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J Clin Invest. 1930;9(2):191-196. https://doi.org/10.1172/JCI100297.

STUDIES IN CONGESTIVE HEART FAILURE

V. The Potassium Content of Skeletal Muscle Obtained by Biopsy

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(Received for publication May 7, 1930)

As a result of their studies of the respiratory exchange of decompensated cardiac patients during and after exercise, Eppinger, Kisch and Schwarz (1927) concluded that the buffering power of the tissues was diminished. Laszlo (1928) found diminished phosphate content of the cardiac and skeletal muscle of such individuals. Harrison and Pilcher determined oxygen utilization during various degrees of edema (1930a) and oxygen debt in patients with congestive heart failure (1930b). In both studies the findings were believed to be indicative of diminished alkaline reserve in the muscles. Observations by Pilcher, Clarke and Harrison (1930) of the hydrogen ion concentration of the blood of patients with congestive heart failure after exercise lead to the same conclusion. In order to obtain more direct data on this point it was thought advisable to investigate the chemical changes in the tissues themselves. As potassium is the most abundant basic element in muscle tissue it seemed wise to study it first. Harrison, Pilcher and Ewing (1930) analyzed samples of cardiac and skeletal muscle obtained from patients who had died of congestive heart failure and found them to be abnormally poor in potassium. It seemed conceivable that such a phenomenon might be related to changes after death and consequently, before proceeding further with our studies on *postmortem* tissues, it was deemed wise to analyze tissues obtained during life. Such a procedure had the additional advantage of allowing us to make more than one observation on the same patient and hence to follow changes in potassium content under various conditions.

METHODS

Patients with various types of cardiac disease were chosen. All of them had or had had edema. Specimens of gastrocnemius muscle weighing one to two grams were removed under novocaine anesthesia with aseptic technique. Care was taken to infiltrate the anesthetic around, rather than in, the portion of muscle to be removed. The fresh muscle was weighed, dried to constant weight in an oven at one hundred to one hundred ten degrees Centigrade and then analyzed according to the technique used by Harrison, Pilcher and Ewing. Results obtained by this procedure have been found to be in fair agreement with those arrived at by a slower and somewhat more accurate method which will be published later.

Three patients were studied before and after the loss of edema. Single observations were made on one cardiac patient and on one individual with edema of renal origin. Investigations were carried out on five patients before and at intervals after the administration of potassium dibasic phosphate. This salt was given because Laszlo had found diminished phosphate and our analyses showed decreased potassium.

Edema was classified by the degree and extent of "pitting." An attempt was made to determine the length of time edema of the calves of the leg had been present but our figures in this regard represent only rough approximations.

RESULTS

Normal skeletal muscle contains about 25 to 28 per cent solids. The potassium content of dried muscle is approximately 1.2 to 1.5 per cent, and that of "wet" muscle is usually in the range of 0.26 to 0.38 per cent (Lematte, Boinot, and Kahane (1928); Norn (1929); Harrison, Pilcher and Ewing (1930)).

As can be seen from table 1, the percentage of solids was diminished in all of the subjects. The potassium content of the "wet" muscle was also invariably low. Dilution due to edema was one factor in this decrease. In some cases such as E. B. and H. C. a dilution with serum containing 8 per cent protein could explain the values found. In M. H. and T. R. the amounts of protein which would have had to

be present is impossibly high. Since, however, the edema fluid of cardiac failure contains a negligible amount of protein (Hass), it seems improbable that such dilution can account for the low values obtained. In subjects T. R. and M. H. loss of edema was followed by a rise in the potassium content of the dry muscle. E. G. and H. C. had, when edematous, normal amounts of potassium in their dry muscle. In this regard it may be of some significance that their edema was of relatively short duration, whereas, the other subjects who exhibited a

TABLE 1

The potassium content of the gastrocnemius muscle of patients with congestive heart failure

Subject	Etiological diagnosis	Date	Solids	Potassium in dry muscle	Potassium in wet muscle	Degree of edema	Duration of edema
		1929	*per cent*	*per cent*	*per cent*		
E. B.	Hypertension, auricular fibrillation	August 29	16.0	0.86	0.138	+	3 months
T. R.	Syphilis, aortic insufficiency, hypertension	August 26	20.2	1.03	0.207	+	2 months
		October 24	21.0	1.18	0.251	±	
M. H.	Arteriosclerosis, hypertension	September 21	13.8	0.88	0.121	+++	5 months
		October 2	18.3	1.60	0.295	0	
E. G.	Syphilis, aortic insufficiency	October 10	14.4	1.39	0.200	+++	2 weeks
		October 22	27.1	1.11	0.300	0	
H. C.	Nephrosis, no cardiac disease	July 31	16.3	1.21	0.201	++	3 weeks

diminished potassium content of the dried muscle had had edema for longer periods. E. G. had a higher potassium content of the dry muscle when edematous than when free of edema twelve days later.

