

# Effects of Volume of Aspirated Fluid During Chlorinated Fresh Water Drowning

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Cardiovascular and biochemical changes were studied in the dog following aspiration of 1 ml. to 35 ml. of chlorinated distilled water per pound body weight. Survival rate was inversely proportional to the quantity of fluid aspirated. Ventricular fibrillation was common in animals who aspirated at least 20 ml. of water per pound but not observed with 10 ml. or less per pound. Three minutes following aspiration, the degree of change in blood volume, plasma hemoglobin, serum sodium, chloride, calcium, and potassium were dependent upon the quantity of water aspirated. Within one hour postaspiration, however, serum electrolytes returned to normal in surviving animals. Asphyxia was present acutely as evidenced by an increase in  $P_{aCO_2}$  and decrease in pH,  $P_{aO_2}$ , and base excess. The latter changes were not as transient as changes in the electrolytes, and significant hypoxemia was still present at the conclusion of the experiment in all but one animal.

In 1902, Revenstorf reported that drowning in fresh water was not simply a matter of asphyxia but that there was also a significant movement of water into the blood stream.<sup>1</sup> The magnitude of water transport and its effect on serum electrolytes, blood constituents and the cardiovascular system subsequent to total immersion was later studied in the dog by Swann *et al.*<sup>2-5</sup> Based primarily on these experiments and on subsequent studies of resuscitation techniques in dogs following total immersion,<sup>6</sup> resuscitation techniques for human

drowning and near-drowning victims have been advocated which emphasize the need for correction of the changes in blood elements, serum electrolytes, and cardiovascular dynamics.<sup>5</sup>

Changes of the magnitude found by Swann in animals have not been demonstrated pre-mortem in human victims of fresh water drowning. Instead, essentially normal serum electrolyte and blood constituents were found.<sup>5</sup> One possible explanation for this discrepancy is that man aspirates smaller quantities of water than those used in total immersion animal studies.

In a previous study in the dog from this laboratory some of the physiological changes were ascertained following aspiration of a fixed volume of 10 ml. of fluid per pound body weight. We found that the changes seen in concentration of blood elements and serum electrolytes secondary to near-drowning in fresh water were rapid but transient, and reverted to normal during recovery. One hour postimmersion there were no significant differences in these parameters among animals who aspirated distilled water, chlorinated distilled water, or isotonic saline solution. We postulated that the relative severity of the respiratory and cardiovascular abnormalities following fresh water aspiration could be related to the volume of fluid aspirated.<sup>7</sup> To test this hypothesis the following experiments were undertaken.

## Procedure

Thirty mongrel dogs weighing 37 to 55 pounds and in apparent good physical condition were divided into 6 groups, according to the volume of water aspirated. After a 15 gauge Rochester needle was inserted into a vein of the foreleg, 50 mg. increments of 2 1/2

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per cent sodium thiopental were given intravenously to produce basal narcosis (cessation of spontaneous movement; respiration and lid reflex remained active). The trachea was intubated, the cuff of the endotracheal tube inflated, and the animal permitted to breathe spontaneously.

Both femoral arteries and the left femoral vein were cannulated with siliconized polyethylene tubing (inside diameter 0.066 inch). The arterial catheters were threaded to the proximal portion of the thoracic aorta and the venous catheter into the inferior vena cava adjacent to the right atrium. The catheters on the left were connected via Statham strain gauges to a multichannel recorder for monitoring of arterial and venous pressures. The right femoral catheter was connected to a triple stopcock assembly for sampling of blood. Lead 2 of the electrocardiogram was recorded continuously.

Twenty minutes prior to immersion, radioactive iodinated serum albumin (RISA) was injected intravenously and the needle flushed with 5 per cent dextrose in water. Five to ten minutes preimmersion, a Wright ventilometer was connected to the endotracheal tube and the respiratory minute volume was measured in triplicate. Respiratory rate was counted and the average tidal volume calculated.

