EP Change in Experimental Round Window Membrane Rupture

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The short-term influence of round window membrane (RWM) rupture on cochlear potentials was investigated with special reference to the endocochlear DC potential (EP). The RWM of the guinea pig was incised with a needle or a glass micropipette without imposing pressure in the perilymphatic space, and the EP as well as the cochlear microphonics (CM) and compound action potentials (AP) of second cochlear turn were recorded before, during and after the operation.

While the EP suffered a moderate decline (about 36 mV in two hours) in five of ten animals, it showed little change in the remaining five animals. Changes of the CM and AP seemed parallel to that of the EP.

This study suggests that hearing loss can be caused by a tear of the RWM; however, such loss does not necessarily occur even in the presence of an obvious rupture. The reduction of the EP is likely to be responsible for the hearing loss in some cases of fresh RWM rupture. However, this hearing loss may not be severe, as demonstrated by the relatively small degree of reduction of cochlear potentials in this study.

Key words: perilymphatic fistula, round window membrane rupture, endocochlear DC potential (EP)

Round window membrane (RWM) rupture, a type of perilymphatic fistula, has been considered to be responsible for profound sensorineural hearing loss. But the electrophysiological mechanism involved in this loss is still unclear. Yasuno et al.1) reported that the endocochlear DC potential (EP) significantly declined after incision of the RWM of the guinea pig and they concluded that rupture of the RWM, in and of itself, causes severe hearing loss. Contradictory results, namely, that RWM rupture does not necessarily cause severe hearing loss, have been reported by several other groups of investigators based on experiments designed to monitor the cochlear potentials such as cochlear microphonics (CM), compound action potentials (AP) or auditory brainstem responses (ABR).

Since the electrophysiological consequences of RWM rupture are still unclear and since measurement of the EP has not been conducted extensively, we investigated the change of the cochlear potentials shortly after incision of RWM with special reference to the EP.

Methods

A mature albino guinea pig (n=10) was anesthetized with pentobarbital sodium, immobilized with suxamethonium chloride and kept under artificial respiration. The cochlea was exposed via the ventral approach. The RWM was incised with a glass micropipette with as little pressure as possible given to the perilymphatic space, and the outflowing perilymph was gently removed with filter paper. The length of the tear was made longer than the radius of the RWM.

The bony wall of the second cochlear turn was perforated and a glass microelectrode with a tip 2-5μm in diameter, filled with 150 mM KCl, was inserted through the stria vascularis into the scala media. The cochlear potentials (EP, CM and AP) were recorded by means of a microelectrode previously connected to a WPI KS-700 amplifier during
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and after the incision of the RWM. Stimuli used for the CM recording were 1 kHz tone bursts, and those for the AP recording were clicks or 1 kHz tone bursts. In animal No. 10, in order to detect the cochlear function closer to the RWM, a silver wire electrode was placed on the round window for recording of the potentials, and 8 kHz tone bursts were used as stimuli.

After the experiment was completed, the cochlear was immersed in formaldehyde solution, and conventional celloidin preparation was made.

![Diagram](image)

**Fig. 1** EP change following RWM rupture. (EP was recorded from the second cochlear turn.) Note that the results are divided into two groups.

**Result**

Fig. 1 shows the change of EP following RWM rupture recorded at the second cochlear turn. The EP suffered a considerable decline in five of 10 animals. In these five animals, the EP decrease at one to two hours after RWM rupture was 29, 25, 37, 37 and 51 mV, respectively. In contrast, the EP showed little change in the remaining five animals.

Figs. 2 and 3 show representative recordings of the CM and AP in each group. As can be seen in the figures, changes in the CM and AP in the former group were great, while there were only slight changes in the latter group. The changes of CM and AP when observed seemed parallel to that of the EP. The results for all the animals are summarized in the table.

