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ARTICLES

Results of BAEP and Auditory Steady State Response in infants with and without UNHS failure

Resultado do PEATE e Resposta Auditiva de Estado Estável em lactentes com e sem falha na TANU

Resultados del PEATC e Respuesta Auditiva del Estado Estable en lactantes con y sin falla de CANU

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Abstract

Introduction: Universal neonatal hearing screening (UNHS) is performed by examining brainstem auditory evoked potential (BAEP), in the population with a risk indicator for hearing loss. The auditory steady-state response (ASSR) is an objective and automatic technique for determining hearing thresholds by specific frequency, but still little explored before hospital discharge. **Objective:** to analyze the results obtained in the BAEP and RAEE tests in infants with risk indicators for hearing loss, before hospital discharge, with and without failure in UNHS. **Methods:** Prospective analytical observational study carried out in infants at risk for hearing loss and who underwent BAEP and ASSR in the same session. **Results:** 66 infants attempted the inclusion criteria, of both genders, the median age was 1.2 months, the mean gestational age was 31 weeks and the mean weight at birth was 1601 g. 53 (80%) infants, called G1, had normal BAEP, and 13 (20%) had abnormal BAEP, called G2. The electrophysiological thresholds of ASSR were statistically lower in infants of G1. **Conclusion:** There was a relationship between the

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findings of the BAEP and ASSR exams in infants at risk for hearing loss, when performed before hospital discharge. The median of the ASSR electrophysiological thresholds was lower for the infants who had normal BAEP and higher for those who had abnormal BAEP in the UNHS.

Keywords: Hearing; Electrophysiology; Risk index; Infant; Neonatal screening; Evoked potentials auditory.

Resumo

Introdução: A triagem auditiva neonatal universal (TANU) é realizada por meio do exame de potencial evocado auditivo de tronco encefálico (PEATE), na população com indicador de risco para deficiência auditiva. A resposta auditiva de estado estável (RAEE) é uma técnica objetiva e automática de determinação dos limiares auditivos por frequência específica, porém ainda pouco explorada antes da alta hospitalar. **Objetivo:** analisar os resultados obtidos no exame de PEATE e RAEE em lactentes com indicadores de risco para deficiência auditiva, antes da alta hospitalar, com e sem falha na TANU. **Métodos:** Estudo observacional analítico prospectivo feito em lactentes com risco para a deficiência auditiva e que realizaram o PEATE e a RAEE na mesma sessão. **Resultados:** Atenderam ao critério de inclusão 66 lactentes, de ambos os gêneros, idade mediana de 1,2 meses, idade gestacional média de 31 semanas, peso médio ao nascimento 1601 g. Tiveram PEATE normal, 53 (80%) lactentes, denominados de G1 e 13 (20%) tiveram PEATE alterado, denominados de G2. Os limiares eletrofisiológicos da RAEE foram estatisticamente menores nos lactentes de G1. **Conclusão:** Houve relação entre os achados dos exames de PEATE e RAEE em lactentes de risco para deficiência auditiva, quando realizado antes da alta hospitalar. A mediana dos limiares eletrofisiológicos da RAEE foi menor para os lactentes que tiveram PEATE normal e maior para aqueles que tiveram PEATE alterado na TANU.

Palavras-chave: Audição; Eletrofisiologia; Indicador de risco; Lactente; Triagem neonatal; Potenciais evocados auditivos.

Resumen

Introducción: El cribado auditivo neonatal universal (CANU) se realiza examinando el potencial evocado auditivo del tronco cerebral (PEAC), en la población con un indicador de riesgo de hipoacusia. La respuesta auditiva en estado estable (RAEE) es una técnica objetiva y automática para determinar los umbrales de audición por frecuencia específica, pero aún poco explorada antes del alta hospitalaria. **Objetivo:** analizar los resultados obtenidos en la exploración de PEAC y RAEE en lactantes con indicadores de riesgo de hipoacusia, antes del alta hospitalaria, con y sin fallo en CANU. **Metodos:** Estudio observacional analítico prospectivo realizado en lactantes con riesgo de hipoacusia a los que se les realizó PEATC y RAEE en una misma sesión. **Resultados:** Los criterios de inclusión cumplieron con 66 lactantes, de ambos sexos, edad media de 1,2 meses, edad gestacional media de 31 semanas, peso medio al nacer 1601 g. Tenían un PEATC normal, 53 (80%) lactantes, llamados G1 y 13 (20%) tenían un PEATC anormal, llamado G2. Los umbrales electrofisiológicos de RAEE fueron estadísticamente más bajos en lactantes del G1. **Conclusión:** Hubo una relación entre los hallazgos de los exámenes PEATC y RAEE en lactantes con riesgo de hipoacusia, cuando se realizaron antes del alta hospitalaria. La mediana de los umbrales electrofisiológicos de RAEE fue menor para los lactantes que tenían un PEATC normal y mayor para aquellos que tenían un PEATC alterado en CANU.