Four minutes prior to immersion, an arterial blood sample was drawn anaerobically into a heparinized, greased syringe and the pH measured in an Astrup AME-1 Micro apparatus.  $P_{a_{CO_2}}$  and base excess were calculated from the Siggard-Andersen nomogram.\*  $P_{a_{O_2}}$  was measured in the Astrup apparatus using a direct-reading Clark-type oxygen electrode. Arterial blood was also drawn at this time into a second heparinized syringe for whole blood studies and into a dry siliconized syringe for serum analysis. Care was taken to avoid hemolysis and to avoid stasis of blood in the catheters by removal and discarding 5 ml. of blood immediately before samples were withdrawn. Heparinized blood was analyzed for total hemoglobin by the cyanmethemoglobin method and for hematocrit using a Guest-Weichselbaum microcapillary centrifuge. Blood volume studies were done utilizing the RISA dilution technique; radioactivity was counted

and blood volume calculated with a Picker Hemoliter Counter. The blood was then centrifuged, plasma removed and analyzed for hemoglobin content by a modified version of the Bing and Baker technique.<sup>9</sup> Serum studies included determination of sodium, potassium and calcium on the Coleman flame photometer using a commercial serum preparation as a control. Serum chloride was determined in the Buchler-Cotlove Chloridometer.

Thirty seconds prior to immersion the endotracheal tube was connected via a Y-adapter to the water reservoir and breathing bypass described previously.<sup>7</sup> At zero time the bypass was occluded and the dogs were allowed to aspirate 1, 5, 10, 20, or 30 ml. of chlorinated\* distilled water per pound of body weight respectively according to the group. On completion of aspiration, the animal was allowed to breathe room air through the emptied reservoir. When all water had cleared from the tubing, the animal was disconnected from the reservoir to minimize respiratory dead space. Five animals were subjected to total immersion as follows: at zero time the bypass was occluded and the water reservoir opened. The animals remained underwater continuously until the onset of ventricular fibrillation. At this time the reservoir was clamped and with the dog in the supine position the fluid in the trachea was allowed to drain spontaneously. The total fluid aspirated minus the tracheal return was considered to be the total immersion volume. The average volume aspirated in these 5 animals was 35 ml. per pound (range 32-45 ml./pound).

Three, 10 and 60 minutes after the onset of immersion, preaspiration determinations were repeated. All surviving animals had their catheters and endotracheal tubes removed and were returned to their cages for survival studies over a period of 14 days.

For statistical analysis, the assumption was made that the increase in blood volume post-aspiration reflected the quantity of fluid transferred to the circulation. The changes from preaspiration levels in each animal for blood volume, plasma hemoglobin, whole blood hemoglobin, hematocrit, serum sodium, serum

\* Five parts trichloro-S-triazinetriene added per million parts distilled water.

TABLE 1. Preaspiration Data

Group (ml./pound)	Average Weight (pounds)	Volume Fluid Aspirated (ml.)	Control Tidal Volume (ml.)	Fluid/ Tidal Volume Ratio
1	47	47	219	0.21
5	41	203	239	0.85
10	44	440	187	2.35
20	47	936	233	4.01
30	43	1302	202	6.44
Total immersion	42	1467	224	6.55

chloride, serum potassium, serum calcium, PaO<sub>2</sub>, PaCO<sub>2</sub>, pH, and base excess were tabulated. Data were analyzed for simple linear correlation between corresponding changes in factors.<sup>10</sup> Data obtained three minutes postaspiration were selected for analysis because the magnitude of change in the majority of the parameters was greatest at this time. For significant correlation between any two factors, a level of significance of one per cent was required ( $df = 23$ ,  $r = 0.505$ ,  $P = 0.01$ ). In addition, for each factor studied, the changes three minutes postaspiration in each of the 6 groups were compared with the changes in the next aspiration group by use of Wilcoxon's Two Sample Rank test. Thus the changes in the group aspirating 1 ml. were compared with the changes in the group aspirating 5 ml., and the changes in the group aspirating 5 ml. were compared with the changes in the group aspirating 10 ml., etc.

TABLE 2. Number of Surviving Dogs in Each Group One Hour and Twenty-Four Hours Postaspiration

Group (ml./pound)	Dogs in Group	Survivors	
		1 Hour Post- aspiration	24 Hours Post- aspiration
1	5	5	4
5	5	5	5
10	5	4	3
20	5	1	1
30	5	1	0
Total immersion	5	0	0

## Results

All data subsequent to aspiration are reported as changes from preaspiration values for each animal. Average control values for weight, tidal volume, total volume of fluid aspirated, and fluid tidal volume ratio are listed in table 1.

