STUDY OF THE BODY TEMPERATURE AND WATER CONTENT IN SHOCK PRODUCED BY THE CONTINUOUS INTRAVENOUS INJECTION OF ADRENALIN, WITH AND WITHOUT ANESTHESIA

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Research Article

STUDY OF THE BODY TEMPERATURE AND WATER CONTENT IN SHOCK PRODUCED BY THE CONTINUOUS INTRAVENOUS INJECTION OF ADRENALIN, WITH AND WITHOUT ANESTHESIA [1]

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INTRODUCTION

It has been pointed out (1) that all factors which are at present known to produce shock or to aggravate the condition if present have one physiological action in common. They are all adequate stimuli for producing hyperactivity of the sympathetic nervous system. More recently, a report (2) has been made that prolonged adrenalin injection produces a rather standardized reproducible shock-like condition, with a depressed blood pressure, increased hematocrit, and reduced blood volume. The observations of these workers have been repeated, using this method to obtain a reproducible state of shock where it was possible to record tissue temperatures and the percentage of total water in various tissues.

METHODS

Dogs weighing from 9 to 28 kgm. were used in this study. They were not limited as to breed, sex, or age, but, in general, young dogs in good health were selected. On the days of the experiment, the animals were not fed, but were allowed to drink water.

Nembutal was used in the experiments performed under anesthesia. A dose of 30 mgm. per kgm. was administered intraperitoneally at the beginning of the experiment, and, in some cases, an additional dose was given at subsequent intervals to maintain the anesthesia. In those experiments without general anesthesia, the dogs were strapped on the table and both the femoral arteries and veins were exposed under a local anesthesia of 2 per cent procain. The right femoral artery was cannulated and connected to a mercury manometer for continuous blood pressure measurement in both groups of animals.

Constant temperature records of various muscles were made at frequent intervals during the whole experiment with specially constructed needle thermocouple equipment. After the control blood samples were taken and the control blood pressures and temperatures for various sites were recorded for 1 hour, the injection of adrenalin was started into the left femoral vein. A Murphy drip apparatus was regulated to deliver the adrenalin at a uniform rate. A 1:5000 dilution of adrenalin was used, and the usual rate was 0.010 mgm. per kgm. per minute for one hour. At the end of the hour, 10 ml. of saline were run through the apparatus into the vein to wash in the last 4 or 5 ml. of adrenalin solution remaining in the rubber tube leading to the needle.

After the dogs expired or were sacrificed, an autopsy was performed at which time duplicate samples of various tissues were taken for the determination of the percentage of total water. This was calculated from the weights of the tissue samples before and after drying at 100° C. for 48 hours.

RESULTS AND DISCUSSION

In studying temperature changes associated with shock, it is necessary to know the effect of the anesthesia used. This was studied by first recording the temperature changes occurring in anesthetized dogs. In order to know precisely the temperature changes associated with the adrenalin shock state, one group of animals was given adrenalin with no anesthesia.

One unanesthetized dog was studied over a period of 15 hours. The thermocouples were inserted and the temperatures recorded every 15 minutes. The rectal temperature remained constant within ±0.2° C. for most of the 15-hour period. The subcutaneous and intramuscular (both trunk and limb) temperatures paralleled each other very closely, there being no appreci-

