Newborn and Infant Hearing Screening for Early Detection of Hearing Loss in Nairobi, Kenya

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Abstract

BACKGROUND

Early detection of hearing loss and subsequent intervention leads to better speech, language and educational outcomes giving way to improved socioeconomic prospects in adult life. This can be achieved through establishing universal newborn hearing screening (UNHS) programs. The objectives of this study were to assess the feasibility of implementing a UNHS program and to also determine the prevalence of hearing loss in newborns in Nairobi, Kenya.

MATERIALS AND METHODS

A cross-sectional pilot study was conducted at the National Hospital and a sub-county hospital immunization clinic. A total of 9,963 babies aged 0-3 years, were enrolled in the hearing screening program through convenient sampling over nine months. A case history was administered followed by Distortion Product Oto-acoustic emissions (DPOAEs) and automated auditory brainstem response (AABR) hearing screening.

RESULTS

The screening coverage rate was 98.6% (9963/10,104). The referral rate for the initial screen was 3.6% (356/ 9,963), and the return rate for follow-up rescreening was 72% (258 babies out of 356) with a loss to follow-up rate of 28% (98/356). The referral rate of the second screen was 10% (26/258). All 26 babies referred from the second screen returned for diagnostic hearing evaluation and were confirmed to have hearing loss, yielding a prevalence of 3/1000.

CONCLUSIONS

Establishing universal newborn and infant hearing screening programs in Kenya is feasible and essential for early detection and intervention for hearing loss. Data management and efficient follow-up systems are an integral part of achieving diagnostic confirmation of hearing loss and early intervention.

***Keywords**: Hearing Screening, Newborn, Infant, Hearing Loss, Early Detection, Kenya*

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Introduction

Newborn and infant hearing screening for the early detection of permanent hearing loss is an important component of early childhood healthcare in developed countries [1,2]. If undetected, early hearing loss in children has adverse effects on the development of speech, language, cognitive and psychosocial skills, with a subsequent negative impact on educational achievements and future employment prospects [3-6]. The World Health Organization (W.H.O) estimates that at least 466 million people globally have disabling hearing loss with 34 million of these being children [7]. Hearing loss is now rated as the fourth leading cause of years lived with

disability [7,8]. Approximately 90% of people with disabling hearing loss defined as hearing loss in the better ear of >30 dBHL in children (0-15 years) and >40dBHL in adults, live in low or middle-income countries [7,9]. At the time this study was initiated, the W.H.O classified hearing loss as Mild (26-40 dBHL), Moderate (41-60 dBHL), Severe (61-80dBHL) and Profound (≥81dBHL) [9]. Hearing loss is referred to as a hidden disability due to its invisible nature which often causes it to go undetected. In developing countries, the reported prevalence of permanent hearing loss in newborn babies ranges between 3-6/1000 while in developed countries the range is between 1-3/1000 [11-15]. It is estimated that ~50% of all hearing loss may be preventable through strategies such as immunization, health education and improving maternal and child health services [16,17].

Undiagnosed hearing loss of any severity can lead to delays in speech and language development in children [3,18,]. Hearing screening programs in low and middle-income countries, including Kenya, are lacking. Subsequently, the detection of hearing loss in children is mainly through parental suspicion [20,21]. The Joint Committee of Infant Hearing (JCIH) recommends screening within the first month of life, a comprehensive audiological evaluation by the third month and appropriate intervention by six months of age [22,23]. Hearing screening for newborns is done in the maternity unit before hospital discharge and can also be done at immunization clinics [24, 25]. Otoacoustic Emissions (OAEs) and Automated Auditory Brainstem Response (AABR) are the two objective physiological tests of auditory function that are widely used in universal newborn hearing screening programs [23,26]. They are reliable, cost-effective, non-invasive, simple to administer and can be effectively conducted by primary healthcare workers who have undergone the necessary training [26, 27]. There are four categories of screening protocols available for use at the first stage of UNHS programs: (a) OAEs only, (b) AABR only, (c) OAE followed by AABR when OAE refers in one or both ears and (d) both OAE and AABR, where a pass is required for both the OAE and AABR screening in one or both ears [28]. The OAE screening takes ~3 minutes, is less expensive and has higher referral rates in comparison to the AABR screening which takes ~12 minutes and is more expensive but has lower referral rates [29, 30]. AABR screening is recommended for babies admitted to the NICU for > 5 days [22]. Efficient tracking systems and good communication between health professionals and parents are necessary to ensure high follow-up return rates [16, 28].