Palabras clave: Audición; Electrofisiología; Índice de riesgo; Lactante; Tamizaje neonatal; potenciales evocados auditivos.

Introduction

According to national and international recommendations, universal neonatal hearing screening (UNHS) should take place soon after birth. When there is an abnormal result in the test, the hearing loss should be ideally diagnosed by the second or third month of life and, if there is a real auditory change, the clinical therapeutic intervention must begin by the third month or up to the sixth month at the latest[1,2].

The process of identifying hearing loss in infants, from screening to diagnosis, requires various procedures such as the evoked otoacoustic emissions and the auditory evoked potentials at a first moment, along with behavioral methods[1-4].

The evoked otoacoustic emissions are the most used UNHS test in infants with no risk indicators of hearing loss. However, even though it evaluates preneural auditory structures, it is not efficient to identify retrocochlear abnormality – which is commonly found in infants with risk indicators of hearing loss[4].

Hence, it is recommended that the brainstem auditory evoked potentials (BAEP) be used in UNHS of infants with risk indicators of hearing loss or who failed the evoked otoacoustic emissions test. BAEP verifies the integrity of the auditory structures up to the brainstem and obtains electrophysiological thresholds. Hearing acuity must be investigated using frequencies, although so far, no frequency has been specified in cases of abnormal results[3,5].

Early identification and intervention, as well as the precise hearing acuity at different frequencies, pose a great challenge to the screening and diagnosis programs.

In the effort to identify infants with hearing loss as early as possible, the JCIH (2019)[1] pointed out that auditory assessment is necessary in cases of UNHS examinations with abnormal results, including infants staying in intensive care or any other hospital unit.

Thus, frequency-specific BAEP is indicated to complement audiological assessments[3,5]. However, this examination takes longer to establish the electrophysiological thresholds at each frequency, assessing each ear separately[5,6], and the tracing analysis is subjective, which requires clinical experience on the part of the evaluator. Furthermore, there are limits to the intensity of the test and variations of the latency values depending on the frequency researched, especially when the children assessed are premature or have had perinatal complications. Thus, it is difficult to perform it in a single session without sedatives[5,6].

Another examination that can be used in the frequency-specific hearing assessment of infants is the auditory steady-state response (ASSR), whose advantage is the objective performance and analysis. It estimates hearing at frequencies of 500 to 4000 Hz and can be conducted in both ears simultaneously. Moreover, it enables research at higher intensities than BAEP to verify residual hearing, which is useful information to select and indicate hearing aids and candidates to cochlear implant[7,8].

These characteristics make its use before hospital discharge very promising. Nonetheless, the correlation between ASSR and the other screening examinations needs to be better explored, especially in the population with risk indicators of hearing loss[9-11].

Therefore, the objective of this study was to analyze the results obtained in the BAEP and ASSR examinations of infants with risk indicators of hearing loss, before hospital discharge, with and without failure in UNHS.

Method

This study was approved by the institution's Research Ethics Committee (process no. 423/2011).

This analytical observational study was conducted between January 2013 and March 2014 at a hearing health reference center.

Only infants with risk indicators of hearing loss that had been submitted to UNHS, staying in the Neonatal Intermediate Care Unit, and whose parents or guardians agreed to participate and signed the informed consent form were included in the study.

Inclusion criteria: having been submitted to UNHS with click-BAEP and ASSR in the same session.

Exclusion criteria: malformation of the outer ear, auditory neuropathy spectrum disorder, abnormal otoscopy observed by the otorhinolaryngologist, or impossibility of concluding both examinations in the same session.

