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REVIEW ARTICLE

An Overview on Audio logical Abnormalities in Gaucher's Disease

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ABSTRACT:

Background: A group of metabolic disorders known as glycosphingolipid (GSL) lysosomal storage illnesses are brought on by mutations in the genes that code for the activator proteins or hydrolases that catabolise GSLs inside lysosomes. The most prevalent lysosomal storage disease, Gaucher's disease (GD), is a multi-systemic, autosomal recessive glycosphingolipid condition. It is brought on by decreased activity of the lysosomal acid β-glucosidase enzyme glucocerebrosidase, which causes glucosylceramide to build up in the lysosomes of the monocyte-macrophage system. The existence of these aberrant cells in different organs causes the symptoms and physiopathological characteristics of GD disease, and each patient's experience with the disease differs significantly. In earlier research, GD patients were evaluated audiologically. The primary method for assessing how the auditory system contributes to the development of disease is still the auditory brainstem response (ABR). However, it is still unknown how aberrant findings relate to brainstem involvement. We review the scientific literature and present our data. **Conclusion:** All GD patients require thorough, ongoing monitoring of their hearing abilities, and other factors, regardless of their original diagnosis. The predictive significance of some of the identified biomarkers for eventual neurodegeneration should be evaluated in future prospective investigations.

Keywords: Audiological abnormalities, Gaucher's disease, Auditory brainstem response.

AUDIOLOGICAL ABNORMALITIES IN GAUCHER'S DISEASE:

Sensorineural hearing loss has been reported as a result of neurological involvement of the auditory system in types II and III illness, according to ENT symptoms. As part of their multidisciplinary care, every patient has an audiological evaluation to check for sensorineural hearing loss.6 [1].

In earlier research, GD patients were evaluated audiologically. The primary method for assessing how the auditory system contributes to the development of disease is still the auditory brainstem response (ABR). However, it is yet unknown how aberrant findings relate to brainstem involvement [2].

Synchronous neuronal activity in the brainstem auditory circuits, such as the cochlear nucleus, superior olivary complex, lateral lemniscus, and inferior colliculus, or eighth cranial nerve, is reflected in ABR waveforms. The pathophysiology of anomalies is speculative because the precise generator sites of the ABR are unknown. The brainstem is known to be affected by neuronopathic GD. Therefore, it is highly probable that the steadily declining ABRs are a reflection of our patients' underlying subclinical brainstem degeneration. It is still

unknown, though, how brainstem involvement relates to CNS progression [3].

It is more likely that there are several lesions, which could impact eighth nerve function, even if some of these anomalies would be consistent with a single lesion in the dorsomedial brainstem and surrounding the saccadic eye movement centres. Indicated that excitatory amino acids, most likely glutamate, could increase excitotoxicity, is responsible for the oculor motor and auditory abnormalities in neuronopathic GD. The oculor motor and auditory systems' high average neuronal firing rates exacerbate this even more. To understand the causes of these anomalies, more research is required [4].

Hughes and Sidransky et al [5] Eight children with type III GD receiving high-dose ERT had their auditory brainstem response (ABR) evaluated, and the results showed a steady decline in ABR responsiveness. They come to the conclusion that different therapy are necessary because ERT does not stop brainstem deterioration.

The degree of brainstem involvement was further demonstrated by the existence of saccade initiation failure and the coupling of defective ABR with abnormalities in the other two brainstem tests. The ipsilateral and contralateral auditory (stapedial) reflex thresholds were compromised in each of the eight cases under study. When both ipsilateral and contralateral impairments are present, that is, when middle/inner ear function is normal, it typically implies central illness that may be 75% sensitively localized to the cochlear and olivary nuclei [6].

On the other hand, elevated reflexes might indicate bilateral involvement of the facial nucleus or its fascicle, which leaves the brainstem ventrolaterally after bending around the sixth nucleus and proceeding dorsomedially. Thus, both fascicles and the horizontal saccade centers in the PPRF may be impacted by a midline lesion close to the genu. Remarkably, type III illness has been linked to sixth nerve palsies [7].

