN) associated with mechanical ventilation,
- ◉ low Apgar scores,
- ◉ low birth weight and
- ◉ persistent mechanical ventilation.

PERINATAL PROBLEMS

- Some research suggest that children with SNHL
 - had longer periods of intubation,
 - mechanical ventilation,
 - oxygen treatment and
 - more frequent treatment with ototoxic medications (Marlow, Hunt & Marlow, 2000).
- In studies of children born preterm or had a stay in the NICU, preterm infants often have coexisting risk factors of hearing loss.

DEFINITION OF PROGRESSIVE HEARING LOSS

DEFINITION OF PROGRESSIVE HEARING LOSS - ALL AUDIOLOGICAL DATA VERIFIED BY TWO CERTIFIED AUDIOLOGISTS

- 1) The audiologic report stated that the child had a progressive loss (or that “the loss had progressed compared to previous testing”),
- 2) or if we had multiple audiograms:
 - 2) Two or more frequencies (in the better ear) were 15dB or more poorer than previous testing indicated, or
 - 3) One or more frequencies (in the better ear) was 20 dB or more poorer than previous testing indicated.

CONSERVATIVE DEFINITION

- ◉ Children whose “worse ear” progressed are not included in this count if there was no progression in the better ear.
- ◉ Children whose ABR thresholds were significantly different from behavioral thresholds unless their behavioral thresholds progressed or there were multiple ABRs were not included or the differences were very significant e.g. mild to severe/profound.
- ◉ Children with acquired hearing loss after the age of 3 years were not included (they could not be included in the longitudinal study which required enrollment in early intervention services)

LONGITUDINAL STUDY

LONGITUDINAL STUDY: BIRTH TO 7 YEARS (YOSHINAGA-ITANO, BACA & SEDEY, 2010)

- N=135 children
- No additional disabilities impacting language/communication development
- N=89 children with moderate-severe to profound hearing loss
- 31% children with hearing aids had progressive HL
- 34.7% children with cochlear implants had progressive HL

LONGITUDINAL STUDY:
PROGRESSIVE HEARING
LOSS

PROGRESSIVE HEARING LOSS BY DEGREE OF HEARING LOSS

- ◉ Longitudinal study: N=146
- ◉ 83 of 146 (56.8%) had confirmation of HL by 3 months
- ◉ By age 4 to 7
- ◉ Mild HL N=21 (14.4%)
- ◉ Moderate HL N=25 (17.1%)
- ◉ Severe HL N=32 (21.9%)
- ◉ Profound HL N=23 (15.8%)

DEGREE OF HEARING LOSS

- 30 of the 146 (20.5%) children had progressive hearing loss reported either prior to or during the time period when the child was 4 to 7 years of age.
- Twelve of the 30 children used conventional amplification, hearing aids and
- 18 had cochlear implants.
- 83% or 25 of the 30 children had either a moderate-severe (20%, N=9), severe (30%, N=9) or profound hearing loss (33.3%, N=10).

PROFOUND HEARING LOSS

- ◉ 33 of 146 children had a profound hearing loss
- ◉ 10 or 30.3% of these children had progressive hearing losses.
- ◉ Five or 15.2% of the 33 children with profound hearing loss had acquired hearing losses.
- ◉ When combining both progressive and acquired hearing loss, 45.5% of the children had either normal, mild or moderate hearing levels at birth.

SEVERE HEARING LOSS

- 42 children had severe hearing losses
- 9 had progressive hearing losses and
- 1 had an acquired hearing loss.
- 24% of children with severe hearing loss had either normal, mild or moderate hearing levels at birth.

