Reversibility of the Endolymphatic Potential after Transient Anoxia

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KUSAKARI, J., KAMBAYASHI, J., KOBAYASHI, T., ROKUGO, M. and KAWAMOTO, K. *Reversibility of the Endolymphatic Potential after Transient Anoxia*. Tohoku J. exp. Med., 1980, 131 (1), 1-5 — The effect of transient local anoxia (10 to 120 min) upon the endolymphatic potential (abbr. EP) was observed in 30 normal guinea pigs. The recovery of the EP was complete in the animal subjected to 10 min anoxia and almost complete in 20 min anoxia. When the duration of anoxia was 30 min or longer, the recovery of the potential was incomplete, and the longer the duration of anoxia, the lower the level of the EP after reoxygenation. These results were discussed in relation to the possible role of a transient anoxia upon sudden deafness. ——— endolymphatic potential; transient local anoxia; reversibility

It is a well-known fact that anoxia produces the dysfunction of the cochlea. Recently, vascular disorder is thought to be one of the possible causes of sudden deafness, and the special attention is paid to the relation between the cochlear damage and the duration of anoxia. Investigation along this line was reported by Konishi et al. (1961), but they mainly observed the effect of anoxia upon the cochlear microphonics and the action potential, and there was only a short description on the endolymphatic potential (abbr. EP). However, the stria vascularis which is the generation site of the EP is the most sensitive part to anoxia among all cochlear tissues (Thalmann et al. 1973). The present experiment was therefore undertaken to examine the effect of transient local anoxia upon the EP.

MATERIALS AND METHODS

Thirty albino guinea pigs weighing 250 to 350 g were used in the present experiment. Tracheotomy was performed under pentobarbital anesthesia (28 mg/kg) and the animal was artificially respired after i.p. administration of succinylcholine chloride. The EP was recorded through the round window using the method described elsewhere (Kusakari et al. 1978). Under an operation microscope, the larynx and the base of the skull were removed and an incision was made in the dura mater to expose the vertebral and basilar arteries. To produce transient local anoxia of the cochlea, the labyrinthine artery in the vicinity of the porus acusticus internus was compressed using a metal stick with the round tip. The

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duration of anoxia ranged from 10 min to 2 hr. The ECG was monitored throughout the experiment and the rectal temperature was maintained at about 37°C.

RESULTS

The EP recorded in the present experiment was 83.6 ± 6.6 mV (means $\pm$ s.d.; $n=30$). The rapid decline of the EP occurred in 2 to 3 sec after the temporary occlusion of the labyrinthine artery and reached 0 mV in 48.8 ± 8.0 sec (survival time, means $\pm$ s.d.). After reaching the lowest level (-30 to -40 mV), the EP gradually increased towards 0 mV. This response pattern to anoxia was quite similar to that produced by other methods, e.g. an aorta section.

The release of the pressure upon the artery produced a rapid elevation of the EP. After reaching the maximum value, the EP declined again and reached to a certain static level which was closely related to the duration of anoxia (Fig. 1). The static levels were 83.0 ± 2.9 mV ($n=4$), 79.0 ± 3.7 mV ($n=4$), $60.6 \pm$

Fig. 1. Representative response patterns to various duration of transient anoxia. Symbols $\downarrow$ and $\uparrow$ indicate the onset and end of anoxia, respectively.

14.2 mV* ($n=7$), 56.6 ± 14.8 mV* ($n=3$), 46.4 ± 18.4 mV* ($n=5$) and 27.2 ± 9.8 mV* ($n=7$) for 10, 20, 30, 45, 60 and 120 min anoxia, respectively. Although the time between the release of the pressure and the start of the recovery (recovery time) was within 10 sec irrespective of the duration of anoxia, the recovery rate of the EP closely related to the duration of anoxia, namely the longer the latter is, the slower the former (Fig. 2).

Fig. 2. Recovery of the EP after transient anoxia. The ordinate notes the magnitude of the potential in mV in reference to the level of the EP just before the reoxygenation (the means of all cases). The abscissa indicates the time in minutes elapsing from the onset of the reoxygenation.

