Eur J Appl Physiol (1983) 52: 47–50

European Journal of
Applied
Physiology
and Occupational Physiology
© Springer-Verlag 1983

Effects of Trichloroethylene Exposure on Hearing

An Investigation of Cochlear Microphonics and Action Potential of the Guinea Pig

Kohtaroh Yamamura[3], Toshiko Ikeda[1], Terukazu Sadamoto[1], Naoki Maehara[3], Izumi Harabuchi[1], Hisashi Takashima[2], and Haruo Kiyosawa[1]

[1] Dept. of Public Health, Sapporo Medical College, S.1, W.17, Sapporo, Hokkaido, 060 Japan
[2] Central Health Institute of J. N. R., Tokyo, 151
[3] Dept. of Hygiene, Asahikawa Medical College, 4-5-3-11 Nishikogura, Asahikawa, 078–11

Summary. Four groups of guinea pigs with normal Preyer's reflex were exposed to trichloroethylene (TCE). Each group consisted of nine to 10 naive male albino Hartley guinea pigs of 9 weeks of age with a body weight of approximately 400 g.

To test the suggestion that TCE causes damage to the cochlear system, a study was conducted involving four experiments.

The results were as follows: No significant difference was observed between the intensity functions of the CM (4 kHz) and AP (7 kHz) potentials of the control groups and those of the TCE-exposed groups by analysis of variance. It was considered that there was no difference in the cochlear reaction to high frequency sound between guinea pig and man. It therefore might be suggested that acute exposure to TCE of a high concentration does not always induce dysfunction of the organ of Corti and the 8th nerve in man.

Key words: Trichloroethylene – Cochlear microphonics – Action potential

Introduction

Trichloroethylene (TCE) has come into wide use as a solvent and degreasing agent for metals, but it is also well known to induce cranial nerve damage, especially to the trigeminal nerve and optic nerve, in workers exposed to it (Buxton and Hayward 1967; Nomiyama and Nomiyama 1979).

An important question, however, is whether or not damage to another cranial nerve, namely the 8th nerve, may be produced by exposure to TCE.

Offprint requests to: K. Yamamura at the above address

Mitchell and Parsons-Smith (1969) reported a case in which a 33-year-old male metal degreaser who used TCE suffered from several attacks of vertigo. In another case, Tomasini and Sartorell (1971) reported upon a 54-year-old male dry cleaner with ten years' working experience and prolonged inhalation of TCE, who had many complaints and suffered from typical sensorineural deafness. Such deafness was considered to be caused by damage to the 8th nerve due to TCE exposure.

Kuberska (1972) examined the auditory function of 50 cases exposed to TCE over an extended period of time, and observed sensori-neural deafness in 40 cases. He went on to stress that examination of the 8th cranial nerve should be periodically performed in persons working in an atmosphere containing TCE vapours, and that the above-mentioned disorders were early signs of TCE poisoning.

Since the cochlear reaction of guinea pigs to a high frequency sound stimulus is considered to be the same as in man, we decided to perform the experiment described herein, involving measurement of cochlear microphonics (CM) and action potentials (AP) to prove objectively whether or not acute impairment of the organ of Corti and the 8th nerve might be induced in guinea pigs by exposure to TCE at high concentrations.

Methods

1. Animals

Seven to 10 naive male albino Hartley strain guinea pigs were used for four experiments. With the exception of experiment 2, all animals were tested at 9 weeks of age, those in experiment 2 being 7 weeks of age. The mean body weight ± 1 SD of the guinea pigs was initially 336 ± 13 g for experiment 2 (n = 9), 444 ± 15 g for experiment 3 (n = 10) and 413 ± 26 g for experiment 4 (n = 7). The housing room temperature was 25 ± 2° C.

2. Exposure

TCE of high purity (99.0% by gas chromatography, WAKO Pure Chemical Industries Ltd. of Japan) was used. Each guinea pig was exposed to TCE in a gas chamber (Nagano et al. 1971). The vapour inhalation schedule for the animals was 4 h/day, 5 days per week at a concentration of 6,000 ppm (5,797 ± 479 ppm) for experiment 2, 12,000 ppm (11,253 ± 580 ppm) for experiment 3 and 17,000 ppm (16,613 ± 1,276 ppm) for experiment 4. The O_2 concentration was about 20% by oxygen analyzer and the CO_2 concentration, 0.4–0.8% by Kitagawa detector. The temperature in the gas chamber was 25 ± 2° C.