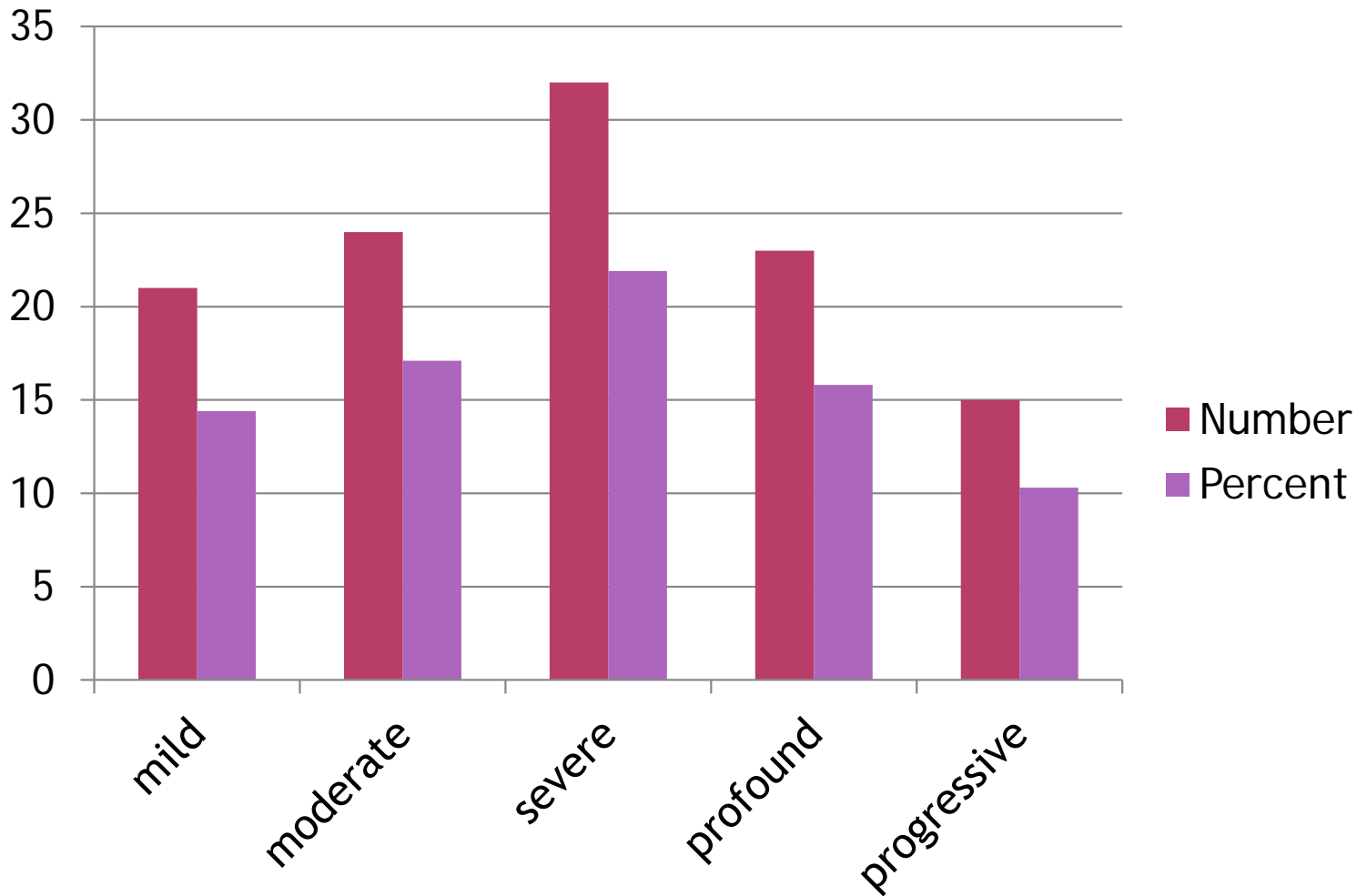
MODERATE HEARING LOSS

- ◉ 31 children between 4 to 7 years of age with moderate hearing loss,
- ◉ 2 had an acquired hearing loss and
- ◉ 4 had progressive hearing losses.
- ◉ 19% of the children with moderate hearing loss at 4 to 7 had an acquired or progressive hearing loss.

MILD HEARING LOSS

- 23 children with mild hearing loss between 4 to 7 years of age,
- 1 had an acquired loss and
- 1 had a progressive loss.
- 9% of the children with mild hearing loss either had an acquired or progressive loss.