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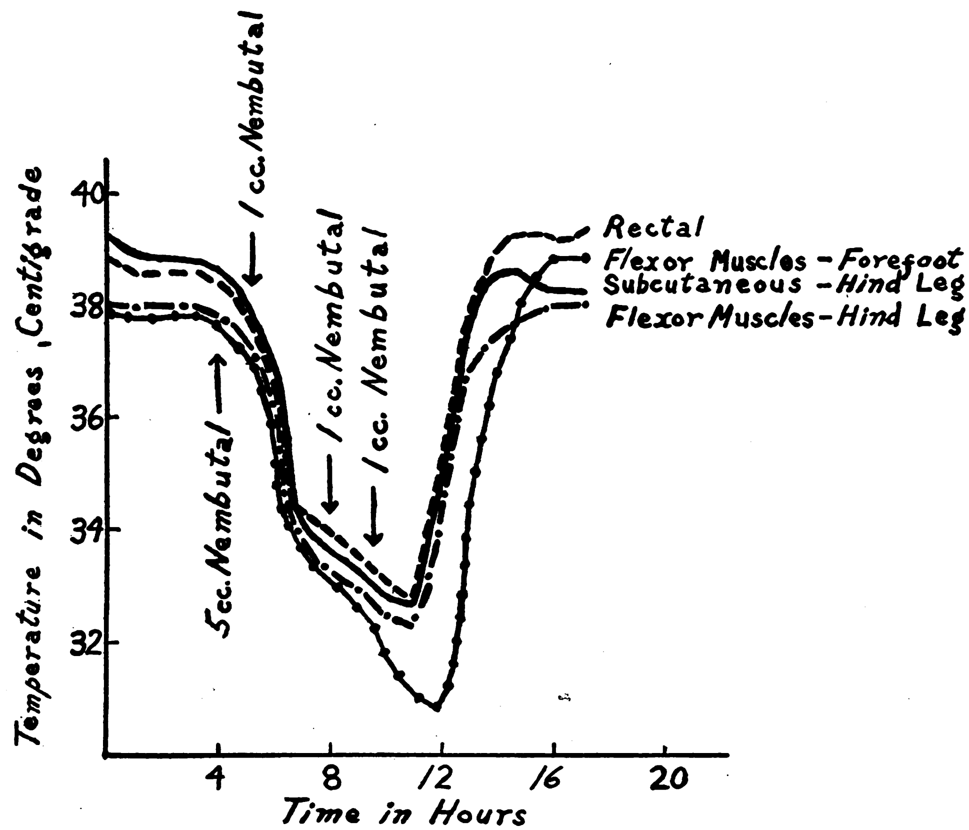

FIG. 1. TEMPERATURE CHANGES AS A RESULT OF NEMBUTAL ANESTHESIA IN A DOG
The Nembutal was injected intraperitoneally over a control period of 4 hours.

able difference between the two. Generally, they were from 0.5° C. to 1.0° C. lower than the rectal temperature.

Three dogs were given Nembutal intraperitoneally after a control period of 4 hours. A typical experiment is shown in Figure 1, which shows the effect of Nembutal to be a generalized parallel fall in the subcutaneous, intramuscular, and rectal temperatures.

Figure 2 represents the average temperature changes in 6 dogs which received adrenalin but no anesthesia. The rectal temperature remained at a constant of 39.9° C. The spinal muscles of the lumbar region followed closely the rectal temperature at 39.5° C., with a tendency to fall slightly after the administration of adrenalin. The flexor muscles of the left hind leg fell steadily in temperature at the rate of 0.3° C. per hour, and the extensor muscles of the foreleg dropped in a parallel fashion. The temperature of the small muscle groups of the extremities (flexor muscles of the forefoot and the extensor muscles of the hind foot) dropped over 1.5° C. during the period of an hour when adrenalin was injected. After the injection of adrenalin was completed, these two groups of muscles lost heat at the rate of about 0.2° C. per hour.

Figure 3 illustrates the behavior of the rectal and intramuscular temperatures in adrenalin shock with Nembutal anesthesia. The curves represent an average of 5 experiments. There are several points of difference in this group of animals compared with the group which received adrenalin without anesthesia. The level of the initial temperatures was roughly 2° C. lower. The rectal temperature fell during and after the adrenalin injection. The temperature of the extensor muscles of the foreleg, the flexor muscles of the hind leg, and the extensor muscles of the hind foot rose during the second hour after the completion of the adrenalin injection.