3. Measurements of CM and AP

The size of the room used for these CM and AP measurements was 4 m × 5 m × 3.5 m. The ceiling and walls of the room were covered with styrofoam 50 mm thick with a carpet covering the floor.

A shield box (950 mm × 700 mm × H 950 mm) was set up on a wooden desk in the middle of the room. Physiological examinations were carried out in this shield box.

When the guinea pigs woke from the narcosis of five exposures to TCE and were moving quickly, sodium pentobarbital (0.4 ml · kg^{-1}) was injected into the abdominal cavity.

Thereafter they were fixed with the face upward and received an injection of succinyl-choline chloride (0.5 ml · kg^{-1}) into the leg muscle.

With a respirator being employed, a surgical operation involving opening of the bulla and exposure of the cochlea was performed, after which an endotracheal vinyl tube was inserted. Employing a microscope, small holes, approximately 50–100 μm in diameter, were made with a dental reamer at the scala vestibuli and scala tympani in the basal turn of the cochlea.

Measurement of CM Potential. Measurement of CM potential followed the method of vestibulo-tympanal differential recording (Tasaki et al. 1952). Into the small holes a pair silver wires (approximately 30 μm in diameter) were introduced using a micromanipulator. The CM potential from the pair of electrodes was introduced into a high impedance amplifier and a synchroscope.

An audiometer was used as the source of stimulus sound to the guinea pigs. To prevent electrical induction, an iron cover was placed over the receiver of this audiometer and a vinyl tube was inserted into a small hole in the cover. Finally, the tip of the vinyl tube was introduced into the external acoustic meatus.

The stimulus sound level (dB) was obtained from the dial value of the audiometer, and the intensity function of the CM was measured (test frequency: 4 kHz). However, an arbitrary value for a sound intensity of 0 dB (visual detection level V.D.L.) was decided upon since it was the stimulus intensity level of 4 kHz which was obtained for CM potentials (peak to peak) below 30 μV in the control guinea pigs on the CR-Oscilator. Such a level was considered to have a dial value of 45 dB on the audiometer, and this was considered as 0 dB or the pseudo-threshold.

Measurement of AP. The measurement of AP was as follows. AP was induced from the silver wire electrode in the scala vestibuli, the indifferent electrode being a thick silver wire in the neck muscle of the guinea pig.

The stimulus sound was as follows: The rise time was 1 ms and the decay time was 2.5 ms with a pure tone of 7 kHz (Teas et al. 1962).

The instruments used for this impulse noise (1 pulse · s^{-1}) were the following:

1 Generator,
2 Electronic Switch,
3 Amplifier (combination of pre-main type),
4 Audiometer,
5 Receiver with iron cover.

The peak level of impulse sound was obtained from the dial value of the above-mentioned audiometer. Measurement of AP input-output function had been done. The pseudothreshold was 45 dB on the audiometer.

Results

The regression coefficients of the stimulus sound vs the logarithm of CM output voltage were statistically significant in experiment 1, experiment 2, and experiment 3 ($P < 0.01$).

In Fig. 2, the CM output voltage and regression lines of experiment 1 and experiment 4 (TCE: 17,000 ppm) may be seen. The regression coefficient of experiment 4 was also statistically significant ($P < 0.01$).

There were no significant differences between the CM output voltage of experiment 1 and those of the other experiments by analysis of variance.

