Z Rechtsmed (1983) 90 : 1–6

Zeitschrift für
Rechtsmedizin

Originalarbeiten / Original Works

The Effects of Drowning Media on the Lung Water Content

An Experimental Study on Rats

K. Yamamoto, Y. Yamamoto, and H. Kikuchi

Dept. of Legal Medicine, Faculty of Medicine, Kyoto University, Kyoto, Japan

Summary. Three kinds of drowning media, i.e., fresh water, isotonic saline, and hypertonic saline were used. After a rat was placed in a desiccator, measuring 17 cm in height and 14 cm in diameter, the vessel was filled with fluid.

The average survival time of about 2.5 min did not differ significantly among the three groups. The hypertonic saline group showed the highest values in both the water content of the lung and the lung/body weight ratio; however, this group did not differ significantly from the isotonic saline group in either of the parameters. The difference between the isotonic saline group and the fresh water group was significant. There was a significant positive correlation between the two parameters. However, the lung/body weight ratio was more sensitive to the nature of the drowning media.

The frequency, with which froth appeared at the nostrils of the animals that were recovered from the fluid differed significantly among the three groups. The froth appeared almost exclusively in the rats drowned in saline solution. The appearance rate seemed to depend on the salinity of the fluid.

There was no significant difference in lactate concentrations among the three groups. The electrolyte (Na and Cl) concentrations in the blood of the right side of the heart reflected the composition of the drowning media.

Key words: Drowning, lung water content – Relative lung weight, drowning

Zusammenfassung. Drei Arten von Ertrinkungsflüssigkeiten (Süßwasser, isotonische Kochsalzlösung und hypertonische Kochsalzlösung) wurden angewandt. Nachdem eine Ratte in einen Exsikkator von 17 cm Länge und 14 cm Breite gebracht wurde, wurde das Gefäß mit Flüssigkeit gefüllt.

Die Zeitdauer bis zum Todeseintritt von durchschnittlich 2,5 min differierte nicht stark zwischen den drei Gruppen. Die zwei „Kochsalzgruppen" zeigten höhere Werte als die „Wassergruppe", sowohl was den Wassergehalt der Lunge als auch das Verhältnis Lungengewicht/Körpergewicht (relatives Lungengewicht) betrifft, aber es gab keine signifikante Differenz zwischen beiden „Kochsalzgruppen".

Offprint requests to: K. Yamamoto, associate professor, MD (address see above)

Die Häufigkeit, mit der Schaum aus den Nasenlöchern abfloß, differierte signifikant zwischen den drei Gruppen. Sie scheint vom Salzgehalt der Ertrinkungsflüssigkeit abzuhängen.

Es gab keinen signifikanten Unterschied zwischen den Milchsäurekonzentrationen der drei Gruppen. Die Elektrolytgehalte (Na und Cl) im Blut der rechten Herzhälfte spiegelten die Natur der Ertrinkungsflüssigkeit wider.

Schlüsselwörter: Ertrinken, Wassergehalt der Lunge - Relatives Lungengewicht, Ertrinken

Introduction

Drowning is the process by which air-breathing creatures succumb up on submersion in a fluid. Fluid obstructs the airway and blocks gas exchange in the lungs, thus producing asphyxia. During the course of drowning, depending on the nature of the drowning medium, serious disturbance of body fluid balance and circulation can occur, the most important change being ventricular fibrillation. Among the organs in fresh cadavers, changes in the lung are usually the most characteristic. A possibility of differential diagnosis between fresh water and sea water drowning on the basis of the gross appearance of the lung has been critically evaluated by Gordon [3]. Features that help to differentiate the two have not been explained in any of the medicolegal textbooks except the one by Fatteh [1]. However, if the gross appearance of the lung depends largely on the composition of the drowning medium, it is considered to render better insight into the mechanism of drowning.

In the present study on rat drowning we placed special emphasis on the water content of the lung.

Materials and Methods

Male albino Wistar rats, each weighing about 200 g, were used. A glass desiccator, measuring 17 cm in height and 14 cm in diameter, was used as a vessel for drowning an animal. Three kinds of fluids, i.e., fresh water (tap water), isotonic saline solution (0.85% NaCl solution), and hypertonic saline solution (1.7% NaCl solution) were used for drowning media. The temperature of each fluid was about 25° C. After a rat was placed in the vessel and a lid with a hole measuring 2.5 cm diameter was put, fluid was poured into the vessel through the hole. As soon as the surface of the water reached the level of the upper border of the hole, it was closed with a rubber stopper. The level of the water in the vessel lowered a little during the experiment, which we thought was due to the swallowing of the rat the nostrils of which appeared above the surface of the water three or four times when it struggled for air. In all the experimental drownings, including additional experiments (see latter part), submersion was continued until final gasping had completed.