These findings demonstrate that muscles as well as subcutaneous tissues become edematous in patients with congestive heart failure. They also suggest that the first effect of edema is that of simple dilution and that a later effect is actual loss of potassium from the muscle.

In table 2 are presented analyses on five patients before and after receiving potassium dibasic phosphate. In all of them the potassium

TABLE 2

The potassium content of gastrocnemius muscle of patients with congestive heart failure before and after the administration of potassium dibasic phosphate

Subject	Etiological diagnosis	Date	Solids	Potassium in dry muscle	Potassium in wet muscle	Degree of edema	Remarks
		1929	*per cent*	*per cent*	*per cent*		
T. P.	Syphilis, aortic insufficiency, angina pectoris	June 4	19.4	0.69	0.135	+	Before receiving K_2HPO_4
		July 3	18.2	0.92	0.167	0	After receiving K_2HPO_4 6 grams daily for four weeks
G. H.	Hypertension	July 10	20.2	1.06	0.213	±	Before receiving K_2HPO_4
		July 28	19.5	1.48	0.288	±	After receiving K_2HPO_4 14 grams daily for two weeks
F. J.	Asthma, chronic bronchitis	June 18	19.8	0.96	0.190	+	Before receiving K_2HPO_4
		July 31	18.0	1.28	0.231	+	After receiving 6 grams daily for 5 weeks
		October 14	21.6	1.20	0.260	±	After receiving K_2HPO_4 6 grams daily for fifteen weeks
J. A.	Hypertension, arteriosclerosis, auricular fibrillation	August 23	16.6	0.85	0.142	+++	Before receiving K_2HPO_4
		September 23	21.5	1.11	0.240	0	After receiving K_2HPO_4 6 grams daily for four weeks
H. M.	Rheumatic heart disease, mitral stenosis, aortic insufficiency	October 24	23.8	1.16	0.274	0	Before receiving K_2HPO_4
		December 6	19.9	1.73	0.345	±	After receiving K_2HPO_4 6 grams daily for six weeks

content of the wet and dry muscle was greater after the salt had been administered. One of the subjects (J. A.) had marked edema at the time the first piece of muscle was taken and no edema when the second specimen was removed. T. P. had slight pitting at the time of the control analysis and no edema later. In their cases the rise in the potassium content might conceivably have been due to loss of edema. However, such an explanation does not hold in the other three cases for they had no less edema at the time of the second analysis.

In only one of the five cases (J. A.) was the water content of the muscles much greater before potassium was given than after it had been administered. Consequently, loss of edema could not have been the cause of the rise in potassium content observed. Although it is conceivable that the changes observed might have occurred spontaneously, it seems more likely that they were related to the administration of the salt.

Another point of interest can be observed in both tables 1 and 2. Even though there was no clinical sign of edema, i.e., no pitting, subjects who had once had edema usually continued to have abnormally low total solid content in their *gastrocnemii*. Four of the five subjects studied had distinctly low muscle solids when entirely free of pitting.

SUMMARY AND CONCLUSIONS

1. The water content of pieces of gastrocnemius muscle removed by biopsy from patients with cardiac edema was invariably increased. The percentage of solids was correspondingly decreased. These changes usually persisted after clinical signs of edema had disappeared.

2. The potassium content of the wet muscle from edematous patients was invariably abnormally low. The amount of potassium in the dry muscle was usually but not always diminished. As edema decreased the potassium content of the wet muscle rose in three subjects; that of the dry muscle increased in two of them.

3. The administration of potassium dibasic phosphate was followed by a rise in the potassium content of the muscle.

4. The findings reported in the previous paper of this series, were not due to postmortem changes.

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