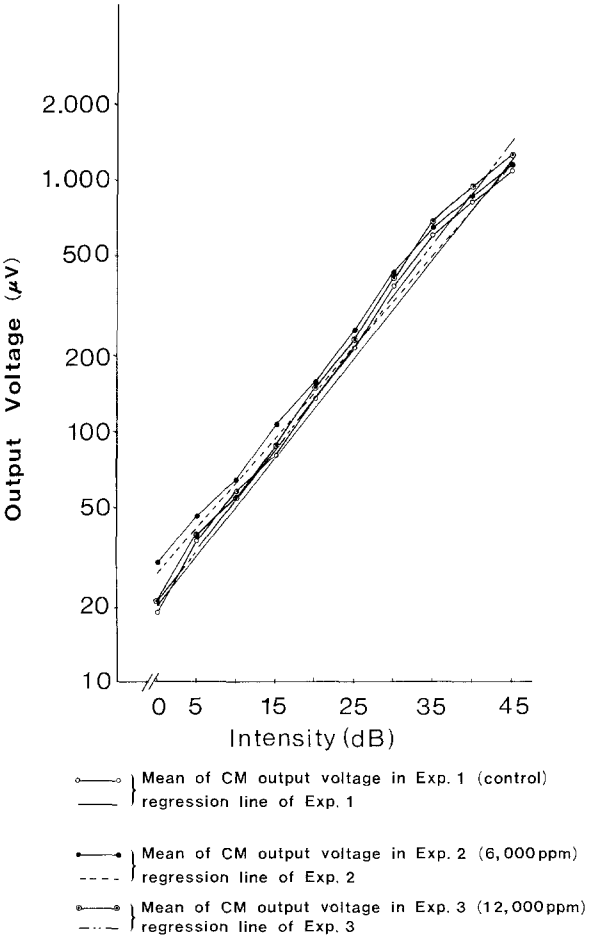

Fig. 1. Intensity function of CM

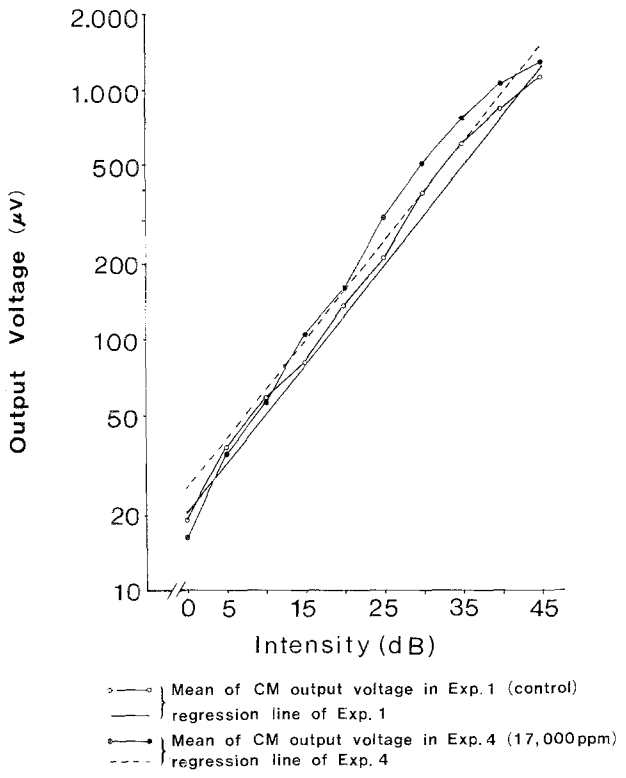

Fig. 2. Intensity function of CM

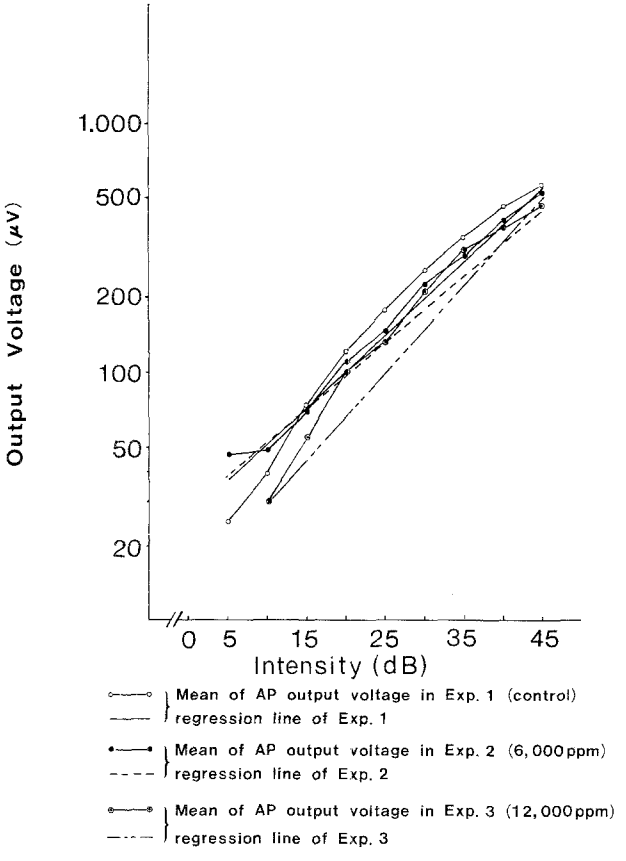

Fig. 3. Intensity function of AP

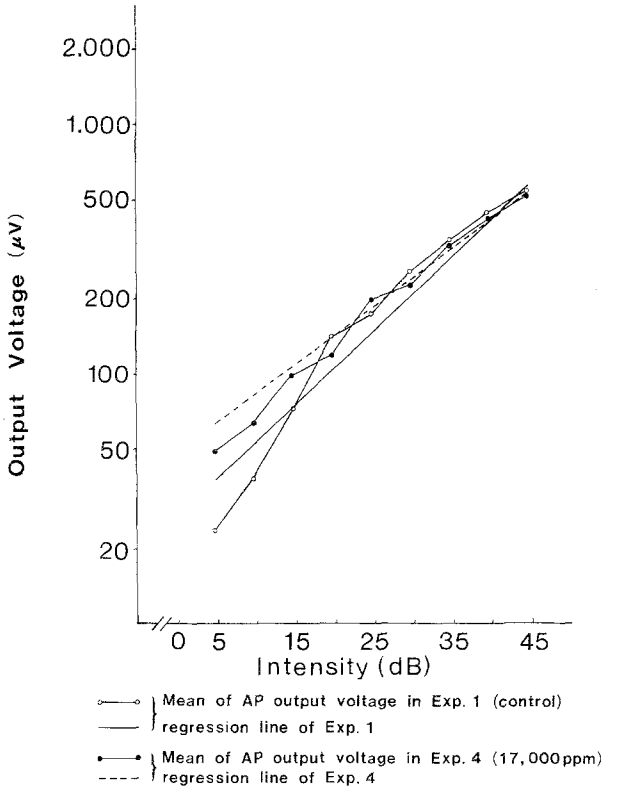

Fig. 4. Intensity function of AP

In Fig. 3, the abscissa was the stimulus sound level (dB) and the ordinate was the peak value of N_1 (μV) in action potential. In this figure, the mean value of the N_1 value and the regression lines of experiment 1, experiment 2, and experiment 3 are shown.

The regression coefficients of experiment 1, experiment 2, and experiment 3 were statistically significant ($P < 0.01$). In Fig. 4, the mean value of the N_1 value and the regression lines of experiment 1 and experiment 4 are shown. The regression coefficient of experiment 4 was also significant ($P < 0.01$). No significant difference existed between the N_1 value of experiment 1 and those of experiment 2, experiment 3, and experiment 4 by analysis of variance.