LONGITUDINAL STUDY: BIRTH TO 4 TO 7 PERCENT BY DEGREE OF HEARING LOSS



ETIOLOGY OF PROGRESSIVE HEARING LOSS

- ◉ Genetic: N=6 20%
- ◉ Cytomegalic Virus: N=4 12%
- ◉ Unknown N=16 53.3%
- ◉ Ototoxicity N=2 (6.6%)
- ◉ Multiple etiologies: N=1 3.3%
- ◉ Mondini N=1 3.3%
- ◉ Treacher Collins N=1 3.3%

LANGUAGE DEVELOPMENT AT 84 MONTHS

- **Expressive One Word Picture Vocabulary Test
 - 92 months (25.6 SD) - progressive hearing loss hearing loss
 - 81 months (27 SD) - stable hearing loss same degree
 - 10 month difference
- Test of Auditory Comprehension of Language
 - 85.6 mo. (19 SD) progressive HL
 - 84.6 mo. (15 SD) stable HL

LONGITUDINAL STUDY: ACQUIRED HEARING LOSS

ACQUIRED HL: AGE AT ACQUISITION

- 17 of the 17 children had information about the age of acquisition of the hearing loss.
- ****58.8%** or 10 of the 17 children acquired hearing loss between .5 months of age to 12 months of age.
 - Of these 10 children 4 children (23.5%) acquired the hearing loss between .5 and 6 months, and
 - 6 (35.3%) of the children acquired the hearing loss between 7 and 12 months of age.
 - is this truly acquired? Or missed mild and progressive?
- Another **35.3%** or 6 children acquired their hearing losses between **13 and 24** months of age and
- 1 child acquired hearing loss (**5.9%**) between **25 and 36** months of age.