*Survival Data.* In table 2 it may be seen that both the one-hour and 24-hour survival rates were inversely proportional to the quantity of water aspirated. The exact time of delayed death in the one and 10 ml. per pound groups is not known because they were found dead in their cages on the following morning. This would place the time of death between 8 and 24 hours postaspiration. The one animal with a delayed death in the 30 ml. per pound group died 6 hours postaspiration. There were no deaths beyond the first 24 hours.

*Cardiac and Vascular Changes.* A decline in systolic arterial blood pressure of at least 30 mm. of mercury was observed within seconds of aspiration in 2 of the 5 animals who aspirated 1 ml. of fluid per pound, 4 of the 5 animals who aspirated 5 ml. per pound and in all animals who aspirated 10 ml. or more of fluid per pound of body weight. This was followed by transient arterial hypertension (an increase in systolic pressure of at least 30 mm. of mercury) in all but 2 dogs who aspirated 5 ml. or more of fluid per pound. Hypertension was not observed in the 1 ml. per pound group.

The most frequent electrocardiographic changes observed following aspiration were bradycardia (less than 100 beats per minute)

TABLE 3. Electrocardiographic Changes Following Chlorinated Distilled Water Aspiration

Group (ml./pound)	Dogs in Group	Animals Showing Abnormality			
		Brady- cardia	Bigem- iny	↑T Wave	Vent. Fibr.
1	5	1	0	0	0
5	5	4	4	0	0
10	5	4	3	2	0
20	5	5	2	4	4
30	5	5	2	5	4
Total immersion	5	5	2	4	5

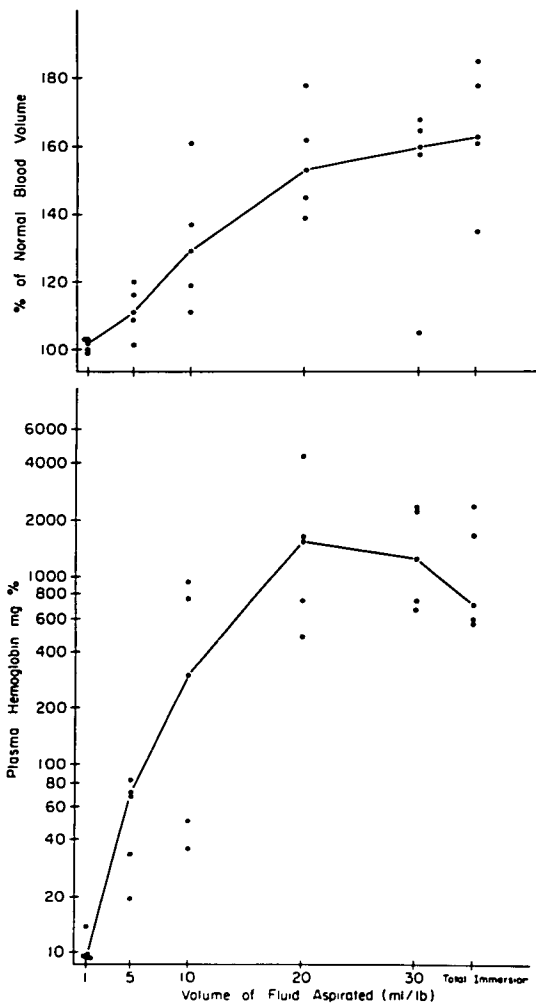


FIG. 1. Changes in blood volume and plasma hemoglobin three minutes postaspiration plotted as a function of the quantity of water aspirated. Each point represents change from preaspiration values for the individual animal.