In Fig. 5 of the synchroscope, typical examples of the wave form of AP (N_1 and N_2) in experiment 2, 3, and 4 are shown respectively. The N_1 peak values of all examples induced by 45 dB stimulus from the audiometer were approximately 600 μV.

Discussion

AP had peaks of N_1 and N_2 with the peak of N_1 depending on the function of the 8th cranial nerve. When AP showed maximum output as induced by strong sound stimulus, it seemed to represent the whole-nerve action of the 8th cranial nerve. Namely,

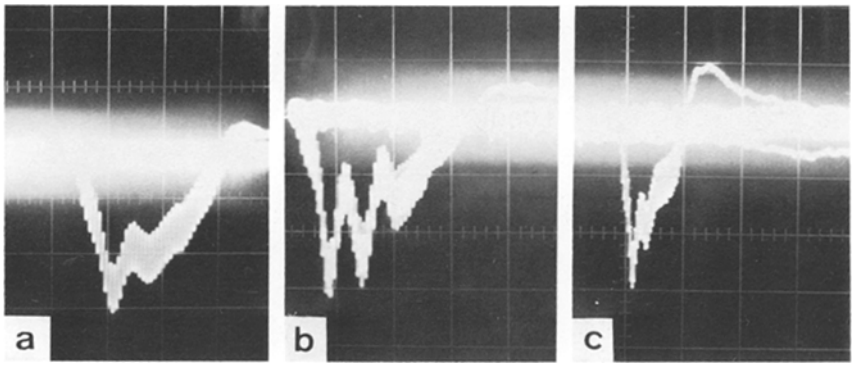

Fig. 5. a AP wafe form in experiment 2 (6,000 ppm), *ordinate:* 200 μV/div, *abcissa:* 2 ms/div. 45 dB above pseudo-threshold. **b** AP wafe form in experiment 3 (12,000 ppm), *ordinate:* 200 μV/div, *abcissa:* 2 ms/div. 45 dB above pseudo-threshold. **c** AP wave form in experiment 4 (17,000 ppm), *ordinate:* 200 μV/div, *abcissa:* 5 ms/div. 45 dB above pseudo-threshold

it was not only a representation of the responding unit in the 8th cranial nerve induced by pure tone stimulus, but also a representative action of the whole unit of the 8th nerve (Ozdamal and Dallas 1976).

