SYMPOSIUM: NEW DATA FOR NOISE STANDARDS.

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I. NEW DATA FOR NOISE STANDARDS.*†

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ABSTRACT.

Continuous and impulse noises, considered "safe" by existing damage risk criteria were combined to model more realistic noise environments. Monaural chinchilla were exposed to one of the following conditions: *a.* 50 impulses with a 40 μ sec A-duration at 158 db SPL peak pressure, 1/minute; *b.* 95 db SPL continuous noise at 2-4 kHz for one hour; and *c.* superimposed combination of the continuous and impulse noise. Quiet thresholds were measured before and after exposure using the auditory evoked response, and histology was obtained, using the surface preparation technique. The audiometric and histological findings agree in showing that the superimposed combination of two "safe" noises produces traumatic effects that more than exceed the additive effects of either component. The existing damage risk criteria do not provide guidelines for such noise combinations.

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INTRODUCTION.

The Walsh-Healy Act[1] clearly outlines the limits of human exposure to continuous noise. All environments below 90 dbA are considered safe for an eight-hour exposure each day; all noise environments above 115 dbA are not acceptable for any duration; and, for noise levels between 90 and

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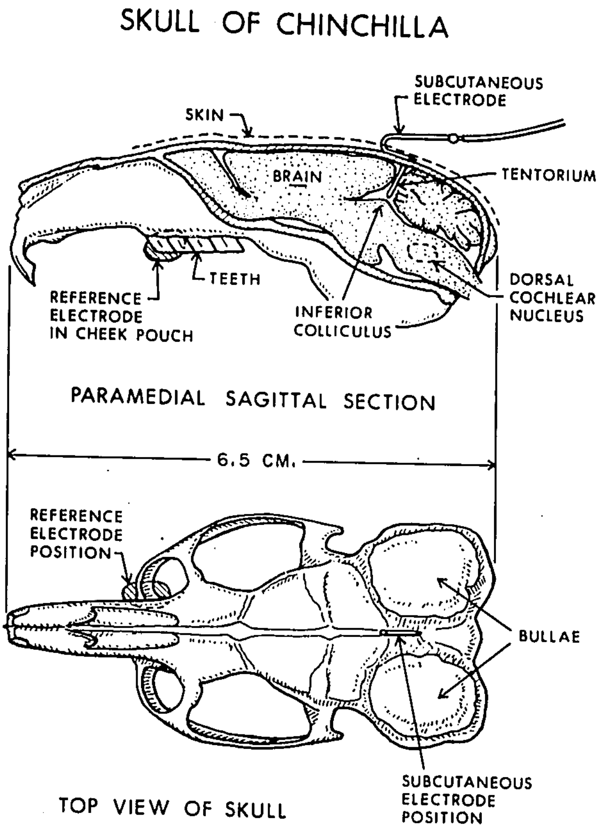

Fig. 1. Chinchilla skull with electrode in place.

115 dbA, there is a tradeoff between the duration of the exposure and the intensity of the noise. There are several damage risk criteria (DRC) for impulse noise. The Walsh-Healy Act rates any impulse over 140 db as unacceptable, regardless of its temporal characteristics. Coles, *et al.*,[2] have published a DRC in which the noxiousness of an impulse is evaluated on the basis of the impulse intensity, duration and number. There are, however, no criteria for noise environments in which continuous and impulse noise occur in combination. This is a potentially serious void in the presently available noise criteria, because a substantial percentage of industrial workers are employed in environments that consist of a combination of both classes of noise; moreover, a recent survey of hearing levels of Army personnel[3] in the divisions of armor, artillery, infantry and aviation, showed that the armor branch was most severely handicapped by noise-induced hearing loss. Specifically, in the armor branch, of those personnel with 10 years' active duty, 41 percent had hearing levels of greater than 50 db at 4 and 6 kHz. This is a handicap that warrants duty limitation. What may be important about this statistic is