Rats acutely exposed to CO served as control against the drowned groups. The same desiccator as the above was used as a vessel for CO exposure. After a rat was placed in the vessel and about 30 ml of air was drawn from it, the same volume of CO was injected into it by a syringe without delay. The volume of CO injected was chosen so that the length of the survival time of this group should be approximately equal to that of the drowned group. The rat was taken out of the vessel after respiration stopped ultimately.

In addition to the above drowning experiments, the following two additional experiments were conducted. In Expt. 1, rats administered 3 g alcohol/kg i.p. were drowned in hypertonic saline solution. Alcohol dissolved in isotonic saline was given at concentration of 10 ml/kg 1 h before the experiment. Control rats received the corresponding volume of isotonic saline solution by the same route. In Expt. 2, after a rat was put into a cage (measuring 20 cm × 10 cm × 11 cm) made of fine wire, the cage was submerged in a fluid (fresh water or isotonic saline solution) contained in a large plastic vessel. The surface of the water lay 2 cm above the cage so that the nostrils of the rat did not appear above the surface of the water. In both additional experiments, the rat was taken out immediately after terminal gasping completed.

After the rat was taken out, the thorax was opened and blood was drawn from the right side of the heart by a heparinized syringe. The lung, after being removed, was blotted with a sheet of filter paper and weighed by an electronic reading balance (Shimadzu Libror, ED-200MO). The lung weight was expressed as percentage of the body weight (relative lung weight). After completion of weighing, the water content was determinated. The whole lung was minced with a scissor. The samples were placed on a small piece of aluminium foil put on the scale of the instrument (Shimadzu Electronic Moisture Balance, ED-200MO) and were irradiated with infrared rays to constant weight.

The water content (%) of a sample was converted automatically from decrease of weight and displayed continuously. After the mince lost about 60% of its original weight, irradiation was attenuated so that the mince should not be burnt black. Under the present conditions of irradiation, about 40 min were required for completion of one determination.

The lactate and alcohol concentrations of the blood were determined enzymatically. Hb concentration was determined by a cyan-methemoglobin method. Na levels were determined flame-photometrically. Cl levels were determined by a chloride counter (Model CL-5S: Hiranuma Sangyo).

Results (Table 1)

As to the length of survial, there was no significant difference among the three drowned groups. The time lapse until the death of the CO group did not differ significantly from that of any drowned group.

As to both parameters, i.e., the lung/body weight ratio and the water content, the trend was the same among the four groups. The hypertonic saline group showed the highest values in both parameters; however, this group did not differ significantly from the isotonic saline group in either the weight ratio or the water content. As to both parameters, the differences between the isotonic saline group and the freshwater group were significant. Both intergroup (between CO and fresh water, and between fresh water and isotonic saline) differences were much greater in the lung/body weight ratio than in the water content. There was a significant positive correlation between the two parameters on pooled data from the four groups (correlation coefficient: 0.87).

After the rats were recovered from the drowning media, froth appeared at the nostrils of many animals drowned in saline solution. A few animals were observed to froth during the process of drowning. The relative frequency, with which froth appeared, was 9/12 for the isotonic saline group and 12/12 for the hypertonic saline group. No froth appeared in either the freshwater group or the CO group.

The lactate concentration of any of the drowned groups was significantly higher than that of the CO group. There was no significant difference among three drowned groups.

Table 1. The number of animals is 11 for the control group and 12 for each of the drowned groups. Relative lung weight indicates the lung weight expressed as percentage of the body weight. Concentrations of lactate, electrolytes, and Hb refer to blood drawn from the right heart

	Survival Time (min)	Relative lung Weight (%)	Lung water Content (%)
Fresh water	2.6±0.4	0.66±0.06	86.8±1.0
0.85% NaCl	2.5±0.5	0.81±0.13	88.2±1.0
1.7% NaCl	2.5±0.6	0.81±0.05	88.8±1.1
Control (CO)	3.1±0.5	0.52±0.07	84.4±1.1

	Lactate (mg/100 ml)	Na (mEq/l)	Cl (mEq/l)	Hb (g/100 ml)
Fresh water	50.1±4.4	143.6±3.8	95.7±2.5	13.9±1.1
0.85% NaCl	52.1±4.6	147.2±6.6	98.3±4.5	14.6±0.8
1.7% NaCl	49.8±3.2	153.5±3.5	104.1±4.8	14.8±0.9
Control (CO)	36.8±6.0	140.2±4.1	96.9±4.1	14.2±0.9

Each figure is given as mean±SD

The hypertonic saline group showed the highest electrolyte concentrations among the three drowned groups. The lowest levels were observed in the freshwater group. The differences between the above two groups were significant as far as both electrolytes are concerned.

