STUDIES ON BLOOD WATER

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In an attempt to determine more accurately the degree of dehydration of patients with definite fluid imbalance, particularly patients with Addison's disease, an effort was made to find a rapid and simplified method of determining the total blood water. The method finally selected embodies the fundamental principles of many procedures described since the original work in 1845.

Venous blood was collected from the arm in routine fashion and 5 cc. were placed immediately into 8 cc. tightly stoppered glass flasks containing 0.1 cc. of a 20 per cent solution of potassium oxalate as the anticoagulant. Glass Petri dishes were layered with one-eighth to one-quarter inch of clean white sand and heated for four hours at a temperature between 96 and 102° C. These were allowed to return to room temperature in a desiccator. The sand was used to afford a larger surface area for the blood film, and to prevent any possible spattering.

The first series of fifty-nine determinations differed from the later work in only two respects: (1) 2 cc. volumetric pipettes were used, and (2) the Petri dish with sand was not weighed until after the addition of the blood sample. Obviously, this eliminated the possibility of expressing the results in this group in terms of per cent by weight. In the second group of determinations, eighty-four in all, Folin 2 cc. volumetric pipettes were used, after being recalibrated. All weights and volumes used in calculating the results are the corrected weights and volumes.

In all but the first group, the previously dried Petri dish with sand was weighed to an accuracy of 1 mg. Two cc. of blood were delivered into each dish and the second weighing was made. The dish was then placed in an electric oven for from four to five hours at a temperature of 96 to 102° C. This time interval was purely an arbitrary one. When comparative determinations were made, however, after keeping duplicate samples in the oven for as long as twenty-four hours, no appreciable difference in the results was obtained. After the drying process, the Petri dish was placed in a desiccator and allowed to return to room temperature before the final weighing was made.

The weight of the blood water in the sample was determined directly by the difference between the readings before and after heating. The percentage of blood water was calculated by dividing the weight of the water by the weight of the blood sample. A final calculation was made by dividing the weight of the blood water by the volume of the blood sample in order to express the results in terms of grams of water per 100 cc. of blood.

TABLE 1

NORMAL VALUES FOR TOTAL BLOOD WATER, EXPRESSED IN PER CENT

Author	*Range Per Cent*	*Sex*
Becquerel and Rodier	76 — 80	males
Becquerel and Rodier	77.3 — 81.3	females
Arronet	78.03 average	
Biernacki	77.3 average	
Schwendter	77.2 — 81.5	
Schneider	80.11 average	
C. Schmidt	78.9 — average	males
C. Schmidt	82.4 — average	females
Stintzing and Gumprecht	76.9 — 80.4	males
Stintzing and Gumprecht	78.5 — 81.6	females
Kuroda	76.14 — 81.34	males
Kuroda	77.50 — 83.56	females
Kuroda, et al	72.5 — 87	
Diaz, Bielschowsky and Minon	78.25 — 81.47	
Brown and Roth	79 — 83	
Wofford, McCullagh and McCullagh	78.24 — 81.32	

RESULTS

A small series of twelve normal individuals was used for this study. Their blood water contents varied from 78.24 per cent to 81.32 per cent, or, when expressed in terms of grams of water per 100 cc. of blood, they varied from 82.81 to 85.37 per cent. The corresponding hematocrit figures were 47 to 39 cc. of packed cells. Table 1 shows that our normal values compare favorably with some of those found in the literature. The determinations of total blood water showed a standard devia-

tion of 2.46 ± .19 and a coefficient of variation of 3.08 ± .24 when the blood water was recorded in per cent by weight; and a standard deviation of 1.86 ± .11 and a coefficient of variation of 2.18 ± .13 when recorded in grams per 100 cc.

In the entire series, a linear relationship was observed between the hematocrit and the blood water. The trend (k) in the first group was − .276 and in the second, − .24. This relationship showed that the total blood water and the hematocrit were almost mirror images of each other. It would seem, therefore, that the hematocrit yields almost as much information about the percentage water content of the blood as does actual blood water determination and, since it entails less time and effort, it is the procedure of choice.