Wave V was either absent or delayed in 12 out of 18 ears (66%), which was the most frequent finding in the ABR. Wave III was either absent or delayed in eight of the eighteen ears (44%). It is believed that the cochlear nucleus produces wave III, whilst the lateral lemniscus and/or contralateral inferior colliculus produce wave V. ABR can detect intra-axial brainstem lesions with a sensitivity of up to 97%. Therefore, intra-axial lower brainstem involvement, starting at the level of the cochlear nucleus and working upward, may be indicated by the abnormal ABR in these patients. All three brainstem tests showed aberrant findings in five patients. The group's worst ABR results were found in Case 1, who had the most extensive neurological involvement [8].

Khan et al. [1] described a youngster with type I Gaucher's disease who had conductive hearing loss as a result of middle ear and mastoid Gaucher cell infiltrations. For the child's educational progress to be maximized, early auditory restoration is essential.

ASSESSING AUDIOLOGICAL MENIFESTAION IN GD

Hearing impairments can be identified and measured with audiometry. The goal of a differentiated and quantitative evaluation of hearing capacity is to provide all the information required to select the best conservative, surgical, technological, or rehabilitative treatment. It should be evident that a single functional test is insufficient to accurately determine the type and severity of the hearing impairment. Functional disorders in the hearing system alter the frequency, intensity, time, and space of the sound signal. Because of this, the "hearing test," which gauges the lowest threshold for pure tone perception, either does not or only partially captures the inadequacies. The strength of contemporary audiometry lies in the range of methods and how they interact [9].

The energy carried per time unit and area is described by the intensity of an acoustic event. The unit of measurement, W/m^2 (Watt per square meter), is not descriptive or useful. There is a straightforward (quadratic) link between this unit and the amplitude or sound pressure, which is expressed in µPa (micropascal). Due to the human ear's broad

dynamic range (there are twelve orders of magnitude between the lowest perceptible and greatest tolerated intensity) and functioning (low sensitivity at high intensities, strong sensitivity for changes and variations at low levels), the decibel (dB) scale, which is named for Alexander Graham Bell, is used instead of intensity or sound pressure parameters. The only physical unit that is arguably used exclusively as tenth ("deci") is this one [9].

In practically all cases, a reference is needed in addition to the dB measurement in order to determine the sound level. The "dB SPL" (sound pressure level) and "dB HL" (hearing level – not hearing loss) are the terms used to describe the mean hearing threshold of normal human hearing at 2 kHz, which is 20 µPa, and the medically normal threshold at the same frequency, respectively. The only way to indicate differences is to use dB without a reference ("hearing loss has increased by 10 dB"). A 10-fold increase in sound intensity or a 100-fold increase in sound amplitude (pressure or density) coincides with a 10 dB rise, approximately doubling the perceived loudness [10]. Since "0 dB" is defined as a logarithmic metric, it does not mean that there is no sound; rather, it relates to the sound intensity as measured by the reference value.

When (time-related) modulations take place, as in the case of frequency-modulated wardle tones in free-field audiometry or amplitude-modulated test tones of the SISI test, the time course of the sound signal is always crucial. The time modulations of frequency and amplitudes, which translate to a syllable frequency of roughly 4 Hz, are the real information carriers in spoken language. In speech audiometry, modulated speech-simulating noise is used to account for this [11].

During audiometric tests, sonic stimuli are delivered using free-field loudspeakers, insert phones, bone vibrators, or ear phones. One way to describe these technological gadgets is as (electroacoustic) transducers. dB is a unit of measurement for their output signal. Because bone vibrators produce a force level rather than a sound, they are a peculiar case. Depending on predetermined technical criteria, this force level can be converted into a sensitivity level (dB HL) [12].

PURE TONE AUDIOMETRY

A higher perceptual threshold for pure tones than that of normally hearing individuals is evidence of the attenuation component of hearing impairment, which is the decreased sensitivity for low intensity sound signals. The most important feature of the lowest perceptible level is the large degree of perceptional uncertainty, which makes measuring challenging. As a result, the patient's information is typically not very accurate or reliable. Another issue is that, although the patient typically has two hearing ears, the threshold must be established for each ear. The contralateral ear can detect the signal even if the test stimulus is presented through earphones rather than in the free sound field. Only when the non-test ear is successfully masked can the threshold for the test ear be precisely determined. Hearing loss is defined as the discrepancy between the measured hearing threshold's dB HL value and the normal values [13].

