Protective Effects of Magnesium on Noise-Induced Hearing Loss: Animal Studies

Fred Scheibe and Heidemarie Haupt

Department of Otorhinolaryngology, Charité Hospital, Humboldt University, D-10117 Berlin, Germany

Abstract: These studies have shown that permanent hearing loss caused by impulse noise exposure (L_peak 167 dB, 1/s, 38 min) can significantly be reduced by prophylactic oral magnesium (Mg) supplementation, as measured by auditory brainstem response audiometry. Moreover, the acoustic trauma can also be decreased significantly by a markedly higher Mg level induced therapeutically. The intracochlear Mg level seems to be an important factor in bringing about these protective effects.

INTRODUCTION

Early animal studies demonstrated that the auditory susceptibility to noise exposure depends on the subjects' magnesium (Mg) status (1, 2). In these experiments, chronic noise exposure was applied and there were extreme Mg differences between the animals tested. The purpose of the present study was to investigate whether small increases in Mg, while still being in the physiological range, may offer protection from acute impulse noise exposure (simulated small-weapon noise). Moreover, in a second series, it was examined whether Mg also has a therapeutic effect on the acoustic trauma.

PROPHYLACTIC EFFECTS

The experiments were performed on anesthetized (ketamine-xylazine) pigmented guinea pigs with either a physiologically high or a low Mg status produced by different diets. The animals were fed an experimental low-Mg (0.01%) diet and received tap water either with an additive of 39 mmol Mg/l (high-Mg group) or without Mg admixture (low-Mg group). To test the Mg status of the animals, the total Mg concentrations in perilymph, cerebrospinal fluid and blood plasma were determined using atomic absorption spectrometry. To test the protective effect of Mg on the noise-induced hearing loss, the animals were exposed to an impulse noise series (L_peak 167 dB, 1/s, 38 min). Hearing function was determined by auditory brainstem response audiometry (frequency range, 0.5-32 kHz). Permanent hearing threshold shifts (PTS) were measured one week after the exposure.

The Mg status of the animals in the high-Mg and low-Mg groups is shown in TABLE 1. The Mg levels of the individual fluids differed significantly in both groups (Student's t-test, P < 0.05). All three fluids showed a significant increase in the high-Mg group as compared to the low-Mg group (P < 0.01); however, the increase in plasma and PL by about 80% and 40%, respectively, was much higher than in the CSF where it was only 10%. This suggests that Mg reaches the inner ear directly via the blood-perilymph barrier rather than via the blood-brain barrier, as assumed in the past. The fluid Mg levels of these two groups are at the upper and lower limits of the physiological range.

As shown in FIGURE 1, the impulse noise exposure caused a considerable PTS of 27-36 dB (3.75-30 kHz) in the low-Mg group. However, prophylactic Mg supplementation (high-Mg group) resulted in a significantly reduced hearing loss (by 14-21 dB) in the frequencies tested.

TABLE 1. Total Mg concentration (mmol/l) in the perilymph, cerebrospinal fluid and blood plasma of the high-Mg and the low-Mg groups. All values are expressed as mean (± SD) for the number of animals (n) tested.

<table>
<thead>
<tr>
<th>Fluid</th>
<th>High-Mg group</th>
<th>Low-Mg group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perilymph</td>
<td>0.80 ± 0.14 (38)</td>
<td>0.58 ± 0.11 (50)</td>
</tr>
<tr>
<td>Cerebrospinal fluid</td>
<td>0.87 ± 0.11 (34)</td>
<td>0.79 ± 0.11 (46)</td>
</tr>
<tr>
<td>Blood plasma</td>
<td>1.24 ± 0.21 (44)</td>
<td>0.68 ± 0.16 (49)</td>
</tr>
</tbody>
</table>

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FIGURE 1. Mean PTS (± SD) at frequencies of 3.75-30 kHz as measured in both experimental groups one week after the impulse noise exposure (*/** P < 0.05/0.01).

THERAPEUTIC EFFECTS

For the therapy experiments, animals with the low Mg status received subcutaneous injections of either a selected dose of Mg (0.285 mmol per 100 g body weight) for three days combined with 39 mmol Mg/l drinking water for one week (Mg group) or saline and water without Mg admixture (placebo group). The 1st injection was given immediately after the impulse noise exposure (L<sub>peak</sub> 167 dB, 1/s, 38 min) of the animals.

As shown in FIGURE 2, the animals of the Mg group had also a significantly lower mean PTS (by 12-20 dB) at the frequencies tested (0.5-32 kHz) than those of the placebo group. The observations are the first to demonstrate that Mg has also a therapeutic effect on the acoustic trauma. The PTS and the Mg level both in the serum and the PL showed a close correlation (r = -0.582/-0.466; P < 0.01). This findings suggest that the perilymphatic Mg level plays an important role in the noise-induced pathophysiology of the auditory system.

FIGURE 2. Mean PTS (± SD) at frequencies of 0.5-32 kHz for the Mg and the placebo groups as measured one week after the impulse noise exposure (*/** P < 0.05/0.01).

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REFERENCES

1. Ising, H., Handrock, M., Günther, T., Fischer, R., Dombrowski, M., Arch Otorhinolaryngol 236, 139-146 (1982).