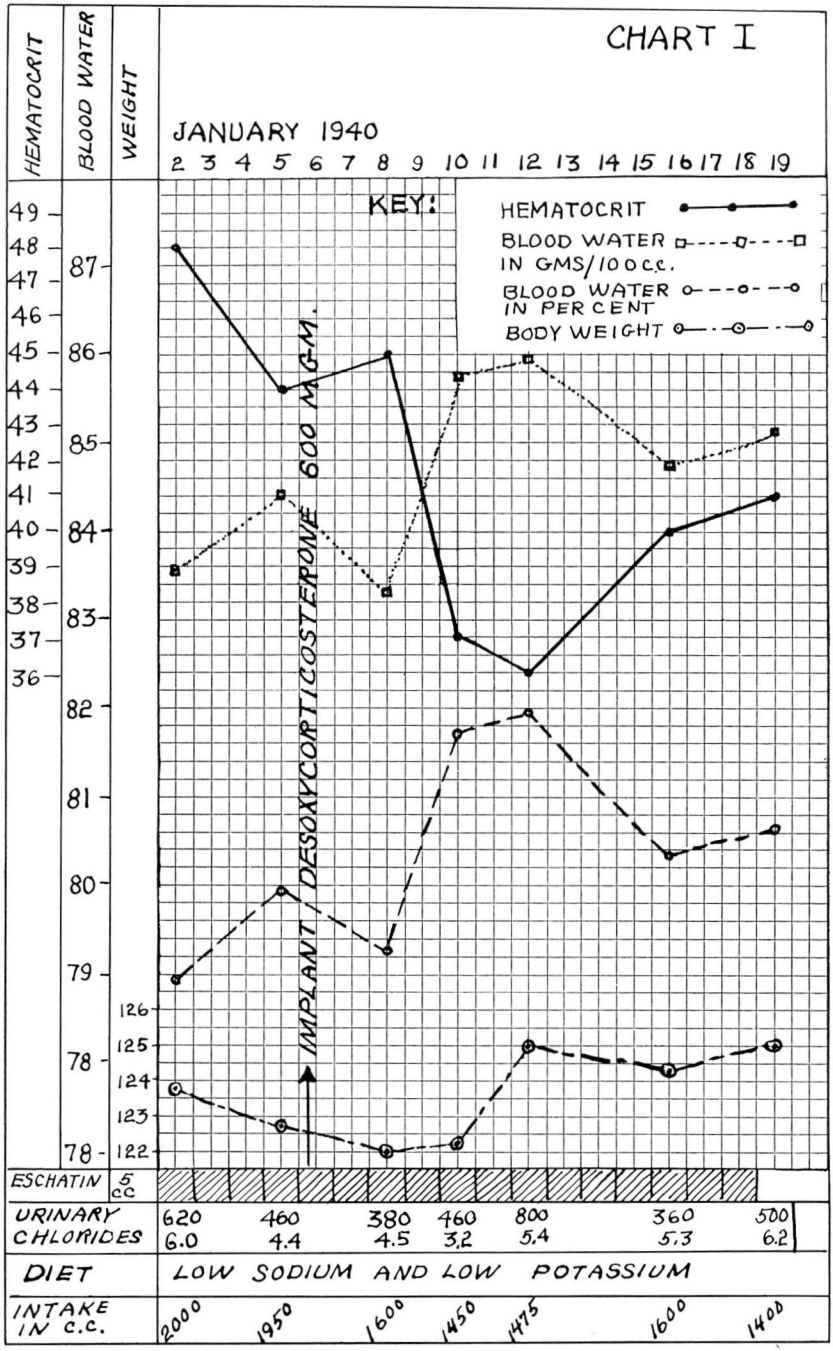
From the line of regression and the coefficient of variation, an equation was derived for calculating the blood water from any given hematocrit reading, with the theoretical error the same as the calculated error in this series of experiments. The equation is as follows:

