QUANTITATIVE CHANGES IN THE FLUID CONTENT OF THE ORGANS OF RATS IN TRAUMATIC SHOCK BY FREEZING.

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With 2 Tables and 3 Figures in the text.

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One of the typical symptoms of injury shock is the occurrence of local oedema at the place of the injury. This oedema can amount to a very high degree. Thus the question arises whether the loss of this fluid of which the body is deprived by the oedema is not enough in itself to cause death.

BLALOCK (1931), who caused shock in dogs with burns, found an increase in weight in the burnt members ranging from 4.1—5.1% of the body weight. PARSON and PHEMISTER (1930) reach the same conclusion. WILSON and ROOME (1934) showed an increase in the injured leg of 3.54% of the body weight. HOLT and MACDONALD (1940) found a 4% fluid loss. CULLEN and FREEMAN (1941) found that when animals' rear extremities are traumatized the weight of the injured member increases by 4.6% of the total body weight. In their opinion this oedema (i. e., the loss of fluid in the organism in connection with the oedema in the injured extremity) is sufficient to cause the death of the animal. NICKERSON (1945) found an average 4.1% increase in weight in injured limbs of dogs. KOLETSKY and GUSTAFSON (1946) found a loss of fluid amounting to 4.8% of the body weight in the injured extremities of rats in tourniquet shock. According to SCOTT'S (1946) observations there is no relation between the frequency of shock mortality and the increase in weight of the injured member. According to WANG et al. (1947), the loss of blood alone cannot account for the high mortality rate in traumatized dogs.

The oedematous fluid occurring in the injured area derives from the fluid content of the blood plasma, with a corresponding thickening of the blood (BROOKS, 1938, WOOD, 1941, FUHRMANN, 1947). Yet the blood does not thicken to an extent corresponding to the amount of oedema in the injured area (O'SHAUGNESSY, 1935, SLOME, 1938). It is therefore beyond doubt that a decrease in the fluid content of the different tissues of the organism must take place simultaneously with the increase in oedematous fluid in the injured area.

In deciding whether the oedema, or loss of fluid can be the cause of death it is not sufficient merely to determine the amount of oedematous fluid, as what we wish to ascertain through our experiments is quite as important, namely:

a.) What organs lose fluid at the time of increase in the fluid content of the injured tissues?

b) To what extent the increase in fluid in the injured area and the local loss of fluid in the different organs could be the direct cause of death from shock.

METHODS.

The experiments were carried out on male rats of 234.7 ± 14.5 g. The animals fasted for 24 hours before the experiment. In 10 animals shock was induced, under ether narcosis, by dipping both hind extremities into liquid air (CSÁKY & MAGYARY-KOSSA, 1947). The animals died 3—8 hours after this treatment with symptoms of injury shock, and were immediately dissected. The different organs were weighed immediately after removal, and again after drying at 110° C to constant weight. Determinations of fluid content were made of the following organs: brain, lungs, liver, kidneys, spleen, heart, blood, gastro-intestinal tract (the content from the pylorus to the rectum together), both hind extremities (which we cut off at the thigh joint, examining the limbs in their entirety). The remaining parts of the dismembered animals were examined in one mass under the designation corpus.

Similar determinations were made of the fluid content of the same organs of 10 230 ± 13.8 g rats raised on the same diet and kept fasting for 24 hours before the experiments. There was no significant difference in the body weights of the two groups — k = 0.288.

EXPERIMENTAL RESULTS.

Figure 1 summarizes the changes in the average weight of the different organs measured. Figure 2 in dry substance and Figure 3 fluid content, of frozen and normal rats, in gs. The lungs, liver, gastro-intestinal tract and heart lost weight; there was an increase only in the frozen hind extremities. Only the liver and heart lost substantially in dry material, the lungs, liver, gastro-intestinal tract and heart in fluid content, while the fluid content increased only in the oedematous hind quarters.