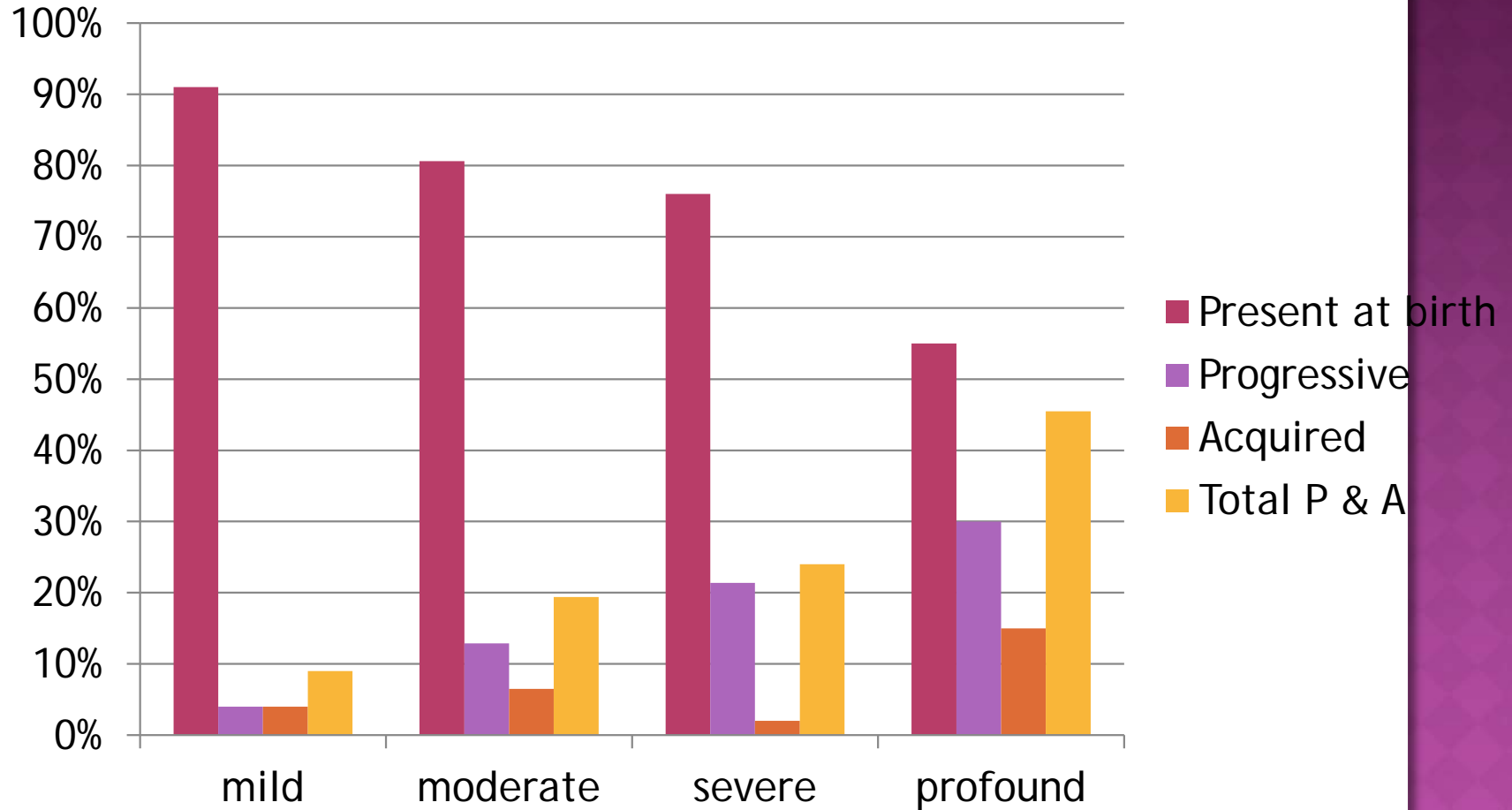
DEGREE OF HEARING LOSS: ACQUIRED HL

- 14 of 17 children with acquired hearing loss had information about the degree of hearing loss at enrollment into early development/intervention services.
- 5 of the 17 children had a profound hearing loss (29.4%),
- 1 had a severe hearing loss (5.9%),
- 4 had a moderate-severe hearing loss (23.5%),
- 2 had a moderate hearing loss (11.8%),
- 1 had a mild hearing loss (5.9%)
- 1 had a low or high frequency hearing loss (5.9%), and
- 3 had missing data.
- Only 1 of the 17 children had both an acquired and progressive HL

ETIOLOGY OF ACQUIRED HEARING LOSSES

- ◉ Genetic N=1 7.1%
- ◉ Cytomegalic virus: N=1 7.1%
- ◉ Meningitis N=2 14.3%
- ◉ Unknown N=7 50%
- ◉ Ototoxicity N=3 21.4%
- ◉ Missing N=3
- ◉ Total: 17 acquired hearing losses of 146 participants

PERCENT OF PROGRESSIVE AND ACQUIRED BY DEGREE OF HEARING LOSS



CROSSECTIONAL STUDY:

TOTAL DATABASE: 853 CHILDREN WITH AUDIOLOGICAL DATA 1985- 2011

- ◉ all children with bilateral hearing loss, excludes children with unilateral permanent hearing loss and auditory neuropathy, but includes permanent conductive, sensori-neural and mixed hearing losses, and all degrees of hearing loss between the ages of birth to 36 months who received early intervention services when the children were birth to 36 months of age.
- ◉ Statistics include children across all cognitive levels including children with additional disabilities.
- ◉ All children in this database are in English-speaking homes.

CROSSECTIONAL STUDY:
PROGRESSIVE HEARING
LOSS

PROGRESSIVE HEARING LOSS

- ◉ 10% of all ages had a progressive hearing loss
- ◉ Ages 1 to 42 months: 6.4% had a progressive HL
- ◉ Ages 43-89 months: 18.5% had a progressive HL

- ◉ 768 of 853 children had stable HL
- ◉ 85 had progressive HLs

PROGRESSIVE HL BY DEGREE OF HL-ACROSS ALL AGES

- ◉ .9% N=2 of 213 in the mild hearing loss category had a progressive HL
- ◉ 4.3% N=8 of 185 in the moderate HL category had a progressive HL
- ◉ 12.3% N=17 of 138 in the moderate-severe HL category had a progressive HL
- ◉ 22.9% N=27 of 118 in the severe HL category had a progressive HL
- ◉ 15.9% N=31 of 195 children in the profound HI category had a progressive HL

