

Shock Due to Freezing: I. Shift of Body Fluids and Associated Blood Concentration Changes.*

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It has been shown by Blalock,¹ Underhill² and the writer³ that in shock due to severe burns there is a loss of fluid from the blood stream into the burned tissues. It is considered by these authors that this loss of fluid is responsible for a large part of the shock resultant to burns. The amount of fluid shift into the tissues has been measured by burning one lateral half of an animal and then after careful sagittal bisection, comparing the weight of the burned and unburned sides;¹ by weighing the fluid expressed from the water-logged burned tissues;² and by burning one lateral half of an animal placed on a balanced apparatus and measuring the amount of displacement caused by the increase in weight of the burned side.³

Accompanying this loss of fluid there is a marked blood concentration and in shock in human beings resulting from severe burns, Underhill⁴ found that hemoglobin readings as high as 209% indicate a marked blood concentration. Blalock found that in experimental burns the hemoglobin may rise to 130%. The writer³ found that in experimental burns the hemoglobin may rise to as high as 162% (Sahli: 17 gm. per 100 cc. = 100%) and the hematocrit reading to 72.

It was thought that the severe general effects of freezing a portion of the body might be due to a similar leakage of fluid from the blood stream into the frozen or thawing tissues with a resultant blood concentration. Solid carbon dioxide was applied to about one-fourth of the body surface of 10 completely anesthetized dogs and left in place for about an hour, at the end of which time the underlying tissues were deeply frozen. In all but the ninth experiment, in which the shift of body fluid was not determined, all of the freezing was done on portions of one lateral half of the animal.

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¹ Blalock, A., *Arch. Surg.*, 1931, **22**, 610.

² Underhill, F. P., Fisk, M. E., and Kapsinow, R., *Am. J. Physiol.*, 1930, **95**, 325.

³ Harkins, H. N., *Proc. Soc. Exp. Biol. and Med.*, 1934, **31**, 994; *Arch. Surg.*, in press.

⁴ Underhill, F. P., Carrington, G. L., Kapsinow, R., and Pack, G. T., *Arch. Int. Med.*, 1923, **32**, 31.

Frequent blood pressure readings, hemoglobin percentages and hematocrit readings were determined. The blood pressure was obtained by placing in the carotid artery a cannula which was connected to a mercury manometer. Hemoglobin determinations were made by the Sahli method and hematocrit readings with the Van Allen hematocrit.

Results. The initial blood pressure averaged 148 and the final blood pressure 81 mm. of mercury. This amount of blood pressure lowering may be considered arbitrarily as within the limits of so-called surgical shock. After a period averaging 21 hours from the time of freezing, 4 of the dogs were dead and the other 6 were killed. Nine of the animals were then carefully bisected by the method previously described³ and a comparison made of the weights of the frozen and unfrozen sides. The average difference amounted to 2.55% of the total body weight. Incision into the tissues that had been frozen revealed sufficient plasma-like fluid to account for the difference in weight. This amount of plasma, if lost from the blood stream, is sufficient to account for a large part of the shock present in these animals.¹ In 8 burn experiments previously reported,³ the amount of fluid shift at death was 2.2% of the total body weight.

The blood concentration changes began almost immediately after the freezing and were present long before the blood pressure had fallen markedly. It is seen from Table I that in all animals there

TABLE I.

Shift of body fluid and associated blood concentration changes in shock due to freezing. The duration of the experiment indicates the time of death of the animal after freezing. The animals in experiments 1, 2, 3, 4, 8, and 9 were killed immediately following the last blood pressure reading; the animals in the other experiments died some time following the last reading. The hemoglobin and hematocrit figures recorded after freezing indicate the highest readings in each experiment. The lateral shift of body fluids is determined by the bisection method.

Exp.	Wt. of dog, kg.	Duration of exp. hr.	Blood pressure		Hemoglobin, %		Hematocrit		Shift of body fluid as % of body wt.
			mm. of Hg. Initial	Final	Control	After freezing	Control	After freezing	
1	12.2	26	160	114	76	131	36	63	5.14
2	13.8	28	138	92	75	136	37	59	0.15
3	16.0	26	164	96	102	113	48	58	2.44
4	7.3	17	156	94	93	104	46	53	1.51
5	8.9	20	118	42	104	160	48	74	4.05
6	11.1	25	168	70	97	128	46	63	2.92
7	11.0	17	159	38	123	159	61	74	2.77
8	8.3	13	120	64	85	116	42	61	1.35
9	23.5	16	158	76	96	163	50	70	—
10	7.1	18	142	120	109	168	54	80	2.59
Aver.	11.9	21	148	81	96	134	47	66	2.55

was an increase in hemoglobin percentage and hematocrit reading. The average hemoglobin percentage before freezing was 96 and after freezing was 134. The average hematocrit reading before freezing was 47 and after freezing 66. The figures obtained in experiment 10 are higher than in any readings obtained in shock due to burns, except by Underhill in human beings. Control experiments showed no marked blood concentration and no fluid shift.³

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Shock Due to Freezing: II. Composition of Edema Fluid.*

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The composition of the fluid that escapes into the subcutaneous tissues after burns has been determined by Beard and Blalock.¹ These authors found that in general the chloride content of the fluid was higher than that in blood plasma, the concentration of sugar and non-protein nitrogen was approximately the same in the 2 media and the protein content of the subcutaneous fluid was about 20% lower than that of the blood plasma. Underhill and Fiske² made similar comparisons between the tissue fluid after burns and the blood serum. Their results agree in general with those of Beard and Blalock, except that they found the non-protein nitrogen content considerably higher in the edema fluid than in the blood serum.

The results of these authors indicate that the fluid that escapes into the subcutaneous tissues after burns very closely resembles blood plasma. The escape of a plasma-like fluid undoubtedly produces more serious consequences than the escape of a simpler solution. Hence, it was considered of importance to determine whether the fluid that escapes into the subcutaneous tissues in large amounts after freezing is of a plasma-like nature similar to that following burns. Nine completely anesthetized dogs in which shock was produced by freezing portions of the body with solid carbon dioxide were dissected after death and large amounts of edematous subcu-

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¹ Beard, J. W., and Blalock, A., *Arch. Surg.*, 1931, **22**, 617.

² Underhill, F. P., and Fiske, M. E., *Am. J. Physiol.*, 1930, **95**, 330.