There was no significant differences in Hb levels among the drowned groups.

In hypertonic saline drowning, the alcohol-treated group with a mean blood alcohol concentration of 2.7 mg/ml did not show any significant difference from the isotonic saline-treated group in either the water content (%) of the lung (87.2±0.7 vs. 87.3±1.3) or the frequency with which froth appeared at the nostrils (6/6 vs. 6/6). On the other hand, the alcohol group showed a significantly lower lactate concentration (mg/100 ml, 35.2±3.8 vs. 46.3±6.9). In this group four of six animals had lost the ability to right themselves immediately before submersion, and respiration and struggling in the drowning medium were much less forceful than in the control group. In the second additional experiment, the water content (%) of the lung in the freshwater group did not differ significantly from that of the isotonic saline group (88.1±2.6 vs. 88.4±3.2), while there was a significant difference in frequency, with which froth appeared. The froth was present in only one of six animals in the freshwater group, but it appeared in all animals drowned in saline solution.

Discussion

The values of the both parameters, the lung/body weight ratio and the lung water content, were higher in the saline group than in the freshwater group. There was

a significant positive correlation between the two parameters; however, the lung/body weight ratio was more sensitive to the nature of the drowning media. Judging from the above paramaters, pulmonary edema was considered to have been more severe in the saline group. Halmagyi [5] injected various fluids (fresh water, physiologic saline, and sea water) into the trachea of nembutal-anesthetized rats and investigated changes in lung weight in terms of lung/body weight ratio. A slight, but significant increase occurred after normal saline, while no change in lung weight occurred after fresh water. The discrepancy on fresh water between Halmagyi's result and the present result is probably due to the different conditions of experiments.

Abundant foam is usually noted to exude from the nostrils and mouth of a drowned victim that has recently recovered from the water. In the present study, the frequency with which froth appeared seemed to depend on the salinity of the water. The foam was noted almost exclusively in the saline group. Froth is produced by the mixture of air, mucus, and water in the presence of respiratory movement [7]. The aim of the additional experiments was to clarify which of the factors mostly contributes to the difference in the appearance rate among the drowned groups. In spite of the fact that the respiration and the struggling of the alcohol-treated group in the drowning medium was much less forceful as compared to that of the control animals, which is partly reflected in the lower lactate concentration in the former group, the appearance rate was equal in the both groups. The second part of the additional experiments confirmed the results that the appearance rate differed significantly between different media. The salinity of the drowning medium seems to have played the major part in the production of foam. According to the experiment of Modell et al. [6], in which one of the fluids (chlorinated distilled water, unchlorinated distilled water, and physiologic saline solution) was injected into the trachea of a sodium thiopental-anesthetized dog at a concentration of 10 ml/pound, major airways of all animals subjected to normal saline aspiration contained copious amounts of clear white foam.

In the present study, the water content of the lung differed among different drowning media, and the electrolyte concentrations in the right heart reflected the composition of the drowning media. However, it is said that observations made in laboratory animals must be applied to accidental drowning in man with caution [4]. Pulmonary edema occurs frequently in the reported human cases of freshwater drowning, whereas it is usually absent in the laboratory animal [4]. Fuller [2] found pulmonary edema in both freshwater and saltwater drowning. The froth, too, is noted in freshwater and sea water drowning in the human. In addition to probable species difference, the context of accidental human drowning may differ significantly from the laboratory experiment [4].

References

1. Fatteh A (1973) Handbook of forensic pathology. Lippincott, Philadelphia Toronto
2. Fuller CRH (1963) Drowning and the postimmersion syndrome. A clinicopathologic study. Milit Med 128 : 22-36
3. Gordon I (1972) The anatomical signs in drowning. A critical evaluation. Forensic Sci 1 : 389-395

4. Greene DG (1965) Drowning. In: Fenn WO, Rahn H (eds) Respiration. American Physiological Society, Washington DC (Handbook of physiology, sec 3, vol II, pp 1195–1204)
5. Halmagyi DJ (1961) Lung changes and incidence of respiratory arrest in rats after aspiration of sea and fresh water. J Appl Physiol 16: 41–44
6. Modell JH, Gaub M, Moya F, Vestal B, Swarz H (1966) Physiologic effects of near drowning with chlorinated fresh water, distilled water and isotonic saline. Anesthesiology 27: 33–41
7. Spitz WU (1980) Drowning. In: Spitz WU, Fisher RS (eds) Medicolegal investigation of death. Thomas, Springfield, Ill, pp 351–366

Received September 6, 1982