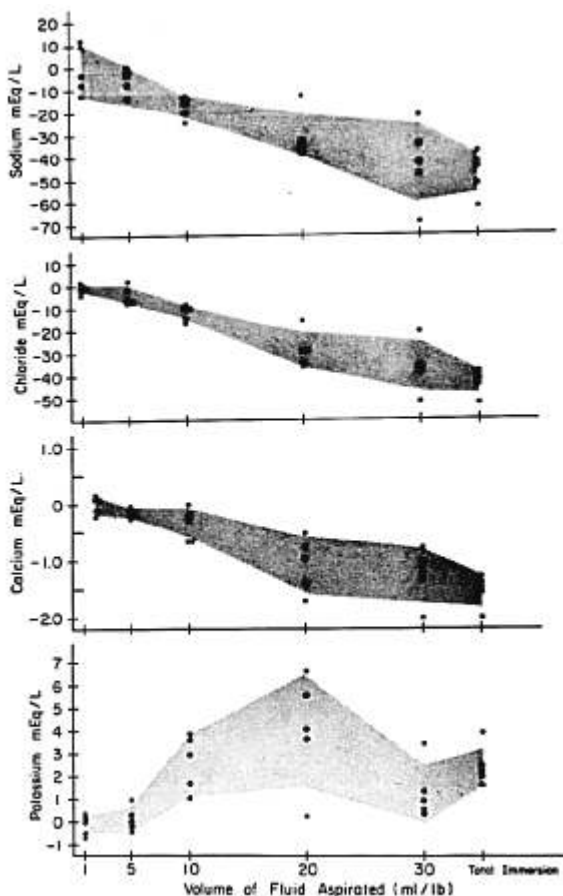


FIG. 2. Changes in serum electrolytes three minutes postaspiration. Values are plotted as change from preaspiration levels in mEq./liter versus volume of water aspirated for each animal. The standard deviation for each group is shaded to more clearly visualize trends. Average baseline values for the 30 dogs were: Na, 145 mEq./liter; Cl, 112 mEq./liter; Ca, 5.2 mEq./liter; and K, 3.6 mEq./liter.

bigeminal rhythm, increased amplitude of the T wave, and ventricular fibrillation. The frequency of these abnormalities within the respective groups is shown in table 3. These changes occurred with increasing frequency as the quantity of water aspirated increased. Ventricular fibrillation was not observed in

animals who aspirated 10 ml. of fluid or less per pound of body weight. The average latent period between aspiration and onset of ventricular fibrillation was 3:11 minutes in the 13 animals that developed this abnormality (range 1:42 to 7:05 minutes).

Venous pressure rose in all animals im-

mediately after aspiration and, in the survivors, gradually returned to normal within the next 30 minutes. These acute changes in venous pressure frequently coincided with struggling and respiratory efforts made by the animal. In those animals who died acutely, venous pressure remained elevated.

**Blood Volume.** Blood volume showed no significant change after aspiration of 1 ml. of chlorinated distilled water per pound body weight; it did, however, increase in all animals that aspirated at least 5 ml. per pound. The maximum value was obtained three minutes postaspiration. Figure 1 shows the change in blood volume three minutes postaspiration, plotted as a function of the volume of water aspirated. Although individual variation was seen, the change was proportional to the volume of fluid aspirated in the 1 to 20 ml. per pound range. The linear regression of blood volume (expressed as per cent of preaspiration blood volume) in relation to the quantity of water aspirated was highly significant ( $P < 0.0005$ ). The slope of best-fit line relating these variables to each other was 0.03, with a 95 per cent confidence interval from 0.021 to 0.037. That is to say that for each milliliter per pound increase in water aspirated the blood volume increased approximately 3 per cent. Following this, a plateau was found between the 20 and 30 ml. per pound and total immersion groups.

A positive correlation was found between the increase in blood volume and the changes in plasma hemoglobin ( $r = 0.587$ ) and serum potassium ( $r = 0.674$ ) concentrations. Conversely, a negative correlation was found between the blood volume and the serum sodium ( $r = -0.718$ , serum chloride ( $r = -0.770$ ), serum calcium ( $r = -0.651$ ),  $\text{PaO}_2$ , ( $r = -0.510$ ) and arterial base excess ( $r = -0.552$ ).