Newborn hearing screening programs are yet to be established in Kenya. The objectives of this study were to assess the feasibility of implementing a UNHS program, and to also determine the prevalence of hearing loss in newborns in Nairobi, Kenya.

Materials and Methods

Study design and setting

This was a cross-sectional study conducted at the Kenyatta National Hospital (KNH) maternity ward, newborn unit (NBU) and newborn intensive care unit (NICU) in the Department of Reproductive Health, and at the Mbagathi sub-county Hospital maternal child health clinic, in Nairobi, Kenya. Convenient sampling was used to enroll the study participants. Since this was a pilot study to assess the feasibility of establishing a newborn hearing screening program, a sample size of ~10,000 newborns was considered adequate.

Study personnel

The study team consisted of four registered community health nurses who were research assistants who facilitated data collection and ensured timely contact with parents and

caregivers for follow-up appointments. The data manager and clerks collected all the study questionnaires from the research assistants daily and ascertained that the questionnaires were filled. Before the commencement of the study, the principal investigators conducted a 3-day-focused training for the research assistants on all study protocols and procedures, including obtaining informed consent and performing hearing screening using the DPOAEs and AABR equipment. Finally, the diagnostic evaluation was conducted by an Audiologist.

Test procedures

Collection of case history information: The case history information was obtained from the baby's file and interviews with the mother. The informed consent process was conducted followed by a clinical examination of the baby. Babies with external auditory canal atresia in both ears were excluded from the study.

Hearing screening: All babies in the KNH maternity ward newborn unit, neonatal intensive care unit, and babies < 3 months of age presenting at the MCH clinic for immunizations (Figure 1) were screened for hearing. For the healthy children born through normal delivery and caesarean ready for discharge from the hospital between 12-24 hours and 3 days after birth respectively, a case history was obtained followed by hearing screening with DPOAEs and AABR. Hearing screening was conducted closer to the time of hospital discharge on all days of the week except on Sunday. DPOAE screening was conducted by presenting a click sound stimulus through a small probe placed in the ear canal. The hearing screen was considered an overall pass when at least three pass results were obtained out of the four frequencies tested between 2-5 kHz in each ear. For AABR screening, a click sound stimulus was presented to the ear through an insert earphone placed in the baby's ear canal. Surface electrodes were placed on the baby's head to record the response. The results for both the DPOAEs and the AABR were displayed either as a "pass" or a "refer". For DPOAE screening, primary tones were presented at levels of L1= 65dB and L2 = 55 dB SPL. A signal-to-noise ratio of 6 dB in three out of four frequencies tested between 2-5 KHz was required to qualify for a pass. The screening procedure was done at the bedside or in a quiet side room after the baby was fed. The screening results were recorded and explained to the mother. No further testing was done for babies whose screening results showed a pass. Those who were referred were given a follow-up appointment within six weeks of hospital discharge. At the follow-up appointment, a two-step hearing screening with DPOAEs and AABR was conducted. Those who were referred at the second stage of rescreening, were in turn referred for diagnostic ABR at the KNH Otorhinolaryngology clinic. All babies admitted to the NICU for more than 5 days underwent initial AABR hearing screening before discharge, with the same follow-up two-step rescreening and diagnostic testing.

Confirmation of hearing loss: Diagnostic tone burst ABR was conducted by presenting the sound stimulus through an insert earphone placed in the baby's ear canal. Surface electrodes were placed on the baby's head to record the ABR response. In this study, hearing loss greater than 30 dB HL whether bilateral or unilateral was considered as permanent congenital hearing loss. A referral was made to the ear, nose and throat specialists upon confirmation of hearing loss which was followed by auditory rehabilitation, usually provision of a hearing aid and instructions to the mother for its use.