The thresholds between 250 Hz and 8 kHz are represented in half octaves using pure tone audiometry. The frequency is raised in sixth-octave increments up to 16 kHz for analysis at higher frequencies (DIN EN 60645-1:2015-11). Measuring the hearing threshold in high frequencies is only necessary and beneficial in the context of specific questions, and it can only be accomplished with a limited number of standardized earphones. (DIN EN 60645-1:2015-11). These include, for instance, the assessment of older people's hearing capacities, the early identification of ototoxic effects, and the early identification of hearing loss brought on by noise[14].

Additionally, a study showed that most tinnitus patients with a normal conventional pure tone threshold have conspicuous high tone audiometry [15].

PURE TONE THRESHOLD IN PEDIATRIC PATIENTS

The evaluation of children's hearing abilities is linked to a number of issues that do not arise in adults, such as a lack of collaboration and the challenge of assessing their response to acoustic stimuli. Only involuntary responses that can only be consistently elicited by intense stimulation above the hearing threshold may be used to evaluate a newborn's hearing. Conscious reactions start as early as the 12th week of life. Only school-age children may provide qualified and trustworthy data regarding the hearing threshold [16].

Certain prerequisites must be met before youngsters can undergo hearing exams. Younger children cannot be kept in an acoustic booth, thus a minimum of 12 m² of soundproof, acoustically isolated space is required. To keep the kids from getting sidetracked from their real work, the area should be devoid of too many visual stimuli, perhaps include neither toys nor portraits. The so-called Mainzer Kindertisch, or children's table, is required for free-field audiometry, where the child is positioned (perhaps on the lap of their parent). Loudspeakers that produce warbled sounds and tones are set up on the table. Pictures are shown (usually on screens controlled by the audiometer) together with additional stimuli like lights at the loudspeakers or a moving train to provide distraction and reward. Building blocks, stack towers, and other suitable playing materials are required for this type of audiometry[9].

Care must be made to make sure the kid is not influenced by the helper's conscious ("You hear this noise, right?") or unconscious ("turn to the source of the sound") contributions if the child is sitting on the mother's or father's lap throughout the test. Since the assessment shouldn't take place in the late afternoon or after a lengthy school day, the child should be awake and focused. A sensitive and compassionate examiner with experience in pediatric audiometry is another prerequisite. The tests must be completed in a laid-back and friendly environment without any time constraints. It's crucial to be honest with the child and properly explain the upcoming tests [9].

SPEECH AUDIOMETRY IN CHILDREN

The speech audiometric tests used for adults can only be used to a limited degree with preschoolers. This is especially true for monosyllables, according to the Freiburg test, whereas the numbers can represent a part of the limited vocabulary of youngsters who are hearing impaired. The five-word sentences on the OLSA may be too much for a child's short-term memory. Additionally, children's limited vocabulary and rapidly declining concentration limit the potential of speech audiometric tests. By modifying the testing procedures and choosing suitable test materials, these facts are taken into consideration [17].

Three sections that are tailored to various ages and developmental stages make up the pediatric Mainz speech exam. There are five groups of ten test words in each of the three sections. Because the primary goal of the test word selection process was to create age-appropriate lists, the test content lacks phonemic balance. Mama, egg, doll, ball, train, bow-wow, car, bear, clock and meow are the ten distinct words that make up the first (and most basic) section; the only difference is the order of the syllables. Twenty-five distinct words that are partially similar to those in the first section make up the second section of the test. Two of the five word groups contain each test word. There are no repetitions in the third section of the test; that is, each of the five groups consists of fifty distinct words. The number or percentage of correctly identified and repeated test items at a given speaking level is the test result[9].

A prevalent problem in speech audiometry is the need for the patient to repeat the test word so that the examiner may assess whether the word was correctly understood. This could result in the occurrence where the hearing test results incorporate potential dysfunctions of the speech-production system. If the test-taker discards any illustrations he would use to demonstrate word recognition, this issue might be avoided. The Göttingen pediatric

speech intelligibility test, which has two sections, embodies this idea. "Göttingen I" is used for kids between the ages of three and four. "Göttingen II" is utilized for preschoolers who are four to five years old. Both assessments focus on speech comprehension using monosyllabic test words [18].