Histological study with a light microscope in 8 animals showed little change in the cochlear struc-

<table>
<thead>
<tr>
<th>Animal</th>
<th>Time after incision</th>
<th>EP change</th>
<th>Threshold change</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>in mV</td>
<td>CM</td>
</tr>
<tr>
<td>1</td>
<td>60 min</td>
<td>77 → 48</td>
<td>20 dB†</td>
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<tr>
<td>2</td>
<td>100</td>
<td>72 → 47</td>
<td>n.t.</td>
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<tr>
<td>3</td>
<td>120</td>
<td>69 → 32</td>
<td>n.t.</td>
</tr>
<tr>
<td>8</td>
<td>110</td>
<td>85 → 48</td>
<td>n.t.</td>
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<tr>
<td>10</td>
<td>130</td>
<td>82 → 31</td>
<td>35 dB†</td>
</tr>
<tr>
<td>4</td>
<td>120</td>
<td>86 → 79</td>
<td>→</td>
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<tr>
<td>5</td>
<td>220</td>
<td>84 → 85</td>
<td>→</td>
</tr>
<tr>
<td>6</td>
<td>110</td>
<td>71 → 82</td>
<td>n.t.</td>
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<tr>
<td>7</td>
<td>140</td>
<td>85 → 85</td>
<td>→</td>
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<tr>
<td>9</td>
<td>150</td>
<td>82 → 86</td>
<td>n.t.</td>
</tr>
</tbody>
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n.t.= not tested
† : elevated threshold
→ : no threshold shift

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Fig. 2 Input-output function curves of the CM and AP before and after RWM rupture in an animal with remarkable EP decline.

Fig. 3 Input-output function curves of the CM and AP before and after RWM rupture in an animal with little EP change.
Discussion

Since Simmons postulated RWM rupture as the cause of sudden hearing loss, several investigators have performed electrophysiological experiments using animal models. When RWM rupture was produced by imposing high positive or negative pressure in the perilymphatic space, various grades of histological and electrophysiological changes were invariably observed. However, when the RWM rupture was created without causing active pressure change in the perilymphatic space (pure RWM rupture), the reported results about the potential changes immediately after RWM rupture were quite variable. Simmons et al., Weisskopf et al., and Yanagihara reported that the RWM rupture by itself did not cause severe hearing loss. Lamm, H. et al. and Lamm, K. et al. showed that the cochlear potentials significantly declined shortly after RWM puncture. These latter authors postulated that the reduction of the potentials was caused by air penetration through the round window. Yoshioka reported that some animals showed moderate hearing loss after incision of the RWM while the others did not, indicating individual differences.

In order to clarify acute changes in the cochlear potentials after pure RWM rupture, it would seem reasonable to first determine the effect of rupture on EP, because the EP, which is generated at the stria vascularis, is very stable under normal conditions and its decrease always causes reduction of other cochlear potentials. However, experiments on EP change after RWM rupture have been very limited. Yanagita et al. exposed animals to high atmospheric pressure and recorded the EP. They found that the EP declined moderately both with and without the RWM rupture and also observed damage to the outer hair cells. They hypothesized that this damage was due to the pressure load. Yasuno et al. reported that the EP of the basal turn of the guinea pig cochlea rapidly decreased without fail after pure RWM rupture. They also found a concomitant decrease of CM.

In the present study, five of ten animals showed EP decline, while the remaining five showed no EP change. Although it is not clear why different results were obtained despite the same experimental set-up being used in every animal (possible reasons might be differences in the incision of the RWM or differences in the patency of the cochlear aqueduct), these results seem to indicate that RWM rupture in and of itself can cause mild to moderate hearing loss, but that such loss does not always result. This variability may partially explain the variety of clinical presentations of RWM rupture.

The CM and AP showed courses similar to that of the EP. This seems to suggest that the reduction of CM and AP are attributable to the decline of the EP, and that the reduction of the EP is likely to be responsible for some clinical cases of acute hearing loss caused by RWM rupture.

Compared with the report of Yasuno et al. which showed a drastic decrease of the EP approaching a value as low as 0 mV in one hour after the RWM incision, the degree of reduction of the cochlear potentials was relatively small in the present study even in the animals showing a decline. Based on these results it is assumed that the hearing disturbance in uncomplicated ruptures of the RWM, if such disturbance occurs at all, may not be severe. However, further study is needed to settle this question.

References

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