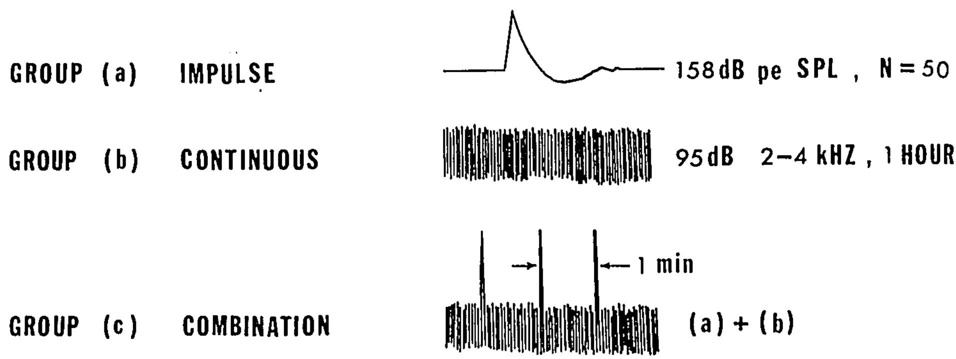

Fig. 2. Schematic of three exposure paradigms.

that the noise to which the armor personnel are exposed is often a combination of impulse and continuous noise.

The purpose of the following experiment was to determine whether there is any interaction between combinations of safe continuous and impulse noise.

METHOD.

A. Subjects.

Three groups of five chinchillas were used as subjects. The animals ranged in weight between 400 and 700 grams. Each animal was anesthetized with sodium pentobarbital (0.5 cc/kg, I.P.) and rendered monaural by means of surgical destruction of the left cochlea. While anesthetized, a chronic electrode was placed on the dura over the region of the inferior colliculus and a reference electrode was inserted into the nasal cavity. The electrodes were attached to a two-prong transistor plug which was fastened to the skull with cranioplastic cement (Fig. 1).

B. Pre-Exposure Audiogram.

Following a recovery period, audiograms were obtained for each animal, using the auditory evoked response (AER) technique.[4] Thresholds were determined at .25, .50, 1, 2, 4 and 8 kHz, the test signal being a 20 msec tone burst with a 5 msec rise-fall time. The threshold was considered to be the halfway point between the lowest intensity eliciting a definite N_1-P_1 response and the highest intensity producing no response. All testing took place in a calibrated acoustic booth. Three post-exposure thresholds were obtained at each of the six test frequencies, the final pre-exposure value being the mean of the three tests.

C. Noise Sources.

The impulse noise waveform was generated using a capacitive spark discharge; the continuous noise source consisted of a standard laboratory