Since the primary goal of providing technical devices to children with hearing impairments is to support their speaking and development, speech audiometry is largely used for the prescription, fitting, and subsequent follow-up of hearing aids in pediatric patients. Both hyperstimulation and hypostimulation can harm the ear or make the supply less successful. Although the success can only be partially verified using functional gain or objective approaches, they can be observed in the speech audiogram because speech comprehension is dependent on speech level. The aim of hearing aids is to achieve a normalised speech discrimination curve or at least a normal level of 50% speech understanding [9].

AUDIOLOGIC TEST BATTERY

Following a hearing test if hearing loss is suspected, a thorough clinical examination that includes recording the child's and family's medical history and evaluating developmental milestones must be carried out an otoscopy must then be performed. The child's age determines which tests OAEs, in what order should the audiological test battery consist of acoustic immitance, behavioral audiometry, ABR, and ASSR [**19].**

Otoscopy

To confirm that putting a probe or earphone into the external auditory canal is not contraindicated (EAC), otoscopy is utilized [19]:

Checking the tympanic membrane's color, location, and anatomical anomalies.

Confirming that the external auditory canal is unobstructed and that there is no middle ear discharge.

A visual examination should search for structural anomalies such as atresia, ear pits, ear tags, and low-set pinna and/or EAC ears.

OAEs

TEOAEs are better suitable for topographic diagnostics because they evaluate cochlear outer hair cell (OHCS) function more qualitatively. More quantitative data regarding hearing loss is provided by DPOAEs. When evaluating cochlear hearing loss in babies, DPOAE audiograms are more accurate than behavioral tests since the conditioned free-field audiogram does not accurately reflect the threshold.

At frequencies where hearing loss exceeds 50 dB, DPOAEs are absent. To obtain frequency-specific information on hearing loss across the whole hearing range, ASSRs must be assessed in situations where DPOAEs are not quantifiable, which only affect a small number of cases[**20].**

Acoustic immitance

To evaluate middle ear effusion, tympanometry and acoustic reflex tests are combined.

Tympanometry

For children younger than six months of corrected age, a higher probe-tone frequency (1000 Hz) seems to offer a more accurate test for detecting middle ear effusion (MEE). False-negative tympanograms in the ears of children with MEE may occur between the ages of 5 and 7 months of corrected age. Most children older than six months are better suited for a 226 Hz probe tone[21].

High-frequency tympanometry should be included of the UNHS test battery as it demonstrates a strong correlation between the findings of the TEOAE test and otologic evaluation (GRADE C). Each panellist made an argument that in order to eradicate MEE, otoscopy and tympanometry must be performed prior to rescreening[22**].**

Acoustic (Stapedial) Reflex Testing (ART)

When screening children older than six months, ipsilateral and contralateral ART should be performed at 500, 1000, and 2000 Hz (GRADE D). When there are cochlear HL levels greater than 80 dB, middle ear effusion, nonintact membrane, cerumen impaction, or specific hearing impairments of retrocochlear origin, the reflex is either absent or not detectable. Its existence permits to rule

out a severe to deep HL in most cases and establishes that the neural reflex arc is intact and that there is no middle ear effusion. Nevertheless, there are no guidelines for its methodical application in children's audiological examination [**23].**

Wideband Acoustic Reflectance

Although further research is required, broadband acoustic reflectance is an intriguing clinical method for evaluating MEE in early newborns[**23].**

Behavioral audiometry

Behavioral techniques

There are various age-appropriate behavioral strategies. Patients under 24 months old are usually assessed using visual reinforcement audiometry (VRA), whereas children ages 2 to 5 are assessed using conditioned play audiometry (CPA). All patients over the age of five undergo conventional audiometry, which is the gold standard for assessing and characterizing hearing loss in children (Table 1) [20].