The sample was characterized according to sex, age (months), presence of prematurity, or any risk indicator of hearing loss defined by the JCIH[1].

The sample was divided into two groups:

- G1: comprising infants who passed the UNHS with click-BAEP.
- G2: comprising infants who failed the UNHS with click-BAEP in at least one of the ears.

The ASSR results were compared with the UNHS findings, considering the click-BAEP results (normal/abnormal) and the ASSR electrophysiological thresholds at the frequencies of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz, in both ears.

The two examinations were recorded in a random order, giving preference to the side available while the infant was in natural sleep, recording BAEP and ASSR in sequence in the same ear to avoid changing the position of the earphones and the impedance of the electrodes.

Click-BAEP technical specifications

The click-BAEP was conducted with the Integrity V500 System, manufactured by Vivosonic (Canada), in ABR (Auditory Brainstem Response) mode, in a silent room, while the patient was lying comfortably in natural sleep in the crib. After cleaning the skin with an abrasive product (Nuprep®), the surface electrodes – Ambu® Neuroline 720 00S (Denmark) – were fixed on specific sites: the positive (active) electrode was fixed on the forehead (Fz); the negative (reference) ones, in the mastoid regions (M_1 and M_2); and the ground (neutral), on the forehead (Fpz). The acoustic stimulus was presented monaurally via insert earphones (ER 3A), with filtered clicks (from 100 to 2000 Hz) lasting 100 μs, rarefaction polarity, and at the rate of 27.7 clicks per second. A total of 2,048 clicks were used in a 20-ms period of analysis, then repeated to confirm wave reproducibility. The impedance of the electrodes was kept below 3 kΩ. To research neural integrity, the initial intensity of the acoustic stimulus was 80 dBnHL; it was then decreased by 20 dBnHL at a time to research the electrophysiological threshold, increasing again every 10 dBnHL to confirm the last intensity in which wave V was visualized. If there was no response at 80 dBnHL, the intensity was increased 10 dBnHL at a time until wave V was visualized, though not exceeding 99 dBnHL.

Two outcomes were established for this examination: normal and abnormal.

It was considered normal when all the BAEP components (waves I, III, and V, and their interpeak intervals I-III, III-V, and I-V) were present at 80 dBnHL and the electrophysiological threshold was ≤ 30 dBnHL.

It was considered abnormal when any of the BAEP components was absent at 99 or 80 dBnHL and the threshold was > 30 dBnHL.

ASSR technical specifications

The ASSR auditory threshold was researched with the same equipment as the click-BAEP, in the ASSR mode. The room conditions, infant's sleep, examination preparation, the type of earphones, and the type and positioning of the electrodes were the same as that of the click-BAEP.

The examination researched the minimum response level when stimulated by a complex acoustic signal at the frequencies of 500, 1000, 2000, and 4000 Hz, modulated at 80 Hz amplitude, whose modulation is indicated for naturally sleeping or relaxed patients[7,8].

The initial intensity was 30 dBnHL for infants with normal click-BAEP and 50 dBnHL for those with abnormal click-BAEP in any degree. In both cases, the procedure increased 20 dBnHL and decreased 10 dBnHL, depending on there being a response, not exceeding 90 dBnHL, in monotic multi-frequency mode. The ASSR electrophysiological threshold was established as the last intensity at which the significant response was obtained.

The analysis parameters were predefined in the equipment's software and it was not possible to change them, except for the intensity of the stimulus. Hence, the ASSR was obtained with the chirp stimulus (narrowband), at the rate of 80 Hz/second. The time of analysis was 120 ms after beginning the stimulus, including the records with up to 3,500 sweeps in the analysis; the residual noise level was up to 40 nV. The response was considered present when the statistical tests identified a response amplitude higher than the noise at the modulation frequency until reaching the maximum sweeps. The maximum time of research proposed by the software for each intensity was 6 minutes; the ASSR threshold was defined as the lowest intensity level that elicited a response with 95% confidence in the sweeping time. The correction factor used by the equipment was -20 dB at 500 Hz, -15 dB at 1000 Hz, and -10 dB at 2000 and 4000 Hz.

Statistics

The normal and abnormal click-BAEP were compared with the ASSR electrophysiological thresholds employing the Mann-Whitney test.