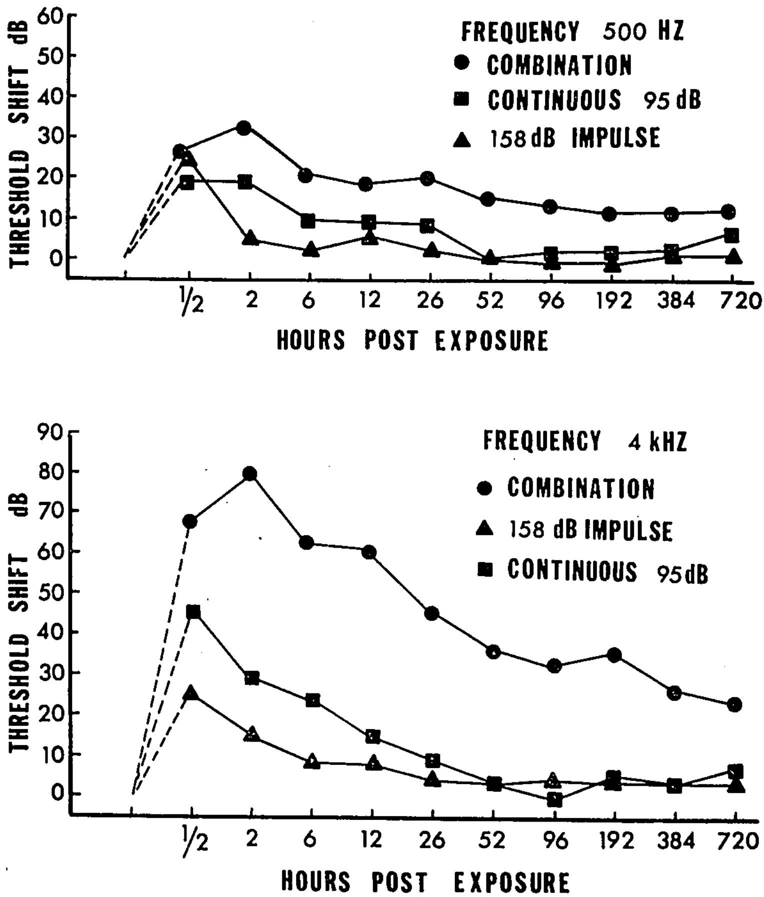

Fig. 3. Median AER threshold recovery curves for exposure groups a, b and c at two typical frequencies.

audio system (*i.e.*, noise generator, filter, amplifier and speaker). The noise exposures all took place in anechoic surroundings, where the impulses take on the pressure-time form of a simple blast wave profile, *i.e.*, $P \sim (1-t/t_A) \exp(-t/t_A)$, where t_A is the duration of the initial positive overpressure.

PROCEDURE.

Three groups of chinchillas were exposed to one of the following noise conditions: *1*. 158 db peak SPL impulses, 1/min. for 50 minutes. The impulse had a 40 μ sec A-duration. *2*. Ninety-five db SPL continuous noise, 2-4 kHz, for one hour. *3*. A superimposed combination of *1* and *2*. Following noise exposure, thresholds were obtained at regular intervals between 0.5 and 774 hours. At the end of 30 days, the animals were sacrificed; their cochleas were perfused with a 1 percent buffered OsO_4 solution,

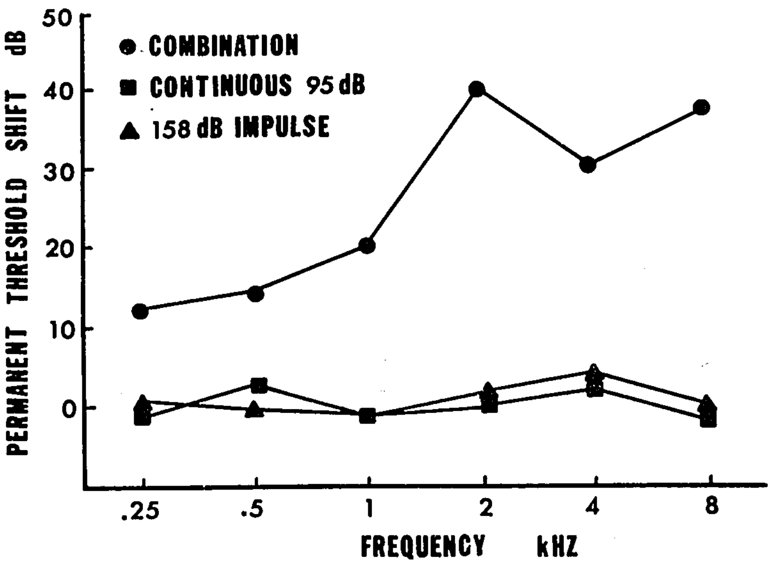

Fig. 4. The median 30-day post-exposure audiogram for exposure groups a, b and c.