Thirty-two animals receiving adrenalin injec-

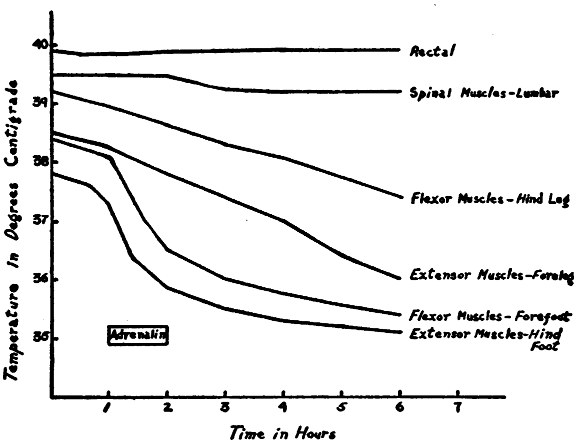

FIG. 2. TEMPERATURE CHANGES AS A RESULT OF ADRENALIN

The curves represent average values for 6 dogs. No anesthesia was given. Adrenalin was given at a uniform rate (0.010 mgm. per kgm. per minute) over a period of 1 hour following a control period of 1 hour.

tions have been studied. The results are summarized in Table I. On the basis of survival time, it appears that Nembutal anesthesia has a deleterious effect in adrenalin shock. If the amount of adrenalin was increased, the survival time was lessened. An attempt was made to raise the peripheral temperatures to normal by application of heat by means of lamps to the 4 extremities. The length of survival of the 5 animals studied shows that the heat applied to the extremities has no beneficial effect in adrenalin shock. Only 3 dogs were studied in which cold applications were made, and the results are inconclusive.

The hematocrit changes are also given in Table I. In 3 animals there was no significant change. The remaining dogs, however, showed an increase in hematocrit ranging from 5 to 30 per cent. The hematocrit did not show any uniform relationship to the degree of shock or survival time of the animal. It seemed to depend on characteristic individual differences in the vascular system and their responses to the experimental procedure. The wide variation in response to adrenalin and other drugs is well known clinically as well as experimentally.

The increase in hematocrit as a result of the adrenalin injections could be due to a loss of plasma into the tissues, to a release of red cells from the spleen and splanchnic area, or to a withdrawal of plasma into the surface films in small vessels by vasoconstriction.

In some animals, the hematocrit may rise as much as 20 per cent within a few minutes after the adrenalin injection is started. It hardly seems reasonable that a loss of plasma into the tissues would occur so rapidly to account for this increased hematocrit. It has been shown in normal men (3) and in unanesthatized dogs (4) that there are no considerable stores of immobilized erythrocytes. The latter group concluded that all the red blood cells of the dog are in active circulation. It should be pointed out, however, that these conclusions may not apply to anesthetized dogs. The most logical explanation of the increase in hematocrit is a removal of plasma into the surface films of the small vessels by vasoconstriction. These workers have emphasized the importance of considering the sluggishly flowing plasma films in studies of plasma volume. They have also shown that the average hematocrit of the entire vascular system is considerably lower than the hematocrit of the large vessels, and the hematocrit of the smaller vessels is still less.

The arterial pressures are given in Table I. Only the normal levels and those at 30 minutes and 1 hour after completion of the adrenalin

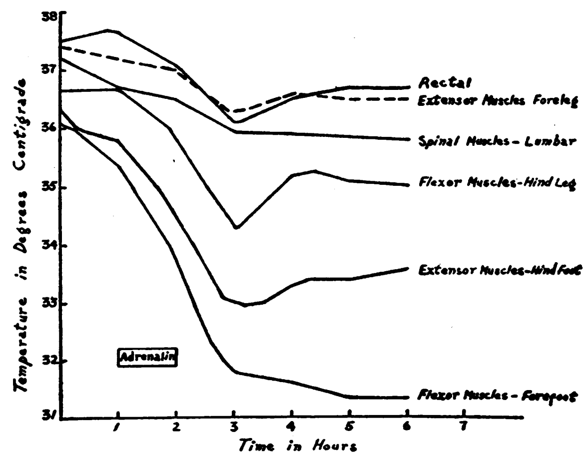

FIG. 3. TEMPERATURE CHANGES IN ADRENALIN SHOCK WITH NEMBUTAL ANESTHESIA

The curves represent average values for 6 dogs. Nembutal was given intraperitoneally. After 1 hour, the adrenalin was injected at a uniform rate (0.010 mgm. per kgm. per minute) over a period of 1 hour.