Table I. shows the dry material and the fluid content of the organs of the two groups of animals and the differences between them in %. From the significance of difference it appears certain that the fluid content of the brain, spleen and corpus in the animals in shock did not differ from the normal; it diminished in the lungs, liver, intestinal tract, heart and blood of the animals in shock, while it increased in the injured limbs.

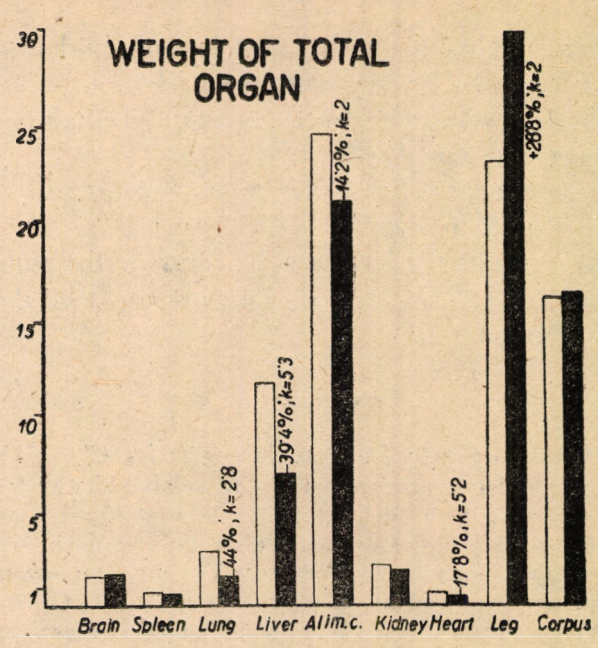

Figure 1. Total weight in gs of organs of rats, normal and in shock. The numbers above the columns give the difference, in %, and the significance of difference (k) between the two groups. In the Figure the corpus is reduced 1:10. By alim. can is meant the gastro intestinal tract from the oesophagus to the rectum.

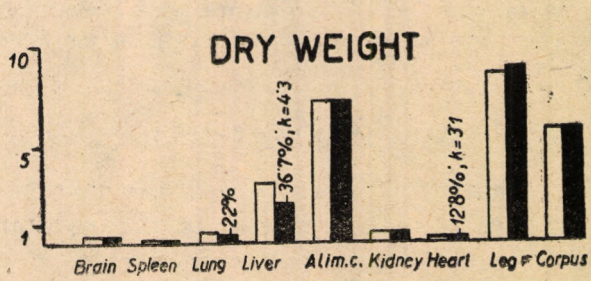

Figure 2. Dry weight. Explanation as in Figure 1.

The data in Table II give more detailed information concerning the amount of fluid loss. The first column shows the average loss or gain in fluid, in gs, in the organs of the animals in shock as compared with the controls. Columns 2 and 3 give the percentage which the changes in fluid content of the different organs in shock bear to the weight and fluid content respectively of the normal organ. Column 4 shows in % how the different organs participate in the total fluid loss (10.44 g), and what % of this fell to the frozen members.

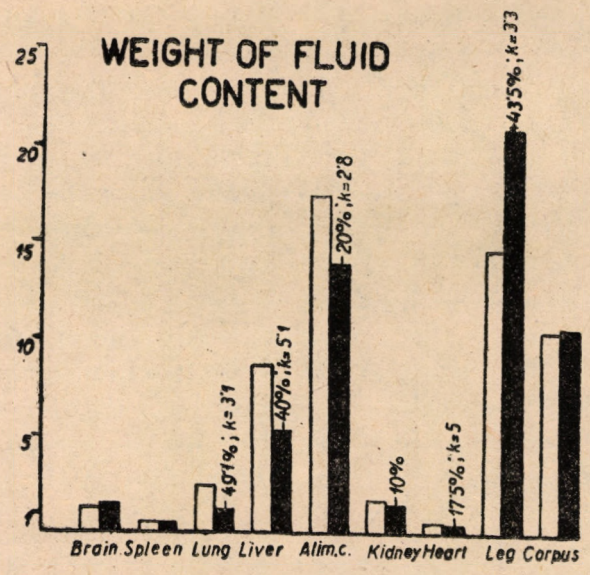

Figure 3. Weight of fluid content. Explanation as in Figure 1.