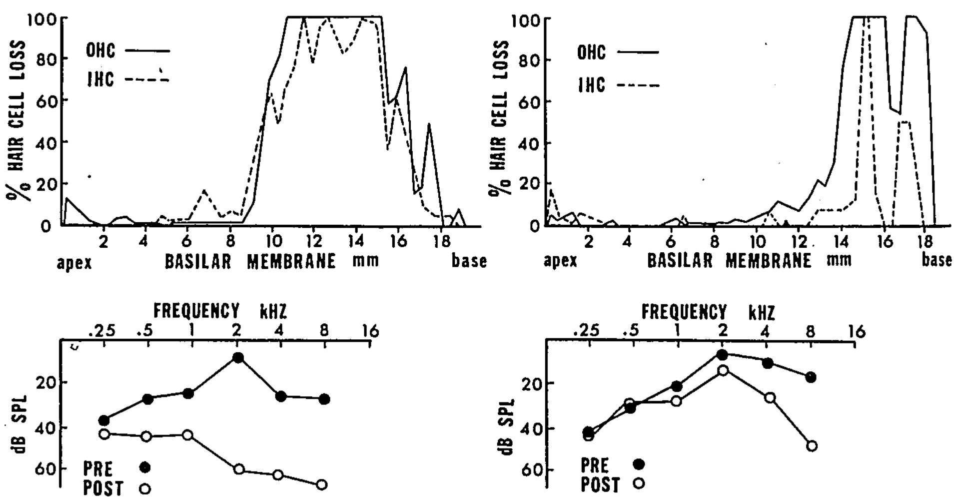

Fig. 5. Typical AER 30-day audiograms and cochleagrams after exposure to combined impulse and continuous noise (group c).

dehydrated, and then dissected for the surface preparation histology. The exposure paradigms are schematically illustrated in Figure 2.

RESULTS.

The median recovery of hearing functions at .5 and 4 kHz are illustrated in Figure 3. The two control groups return to within 10 db of pre-exposure hearing levels by 24 hours. The combination group developed con-

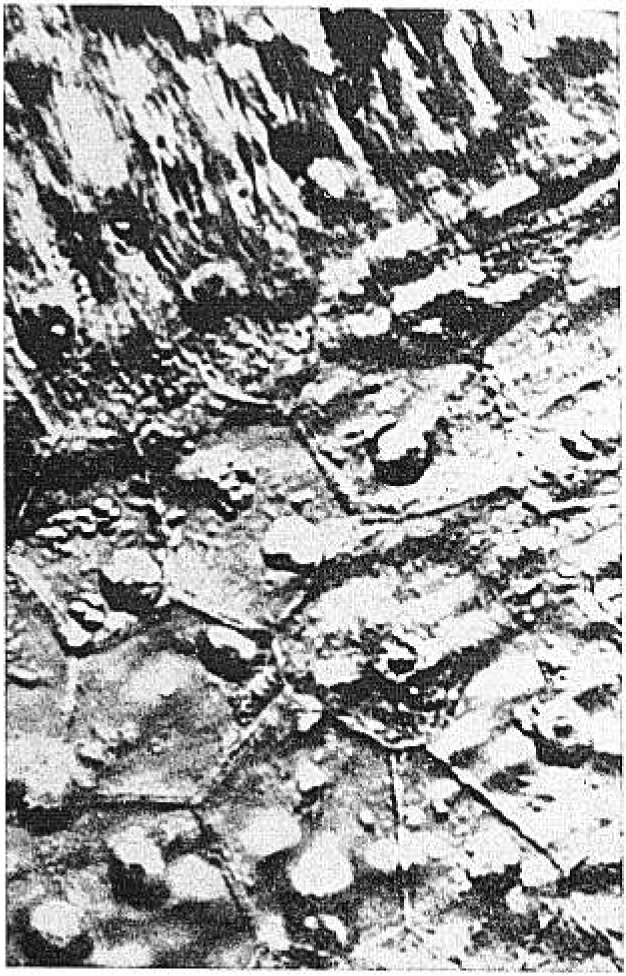

Fig. 6-A. Photomicrograph of basilar membrane showing total loss of the organ of Corti.

siderably larger TTS which varied from 26-50 db for $.25 \leq f \leq 1$ kHz, and 65-83 db for $2 \leq f \leq 8$ kHz. The maximum TTS consistently occurred at 2 to 12 hours after exposure; this "growth" of TTS is a phenomenon typically associated with impulse noise exposure.[5,6] The 30-day audiograms illustrated in Figure 4, show that the control groups sustained no measureable permanent hearing losses. The histological analysis of the 10 chinchillas of the two control groups, showed that only one animal from the 158 db impulse noise exposure had a significant hair cell lesion. The combination group had resolved to 10-15 db permanent losses at low frequencies (.25 to 1 kHz) and 30-45 db losses at the high frequencies (2 to 8 kHz). Generally, the pattern of the audiogram could be considered to be a classic example of noise-induced hearing loss. It should be noted that these results cannot be explained on the basis of an addition of the two noise

