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Damage of the Basilar Membrane by Acoustic Stimulation

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Schädigung der Basilarmembran durch akustischen Reiz

Zusammenfassung. Nach akustischer Traumatisierung von mehr als 130 dB kommt es zu typischen Rissen in der Basilarmembran in den Schneckenabschnitten mit maximalem Schaden. Es werden die Lage, die Größe und die Anzahl dieser Risse bei verschiedenen Schallexpositionen analysiert.

Schlüsselwörter: Akustische Traumatisierung – Basilarmembran

Summary. Sound exposures of more than 130 dB lead to typical tears in the basilar membrane in the area of maximal damage. The position, size, and number of these tears are evaluated.

Key words: Acoustic trauma – Basilar membrane

Introduction

Direct mechanical damage occurs in the guinea pig cochlea with sound exposures of more than 130 dB [1, 4, 6, 7]. With intensities of more than 140 dB the organ of Corti is frequently completely whiped off the basilar membrane, and the cells of the tympanic lamina are shaken off in the region of the upper basal and lower second turn [3]. In these regions, where only the bare basilar membrane and the mechanically resistant Vas spirale remains, radial tears in the basilar membrane are found in various numbers and sizes [2].

Material and Method

One hundred sixteen guinea pigs had one ear exposed to noise of 140 dB or more under general anesthesia for varying times from 30 s up to 20 min. In 70 animals white noise in the form of impulses of various shapes, in 18 animals continuous white noise, and in 28 animals narrowband noise of

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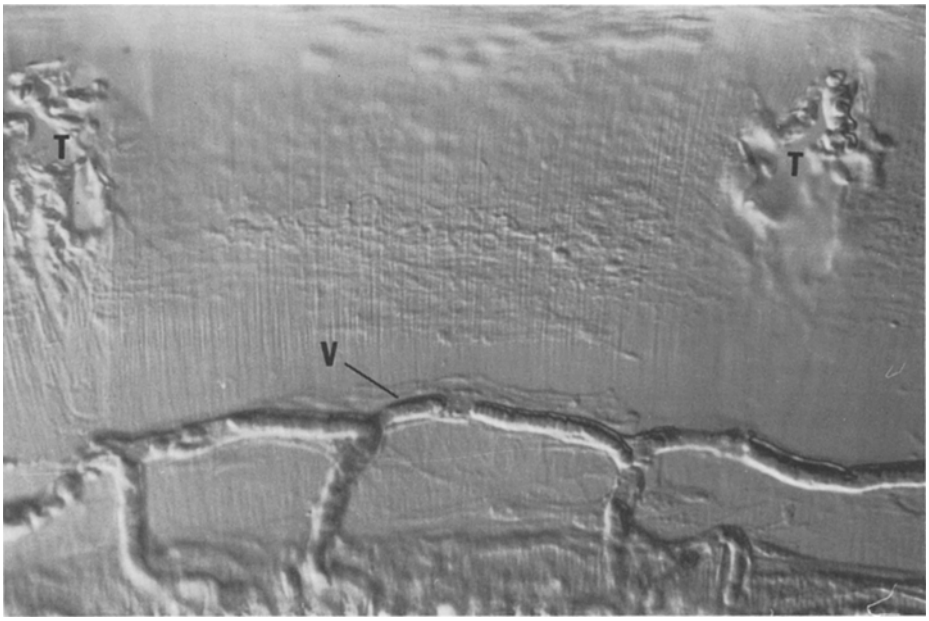