TABLE I

A summary of the results of adrenalin shock in 32 animals

Adrenalin dose in	Survival time after adrenalin injection was begun		Hematocrit			Blood pressure			Change in serum electrolytes		
			Normal	Immediately after completion of adrenalin injection	Pre-exitus	Normal	Hours after completion of adrenalin injection: ½	Hours after completion of adrenalin injection: 1	K	Mg	Na
mgm. per kgm. per min. for 60 min.	*hours*	*min.*	*per cent*			*mm. Hg*			*per cent*		
Seven dogs with Nembutal and standard dose of adrenalin											
0.010	8	32	40	52	54	130	50	40	−3	+21	−5
0.010	4	43	47	63	62	150	100	85	−2	+28	+4
0.010	2	7	57	58	59	170	110	40	+1	+1	+2
0.010	1	20	52	70	68				+5	+31	+9
0.010	6	30	56	60	64	140	90	80			
0.010	1	25	52	50	50	115	Died				
0.010	0	48	52	Died		90	Died				
Ten dogs with no anesthesia and standard dose of adrenalin											
0.009	Indefinitely		49	51		150	50	60			
0.010	Indefinitely		57	62		150	100	80			
0.010	1	56	40	47	47	150	50	Died	−2	−2	0
0.008	5	30	40	40	39	165	70	90	+7	−25	−4
0.010	Indefinitely		48	60		130	50	40			
0.010	Indefinitely		42	60		130	80	70	−3	+7	0
0.010	Sacrificed		52	56	57	170	40	35	−4	−5	−1
0.010	Sacrificed		44	44	44	90	35	35	+2	+2	+2
0.010	Sacrificed		50	53	56	170	100	95			
0.010	2	28	62	69	69	180	55	35	+15	+25	−2
Seven dogs with Nembutal and larger dose of adrenalin											
0.011(112″)	1	30	45	53	53	140	50	Died	+7		
0.020 (40″)	0	40	49	63	63						
0.025	6	Sacrif.	42	56	56	150	70	60			
0.028 (95″)	2	45	38	46	45	145	80	40			
0.023(114″)	3	3	32	52	49	140	30	20			
0.029	1	0	44	50	50	130	Died		+5	+23	+3
0.011 (90″)	1	33	44	53	53	150	Died				
Five dogs with heat applied after adrenalin injection											
0.010	2	5	53	63	63	140	70	55			
0.010	2	15	46	53	53	120	55	70			
0.011(45″)*	1	2	54	63	53	115	Died		+19	+17	+2
0.015(80″)*	1	28	48	55	55	140	Died		−3	+12	+4
0.017*	0	36	43	53	53	170	Died		+22	+10	0
Three dogs with Nembutal. Cold applied after adrenalin injection											
0.010	5	7	39	50	52	150	48	36	+1	+18	−1
0.018(114″)	1	54	52	64	64	120	Died		+1	+9	−1
0.014	0	38	55	65	65	90	Died		+1	+22	−1

* Nembutal anesthesia given.

TABLE II

Percentage of water in the tissues taken from normal animals and from animals in adrenalin shock

The figures in parentheses represent the number of animals. The Fisher "t test" was employed for the statistical analysis of the data.