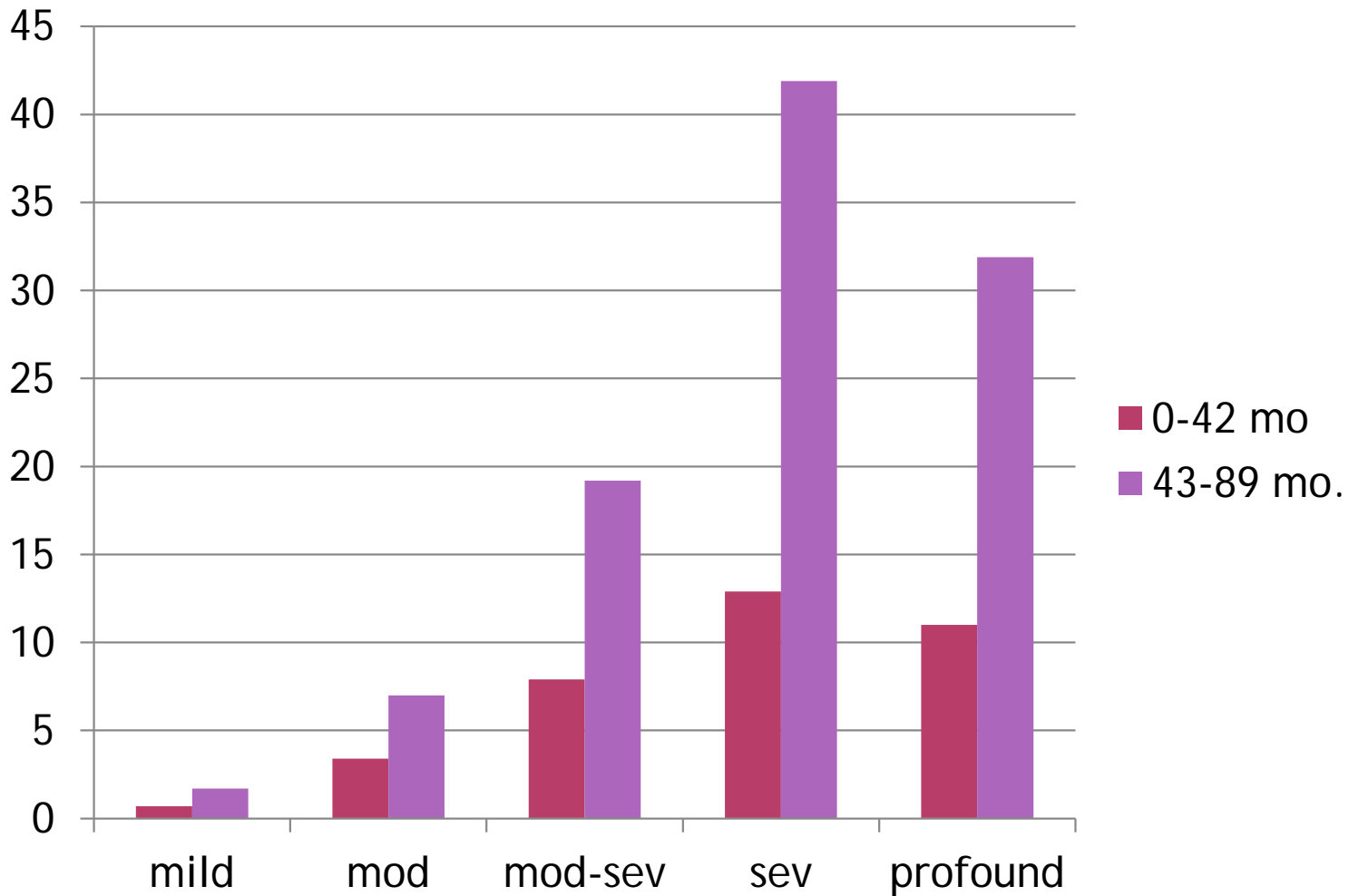
AGES 1 TO 42 MONTHS: N=550

- ◉ .7% N=1 of 151 children with mild HL had a progressive HL
- ◉ 3.4% N=4 of 117 children with a moderate HL had a progressive HL
- ◉ 7.9% N=5 of 79 children with a moderate-severe HL had a progressive HL
- ◉ 12.9% N=9 of 70 children with a severe HL had a progressive HL
- ◉ 11% N=15 of 136 children with profound HL had a progressive HL

43 TO 89 MONTHS N=259

- N=48 of 259 children had a progressive HL
- 1.7% N=1 in 60 children with a mild HL had a progressive HL
- 7% N=4 of 57 children with a moderate HL had a progressive HL
- 19.2% N=10 of 52 children with a moderate-severe HL had a progressive HL
- 41.9% N=18 of 43 children with a severe HL had a progressive HL
- 31.9% N=15 of 47 children with a profound HL had a progressive HL

PERCENT OF PROGRESSIVE HL BY DEGREE OF HL



CROSSECTIONAL STUDY: ACQUIRED HEARING LOSS

ACQUIRED HL

- Of the 795 children in the database, 521 had a reported onset of hearing loss.
- 380 of the 521 (72.9%) children had onset of hearing loss from birth.
- 72 of the children (13.8%) had an acquired hearing loss and
- 69/72 the parents/audiologists did not know the onset of the hearing loss.