Behavioral testing under the age of 6 months

Measurements for infants younger than six months are based on the observation of reflex responses brought on by hearing an auditory stimulus. In many nations, a variety of conventions have been created. It is advised in France that when evaluating newborns (those under five months old), behavioral tests that are adjusted for developmental stage and conducted in the parents' presence should be included in addition to objective examinations**[24].**

"The Delaroche protocol" is the name given to this audiometric evaluation process. The Delaroche technique emphasizes quantitative data as well as information on the child's growth, relational skills, and communication abilities all of which are crucial for the planning and outcome of intervention. Madell created the "Sucking Test Protocol" in 2008 to assess hearing in infants under six months old (GRADE D). Due to time constraints or a shortage of qualified audiophonologists, all panelists concurred that not all referral centers offer audiometry for children under six months. In these situations, they favor using ABRs as an additional test to identify newborn hearing loss [19].

Objective electrophysiological tests

Today, ASSR testing is probably going to be able to simply replace ABR. Particularly for kids who are too young for trustworthy behavioral testing, ASSR testing has become a viable electrophysiological method that can be utilized in place of ABR testing to validate behavioral audiometry thresholds [19].

ABR

Through good nerve fiber synchronization over the 2–4 kHz frequency range, the ABRs enable targeted stimulation of the auditory system. Between 1000 and 4000 Hz, the click stimulus offers estimate across a wide frequency range. However, we require a thorough evaluation of evoked potential that includes accurate information pertaining to the ear and frequency in conjunction with the tone burst stimuli [25].

A brief tone stimulus that is more frequency-specific is called a tone burst (TB). TB ABR is a very good indication of infants' and babies' hearing, just like click-produced ABR. That click expedites the acquisition of ABR responses in the first place, and while low-frequency (500 Hz) TB evaluates low-frequency hearing, it also enables the evaluation of high-frequency hearing [26].

The cochlear travel wave delay, which causes frequency zones to be stimulated sequentially, is the cause of the challenge with click stimuli. A set of stimuli called the CE-Chirp was created to improve neuronal synchronization and make up for the cochlear travel wave delay [27].

According to the JCIH 2007 guidelines, the gold standard test for estimating the audiogram of newborns aged one to three months is the TB ABR (Fig. 1). However, in order to assess hearing thresholds, the NHS now accepts Chirp stimuli and suggests tone-pip click stimulation [28].

For newborns aged one to three months, it is advised to estimate the audiogram by evaluating hearing thresholds using ABR.

There are no uniform guidelines on the stimulus kind, which varies based on national guidelines (GRADE D) [29] figure 1.

In order to distinguish between sensory, conductive, and mixed HL and to ascertain the configuration of HL in each ear, the NHS and JCIH recommend that doctors use air conduction TB stimulation to record ABR and, when thresholds are raised, bone-conduction TB stimuli (GRADE D) [29].

Farinetti et al. [19] suggested combining click-ABR with low-frequency TB-evoked ABR threshold measurements for both ends of the audiogram (250–500 Hz for TB, and 2–4 kHz for click) in order to rapidly offer clinical information. (Grade B).

ASSR

Compared to ABR, ASSR testing offers numerous benefits.

This test is useful for determining residual hearing since it allows measurement of hearing thresholds in the low to upper frequencies (e.g., 500 to 4000 Hz) (GRADE B). According to François et al. [29], ASSR should be performed prior to ABR (GRADE C) in order to evaluate hearing threshold rather than delay. The air conduction ASSR, ABR, and Pure Tone Audiometry (PTA) thresholds have been found to be strongly correlated (with a difference ranging from 5 to 15 dB). This test employs an automatic detection technique and is an objective answer detection approach. One benefit of ASSR testing is its ability to measure simultaneous responses to several frequencies in both ears (dichotic multiple-stimulus approach) [29].

Lower correlations between ASSR and PTA thresholds on the 500 Hz and 4000 Hz frequencies were seen in children with ANSD and regrettably, this test is lengthier than the ABR. To prevent saturation, the maximum presentation level typically remains between 90 and 105 dB HL. At levels more than 110 dB HL, insert earphones can lessen the possibility of artifactual reactions. Although it cannot differentiate between severe and profound hearing loss, absent ABR is consistent with considerable hearing impairment [30].

In preterm newborns or infants with an increased risk of ANSD, ASSR should supplement OEAs and ABRs rather than replace them (GRADE B) [31].