The differences were considered significant if $p < 0.05$. The analysis was conducted in SPSS (Statistical Package for the Social Sciences), version 21.0.

Results

A total of 73 infants were recruited, who performed UNHS with risk indicators of hearing loss and whose clinical condition was stable while at the hospital. Of these, 66 met the inclusion criteria.

The mean gestational age was 31 weeks (minimum 24 and maximum 41 weeks); the mean birth weight was 1,601 grams (minimum 500 grams and maximum 4,160 grams); 31 of them (47%) were males and 35 (53%), females.

All of them were assessed at the median age of 1.2 months (minimum 0.2 and maximum 8.6 months). The sample characterization regarding prematurity and the risk indicators of hearing loss are shown in Table 1.

Table 1. Profile of the sample (n=66).

Variable	N	%
Premature	57	86
Low Apgar score	16	24
Use of mechanical ventilation	21	32
Ototoxic drug usage	36	54
Low weight	43	65
ICU stay	61	92
Neonatal infection	35	53
Meningitis	10	15
Ventricular hemorrhage	7	10
Seizures	8	12
Congenital syphilis	5	7
Hyperbilirubinemia	1	1
Drug-using mother	3	4
Craniofacial malformation	1	1
Cytomegalovirus	2	3

Legend: n = number of subjects; Low Apgar = one-minute Apgar lower than 4 and/or five-minute Apgar lower than 6.

G1 included 53 (80%) of the infants, whose click-BAEP was normal bilaterally. G2, in its turn, comprised 13 (20%) of them, whose click-BAEP was abnormal – five with unilateral and eight with bilateral abnormality (i.e., 21 out of the 26 ears had some degree of abnormality) (Table 2).

Table 2. Number of abnormal thresholds per ear (> 30 dBnHL) in the click-BAEP in G2.

BAEP	40 dBnHL	50 dBnHL	60 dBnHL	70 dBnHL	90 dBnHL	Total
RE	4	0	0	1	5	10
LE	1	2	1	0	7	11

Legend: RE = right ear; LE = left ear; BAEP = brainstem auditory evoked potential; dBnHL = decibel normal hearing level.

In the ASSR, the percentage of responses found at the frequencies of 500, 1000, 2000, and 4000 Hz were respectively 94%, 92%, 91%, and 91% in the right ear and 90%, 92%, 92%, and 91% in the left ear.

In G1, the ASSR electrophysiological thresholds found at the frequencies of 500, 1000, 2000, and 4000 Hz in both ears were higher at the low frequencies and lower at the high frequencies, which traced an upward curve.

The ASSR electrophysiological thresholds of the infants in G2 varied at the frequencies of 500, 1000, 2000, and 4000 Hz in both ears.

Thus, the median ASSR threshold obtained at the frequencies of 500, 1000, 2000, and 4000 Hz in the right and left ears differed between the two groups (Figures 1 and 2).

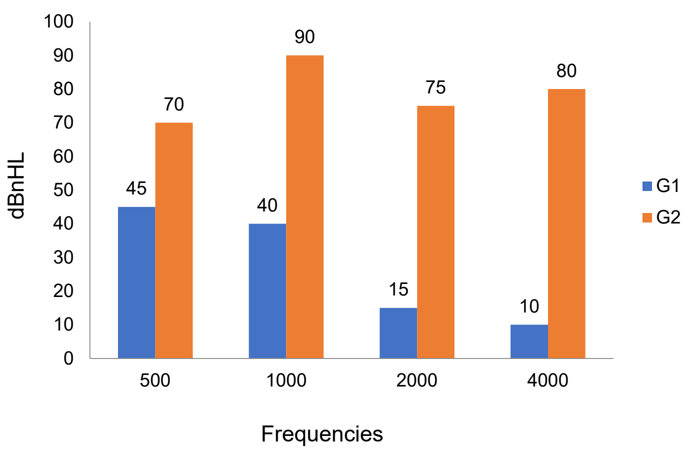

Figure 1. Median ASSR threshold values in dBnHL at the frequencies of 500, 1000, 2000, and 4000 Hz in the right ear, in both groups.