TABLE I.

Fluid content of organs of rats, normal and in shock, in %.

Organ	Normal %	In Shock %	Difference	Sig. diff.
Brain	78.1	78.4	+ 0.3	+ 0.48
Spleen	75.2	74.3	— 0.9	— 0.69
Corpus	64.9	66.0	— 1.1	— 0.71
Lungs	81.4	74.6	— 6.8	— 4.83
Liver	74.2	73.2	— 1.0	— 2.3
Abdomen	71.9	66.1	— 5.9	— 2.42
Kidneys	77.2	74.8	— 2.4	— 1.84
Heart	78.7	70.8	— 7.9	— 12.3
Legs	62.9	70.8	+ 7.9	+ 7.75
Blood	78.7	75.7	— 3.0	10.8

From Table II, column 1 it is seen that the total fluid loss (10.44 g) is greater than the fluid accumulated in the frozen limbs.

In columns 2 and 3 of this Table appear the changes in fluid content of the lungs, liver and injured extremities. The lungs of the animals in shock lose almost half (49.1%) their normal fluid content, more than a third of their total weight. In shock the liver loses 40% of its fluid, 30% of its total weight. In the intestinal tract, heart muscle and blood the difference is slighter. Two-thirds of the total fluid loss is equal to the sum of the fluid loss of the liver and alimentary canal. There is an increase in fluid content in the injured limbs of 43.4%. This is 27.4% of the normal weight of the two hind limbs.

It can be seen from column 4 of Table II that the injured limbs retain 61.2% of the total fluid lost. This loss is greatest in the liver (33.9%) and gastro-intestinal tract (33.9%), less in the corpus (18%) and lungs (11%).

TABLE II.

Changes in fluid content, in the whole organism and in the different organs.

Organ	Fluid loss, or gain, in gs.	Fluid loss, or gain, as % of total organ		% to which different organs participate in total fluid loss
		Weight	Fluid content	
Brain	+0.06	3.59	4.61	+0.57
Spleen	—0.03	3.89	5.08	—0.28
Corpus	—1.88	1.15	1.78	—18.0
Lungs	—1.18	40.0	49.1	—11.3
Liver	—3.54	30.05	40.4	—33.9
Intes. tract	—3.54	14.3	20.2	—33.9
Kidneys	—0.17	7.09	10.1	—1.62
Heart	—0.10	13.6	17.5	—0.96
Limbs	+6.39	27.4	43.4	+61.2
Total loss	—10.44			
Total surplus	+6.45			
Difference	—3.99			

The mean value of the animals' body weight before freezing was 234.7 g; after death due to shock, 229.2 g. The 5.5 g difference is lost through urination and faeces, and through the skin and lungs as well. The total fluid lost from the organs is 3.99 gs more than the fluid increase in the injured limbs. This difference is the fluid loss of the entire organism during shock (6—8 hours).

To determine what % of the fluid loss in the lungs is due to the blood in them we proceeded as follows: The two hind limbs of 35 rats weighing 280 gs, which had been kept fasting for 36 hours, were frozen in the way described above. Directly death took place, we opened the chest, and attached a cannula in the pulmonary artery and removed the lungs. We washed off the outside blood, then slowly injected 5 ml physiological NaCl to wash the blood out of the lungs. The lungs then became completely white. We added 15 ml HCl solution to the blood and salt solution flowing from the vv pulmonary, so that the 20 ml finally obtained corresponded to 0.1 n HCl. After a wait of 5 minutes we determined the haemoglobin content in 2 ml of the solution with a Zeiss-Ikon haemometer. Parallel with this we also made Hb and haematocrite determinations of the blood.