Since the electrophysiological tests typically come before the behavioral tests, it is not advised to include high intensities (> 120 dB HL) because the cochlea may be harmed by these extraordinarily high intensities, and the clinician may not be aware of the behavioural test results (GRADE B), in the normal examination of juvenile cochlear implant (CI) candidates [32].

When ANSD is suspected or ABR responses are not consistent, an electrocochleography (ECochG) is advised (GRADE D) [20].

Table 1: Audiological test battery [19].

Test	Birth to 6 months	6 to 36 months	3 to 5 years
OAEs	TE or DPOAEs	TE or DPOAEs	TE or DPOAEs
Acoustic immitance	High-frequency (1000 Hz) probe-tone	Low-frequency (226 Hz)	Low-frequency (226 Hz)
ABR	Tone bursts, click, or chirp AC and BC ABR Insert earphones[a]	When? Behavioral audiometry unreliable, inconclusive 2 attempts at behavioral audiometry unsuccessful within a period of 2 months Suspicion of neural disorders An AABR has never been performed for HL < 3 years	When? Behavioral audiometry unreliable, inconclusive 2 attempts at behavioral audiometry unsuccessful within a period of 2 months Suspicion of neural disorders
ASSR	Insert earphones[a] for AC BC transducer needed if AC elevated Alone is not adequate to acquire specific information		

Behavioral assessment	Alone is not adequate for determining hearing thresholds	Visual reinforcement ± Conditioned play audiometry (insert) + Speech audiometry	VRA ± CPA + Speech audiometry

OAE: otoacoustic emission **TE:** transientreinforcement audiometry; **CPA:** conditioned evoked; **DP:** distortion product; **ABR:** auditoryplay audiometry. a: The 2014 guidelines provided brainstem response; **AC:** air conducted; **BC:**by the French audiological society recommend bone conducted; **AABR:** automated auditoryusing either insert earphones or supra-aural brainstem response; **ASSSR:** auditory steady-headphones (TDH-39) for pediatric hearing tests state response; **HL:** hearing loss; **VRA:** visual(GRADE D).

