ELSEVIER

Legal Medicine 7 (2005) 96–102

LEGAL MEDICINE

www.elsevier.com/locate/legalmed

# Electrolyte analysis in pleural effusion as an indicator of the drowning medium

Hiromasa Inoue, Tomomi Ishida, Akiko Tsuji, Keiko Kudo, Noriaki Ikeda*

*Department of Forensic Pathology and Sciences, Graduate School of Medical Sciences, Kyushu University, Maidashi 3-1-1, Higashi-ku, Fukuoka 812-8582, Japan*

Received 26 April 2004; received in revised form 21 September 2004; accepted 24 September 2004
Available online 23 November 2004

**Abstract**

In medico-legal autopsies for drowned bodies, the location of drowning needs to be determined. To investigate the usefulness of electrolyte analysis in pleural effusion as an indicator of the location where the deceased has drowned, we determined the concentrations of electrolytes in the pleural effusion of rats drowned in four kinds of water. The concentrations of sodium and chloride ions in the pleural effusion of rats that drowned in seawater were significantly greater than those of rats that drowned in freshwater at both 1 day and 3 days after drowning. The concentration of potassium ions in pleural effusion 1 day after drowning showed no difference between each group, although it then increased from 1 to 3 days after seawater drowning, whereas it decreased from 1 to 3 days after freshwater drowning. The concentration of total protein in pleural effusion increased from 1 to 3 days after drowning, however, there was no significant difference in the concentration of total protein in pleural effusion between each group at either 1 day or 3 days after drowning. These results suggest that analysis of electrolytes in pleural effusion may be useful for determining whether drowning has occurred in seawater or in freshwater.


*Keywords:* Drowning; Pleural effusion; Electrolytes; Total protein; Plasma

## 1. Introduction

In medico-legal autopsies where drowning has occurred, the problem is always to ascertain whether the individual has drowned in seawater or in freshwater. A diagnosis of drowning is made by macroscopic findings, such as froth in the air passage, hyperinflation of the lungs, bilateral hemorrhage within the petrous temporal bones and pleural effusion, and microscopic detection of diatoms in multiple organs [1–7]. Moreover, diatom analysis is suitable for estimating the location of drowning, but in the case of drowning in freshwater diatoms may sometimes go undetected. There have been some reports on new methods for the diagnosis of drowning, such as the blood concentration of strontium or fluorine, or the use of immunohistochemical and molecular biological techniques [7–13]. However,

* Corresponding author. Tel.: +81 92 642 6124; fax: +81 92 642 6126.
*E-mail address:* norii@forensic.med.kyushu-u.ac.jp (N. Ikeda).

1344-6223/$ - see front matter © 2004 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.legalmed.2004.09.002

these analyses may be too specialized for routine examination or may not give positive evidence.

It is well known that pleural effusion is often recognized within the thoracic cavities of a drowned body [14–17]. According to some investigators [15,16], pleural effusion is more likely to occur if the individual has drowned in seawater rather than in freshwater. If there is a significant difference in the volume of pleural effusion between individuals who has drowned in seawater and those who has drowned in freshwater, then it is also likely that there is a difference in the character of the pleural effusion between drowning in seawater and in freshwater. We therefore performed electrolyte analysis of pleural effusion to determine whether this method might be useful for determining the location of drowning. We measured the concentrations of some electrolytes in the pleural effusion of rats that had drowned in four kinds of water, each of which contained a different concentration of electrolytes.

## 2. Materials and methods

This experiment was reviewed by the Committee of Ethics on Animal Experiments in the Faculty of Medicine, Kyushu University and carried out under the control of Guidelines for Animal Experiments in the Faculty of Medicine, Kyushu University and the Law (No. 105) and Notification (No. 6) of the Government of Japan. Moreover, we followed the 'Guide for the Care and Use of Laboratory Animals' published by the US National Institutes of Health (NIH publication no. 85-23, revised 1996).

### 2.1. Animals and procedure

Thirty-eight 9-week-old male Sprague–Dawley (SD) rats (Kyudo Co. Ltd, Kumamoto, Japan) were used in this experiment. The rats were anaesthetized with an intraperitoneal injection of 10% pentobarbital sodium solution before being immersed in either artificial seawater (Red Sea Salt, Red Sea Fish Pharm, Eilat, Israel), seawater diluted with 50% freshwater, seawater diluted with 75% freshwater, or freshwater alone. The rats remained in the water until they expired from drowning.

### 2.2. Electrolytes in plasma and pleural effusion

To determine the plasma concentrations of sodium ions, potassium ions, chloride ions and total protein, we collected arterial blood through the left ventricle immediately after death. Blood was collected from three rats under each of the four different drowning conditions.

To examine the concentrations of sodium ions, potassium ions, chloride ions and total protein in the pleural effusion, pleural effusion was gathered from the bilateral thoracic cavities of rats 1 day after drowning. Pleural effusion was collected from five rats under each of the four different drowning conditions. Moreover, to estimate the effect of postmortem change, a group of drowned rats was left in either artificial seawater ($n=3$) or freshwater ($n=3$) for 3 days, and then pleural effusion was gathered from the bilateral thoracic cavities.

We measured the concentrations of sodium ions, potassium ions, and chloride ions using the ion-selective electrode method, and the concentration of total protein using Biuret's method.

### 2.3. Statistical analyses

All analyses were performed using JMP® version 5, Japanese Edition (SAS Institute, Inc., Cary, NC, USA). The difference between the two groups was tested with an unpaired Student's *t*-test. The difference between multiple groups was determined with a one-way analysis of variance (ANOVA). The significance of individual differences was evaluated using Tukey–Kramer's procedure as a post-hoc test. Linear regression analysis was used to determine the relationship between electrolytes in plasma or pleural effusion and electrolytes in the water that was used to drown the rats. A *P*-value of less than 0.05 was considered statistically significant.

## 3. Results

Table 1 shows the concentrations of sodium ions, potassium ions, chloride ions, and total protein in seawater, 50% seawater, 25% seawater, and freshwater, respectively. The reference values used in Table 2 are the standard blood biochemical data for