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PAPER

PATHOLOGY/BIOLOGY

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Vitreous Humor Sodium Levels in Immersion Deaths

ABSTRACT: To determine whether vitreous humor sodium levels might be of use in evaluating deaths associated with immersion, samples of vitreous humor were prospectively evaluated at autopsy over a 4-year period from 2006 to 2009. There were 19 cases of saltwater immersion (age range 9–76 years; mean age 44 years; M:F, 2.8:1) and 16 freshwater immersions (age range 2–81 years; mean age 27 years; M:F, 2.2:1). In the group of saltwater drownings, vitreous humor sodium levels were elevated, ranging from 145 to 184 mM (mean = 160.2 ± 9.9 mM), and in the cases of freshwater drowning, the levels were reduced, ranging from 73 to 148 mM (mean = 129.8 ± 17 mM; $p < 0.0001$). Alterations in electrolyte levels may have been because of hemoconcentration or dilution from electrolyte fluxes in the lungs, or from passive diffusion during immersion. This study has demonstrated that vitreous sodium level is an easily performed test that may be a useful adjunct to the investigation of possible immersion deaths.

KEYWORDS: forensic science, drowning, saltwater, freshwater, electrolytes, vitreous humor, immersion

The diagnosis of drowning is often a difficult exercise based purely on pathological features, as the typical features of pulmonary edema and congestion are nonspecific, and wrinkling of the hands and feet, or so-called washerwoman changes, merely indicate prolonged exposure to water (1–4). In cases where a body is found near, but not in water, it may even be difficult to determine whether immersion has been involved in the terminal episode. To evaluate the usefulness of vitreous humor sodium levels as a marker of immersion in either salt or freshwater, the following study was undertaken.

Materials and Methods

Samples of vitreous humor were prospectively collected by syringe aspiration from all cases with a history of possible immersion presenting to the Forensic Science SA mortuary over a 4-year period from 2006 to 2009. The fluids were submitted on the day of autopsy for routine biochemical analyses to determine sodium levels using standard methodology with an ion selective electrode. Statistical evaluation was performed using Student's *t*-test for comparison of means.

Results

A total of 35 cases were subject to analysis. These consisted of 19 cases of saltwater immersion (age range 9–76 years; mean age 44 years; M:F, 2.8:1) and 16 cases of freshwater immersion (age range 2–81 years; mean age 27 years; M:F, 2.2:1). The causes of death based on scene and autopsy findings were as follows: saltwater drowning ($n = 14$), saltwater drowning complicating cardiac disease ($n = 4$), saltwater drowning complicating trauma ($n = 1$), freshwater drowning ($n = 11$), freshwater drowning complicating cardiac disease ($n = 2$), freshwater drowning complicating trauma ($n = 2$), and freshwater drowning complicating mixed drug toxicity ($n = 1$).

In the group of saltwater drownings vitreous humor sodium levels were elevated, ranging from 145 to 184 mM (mean = 160.2 ± 9.9 mM), and in the cases of freshwater drowning, the levels were reduced, ranging from 73 to 148 mM (mean = 129.8 ± 17 mM; $p < 0.0001$). The normal range for sodium is 136.7–145.1 mM (3).

Discussion

Death from drowning results from a variety of mechanism including simple asphyxia from replacement of inhaled air by water and electrolyte disturbances related to fluid movement between the lungs and vasculature (5). As noted, the diagnosis at autopsy may be difficult as there are no pathognomonic pathological features. Laboratory testing has also proved disappointing with the Gettler chloride test not producing reliable results (this relies on differences in electrolyte levels between the left and the right sides of the heart). The results of diatom analyses for microscopic silicaceous organisms derived from inhaled water have also proven to be inexact (6,7).

In previous work (3), the authors demonstrated a significant difference in sodium levels in left ventricular blood in salt compared to freshwater drowning, that is the levels of sodium in cases of saltwater drowning ranged from 123 to 183 mM (mean = 153 ± 14.4 mM) compared to levels in freshwater drowning of 93–147 mM (mean = 117 ± 14.2 mM). This was attributed to the effects of hemodilution in freshwater drowning and hemoconcentration in saltwater drowning. A similar trend in electrolyte values has

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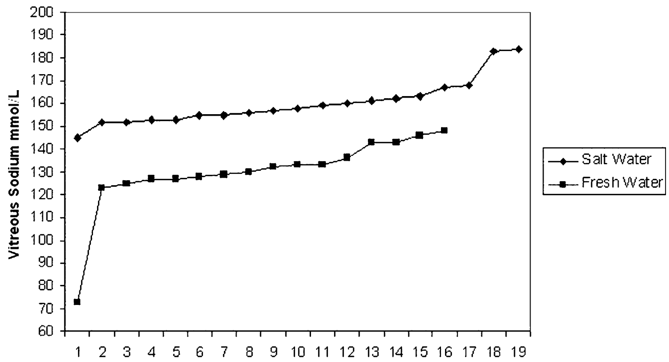

FIG. 1—*Comparison of postmortem vitreous sodium levels in cases of salt and freshwater drowning.*

been demonstrated in blood and other fluids, including pleural and pericardial effusion fluid, following drowning (8–10).

In the current study, an analysis was undertaken of vitreous humor sodium levels to determine whether changes might also occur in this compartment depending on the type of immersion, as this provides a readily accessible site for sampling. This was confirmed, with elevated (160.2 ± 9.9 mM) and reduced (129.8 ± 17 mM) vitreous sodium levels related to salt and freshwater immersion. Apart from three overlapping cases (a saltwater immersion with a sodium level of 145 mM and two freshwater drownings with sodium levels of 146 and 148 mM), there was clear separation of the sodium levels results in the two groups (Fig. 1).

The significance of this finding is that vitreous sodium analysis is an easily performed test that can be used to assist in determining whether immersion in salt or freshwater may have occurred. This could be of particular use in a case where an individual has been found on a beach between the low and high water mark or in a case where a body may have been moved from a bath or waterway after death.

One aspect that is unclear from this study is whether the changes in vitreous sodium levels were related to blood electrolyte changes from hemodilution or hemoconcentration following inhalation of water, or whether the changes merely reflected diffusion across the external membranes of the eyeball from contact with water during the time of immersion. Changes in left ventricular blood electrolyte levels in individuals who have been immersed for only short periods of time most likely indicate that electrolyte changes do occur because of ion fluxes across the alveolar membranes (3). On the other hand, prolonged soaking of eyeballs in hypotonic or hypertonic solutions might also contribute to these trends in electrolyte levels. Thus, it is possible that at least two mechanisms may have contributed to the electrolyte changes found in the current study, inhalation and/or diffusion (11–13).

A preponderance of men was noted in both the salt and freshwater drowning groups, as has been documented in a number of other studies. The younger mean age in the freshwater immersion group was a reflection of the number of deaths of children in bathtubs, pools, and water tanks (14).

Whatever the underlying pathophysiological mechanisms for the alterations in electrolyte levels that were demonstrated, it is apparent from this study that vitreous sodium levels may be a useful adjunct to the investigation of possible immersion deaths. In saltwater immersion, the average vitreous humor sodium level was 160 mM, and in freshwater immersion, it was around 130 mM. Given that sodium levels in serum may decrease after death at an average rate of 0.9 mEq/L (15,16), the finding of an elevated sodium level may be of particular significance (17).

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