**Plasma Hemoglobin.** Plasma hemoglobin concentration showed no significant change in the 1 ml. per pound group, but increased in all animals in the 5, 10, 20 and 30 ml. per pound and total immersion groups. Concentration peaked three minutes postaspiration, then gradually decreased in the survivors. Figure 1 indicates the magnitude of increase in plasma hemoglobin plotted on a logarithmic scale as a function of the volume of fluid as-

pirated. The difference between the 5 ml. and the 20 ml. per pound groups is significant ( $P = 0.01$ ). Following this, a plateau was noted between the 20 ml. and 30 ml. per pound groups similar to that seen with the blood volume.

Two animals with a plasma hemoglobin above 740 mg./100 ml. survived the acute experiment only to die within 24 hours. The highest value observed in animals making a complete recovery was 477 mg./100 ml.

A positive correlation was observed between the increase in plasma hemoglobin and increase in blood volume ( $r = 0.587$ ). Conversely, a significant negative correlation was present between the plasma hemoglobin and the serum sodium ( $r = -0.766$ ), serum chloride ( $r = -0.777$ ) and serum calcium ( $r = -0.734$ ).

**Serum Electrolytes.** No significant change in serum electrolytes was observed following the aspiration of 1 ml. or 5 ml. of chlorinated distilled water per pound of body weight. However, all animals in the 10, 20 and 30 ml. per pound and total immersion groups, showed a significant decrease in serum sodium chloride, and calcium concentrations at three minutes postaspiration. Figure 2 shows these changes plotted as a function of the quantity of water aspirated. The statistical relationship of these changes to changes in blood volume has already been noted. Although there is a close relation between the decrease in concentration of serum sodium and chloride and increasing volumes of water from the 5 ml. per pound to total immersion groups ( $P = 0.01$ ), the values observed in the 30 ml. per pound group are not statistically different from those in the 20 ml. per pound or total immersion animals ( $P \geq 0.10$ ). Serum calcium values showed a similar pattern. In the 16 animals that survived, a return toward preaspiration values was observed and at the conclusion of the 60-minute experiment electrolytes were approximately normal regardless of the quantity of fluid aspirated (sodium 133-151, mean 142 mEq./liter; chloride 97-122, mean 106 mEq./liter; calcium 4.2-5.8, mean 5 mEq./liter).

Serum potassium increased in all animals who aspirated 10 ml. or more of water per pound body weight. The magnitude of these changes three minutes postaspiration was greater, however, in the 10 ml., 20 ml., and

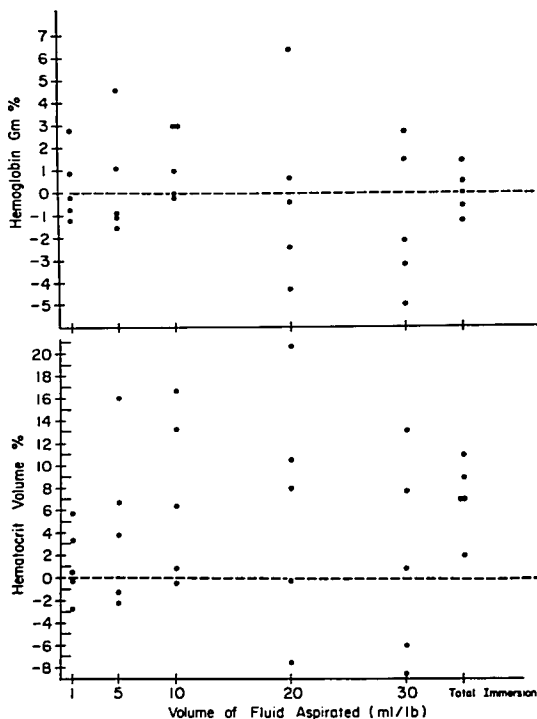


FIG. 3. Changes in hemoglobin and hematocrit three minutes post-aspiration plotted as a function of the quantity of water aspirated. Each point represents the change from preaspiration values for the individual animal. Average baseline values for the 30 dogs were: hemoglobin 12.7 g./100 ml. and hematocrit 37 per cent.

total immersion groups than in the 30 ml. group (fig. 2). Serum potassium showed a positive correlation with changes in blood volume ( $r = 0.674$ ) and a negative correlation with changes in serum calcium ( $r = -0.569$ ). Although both serum potassium and plasma hemoglobin increased postimmersion, the correlation between these two parameters was only of borderline significance ( $r = 0.394$ ). As with the other electrolytes, serum potassium returned to normal in the 60 minute samples in all but one survivor (potassium 2.6-6.4, mean 3.9 mEq./liter).