	Heart	Liver	Spleen	Bone	Testicle	Intestine	Chest muscle	Lung	Kidney	Leg muscle	Skin	Brain
Normal	78.1(12)	73.9(14)	77.6(14)	34.5(3)	84.5(4)	79.2(14)	74.1(13)	79.9(12)	81.4(15)	76.9(7)	59.4(13)	80.1(6)
Adrenalin shock	81.6(22)	75.6(22)	78.7(20)	40.7(3)	85.1(3)	79.5(20)	72.5(21)	78.8(21)	80.2(20)	76.0(9)	55.5(19)	76.7(3)
Difference	+3.5	+1.7	+1.1	+6.2	+0.6	+0.3	−1.6	−1.1	−1.2	−0.9	−3.9	−3.4
Statistically significant ($P \leq 0.05$)	+	+	+	−	−	−	+	−	+	−	−	−

injection are included here. There is an initial rise in the blood pressure when the adrenalin injection is started which is followed by a marked fall. In general, the drop in blood pressure continues until the animal expires. Similar patterns have been reported (5, 2) in arterial blood pressure as a result of sufficiently large doses of adrenalin.

Spectrographic analysis of serum potassium and sodium showed no consistent variation, while serum magnesium showed an average increase of 17 per cent in the 11 anesthetized animals examined. This has been noted as a rather consistent effect of Nembutal in many subsequent experiments and has no relation to adrenalin injection. The latter does not inhibit this effect.

A summary of the data concerning the percentage of water in the tissues in both normal controls and animals subjected to adrenalin shock is given in Table II. Since there was no apparent difference between the animals given Nembutal and those not given anesthesia, they have been grouped together. In the adrenalin experiments, the heart is subjected to an enormous strain, pericardial effusion usually occurs, and histological sections show some edema of the muscle. This evidence of increased fluid in the muscle is substantiated by an average increase of 3.5 per cent over the average normal water percentage determined by wet and dry weights in a rather large series of dogs. This increase in water content of the heart is highly significant when treated statistically. The Fisher "t test" was employed for the statistical analysis of the data, and a P value of 0.05 or less has been considered significant in this work. In the case of the heart, the P value was less than 0.01. By the same method, the liver and spleen show an increased total water content of 1.7 and 1.1 per cent, respectively. These increases are statistically significant. Samples of bone were taken from 3 control dogs and 3 adrenalin-shock dogs, and the average increase was 6.2 per cent in the adrenalin-treated animals. This gain, however, was not significant statistically, and is only suggestive in that the values in the different dogs varied over a rather wide range, and the number of animals studied was small. Of the tissues examined, only the chest muscle and kidney were found to have a significant decrease in water content as a result of adrenalin shock. The data suggest that the brain may lose water, but more animals must be investigated before this can be made certain. The average decrease in water content of skin as a result of adrenalin shock was 3.9 per cent, but this was not significant statistically. No consistent wet and dry weight measurements were obtained on the skin, probably because the amount of adherent fat, hair, and fascia varies widely. The fluid loss or gains as indicated by the water content of the tissues do not suggest that any large shift of water from the circulation has occurred in any one place, but rather that the change must be a diffuse one.

SUMMARY AND CONCLUSIONS

(*1*) Nembutal anesthesia results in a generalized parallel fall in the subcutaneous, intramuscular, and rectal temperatures of the dog.

(*2*) Injection of adrenalin under the conditions described has no effect on the rectal temperature. The peripheral muscle temperature drop is accentuated.

(*3*) On the basis of survival time, Nembutal anesthesia appears to have a deleterious effect in adrenalin shock.

(*4*) Applications of heat to the 4 extremities, in attempt to raise the peripheral temperatures to normal, did not result in a beneficial effect in adrenalin shock.

(5) In general, the hematocrit was elevated as a result of the injection of adrenalin.

(6) The initial rise in arterial blood pressure when the adrenalin injection is begun is followed by a fall which continues fairly steadily until the animal succumbs.

(7) The most significant finding in the change in percentage of water in the tissues as a result of adrenalin shock was an increase in water content of the heart. Pericardial effusion usually occurs, and edema of the heart was also demonstrated histologically. The quantity of water involved is of no significance to the total water balance.

(8) The findings indicate that, in this type of shock, there is no specific mobilization of water in the tissues which accounts for the rather frequent finding of a rise in hematocrit (hemoconcentration).

(9) Serum potassium and sodium showed no consistent changes. A rather consistent increase (average of 17 per cent) in serum magnesium was found in those dogs given Nembutal anesthesia and was attributed to the latter.

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