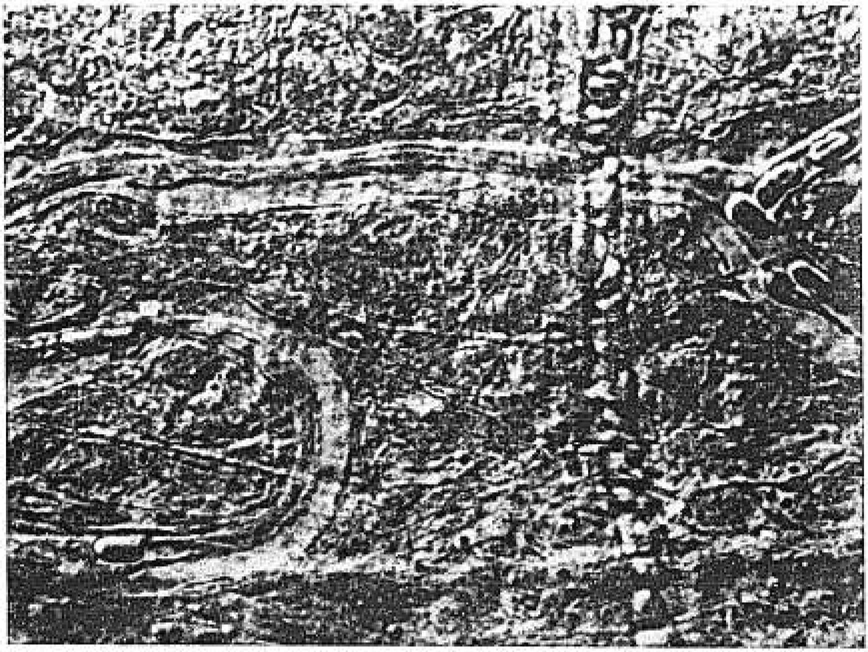

Fig. 6-B. Photomicrograph of spiral ligament showing non-patent capillaries.

intensities, because the background noise, on the average, adds a fraction of a db to the impulse.

The histological and the audiometric results for the individual animals are in general agreement. The least and most affected animals are shown in Figure 5. The chinchilla on the left has lost almost the whole population of inner and outer hair cells in the basal half of the cochlea, while the chinchilla on the right has a less extensive lesion of primarily outer hair cells, again in the base of the cochlea. Figure 6 is a photomicrograph illustrating the appearance of the organ of Corti in areas most severely affected by the combined noise exposure. In this region of the cochlea, the entire sensory epithelium with the supporting cells has degenerated leaving only a covering of low profile, cuboidal epithelial cells. There is also an obvious absence of the mylinated VIIIth nerve fibers in this area. In addition to losses in the organ of Corti, there is also a systematic occlusion and subsequent degeneration of the capillaries of the spiral ligament and occasionally a severe atrophy of the stria vascularis. These vascular changes are not always in a region in juxtaposition to the lesions of the organ of Corti (Fig. 6-B).

In summary, two points can be made from the results of this experiment: *1.* using the chinchilla as a subject, it is possible to have a combination of individually "safe" impulses and continuous noise that is extremely traumatic; and *2*. there is potentially a serious void in the existing noise criteria.

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ANNUAL OTOLARYNGOLOGIC ASSEMBLY.

The Annual Otolaryngologic Assembly of 1974 will be held October 26 through November 1, 1974, in the Eye and Ear Infirmary of the University of Illinois Hospital. The Department of Otolaryngology of the Abraham Lincoln School of Medicine, University of Illinois at the Medical Center, offers a condensed basic and clinical program for practicing otolaryngologists under the direction of Emanuel M. Skolnik, M.D., with Burton J. Soboroff, M.D., as co-chairman. This program is designed to bring to specialists current information in medical and surgical otorhinolaryngology.

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A separate, but correlated course, "Conference on Radiology in Otolaryngology and Ophthalmology" will be held this year on Friday and Saturday, November 29-30, under the guidance of Galdino E. Valvassori, M.D.

For further information about the radiology conference, write: Professor Valvassori, Radiology Department, Abraham Lincoln School of Medicine, P. O. Box 6998, Chicago, Ill. 60680. 5,6,7,8,9