**Whole Blood Hemoglobin and Hematocrit.** The changes in whole blood hemoglobin and hematocrit were inconsistent and both re-

mained either essentially normal or became elevated in the majority of animals regardless of the volume of water aspirated. Scatter graphs of the whole blood hemoglobin and hematocrit determinations three minutes post-aspiration are seen in figure 3. In none of the groups is there a consistent pattern of variation from control values.

**Blood Gas and Acid Base Parameters.** A decrease in  $Pa_{O_2}$  and pH associated with an increase in  $Pa_{CO_2}$  was observed three minutes postaspiration in all 29 animals † regardless of the quantity of fluid aspirated ( $P < 0.01$ ).

† These determinations were not done in one animal in the total immersion group because the blood sample clotted.

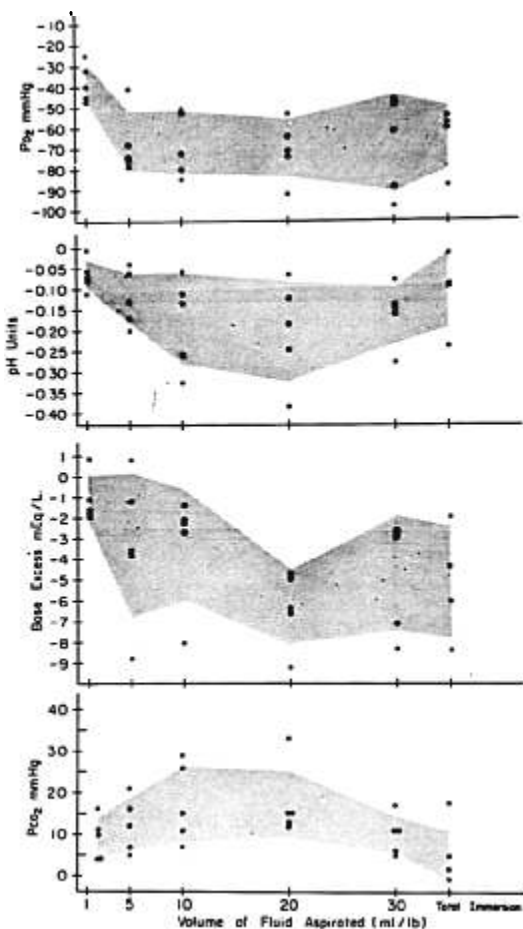


FIG. 4. Changes in arterial pH,  $P_{aO_2}$ ,  $P_{aCO_2}$ , and base excess three minutes postaspiration plotted as a function of the quantity of water aspirated. Values are plotted as change from preaspiration levels for each animal. Standard deviation for each group is shaded to more clearly visualize trends. Average baseline values for the 30 dogs were: pH, 7.46;  $P_{aO_2}$ , 99 mm. of mercury;  $P_{aCO_2}$ , 25 mm. of mercury, and base excess,  $-4.7$  mEq./liter.

Base excess decreased in all except 2 animals; one in the 1 ml. per pound group and one in the 5 ml. per pound group. In figure 4 the magnitude of these changes three minutes postaspiration is plotted as a function of the

quantity of water aspirated. It appears from these graphs with the exception of the 1 ml. per pound group, that the severity of arterial hypoxemia, hypercarbia, and acidosis was not directly dependent upon volume of fluid as-



pirated. Statistically, a positive correlation existed between the  $P_{a_{O_2}}$  and base excess ( $r = 0.651$ ) and  $pH$  ( $r = 0.732$ ). All three of these parameters demonstrate a significant negative correlation with the  $P_{a_{CO_2}}$ .

Sixty minutes postimmersion,  $P_{a_{CO_2}}$  had returned to normal in all surviving animals. However, at one hour  $pH$  and base excess still indicated a metabolic acidosis in virtually all of the survivors who had aspirated 5 ml. or more of fluid per pound body weight.