Fig. 3. The abscissa gives the duration of anoxia. The open circles and vertical bars indicate the static values of the EP after a transient anoxia of indicated duration (means $\pm$ s.d.). The filled circles and vertical bars show the lowest levels obtained in the second anoxia (means $\pm$ s.d.), which indicate the magnitude of -KDP. Therefore, the difference between upper and lower lines represents the magnitude of +KSP.

* Significant reduction ($p < 0.01$).

When the EP reached the static level about 1 hr after reestablishing the blood supply, the animal was subjected to anoxia by the aorta section. The EP declined and reached the lowest value as in the normal animal when the duration of the previously exposed anoxia was 10 or 20 min. However, when the recovery from the previously exposed anoxia was incomplete and the EP stayed at the lower level, the lowest value produced by the second anoxia was higher than that in the normal animal. The lowest value produced by the second anoxia in relation to the duration of the first anoxia were as follows: -34.0 ± 1.0 mV, -29.5 ± 0.7 mV, -24.0 ± 6.3 mV, -20.0 ± 7.0 mV, -11.6 ± 5.2 mV and -4.6 ± 1.2 mV (means $\pm$ S.D.) for 10, 20, 30, 45, 60 and 120 min of the first anoxia, respectively (Fig. 3).

DISCUSSION

The EP is the positive DC potential recorded in the scala media of the cochlea and its function is known to be an increase in sensitivity of the sensory hair cells. Although many investigations concerning its generation mechanism has been reported, presently most investigators seem to support the dual nature of the EP proposed by Kuijpers (1969). He proposed that the EP is the sum of two potentials of the opposite polarity, a large positive potential (100 to 120 mV) and a small negative potential (-20 to -40 mV). A positive potential is thought to be an oxygen dependent K secretion potential produced by an active transport mechanism at the stria vascularis (abbr. +KSP) and a negative potential is a K dominated diffusion potential (abbr. -KDP). Therefore, when the animal is subjected to anoxia, an oxygen dependent positive potential is rapidly abolished and the EP becomes negative, representing only -KDP. Although -KDP is not sensitive to anoxia, the membrane permeability and ionic composition of the endolymph are changed in cases of a prolonged anoxia, resulting in the gradual reduction of -KDP.

Biochemical studies of the endolymph (Silverstein 1966; Mendelsohn and Konishi 1969) revealed that anoxia caused a fall in the K^+ concentration and a rise in the Na^+ concentration. When the re-oxygenation is made after a certain period of anoxia, the reversibility of the EP depends upon how much the stria vascularis regains its function and the ionic concentration of the endolymph is normalized. To know the reversibility of -KDP, the animal was subjected to anoxia again and examined the lowest level which exhibited the magnitude of -KDP when the EP reached the static level. Furthermore, in addition of the absolute value of this lowest level to the level of the EP just before the 2nd anoxia, the magnitude of +KSP is estimated at that time.

The results obtained in the present experiment are summarized in Fig. 3. Namely, the magnitude of +KSP and -KDP returned to the pre-anoxic value within 1 hr after 10 to 20 min anoxia, but significant reduction was observed after the anoxia of 30 min or longer. Therefore, the duration of anoxia from which the stria vascularis can fully recover is less than about 20 min.

In the present study, the EP recovered to the level of 27.2 ± 9.8 mV after 120

min anoxia. It is really surprising that the stria vascularis can recover even in part after this long period of anoxia. Konishi et al. (1961) also reported the partial recovery of the EP after 60 min anoxia. Light microscopical studies along this line indicate that the stria vascularis exhibits marked damage and separation from the underlying spiral ligament within 1 hr of anoxia (Kimura and Perlman 1958). However, findings obtained in animals sacrificed 24 hr after 2 hr transient anoxia suggest an improvement to a certain extent by re-oxygenation (Perlman et al. 1959).

Recently, the vascular disorder in the inner ear is thought to be one of the causes of sudden deafness (Gussen 1976). In this disease, some patients show complete or partial recovery but some do not exhibit any improvement. The results obtained in the present study suggest that this difference in prognosis depends upon the duration of anoxia.

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