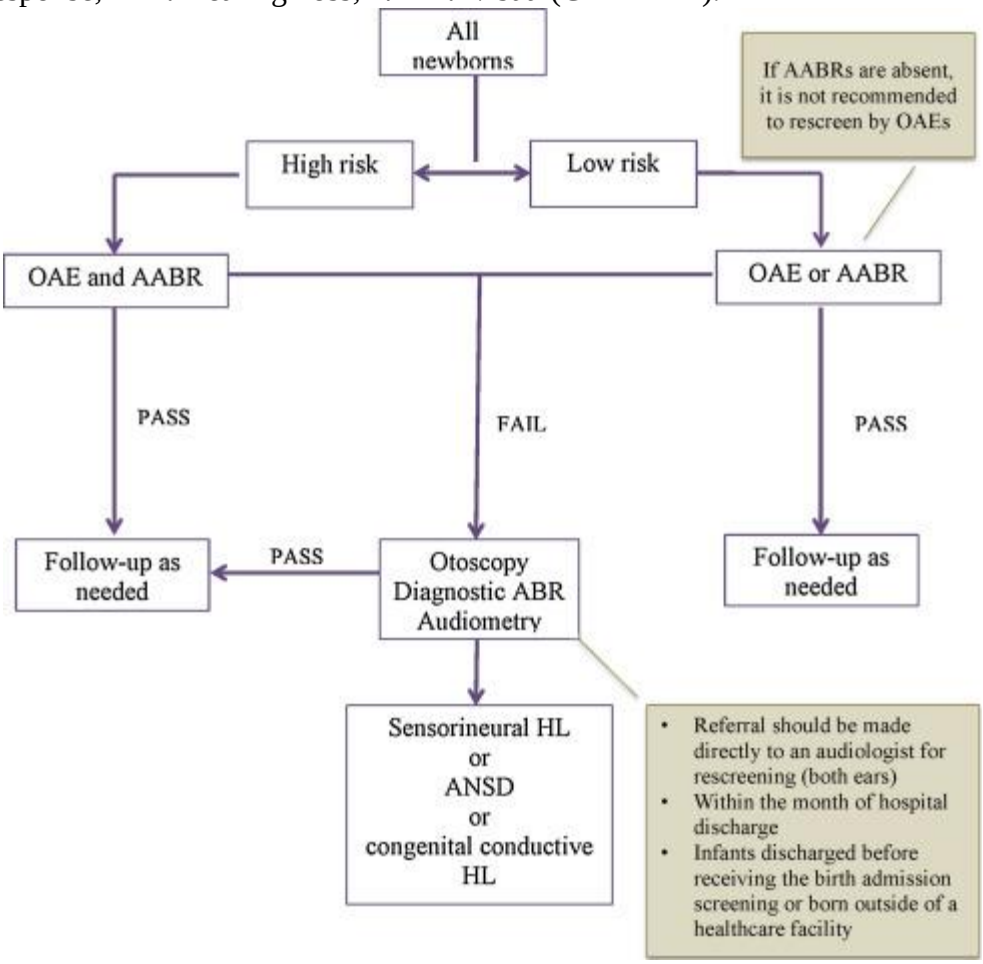

Fig. 1: Screening and rescreening protocols (GRADE D) [19].

AABR: automated auditory brainstem response; **OEA**: otoacoustic emission; **ABR**: auditory brainstem response; **ANSD**: auditory neuropathy spectrum disorder; **HL**: hearing loss.

CONCLUSION:

All GD patients require thorough, ongoing monitoring of their hearing abilities, and other factors, regardless of their original diagnosis. The predictive significance of some of the identified biomarkers for eventual neurodegeneration should be evaluated in future prospective investigations.

REFERENCES:

1. **Khan A, Stimpson P, Karmolinski A, Patel N.** Middle-ear involvement in type I Gaucher's disease–a unique case. J Laryngol Otol. 2013 Dec;127(12):1226-9.
2. **Zhong W, Li D, Fei Y, Hong P.** A review of type 3 Gaucher disease: unique neurological manifestations and advances in treatment. Acta Neurol Belg. 2024 Feb 28:1-1.

