

## Clinical Workshop

C. PHILIP LARSON, JR., M.D., Editor

### The Effect of Warming on the Serum Potassium Content of Stored Blood

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Potassium ions in blood stored at 4 C are known to pass from the erythrocytes to the plasma, reaching abnormal limits within the first seven days of storage. It is a common belief that with rewarming of the blood prior to transfusion, potassium ions re-enter the erythrocytes, thereby reducing the danger of hyperkalemic complications.<sup>1,2</sup>

Documentation of the re-entry of potassium ions into stored erythrocytes has been difficult to find. It seems possible that upon transfusion excess potassium ions of stored blood may take any one of several courses, including excretion via the kidney, re-entry into the original erythrocytes, passage into the erythrocytes of the recipient, or passage into the cells of muscle or other tissue.<sup>3-6</sup> To what extent any of these possible routes is followed and what factors may alter the distribution of potassium ions are problems that invite more accurate investigation.

The purpose of this study was to determine the extent to which potassium was taken up by original blood cells in the process of simply warming blood from the 4 C storage temperature to room temperature (25 C) and to body temperature (37 C).

#### METHOD

Ten 450-ml units of fresh human blood were collected in Fenwal plastic bags each containing 63 ml of citrate phosphate dextrose pre-

servative (CPD).<sup>7,8</sup> Each unit was then divided into aliquots in 15-ml graduated plastic centrifuge tubes. On days 0, 7, 10, 14, 21, and 28 of storage, samples of the ten blood units were removed and tested in triplicate for serum potassium, sodium, pH, and hemoglobin at 4, 25, and 37 C. Prior to measurement of serum potassium the samples were shaken gently to insure complete mixing.<sup>9</sup> The pH of each sample at 4 C was recorded and these samples were spun down in a refrigerated centrifuge. The plasma was extracted from the sample using Pasteur pipettes. Sodium, potassium, and hemoglobin determinations were then carried out. Simultaneously, samples were warmed for 60 minutes in water baths at 25 C and 37 C and the procedure used to test the samples at 4 C was repeated at these temperatures.<sup>10</sup> Serum potassium and sodium were determined on an Instrumentation Laboratories Model 143 flame photometer.† Plasma hemoglobin tests were run according to Hank modification<sup>11</sup> of the Crosby and Furth benzidine technique. Spectrophotometric measurements of plasma hemoglobin were made on a Coleman Junior II spectrophotometer.§

#### RESULTS

As shown in table 1, our findings demonstrated very slight re-entry of potassium ions into the original stored erythrocytes upon warming *in vitro*. The mean of the original serum potassium levels tested on day 0 was

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TABLE 1. Serum Potassium, Sodium, pH and Hemoglobin in Stored Blood on Days 0, 7, 10, 14, 21, and 28, at a Storage Temperature of 4°C and after Warming to 25°C and 37°C\*

	Day 0	Day 7	Day 10	Day 14	Day 21	Day 28
K (mEq/l) (4°C)	6.58	13.84	18.36	22.90	28.20	33.81
K (25°C)	—	12.83	17.32	22.23	27.44	33.41
K (37°C)	—	12.10	16.32	21.15	26.87	33.00
Na (mEq/l) (4°C)	157.3	157.9	156.3	155.4	153.4	152.9
Na (25°C)	—	157.5	155.0	154.5	152.0	150.1
Na (37°C)	—	154.9	154.8	153.2	152.4	150.3
pH (4°C)	7.10	6.93	6.85	6.78	6.67	6.59
pH (25°C)	—	7.08	6.93	6.89	6.75	6.66
pH (37°C)	—	7.13	6.97	6.90	6.80	6.69
Hb (mg/100 ml) (4°C)	11.5	25.3	31.2	39.8	80.7	110.5
Hb (25°C)	—	29.2	35.1	43.7	85.1	120.5
Hb (37°C)	—	31.1	37.0	47.1	91.3	124.4

\* Day 0 is the day blood was drawn. Each figure represents the mean of ten units studied. All analyses of serum potassium values are accurate to two places to the right of the decimal.