The  $P_{a_{O_2}}$  remained significantly decreased in all survivors with the sole exception of one animal in the 1 ml. per pound group. The mean preaspiration  $P_{a_{O_2}}$  for these dogs was 102 mm. of mercury whereas 60 minutes postaspiration the mean  $P_{a_{O_2}}$  was 56 mm. of mercury.

### Discussion

It is apparent from these studies that the increase in blood volume subsequent to fresh water aspiration is directly dependent upon the total quantity of water aspirated. A limiting factor is the rate of transport of fluid across the alveolar capillary membrane. In addition to the volume of water aspirated, other factors could conceivably alter the speed and extent of transport: age of the animal; pre-existing pulmonary disease; phase of respiration at the time of aspiration; breath holding, etc. Some of these may have been responsible for the variations observed in the animals within each group.

Efficient circulation is also necessary for maintenance of fluid transport. The early onset of ventricular fibrillation in the majority of animals aspirating at least 20 ml. per pound would therefore be a limiting factor, thus explaining the plateau seen in the increase in blood volume between the 20 and 30 ml. per pound groups.

An increase in blood volume to 153-185 per cent of normal three minutes postaspiration was observed in 11 of 15 animals who aspirated 20 ml. per pound or more of chlorinated distilled water. Since the blood samples were taken from the thoracic aorta, they reflect changes immediately distal to the lungs and are probably larger than the actual blood volume. The values are only slightly less than those reported by Swann and Spafford.<sup>3</sup>

Using deuterium oxide they found that as much as 51 per cent of the blood volume represented aspirated water 2 minutes following total immersion in dogs.<sup>3</sup>

The absence of obvious gross hemolysis in all animals in the 1 ml. and 5 ml. per pound and 2 of the 5 animals in the 10 ml. per pound groups is consistent with the low plasma hemoglobin levels found in these animals, three minutes postimmersion (5-81 mg./100 ml.). With further increases in blood volume, owing to larger volumes of hypotonic solution, the degree of hemolysis increased. Finally, under conditions of total immersion, a leveling off was seen, probably owing to the rapidity of circulatory failure and resultant decreased availability of fresh blood.

In this study we were unable to demonstrate a consistent decrease in concentration of whole blood hemoglobin following fresh water aspiration as reported by Swann *et al.*<sup>2</sup> Likewise, the inconsistent changes in hematocrit three minutes postaspiration were not expected. Similar findings in hemoglobin and hematocrit were reported by Farthmann and Davidson attributed by them to formation of pulmonary edema.<sup>11</sup> The rapidity of change, however, would make this explanation unlikely. Another possible explanation for an increased hematocrit in 15 of the 25 animals is that with the influx of a hypotonic solution into the blood stream the red cells swell and assume a greater volume. Evidence for this *in vitro* has been shown in our laboratories. The magnitude of change, however, is limited by the capacity and fragility of the cells themselves. A third possibility is that the lightly anesthetized dog may release from the spleen a substantial number of red blood cells into the systemic circulation when subjected to an acute stress.<sup>12</sup> In another experiment, 6 dogs were subjected to aspiration of 10 ml. of chlorinated fresh water per pound of body weight 2-4 weeks after splenectomy. Slight decreases in hemoglobin and hematocrit were found three minutes postaspiration in these animals. A statistical difference between the changes in these dogs and the comparable group of intact animals in the present study was found between these parameters, three minutes postaspiration ( $P = 0.05$ ). No sig-

nificant differences were seen, however, in the 10 or 60 minute postaspiration samples.

As might be expected, the serum electrolytes bore an inverse relation with changes in blood volume three minutes postaspiration. These changes may be attributed directly to hemodilution. The increase in serum potassium in all animals aspirating at least 10 ml. of water per pound is most likely the result of onset of acute severe hypoxia. Hemolysis could also contribute but the extent would be limited, since the red blood cell of the dog contains only about 10 mEq./liter of potassium, compared to 136 mEq./liter in man.<sup>12</sup> It is important to note that all of these electrolyte values spontaneously returned to normal by the end of the experiment. This would indicate that in aspiration of sub-lethal volumes of chlorinated fresh water there is a rapid redistribution of absorbed fluid, and normal electrolyte balance is restored.