3. **Eggermont JJ.** Auditory brainstem response. Handb Clin Neurol. 2019 Jan 1;160:451-64.
4. **Campbell PE, Harris CM, Sirimanna T, Vellodi A.** A model of neuronopathic Gaucher disease. J Inherit Met Dis. 2003 Oct;26(7):629-39.
5. **Hughes D, Sidransky E.** Gaucher disease: Treatment. UpToDate. Last updated April. 2018;10.
6. **Tantawy AA, Sherif EM, Adly AA, Hassanine S, Awad AH.** Evoked potentails and neurocognitive functions in pediatric Egyptian Gaucher patients on enzyme replacement therapy: a single center experience. J Inherit Metab Dis. 2013 Nov;36:1025-37.
7. **Harris CM, Taylor DS, Vellodi A.** Ocular motor abnormalities in Gaucher disease. Neuropediatrics. 1999 Dec;30(06):289-93.
8. **Bamiou DE, Campbell P, Liasis A, Page J, Sirimanna T, Boyd S et al.** Audiometric abnormalities in children with Gaucher disease type 3. Neuropediatrics. 2001 Jun; 32(03): 136-41.
9. **Hoth S, Baljić I.** Current audiological diagnostics. GMS current topics in otorhinolaryngology, Head Neck Surg. 2017;16..
10. **Petit C, El-Amraoui A, Avan P.** Audition: hearing and deafness. InNeuroscience in the 21st Century: From Basic to Clinical 2022 Oct 18 (pp. 1075-1142). Cham: Springer International Publishing.
11. **Hoth S.** Audiometrie Die Untersuchung des Gehörs und seine technische Versorgung. Medizintechnik: Verfahren Systeme Informationsverarbeitung. 2007:193-246.
12. **Maclennan-Smith FJ.** Validity of Diagnostic Pure Tone Audiometry Using a Portable Computerised Audiometer Without a Sound-Treated Environment. University of Pretoria (South Africa); 2013.
13. **Hoth S.** Die Schwelle in der Begriffswelt des Audiologen. Z Audiol. 2009;48(1):46-9.
14. **Crundwell G, Gomersall P, Baguley DM.** Ototoxicity (cochleotoxicity) classifications: A review. Int J Audiol. 2016 Feb 1;55(2):65-74.
15. **Vielsmeier V, Lehner A, Strutz J, Steffens T, Kreuzer PM, Schecklmann M et al.** The Relevance of the High Frequency Audiometry in Tinnitus Patients with Normal Hearing in Conventional Pure-Tone Audiometry. Biomed Res Int.2015;2015(1):302515.
16. **Tullo MG, Cerulli Irelli E, Caramia F, Tessari G, Di Bonaventura C, Turchetta R et al.** The spectrum of neurological and sensory abnormalities in Gaucher disease patients: a multidisciplinary study (SENOPRO). Int J Mol Sci. 2023 May 16;24(10):8844.
17. **Feldhusen F, Möhring L, Brunner M, Troost J, Spielberger C, Braun-Frank L, et al.** Audiologische Diagnostik bei Kindern: Verwendbarkeit von unterschiedlichem Sprachmaterial. HNO. 2004 Feb; 52:156-61.
18. **DeRuiter M, Ramachandran V.** Basic audiometry learning manual. Plural Publishing; 2021 Oct 1.
19. **Farinetti A, Raji A, Wu H, Wanna B, Vincent C.** International consensus (ICON) on audiological assessment of hearing loss in children. Eur Ann Otorhinolaryngol Head Neck Dis. 2018 Feb 1;135(1):S41-8.
20. **Janssen T.** A review of the effectiveness of otoacoustic emissions for evaluating hearing status after newborn screening. Otol Neurotol. 2013 Aug 1;34(6):1058-63.
21. **Margolis RH, Bass-Ringdahl S, Hanks WD, Holte L, Zapala DA**. Tympanometry in newborn infants-1 kHz norms. J Am Acad Audiol. 2003 Jul;14(07):383-92.
22. **Kilic A, Baysal E, Karatas E, Baglam T, Durucu C, Deniz M et al.** The role of high frequency tympanometry in newborn hearing screening programme. Riv Eur Sci Med Farmacol. 2012 Feb 1;16(2):220-3.
23. **Joint Committee on Infant Hearing.** Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs. Pediatrics. 2007 Oct 1;120(4):898-921.
24. **Farinetti A, Raji A, Wu H, Wanna B, Vincent C**. International consensus (ICON) on audiological assessment of hearing loss in children. Eur Ann Otorhinolaryngol Head Neck Dis. 2018 Feb 1;135(1):S41-8.
25. **Baldwin M, Watkin P.** Predicting the degree of hearing loss using click auditory brainstem response in babies referred from newborn

hearing screening. Ear and hearing. 2013; 1; 34(3): 361-9.
26. **McCreery RW, Kaminski J, Beauchaine K, Lenzen N, Simms K, Gorga MP.** The impact of degree of hearing loss on auditory brainstem response predictions of behavioral thresholds. Ear and hearing. 2015 May 1;36(3):309-19.
27. **Elberling C, Callø J, Don M.** Evaluating auditory brainstem responses to different chirp stimuli at three levels of stimulation. J Acoust Soc Am. 2010 Jul 1;128(1):215-23.
28. **Stevens JC, Sutton GJ, Wood SA, Mason S.** Guidelines for the early audiological assessment and management of babies referred from the newborn hearing screening programme. Newborn Hearing Screening Programme (England).
29. **François M, Dehan E, Carlevan M, Dumont H.** Use of auditory steady-state responses in children and comparison with other electrophysiological and behavioral tests. Eur Ann Otorhinolaryngol Head Neck Dis. 2016 Nov 1;133(5):331-5.
30. **Shinn JB, Musiek FE.** The auditory steady state response in individuals with neurological insult of the central auditory nervous system. J Am Acad Audiol. 2007 Nov;18(10):826-45.
31. **da Silva IA, da Silva TM, Camara CA, Queiroz N, Magnani M, de Novais JS et al.** Phenolic profile, antioxidant activity and palynological analysis of stingless bee honey from Amazonas, Northern Brazil. Food chemistry. 2013 Dec 15;141(4):3552-8.
32. **Grasel SS, Almeida ER, Beck RM, Goffi-Gomez MV, Ramos HF, Rossi AC et al.** Are Auditory Steady-State Responses Useful to Evaluate Severe-to-Profound Hearing Loss in Children?. Biomed Res Int. 2015; (1):579206.

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