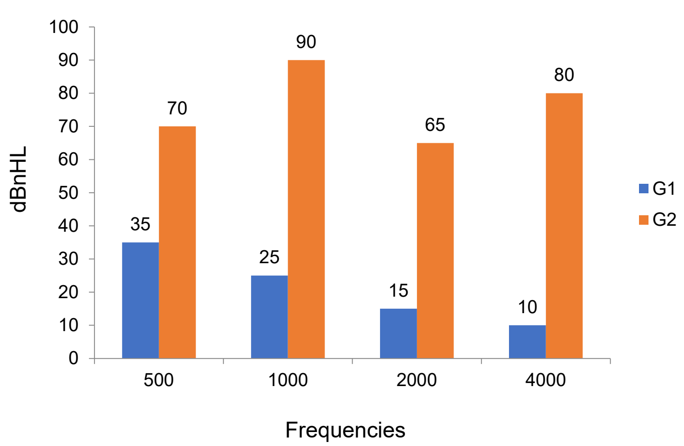

Figure 2. Median ASSR threshold values in dBnHL at the frequencies of 500, 1000, 2000, and 4000 Hz in the left ear, in both groups.

The comparison of both groups' examination results revealed that the ASSR median values per frequency were significantly higher in both ears when the click-BAEP was abnormal (Table 3). This comparison was made with the Mann-Whitney test, as the analysis involved categorical and numerical variables.

Table 3. Normal and abnormal click-BAEP compared with ASSR electrophysiological threshold.

		G1 (n=53)			G2 (n=13)			
Ear	**ASSR frequency (Hz)**	**Med***	**Min***	**Max***	**Med***	**Min***	**Max***	**p**
RE	500	45	0	90	70	30	90	0.029
	1000	40	0	75	90	20	90	< 0.001
	2000	15	0	85	75	15	90	< 0.001
	4000	10	0	60	80	10	90	< 0.001
LE	500	35	0	90	70	30	90	< 0.001
	1000	25	0	90	90	40	90	< 0.001
	2000	15	0	90	65	40	90	< 0.001
	4000	10	0	90	80	45	90	< 0.001

Legend: *values given in dBnHL; Mann-Whitney test; ASSR = auditory steady-state response; Med = median; Min = minimum; Max = maximum; RE = right ear; LE = left ear; G1 = group 1; G2 = group 2; Hz = Hertz.

Discussion

Through the years, studies have investigated and established hearing acuity in infants[12,13]. Dealing with their hearing health, especially when the infants have risk indicators of hearing loss, is a rather challenging job, as this population cannot yet tell their symptoms. In this study, 86% of the participants were premature, and the most prevalent risk indicator was the prolonged ICU stay, followed by birth weight lower than 1,500 grams and ototoxic drug usage. These factors may explain why 20% of the sample failed UNHS either unilaterally or bilaterally.

In UNHS, click-BAEP is usually the first measure taken in infants with risk indicators of hearing loss to investigate retrocochlear auditory change[14,15]. However, the click stimulus cannot estimate the frequency-specific threshold in a range from 500 to 4000 Hz[14]. This is an important datum to be investigated in a risk population, as many complications may affect other regions of the cochlea that are not researched with this examination.

The international recommendations[1] propose increasingly earlier audiological diagnosis and encourage it to be made at the inpatient units (particularly when there is no estimated date of discharge). Therefore, this study aimed to investigate the ASSR results as a tool to complement the examinations commonly used in UNHS. It is a technique that provides further information on the infant's hearing both at low and high frequencies, which enables a curve to be objectively traced similar to that of an audiogram[16].

Hence, the ASSR response characteristics in UNHS need to be better investigated, especially when conducted before hospital discharge, to broaden its applicability[17]. The speech-language-hearing therapist needs this information to get acquainted with the response pattern expected for both potentially hearing and non-hearing individuals, speeding the diagnosis process and helping their practice with new recommendations.

Some studies show, for instance, that it is not always possible to find the threshold of all the frequencies assessed with ASSR[18]. Nonetheless, this study detected ASSR electrophysiological thresholds in more than 90% of the sample, in all the frequencies and different degrees of hearing.

Likewise, Rodrigues and Lewis (2014)[19] found ASSR electrophysiological thresholds in 90% of the infants who were not at risk of hearing loss, which was obtained with monotic multi-frequency stimulation. Despite the difficulty to compare studies because of the differences in sample selection and methodology employed, these findings are coherent, showing that the differences in protocol behave similarly and enable a good response acquisition.