Data management and quality control

The questionnaires were checked for completeness at the study site daily before submission to the data centre. Patient identity was anonymized to conform to the confidentiality requirements. Quantitative data from the field questionnaires were entered into a computer database designed using the MS Access

application. Regular data backup was done using external storage drives. In addition, ~500 records were randomly selected and double-entered for comparison purposes, establishing that no errors were detected. Data analysis was performed using IBM SPSS version 25.0 statistical software. Descriptive statistics such as frequencies and proportions were used to summarize all categorical variables. Pearson's Chi-square test was used to test for the difference in case referral across points of enrolment of the study participants. The threshold for statistical significance was set at $p<0.05$. Data collection tools were tested and validated before data collection.

Ethical considerations

Ethical approval to conduct this study was obtained from the Kenyatta National Hospital and University of Nairobi (KNH/UON) Ethics Committee. Written informed consent was obtained from all subjects involved in the study.

Results

A total of 10,104 babies were eligible for screening; of these 9,963 of the mothers consented to participate. Those who were not screened for reasons of early discharge or death of a baby were 1.4% (141/10,104), yielding a screening coverage of 98.6% (9,963/10,104).

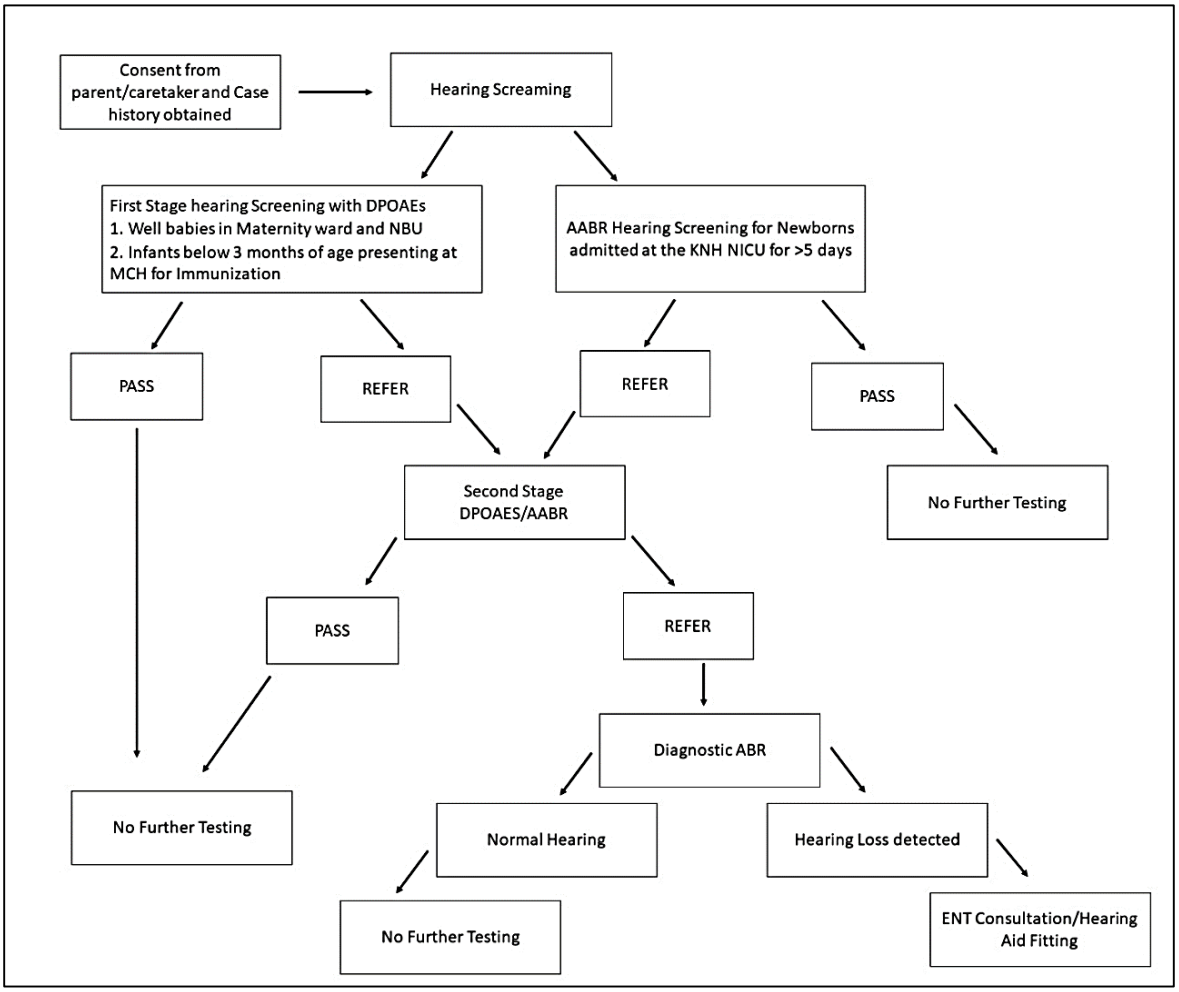

Figure 1:
Study Flowchart

The results are presented in three sections: (1) Background characteristics, (2) Screening results, and (3) Confirmation of hearing loss.

Background characteristics

Table 1 presents the neonatal and maternal background characteristics**.** The highest number of enrolments were from the maternity ward (82.2%), with 12.9% from the NBU and 4.9% from the Immunization Clinic. Of the 1287 newborns admitted to the NBU, 56.6% were admitted to NICU. Of the 728 admitted to the NICU, 23.5% stayed for more than 5 days. Most of the deliveries reached full term (48.8) or early term (31.1%), with 8.5% born preterm.

There was a comparable male (50.9%) to female (49.1%) distribution among the infants. A majority of the infants (89.0%) had normal birth weight, with 8.7% having low birth weight and 0.4% with very low birth weight. Almost all infants (99.5%) were born in a health facility (91.8% were born in KNH) with 0.5% being home deliveries.