$$y = 80 - (45 - x)\,k$$

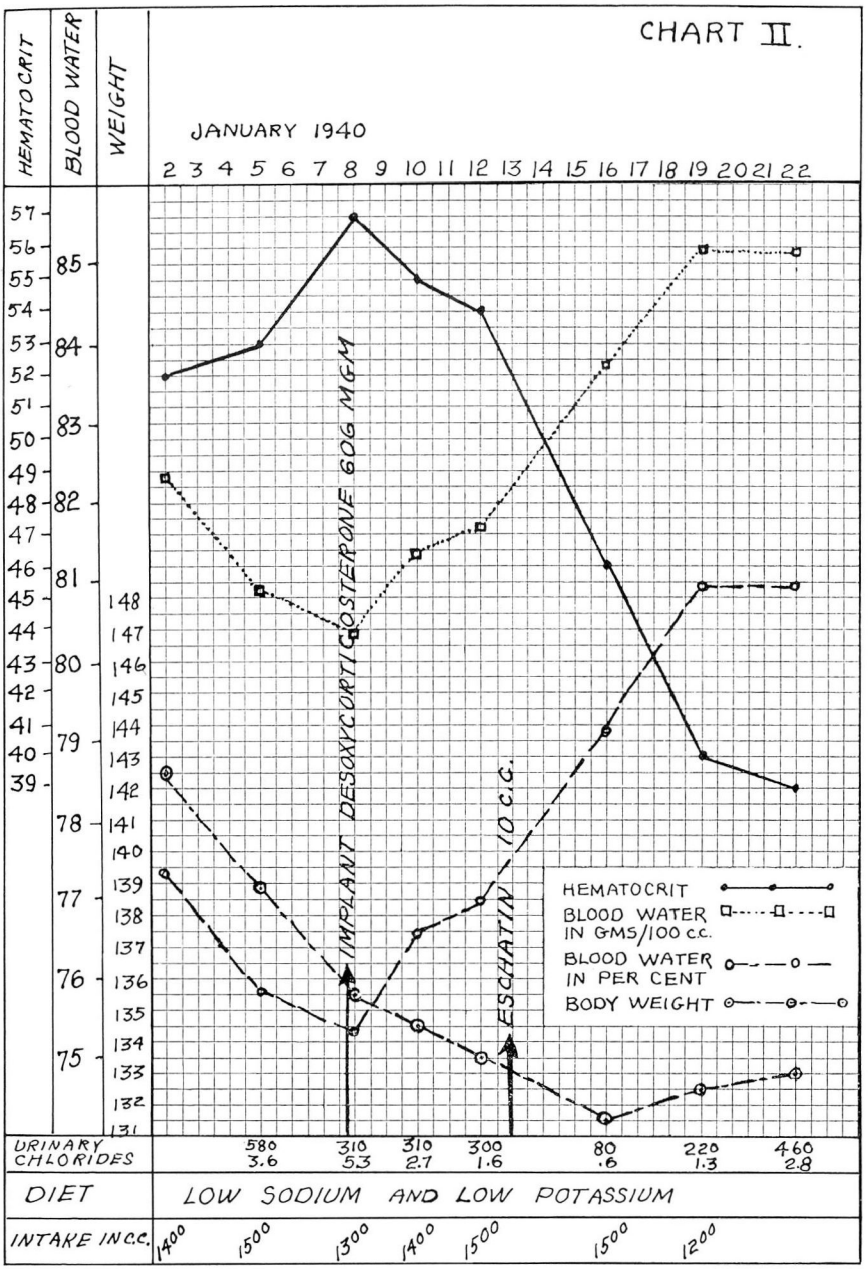
y = blood water in per cent by weight
x = hematocrit reading in cc. of packed cells
k = trend

Six cases of Addison's disease were studied in detail. Even though it is assumed that relatively little shift occurs in the quantity of water circulating in the blood in normal individuals, tremendous variations were found in three of the six cases of Addison's disease. In the first two patients, the changes were observed following implantation of 600 mg. of desoxy-corticosterone (Charts I and II), and in the third, the change was observed as the patient recovered from an acute addisonian crisis. Her blood water content increased from 78.17 per cent to 85.38 per cent within three days. In one other patient who received an implant of desoxy-corticosterone, there was no abrupt shift in hemoconcentration. The first two patients were on low sodium and low potassium diets throughout the period of these studies. Although specimens of food were not analyzed daily, the diet was accurately weighed and an attempt was made to keep constant the intake of sodium and potassium. Their sodium intake approximated 2 gm. per day and the potassium intake varied from 1.4 to 1.6 gm. per day. In the third patient, the intake of sodium chloride decreased from 37 to 20 gm. per day, while the daily intake of potassium ranged from 1.0 to 1.6 gm. The last patient received a low potassium diet containing about 1.6 gm. of potassium daily, but with no additional sodium chloride.

The weight changes were not significant. In one of the cases, there was a steady loss of weight which continued for eight days after the blood water content began to increase. In this patient, the urinary chlorides reached a minimum when the weight curve was at its lowest point. In the other patients, there was a corresponding reflection of the urinary



URINARY CHLORIDES ARE STATED AS MG. PER 100 C.C. AND AS TOTAL EXCRETION PER DAY IN GRAMS



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chlorides and changes in body weight. No relationship was noted, however, between body weight and blood water.

From the miscellaneous cases studied here, some interesting observations were made. Those patients with polycythemia vera showed no striking deviations from normal. One case with a severe hypochromic anemia had an increased blood water percentage which was in keeping with the decreased hematocrit reading. Other patients with hypochromic anemia did not show this variation. One patient with massive hemorrhage from a peptic ulcer revealed a marked increase in the water content of the blood with a corresponding decrease in hematocrit levels. When considered in groups of disease entities, these patients did not reveal any constant similarities in their blood water contents.

Summary

1. A simple method for determining the water content of the blood is described.

2. The results are expressed both as per cent by weight and as grams per 100 cc.

3. In this series, the normals compared closely with those of other workers.

4. The blood and hematocrit readings bore an inverse relationship which could be expressed mathematically.

5. No correlation could be made between the water content of the blood and the volume index, color index, total red cell count, hemoglobin, or blood volume.

6. Considerable shifts in the blood water content were found in individual patients from day to day.

7. An equation was derived from which the water content of the blood could be calculated from any given hematocrit reading.

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