Fig. 1

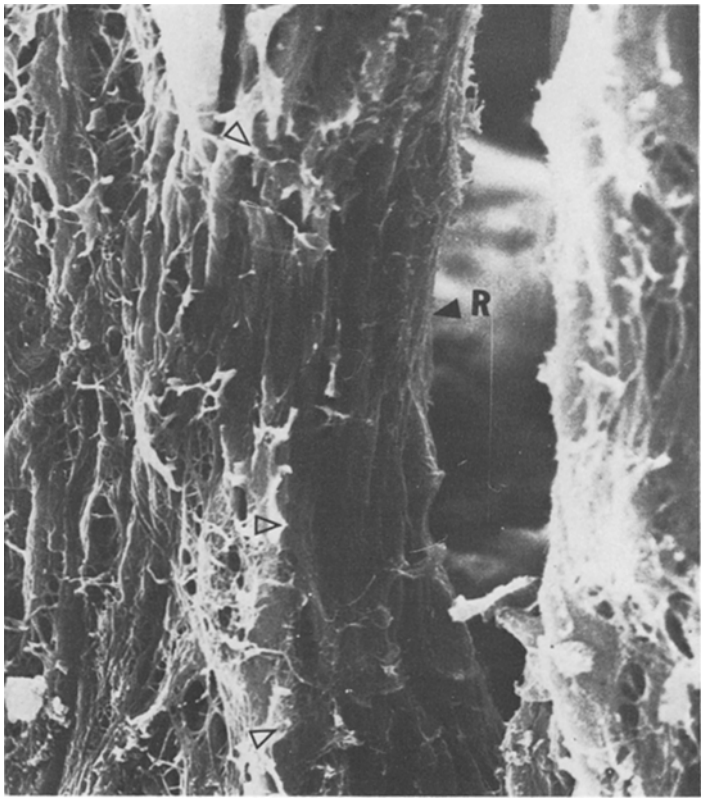

Fig. 2

various frequencies was used. In 93 guinea pigs the cochleas were fixed immediately after the exposure and in 23 only after a surviving time of 2–3 months. The cochleas were prepared according to the technique of bloc surface [5] and evaluated with interference contrast of Nomarsky or with the electron microscope.

Results

In 52 cochleas (= 45%) there was a complete loss of the organ of Corti and the tympanic lamina over a certain distance in the upper basal and lower second

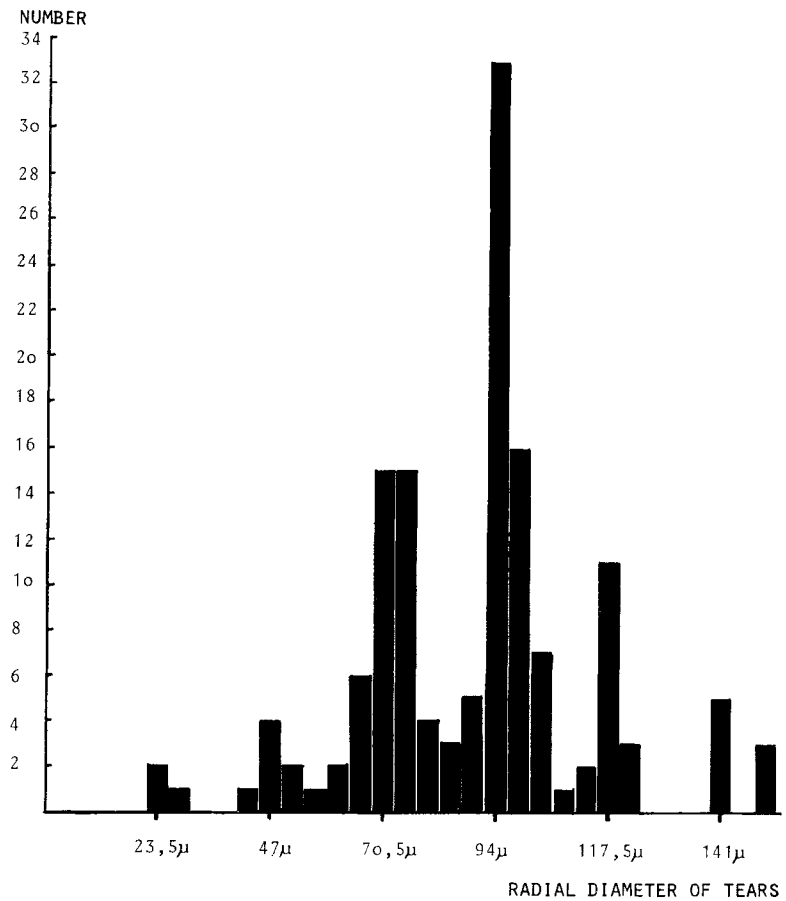

Fig. 3. Distribution of radial diameter of BM tears (results from 29 GP cochleas immediately following exposure to 140 dB white noise for 30 s to 20 min)