Table 1:
Neonatal and Maternal Background Characteristics

Variables	N=9963	%
Location code		
Maternity Ward	8188	82.2
NBU	1287	12.9
Immunization Clinic	488	4.9
Patient was admitted to the NICU from NBU		
Yes	728	56.6
No	559	43.4
Length of stay in NICU, in days (n=728)		
>5 days	171	23.5
<=5 days	557	76.5
Gestation age classification (in weeks)		
Preterm (<34 weeks)	123	1.2
Late preterm (34 - 36 weeks)	727	7.3
Early term (37 - 38 weeks)	3097	31.1
Full term (39 - 40 weeks)	4859	48.8
Late-term (41 - 42 weeks)	1063	10.7
Post-term (>42 weeks)	94	0.9
Gender of the baby		
Male	5069	50.9
Female	4894	49.1
Birth weight		
Very low (<1500g)	43	0.4
Low (1501g - 2499g)	863	8.7
Normal (2500g - 4200g)	8864	89.0
Overweight (>4200g)	193	1.9
Place of birth		
Health facility	9913	99.5
Home	50	0.5
Health facility (n=9913)		
KNH	9103	91.8
Other	810	8.2

Screening results

The number of babies referred at the initial screening is illustrated in Figure 1 and Table 2 which indicate an overall referral rate of 3.6% (356/9,963). The majority referred at the initial screening were from the Maternity unit, 88.2% (314/356), followed by the Immunization clinic, 8.1% (29/356) and the lowest from the Newborn Unit, 3.6% (13/356). Thereafter, 258 of the 356 babies (72.4%) were brought back for follow-up rescreening, 233 from the Maternity unit (65.4%), 16 from the Immunization clinic (4.5%), and 9 from the newborn Unit (2.5). A total of 98 of the 356 babies (27.6%) were lost to follow-up, 81 from the Maternity ward (22.8%), 13 from the Immunization clinic (3.7%), and 4 from the newborn Unit (1.1%). There was a significant difference in the proportion of case referrals across points of enrolment ($p<0.001$), with the highest referral observed at the immunization clinic (5.9%, 29/488), followed by the maternity (3.8%, 314/8188), and the lowest at the Newborn Unit (1.0%, 13/1287).

Confirmation of hearing loss

All 26 babies referred for diagnostic hearing testing were brought back for the tests and they were all confirmed to have hearing loss of 30dBnHL or greater **(Table 3).** 21/26 (80.9%) infants had bilateral hearing loss while five 5/26 (9.1%) had unilateral hearing loss. Six babies (23%) had mild hearing loss (26-40 dBHL), eleven (42%) moderate hearing loss (41-60 dBHL), six (23%) severe hearing loss (61-80 dBHL) and three (12%) profound hearing loss (> 81 dBHL). The prevalence of confirmed diagnosis of hearing loss for all categories of hearing loss was 0.3% (95% CI: 0.2% - 0.4%).