TABLE 2. Computed Statistical Variances (Standard Deviations) for Experimental Data in Table 1\*

	Day 0	Day 7	Day 10	Day 14	Day 21	Day 28
K (mEq/l) (4°C)	±1.03	±1.91	±1.89	±1.91	±1.96	±1.65
K (25°C)	—	±1.83	±1.94	±1.85	±2.02	±1.71
K (37°C)	—	±1.93	±1.92	±1.90	±1.89	±1.74
Na (mEq/l) (4°C)	±3.10	±3.40	±2.70	±2.10	±2.40	±2.90
Na (25°C)	—	±3.45	±2.60	±2.05	±2.45	±2.85
Na (37°C)	—	±3.35	±2.75	±2.00	±2.45	±2.95
pH (4°C)	±0.39	±0.35	±0.33	±0.40	±0.36	±0.41
pH (25°C)	—	±0.29	±0.38	±0.37	±0.43	±0.33
pH (37°C)	—	±0.30	±0.41	±0.45	±0.31	±0.48
Hb (mg/100 ml) (4°C)	±1.50	±2.18	±2.59	±3.10	±3.92	±4.93
Hb (25°C)	—	±2.15	±2.67	±3.03	±3.79	±4.65
Hb (37°C)	—	±2.09	±2.63	±3.01	±3.75	±4.78

\* Figures for potassium are accurate to two places to the right of the decimal. The differences in K and pH at the three temperatures are not statistically significant.

6.58 mEq/l. Seven days later, serum potassium in blood at 4°C had increased to 13.84 mEq/l. Upon warming, this decreased only to 12.83 mEq/l at 25°C and to 12.10 mEq/l at 37°C. After 28 days, serum potassium at 4°C was 33.41 mEq/l at 25°C and 33.00 mEq/l at 37°C. Re-entry of potassium ions into erythrocytes at 25°C on the seventh day represented only 7.3 per cent return, while that

on the twenty-eighth day, from 33.81 to 33.41 mEq/l, represented only 1.18 per cent return. When the blood was warmed to 37°C the figures were but slightly improved, with a 12.50 per cent return at day 7 and a 2.39 per cent increase in the return at day 28. As stated previously, all measurements were made in triplicate, and correlation, as shown in table 2, was sufficient to give reliable figures.

Results of measurement of serum sodium showed a very slight decrease with storage, from 157.3 mEq/l at the start to 152.9 mEq/l at day 28, with a final reduction to 150.3 mEq/l on warming to 37 C. The pH showed the expected change from 7.10 to 6.59 during 28 days of storage at 4 C, and rose only to 6.69 on being warmed to 37 C. Finally, serum hemoglobin showed a considerable increase (11.5 to 110.5 mg/100 ml) after storage for 28 days at 4 C, and in all samples showed greater levels (more hemolysis) when warmed.

### DISCUSSION

Evidence presented here suggests that the passage of potassium ions from erythrocytes to serum in stored blood is not readily reversible by warming *in vitro* alone. Any potassium re-entry greater than that found here would suggest the presence of other factors. It has been reported that serum pH and the concentration of 2,3-diphosphoglyceric acid (2,3-DPG) are intimately involved in potassium migration,<sup>6</sup> and our studies demonstrate an inverse relationship between potassium and serum pH.

The insignificant change in sodium concentrations suggests that sodium has little effect on the movement of potassium ions during storage. The effect of hemolysis on potassium levels in erythrocytes and serum must be considered. Obviously, destruction of red corpuscles will cause irreversible release of potassium from erythrocytes to serum and, if excessive, will wipe out any reduction of serum potassium which might occur upon warming of bank blood.

In this study, hemolysis, as measured by serum hemoglobin levels, rose from 11.5 to 110.5 mEq/l during 28 days of storage, and with warming showed a further increase to 124.4 mEq/l. This amount of hemolysis, when related to 1,500 mg/100 ml (15 gm/100 ml) of whole blood, shows that the stored blood was only 1/150, or 0.7 per cent, hemolyzed. The potassium present as a result of hemolysis would be approximately 0.49 mEq/l, or 1/250 of the final 124.4 mEq/l of potassium. This could have played little part in preventing potassium re-entry into erythrocytes.

Decreasing serum pH and 2,3-DPG appear to have greater potential<sup>12</sup> for enhancing re-entry of potassium into erythrocytes after storage, and is now under investigation.

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