It is apparent, therefore, that changes in concentration of serum sodium, chloride, calcium, potassium, whole blood hemoglobin, and hematocrit are not a continuing problem following near-drowning in fresh water. Since the values found 60 minutes postaspiration correlate closely with those reported by Fuller in human victims of near fresh water drowning,<sup>6</sup> it is reasonable to assume that the apparent discrepancy found heretofore between fresh water drowning studies in dogs and accidental fresh water near-drowning in man can be attributed to differences in the volume of water aspirated.

The occurrence of ventricular fibrillation as the terminating factor in death from fresh water drowning has been emphasized by many investigators,<sup>14, 15, 16</sup> yet documented in only two cases of human drowning, one fresh water<sup>17</sup> and one salt water immersion victim.<sup>18</sup> In the present study ventricular fibrillation was found not to occur if the animal aspirated 10 ml. or less of fluid per pound of body weight. Thus, if we can transfer these data to man, it may be postulated that victims of fresh water aspiration who absorb a sufficient quantity of fluid to cause death from ventricular fibrillation most probably have incurred irreversible changes when removed from the water. Resuscitation efforts in these

victims have been largely unsuccessful. Since electrolyte concentrations and blood pressure levels rapidly returned to normal in all dogs who survived, it is doubtful that delayed ventricular fibrillation occurs subsequent to fresh water aspiration. Therefore, with the exception of those animals who die acutely of ventricular fibrillation, the blood constituent and electrolyte changes following fresh water aspiration do not appear to be of great consequence.

On the other hand, significant arterial hypoxemia and acidosis were seen three minutes postaspiration in all animals regardless of the quantity of water aspirated. The magnitude of the decrease in arterial oxygen tension and base excess three minutes postaspiration was generally found related to increases in blood volume, but not necessarily to volume of fluid aspirated. This apparent discrepancy can best be explained by considering the phase of respiration at the time of aspiration. If aspiration began following peak inspiration, flow of water into the lungs and subsequent absorption would be delayed, whereas more oxygen would be available from the trapped air than if aspiration began immediately following the expiratory phase. In any case, persistent severe arterial hypoxemia was still present 60 minutes postaspiration.

In conclusion, postaspiration changes in serum electrolytes, blood volume, and plasma hemoglobin vary with the quantity of water aspirated. These changes are abrupt, but in near-drowning they are transient and usually revert to normal without therapy. Thus, in treating the majority of human victims of near-drowning in fresh water, the emphasis of therapy should be upon correction of persistent arterial hypoxemia and acidosis. While intensive efforts toward this end are being exerted, serum electrolyte, blood volume and plasma hemoglobin values should be determined and steps taken to correct abnormalities. It should be emphasized that the concentrations of hemoglobin and hematocrit are unreliable indicators of disturbed fluid and electrolyte balance in these victims; whereas, blood volume, serum sodium, and serum chloride are the most reliable parameters in guiding further fluid and electrolyte replacement.

### Summary

Cardiovascular and biochemical changes secondary to chlorinated fresh water aspiration were studied in 30 mongrel dogs who aspirated from 1 ml. to 35 ml. (total immersion) of fluid per pound body weight. Survival rate following aspiration was inversely proportional to the quantity of fluid aspirated. Ventricular fibrillation occurred frequently following aspiration of at least 20 ml. of fluid per pound but was not seen in animals aspirating 10 ml. of fluid per pound or less. Three minutes following aspiration changes in blood volume, plasma hemoglobin, serum sodium, chloride, calcium and potassium were largely dependent upon the quantity of water aspirated. Within one hour postaspiration, however, the serum electrolytes returned to normal in surviving animals.

Asphyxia was present acutely as evidenced by an increase in  $P_{aCO_2}$  and decrease in  $pH$ ,  $P_{aO_2}$ , and base excess. These changes in arterial  $pH$  and blood gases were not as transient as the changes in electrolytes and significant arterial hypoxemia was still present at the conclusion of the experiment in all but one animal. Thus, in treating the majority of human victims of near drowning in fresh water, the emphasis of therapy first should be upon correction of the arterial hypoxemia and acidosis, and secondarily the fluid and electrolyte changes.

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