Discussion

This study is the first of its kind in Kenya, demonstrating the feasibility of implementing a UNHS program, the needed infrastructure, and the prevalence of significant hearing loss in the newborn population. The study attained a screening coverage of 98%, exceeding JCIH's recommended screening coverage of 95%. This screening coverage was comparable to that obtained in other developing countries 98.7% (Nigeria) [13] and 95% (South Africa) [27] respectively.

There was a maternal willingness to participate in the screening process, which was achieved through educating mothers on the importance of hearing screening and the early detection of hearing loss as well as the effects hearing loss could have on a child's development of speech and language.

Table 2:
Summary of Initial Screening Results

Screening Outcomes	Maternity ward (n=8188)	Newborn Unit (n =1287)		Immunization (n=488)	Total (n=9963)
		NBU	NICU		
PASS	7874	551	723	459	9607
REFER	314	8	5	29	356
TOTAL	8188	559	728	488	9963

Table 3:
Summary of Diagnostic Results

Summary Of Diagnostic Results			
Categories of Hearing Loss	Bilateral	Unilateral	n= 26 (%)
Mild 26-40 dBnHL	4	2	6 (23)
Moderate 41-60 dBnHL	9	2	11(42)
Severe 61-80 dBnHL	5	1	6 (23)
Profound >81dBn HL	3	0	3 (12)
Total	21/26	5/26	

None of the mothers declined to give consent for screening. The short hospital stay of 12-24 hours for healthy babies could have contributed to some babies being discharged before the hearing screening was conducted. Babies delivered through caesarean section and those admitted to the newborn unit had a minimum hospital stay of three days which made it possible to screen all of them before discharge from the hospital. The nursing staff was sensitized to the need to have all babies screened before discharge with a view to optimising screening coverage through their cooperation. All mothers whose babies were screened for hearing were given an informational booklet that included the screening results. A referral letter was issued to those who required follow-up screening, they were also informed that the follow-up services would be free-of-charge. The higher percentage of hospital births (99.5) observed in this study compared to home births (0.5%) could be attributed to the free maternity services provided in public hospitals in Kenya.

The overall referral rate of 3.6% obtained in this study was within JCIH's expectations of no more than 4% for a UNHS program. The referral rate for infants less than 3 months of age attending the immunization clinic was 5.9% which was higher than that of well babies in the maternity ward (3.8%) and NBU (1.0%). Higher referral rates have been found for OAE-only screening protocols, 11% (South Africa); lower referral rates where two-step screening protocols were used, 3.5% (Nigeria), 2.2% (India), 2.0% (Hong Kong), and 1.33% (Saudi Arabia). [13,29,33,33]. Higher referral rates are expected when babies have a shorter hospital stay due to the presence of vernix caseosa in the ear canal, and middle ear fluid and screening in a noisy environment.