ETIOLOGY: ACQUIRED HL (DATABASE INCLUDES BIRTHDATES FROM 1985 TO 2011)

- Of the 72 with reported acquired hearing loss, the following etiologies were reported:
- hereditary (N=3, 4.2%)
- CMV (N=4, 5.6%)
- other syndrome (N=1, 1.4%)
- meningitis (N=35, 49.3%) *note diff with longitudinal study
- high fever (N=1, 1.4%)
- trauma (N=1, 1.4%)
- unknown etiology (N=13, 18.3%)
- ototoxicity (N=6, 8.5%)
- other (N=5, 7%). In the "other" category, 1 was reported to be due to EVA (enlarged vestibular aqueduct), 1 from otosclerosis, and 3, the information was not provided.

RAMIFICATIONS OF THE
PREVALENCE OF PROGRESSIVE
AND ACQUIRED HEARING LOSS IN
THE EARLY YEARS

COLLABORATION: AUDIOLOGY & EARLY DEVELOPMENT/INTERVENTION SERVICES

- ◉ Change from ABR threshold to pure tone threshold - how much is change of test and how much is progression - Be careful about the label of "degree of HL" from ABR - 46% change reported in a 2005 article - unsure of our exact statistics but change of degree of HL frequent and likely 1 of 2 in our database
- ◉ Re-think frequency of audiological evaluations after 3 years of age
- ◉ Teach parents to do daily Ling 6 sound checks
- ◉ Schedule audiological evaluations at the first sign of progression of hearing loss
- ◉ Counsel parents to observe any changes in hearing status

STATE DATABASES

- There is a critical need to collect longitudinal hearing loss data on the children identified with hearing loss from universal newborn hearing screening programs if audiologists reported all newly identified pediatric HLs to the state EHDI databases we could track progressive and acquired HL
- There is a critical need to add children with acquired hearing loss in childhood to this database.

UNKNOWN ETIOLOGIES OF PROGRESSIVE HEARING LOSS

- The need for more information about etiologies of progressive hearing loss
 - Urine/blood samples for CMV titers on all children failing UNHS prior to hospital discharge?
- The need for more information about etiologies of acquired hearing loss
 - Should there be urine/blood samples taken universally for all children failing UNHS.

PROGRESSIVE HL IS MORE FREQUENT THAN PREVIOUSLY SUSPECTED

- Progressive hearing loss appears to be much more frequent than we had previously suspected - especially among children with severe to profound HL
- Progressive and acquired hearing loss is more frequently documented between 3.5 and 7 years of age.
- We do not know the number of children who progress from the initial physiological diagnostic evaluation to the first behavioral audiogram.

HEARING LOSS PRESENT AT BIRTH

- Progression of HL and age at acquisition of HL should be taken into account when analyzing predictors of developmental outcomes of children with HL

AMPLIFICATION/UNDER-AMPLIFICATION

- Changes in the child's hearing levels will require modification of the amplification settings
- Frequent audiological evaluations should occur in early childhood

GENETIC TESTING

- New genetic chips that test for a wide range of genetic causes of hearing loss significantly reduce the cost of the testing
- Free testing may be available if family is willing for other members of the family to also be tested

CMV TESTING

- ◉ Saliva testing may be possible
- ◉ Inexpensive cost for CMV screen - may be around \$8.00-9.00

- ◉ Treatment for CMV
- ◉ Perhaps short term oral valganciclovir treatment - promising results for prevention of HL for asymptomatic CMV - but there are some possible side effects of valganciclovir

ACKNOWLEDGEMENTS: FUNDING

- ◉ Centers for Disease Control
- ◉ AUCD #433
- ◉ Developmental Outcomes Feasibility Study
- ◉ AUCD
- ◉ Association of University Centers on Disability

- ◉ Longitudinal data collection also funded previously: NIH-NIDCD, Office of Education, Maternal and Child Health

CHRISTIE.YOSHI@COLORADO.EDU