Fig. 1. Surface view of damaged area of upper basal turn of a GP after exposure to 140 dB white noise for 20 min. The vas spirale (*V*) is the only structure to remain on the bare basilar membrane (BM). Two radial tears (*T*) in the BM are clearly visible

Fig. 2. BM tear under scanning electron microscope: rupture of the weak longitudinal links (arrows) between the radial fibrillar fasciles (*R*)

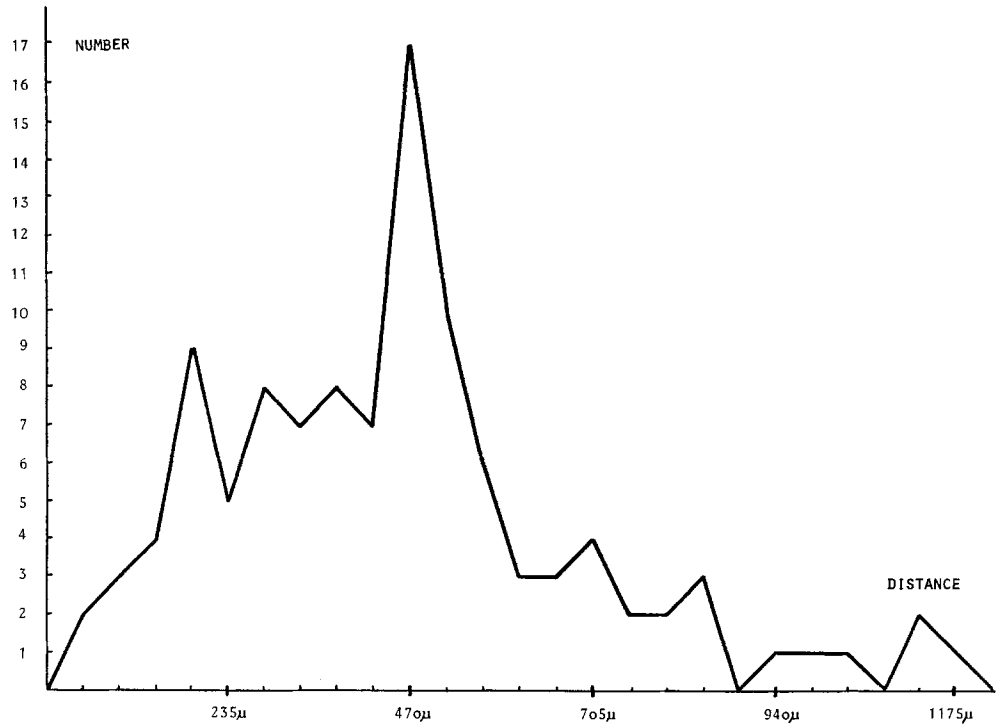

Fig. 4. Distribution of distances between BM tears (results from 29 GP cochleas immediately following exposure to 140 dB white noise for 30 s to 20 min)

turns. In 33 cases of these heavily damaged cochleas, radial tears in the basilar membrane were found (Fig. 1), obviously as a consequence of the rupture of the relatively weak longitudinal links between the radial fibrillar fascicles of the basilar membrane as clearly seen under the scanning electron microscope (Fig. 2).

The radial diameter of the basilar membrane tears seems to follow certain patterns (Fig. 3). The diameters are grouped with surprising regularity around the integral multiples of a basic value of 23.5 µm. The envelope of these peaks shows a simple uni-modal distribution. The most frequently observed value of 94 µm corresponds to about $^1/_3$ of the basilar membrane in the upper basal turn.