The same thing was performed on 20 male rats of 277 g weight, fasted for 36 hours, 10 of which were killed by a blow at the back of the neck, 10 with lighting gas. No difference was found in the determinations due to the modes of death.

These experiments show that the Hb content of the lungs is the same in shock animals as in normal ones.

There is a rise in the Hb value of the blood in shock. It rises from 90.3 ± 2.4 to 122.1 ± 1.5, an increase of 35%. S. D. = 11.3.

The haematocrite values rose from the normal 44.7 ± 1.2 to $63.4 \pm 0.8\%$, an increase in corpuscular elements of 41.8%.

From these results it is apparent that the lungs lose no blood. The fluid loss from the lungs through the blood is no more than the blood itself loses. The blood content of the lungs can be calculated from the Hb value to be 0.4 ml normally, and in shock 0,5 ml, hence of the total fluid loss from the lungs (1.18 gs), only one-fourth, 0.08 g, belongs to blood fluid loss from the lungs.

DISCUSSION.

It should be mentioned that the symptoms of shock caused by freezing with liquid air are identical with those of traumatic shock. The increase in weight of the injured limbs is 2.91% of the total body weight (4.37% of the fluid content.). This

value is only very slightly lower than BLALOCK's (3.34%), CULLEN and FREEMAN's (4.6%) and NICKERSON's (4.1%).

It is also apparent from the experiments described that the fluid flowing to the injured place does not derive exclusively from the blood plasma, but that, simultaneously with the increase in fluid in the injured member, there is a decrease in the fluid in the different organs.

But the different organs do not share equally in this fluid loss, as we show in detail in the experiments.

It is especially emphasized that the fluid content of the brain and the spleen are exactly the same in normal and in shock animals. Practically speaking there is also very little fluid loss in the kidneys and corpus.

The most significant change is the decrease in the fluid content of the lungs. The lungs of normal animals are 81% fluid, those of shock animals 74.6%. This reduction is 41.3% of the total weight of the lungs, and 49.1% of the total fluid content. It is interesting that some authors (DUBOIS, 1945) found that the principal cause of disturbed 0_2 metabolism in rabbits in shock was oedema of the lungs.

There was also an important decrease in fluid content in the liver, heart and intestinal tract as well as in the lungs.

Of especial interest is the fact that in the lungs and intestinal tract there is a loss only of fluid, while in the liver and heart there is also a significant loss in dry material. But the increased weight in the limbs frozen with liquid air consists only of oedematous liquid.

Lastly, we consider it worthy of mention that the increase in fluid content of the injured member was less than the total fluid loss of the various organs. This difference could occur from loss of water under shock from urination and fluid-evaporation in the lungs (given 6—8 hours to develop).

Our experiments give a quantitative picture, which can be evaluated statistically, of the organs of rats after freezing the extremities with liquid air. Whether such extensive changes in the fluid content of the different organs can themselves cause death from shock is not decided by these experiments. Investigations in this connection will be dealt with in a subsequent paper.

SUMMARY.

After freezing rats in both hind extremities with liquid air, investigation was made of changes which took place in the weight, dry material and fluid content of the organs.

1. There was a loss in the total weight of the lungs (44%), liver (39.4%), gastro-intestinal tract (14.2%) and heart muscle (17.8%), and an increase in weight only in the injured limbs (of 28.8%). The weight of the brain, spleen, kidneys and corpus remained unchanged.

2. In dry material the liver lost 36.7% and the heart 12.8%.

3. Greatest loss of fluid content was in the lungs (49.1%) and liver (40%); less in the gastro-intestinal tract (20%) and heart (17.5%). There was no change whatsoever in fluid content of the brain and spleen. The fluid content of the frozen limbs was 27.4% of the original weight, 43.4% of the original fluid content.

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