Using the input-output function of AP, the authors investigated whether or not acute exposure to a high concentration of TCE induced damage to the 8th cranial nerve of the guinea pig. After TCE exposure, AP was obtained from the electrode in the scala vestibuli of the basal turn.

There were no significant differences between the AP of the input-output function of the control experiment and those of the other experiments.

From these results, it was speculated that acute exposure to TCE at a high concentration does not induce damage to the 8th cranial nerve of the guinea pig.

The CM intensity function of 4 kHz which was considered to be representative of the function of the hair cells of the basal turn, did not show any significant difference in the guinea pigs receiving acute TCE exposure of a high concentration.

With regard to hair cell damage, the pseudo threshold of CM is more than 20 dB higher than that in normal guinea pigs (Davis 1953). Therefore, hair cell damage was not considered in these acute TCE exposures. With regard to the guinea pig's cochlear reaction to the high frequency test tones used in this experiment we, like Békésy (1960) considered it to be the same as that in man (resonance curves for cochlear partition). At least for high frequency sound (Wagner and Manning 1976), the behavioral absolute hearing threshold of the guinea pig bears resemblance to that of man.

In guinea pig it has been shown that a dose of an ototoxic drug, for instance, streptomycin sulfate (SM), to the inner ear may be 10 times larger than that for humans when deafness occurred (Ogawa 1975). From these results one may deduce that exposure to a high concentration of TCE of one tenth the amount given to the guinea pigs would induce impairment in the human ear.

Therefore the results of this experiment might suggest that acute TCE exposure alone does not induce hearing loss in the human ear.

However, the reported cases of hearing loss induced by TCE exposure have been cases of chronic exposure to TCE (Tomasini and Sartorell 1971; Kurberska 1972). Therefore, the authors in their next investigations are considering taking an electro-physiological approach to chronic TCE exposure in the guinea pig.

References

Békésy G (1960) Experiments in hearing. Robert E Krieger Publishing Co, New York, pp 502–504

Buxton PH, Hayward M (1967) Polyneuritis cranialis associated with industrial trichloroethylene poisoning. J Neurol Neurosurg Psychiatry 30: 511–517

Davis H (1953) Acoustic trauma in the guinea pig. J Acoust Soc Am 25: 1180–1189

Kuberska JS (1972) Zagadnienia wybrane z dziedziny przewlerlych przemystowych zatruc trojchloroetylenem. Folia Med Lodz 16: 67–90

Mitchell ABS, Parsons-Smith BG (1969) Trichloroethylene neuropathy. Br Med J 1: 422–423

Nagano C, Ikeda T, Nishi M, Okada A (1971) A trial manufacture of gas exposure facility for animals. Hoppo Sangyo Eisei 31: 33–36 (in Japanese)

Nomiyama K, Nomiyama H (1979) Health effects of trichloroethylene in human subjects. Jpn J Ind Health 21: 311–334 (in Japanese)

Ogawa A (1975) The effects of ototoxic antibiotics on the sensory epithelia of the inner ear: a functional and histochemical study. Audiology Japan 18: 1–19 (in Japanese)

Özdamar Ö, Dallas P (1976) Input-output functions of cochlear whole-nerve action potentials: Interpretation in terms of one population of neurons. J Acoust Soc Am 59: 143–147

Tasaki I, Davis H, Legouix JP (1952) The space-time pattern of the cochlear microphonics (Guinea Pig) as recorded by differential electrodes. J Acoust Soc Am 24: 502–519

Teas CD, Eldredge DH, Davis H (1962) Cochlear responses to acoustic transients: an interpretation of whole-nerve action potentials. J Acoust Soc Am 34: 1438–1459

Tomasini M, Sartorell E (1971) Intossicazione cronica da infalazione di trielina commerciale con compromissione dell'viii palo di nervi cranici. Clinica del Lavoro 62: 277–280

Wagner JE, Manning PJ (eds) (1976) The biology of the guinea pig. Academic Press, New York, pp 284–285

Accepted May 29, 1983