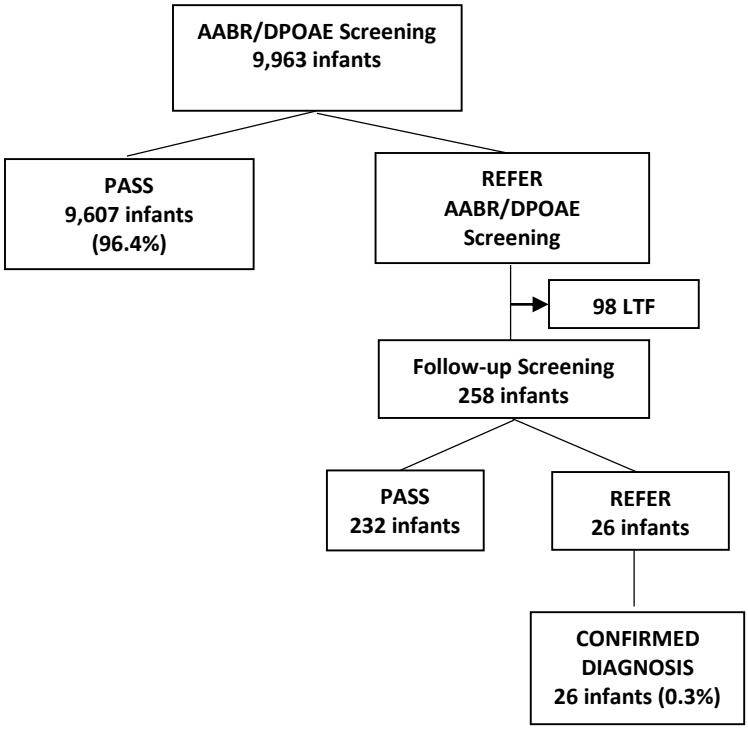

Figure 2:
Flow chart on the diagnosis of hearing loss

The lower referral rates obtained in this study could partly be attributed to the low ambient noise levels which were achieved by conducting screening after the routine ward activities and baby feeding times. Screening was done at higher frequencies of 2-5Khz which is associated with lower referral rates as it is less likely to be affected by vernix and middle ear fluid [34].

Tracking for follow-up rescreening and diagnostic testing was done through mobile telephone calls to the parents or caregivers. The return rate for follow-up rescreening was 72.4% which is below the recommended rate of more than 95%. [22, 23]. Poor follow-up return rates have been reported as a challenge for hearing screening programs. [27,29,35-37]. The major contributing factors to the loss of follow-up in this study were parental reluctance for further evaluation, and an inability to track those who gave incorrect telephone contacts or numbers that belonged to relatives or neighbours. Some mothers were unable to meet travel costs for follow-up appointments. The return rate for diagnostic hearing evaluation was 100% (26/26) which was the result of enhanced parental education on the importance of the return visit, aligning the appointment with other follow-up clinics and providing mothers a choice of return dates. Each of these infant's families was provided appropriate counselling and free hearing aids. The prevalence of hearing loss in this study was 3/1000 (**Table 3).**

It is critical to have a continuum of care from screening to validation of the screening results through diagnostic audiology testing, to effective interventions such as hearing aids, cochlear implants and sign language instruction, to addressing the stigma of hearing impairment in society. This continuum of care requires comprehensive infrastructure, including adequate numbers of trained screening staff, tracking capability with efficient data systems and trained personnel, a sufficient number of accessible audiologists, and public funding through the Ministry of Health. Full time adequately trained staff, as well as the support of the medical community, particularly primary care physicians [38], is essential for the success of such a UNHS program. The medical school curriculum should include the huge impact of neonatal hearing impairment on the long-term development of children into adulthood, and the economic cost over a lifespan. The cost-effectiveness of newborn screening should be included, along with a description of newborn screening tests, such as OAE and AABR.

Screening for hearing impairment can be coordinated with other universal health interventions, such as immunization programs, to make them cost and time-effective. The Ministry of Health provides a mother and child health (MCH) handbook which is used to record a child's health record from birth up to age 5 years. We recommend the inclusion of hearing screening in the MCH handbook so that this can be conducted during the immunization clinic visits.

A benefit of an effective screening program is the ability to reassure the vast majority of parents that their child has normal hearing. Sustaining a successful UNHS program requires both expertise and passion. Selecting a champion(s) with charisma is critical. This may be a professional (audiologist or otolaryngologist), a parent, a child, or a public figure with hearing impairment.

Conclusion

UNHS is an effective program for early identification and intervention for hearing impairment. A well-coordinated multidisciplinary approach involving health professionals such as audiologists, nurses, paediatricians, medical specialists, government policymakers in health and education and parents is critical to making this program effective. The sustainability and effectiveness of the UNHS

program will depend on government goodwill and policies providing adequate funding.

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Author contributions

- Serah N. Ndegwa, conceptualization, methodology, software, validation, investigation, resources, data curation, writing, and project administration.
- Debara Tucci, funding acquisition, conceptualization, methodology, software, validation, resources, data curation, writing.
- James Lemons, funding acquisition, conceptualization, methodology, resources, writing and editing.
- Florence Murila, methodology, investigation, resources, data curation, original draft preparation, review and editing.
- Moses Mwangi, methodology, data analysis and interpretation, data curation.
- Susan Shepherd, review and editing, resources.
- Isaac Macharia, John Ayugi, review and editing.

Conflicts of Interest: The authors have no conflicts of interest.

Data Availability Statement: The tools used in this study including the study questionnaire, are available from the first author, upon request.

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