Also, the distance between the individual tears exhibits certain patterns with a clear predilection for values between 200 and 500 µm (Fig. 4). The extent and the localization of the areas with complete loss of the organ of Corti and tympanic lamina is quite different between animals prepared immediately after the exposure and those with surviving times of 2–3 months. In the first group, the organ of Corti is exclusively missing in the upper basal and lower second turns, whereas in the second group the lesion extents toward the base of the cochlea. The tympanic lamina is shaken off over wide areas mainly from the zone of maximum damage toward the cochlea apex. After relatively short surviving

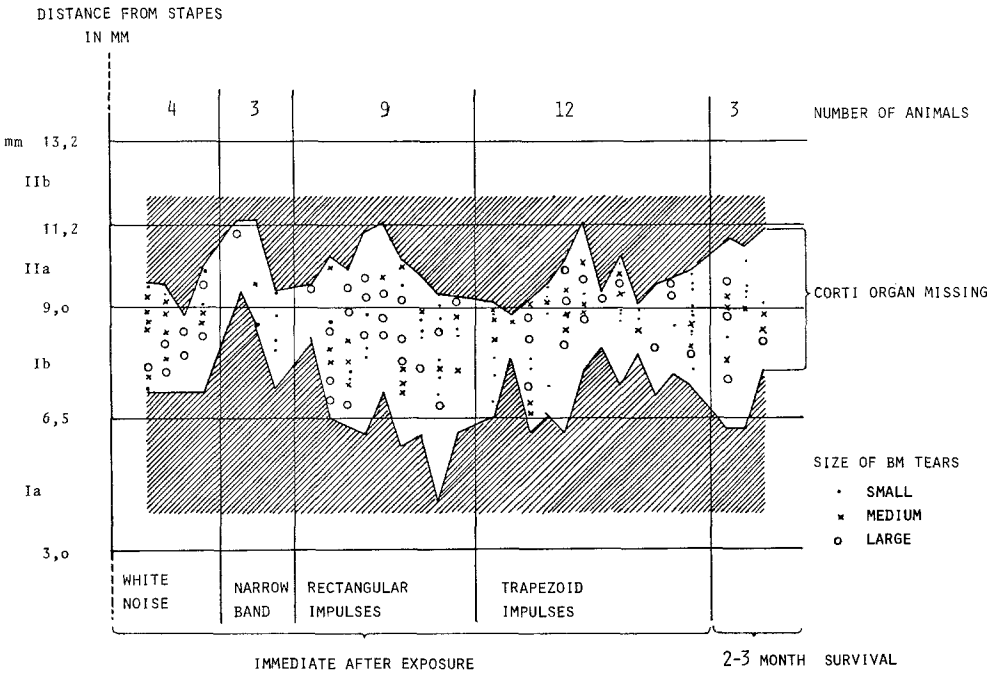

Fig. 5. Basilar membrane tears in areas of heavy damage (white zone) in 31 GPs after different types of noise exposure

times it shows a certain tendency of restitution. There is a gradual transition from the missing to the normal tympanic lamina characterized by a general disorder or huge clews of dislocated tympanic lamina cells attached to the lower surface of the basilar membrane. Similar transitional zones of mechanical damage are also observed in the organ of Corti [1, 4, 6]. The correlation of the size and localization of the basilar membrane tears (Fig. 5) shows that the small- and medium-sized tears are frequently close together, whereas the largers tears always have larger intervals. No significant differences in basilar membrane damage was found among the types of exposures used with the exception of narrowband noise which produced only few and very small basilar membrane tears.

Discussion

High-intensity noise exposures of 130 dB and more produce not only direct mechanical damage to the cells of the organ of Corti and the tympanic lamina, but also tears in the basilar membrane. The primary localization of such mechanical damages in the upper basal turn indicated that the mechanical forces acting on the basilar membrane are greatest in this area.

The obvious predilection of certain intervals between the tears of the basilar membrane could represent energy maxima of the mechanical events in the

cochlea during stimulation. This, however, would not be compatible with the travelling wave concept. It is more probable that the tears in the basilar membrane change its mechanical properities so that in the neighborhood of existing tears the membrane is less vulnerable, and further tears will only occur at a certain distance from the existing tears.

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