It is known that the thresholds are harder to detect with ASSR at low frequencies than at high ones, which increases both the time of research and the threshold value. This explains the upward curve pattern found in this and other studies, with worse thresholds at low frequencies and better ones at high frequencies[20]. This finding may be explained by the desynchronization of the response neurons caused by a delay in the transmission time of the cochlear receptors and neurons, resulting in a decreased amplitude of the signals registered at the frequency of 500 Hz, both in adults and children[21].

However, this behavior is also commonly observed in people with normal hearing or milder hearing losses. As for those with more severe degrees, the ASSR thresholds have a strong correlation with the behavioral thresholds[1,8,16]. This study observed that infants in G1 had ASSR responses compatible with individuals who usually have normal results in the behavioral assessments, whereas those in G2 had results compatible with people with some degree of hearing loss.

Similar results are described in the literature, which shows that ASSR electrophysiological thresholds are high in groups of people with hearing loss, regardless of the methodology employed[22].

Hence, the comparison of the click-BAEP results (normal or abnormal) with the 80-Hz ASSR results (at all frequencies in both ears) showed that, when the BAEP was normal, the ASSR thresholds were lower. Accordingly, when the BAEP was abnormal, the ASSR thresholds were higher at all frequencies (Figures 1 and 2). Therefore, the ASSR furnished information similar to that of the BAEP at high frequencies, besides the hearing acuity at low frequencies.

Concerning UNHS, some studies have already suggested the use of ASSR as a complementary test. Pinto et al. (2012)[9] compared the values obtained in ASSR with the results of the transient evoked otoacoustic emissions (TEOAE) in infants. They observed that all those with TEOAE responses also have ASSR responses at 50 dBnHL, concluding that there is a correlation between these examinations.

Nodarse et al. (2010)[10], in their turn, compared the BAEP results in infants whose electrophysiological threshold was at 40 dBnHL with the ASSR results. They noted that the ASSR thresholds at 500 Hz and 2000 Hz ranged from 25 to 50 dBnHL bilaterally. These data reinforce the agreement between the findings in different research approaching a neonatal population.

Nevertheless, the infants' age must be considered when analyzing the results. Studies show that in children up to approximately 18 months old with normal hearing, the thresholds range from 20 to 55 dBHL, while in younger ones the responses are generally higher. This suggests maturational changes in this examination as well[20,21].

In this research, the infants at a median age of 1.2 months whose click-BAEP was normal had varying ASSR values, whose median ranged from 10 dBnHL to 45 dBnHL, depending on the frequency tested.

Other studies have verified a good correlation between the click-BAEP and ASSR findings in children under 6 years old[23]. Moreover, in children whose BAEP thresholds could not be measured, the ASSR – which can research higher intensities – indicated whether there was a residual hearing[24].

As in other electrophysiological examinations, the ASSR thresholds may have higher values due to the maturation of the auditory system – particularly in premature populations with risk indicators of hearing loss[25]. Given these circumstances, the speech-language-hearing therapist must interpret and correlate the results and ask for a retest and complementary examinations after hospital discharge.

Although the present study approached only infants at risk of hearing loss before hospital discharge, a good relationship was also found between the click-BAEP and ASSR examinations. When the click-BAEP thresholds were lower, the ASSR thresholds were lower as well – which demonstrates the ASSR reliability in early assessment of hearing sensitivity. As a result, aspects related to referral and follow-up can be optimized, as cases precisely diagnosed before hospital discharge speed up early detection of hearing loss and, consequently, the therapy[26].

Even though ASSR is not part of the initial hearing screening protocols, this study had an experimental approach, demonstrating a cross-verification between these tests. Furthermore, it can be applied while the infant is still at the hospital, furnishing additional information on the hearing conditions at low frequencies, relieving the evaluator from having to make judgments of the interpretation of the results.

Conclusions

There was a relationship between the BAEP and ASSR findings in infants at risk of hearing loss when performed before hospital discharge. The median ASSR electrophysiological threshold was lower in infants whose click-BAEP was normal and higher in those whose click-BAEP was abnormal in UNHS.

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