STUDIES IN CONGESTIVE HEART FAILURE

VIII. The Effect of the Administration of Dibasic Potassium Phosphate on the Potassium Content of Certain Tissues[1]

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Previous investigations have shown that the potassium contents of both the skeletal and the cardiac muscle of patients dying of congestive heart failure were diminished (Harrison, Pilcher and Ewing, 1930). Analyses of tissue obtained by biopsy indicated that edema was probably the cause of the loss of potassium from the skeletal muscle (Pilcher, Calhoun, Cullen and Harrison, 1930). Studies on hearts of subjects dying under various conditions led to the belief that overwork was probably responsible for the loss of potassium from the cardiac muscle (Calhoun, Cullen, Clarke and Harrison, 1930). In order to determine whether or not this chemical change is irreversible the observations described in this paper were carried out.

METHOD

According to the technique described in our previous publications tissues were obtained at the postmortem table and were analyzed for potassium and for total solids. Specimens were obtained from the heart and from the gastrocnemius muscle in all the cases. In some instances portions of the liver and kidney were also analyzed.

The potassium content and total solids were determined in tissue from three classes of patients, (1) patients with heart disease who had never received potassium, (2) patients with heart disease who had

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received potassium, (3) a control group of patients without heart disease and whose hearts appeared normal at autopsy.

In the series of patients who died of heart disease there were fourteen individuals with clinical and pathological evidence of failure of both ventricles, i.e., both systemic and pulmonary congestion. All of these subjects had had some pitting edema in the past, and in many edema had been massive. Seven of these subjects had been treated in the usual way and had not received potassium salts. The other seven subjects had had the usual treatment and had also taken potassium dibasic phosphate by mouth for varying periods of time. (This salt of potassium was chosen because Laszlo (1928) found decreased phosphate content of the skeletal and cardiac muscle in patients with cardiac disease.) Five of them received this salt in doses of six grams daily. One patient was given twice as much. The seventh individual took potassium iodide for six months and potassium dibasic phosphate for two weeks. The length of time during which potassium salts were administered to each subject is given in the tables.

Complete data concerning the clinical state of these patients who were given potassium phosphate will be presented in a later paper.

RESULTS

The values for total solids and for potassium obtained in this study are presented in tables 1 to 5, each table reporting the value of all three groups of cases for one type of tissue. The average values for the entire series are summarized in table 6. The data for potassium in dry tissue is presented graphically in figure 1. In the tables, the potassium values are given for both "dry" and "wet" muscle, but figure 1 presents only the values for "dry" muscle since a similar chart based on "wet" muscle gives entirely comparable results. In the discussion of potassium contents of the various tissues the percentage for "dry" muscle is used throughout.

TABLE 1

The solids and potassium content of skeletal muscle

Subject	Chief diagnosis	Solids	Potassium in dry tissue	Potassium in wet tissue	Daily dose of K_2HPO_4	Duration of administration of potassium	Remarks
		per cent	*per cent*	*per cent*	*grams*	*weeks*	
W. S.	Acute peritonitis	24.3	1.36	0.337	0	0	No cardiac disease
E. A.	Lymphosarcoma	22.2	1.39	0.309	0	0	
R. D.	Brain tumor	27.1	1.14	0.308	0	0	
O. F.	Pulmonary tuberculosis	25.6	1.50	0.387	0	0	
J. F.	Syphilitic myocarditis	17.9	0.87	0.156	0	0	Cardiac failure; never received potassium dibasic phosphate
J. J.	Syphilitic aortic insufficiency	19.8	0.79	0.157	0	0	
J. B.	Chronic nephritic hypertension	25.1	1.18	0.297	0	0	
E. R.	Cardiac hypertrophy	17.7	0.78	0.138	0	0	
J. R.	Hypertension	18.5	0.86	0.155	0	0	
F. H.	Hypertension	26.9	0.99	0.266	0	0	
E. H.	Mitral stenosis	16.3	1.39	0.227	0	0	
G. H.	Hypertension	19.5	1.48	0.288	12	2.5	Cardiac failure; received potassium dibasic phosphate
J. C.	Syphilitic aortic insufficiency	21.9	0.81	0.177	6	5.0	
H. M.	Mitral stenosis	17.9	1.65	0.297	6	6.3	
B. P.	Hypertension	30.2	1.20	0.363	6	28.7	
A. D.	Hypertension	27.0	1.20	0.324	6	42.3	
A. A.	Coronary arteriosclerosis	17.6	1.26	0.222	6	55.3	

TABLE 2

The solids and potassium content of right ventricle

Subject	Chief diagnosis	Solids	Potassium in dry tissue	Potassium in wet tissue	Daily dose of K_2HPO_4	Duration of administration of potassium	Remarks
		per cent	*per cent*	*per cent*	*grams*	*weeks*	
E. A.	Lymphosarcoma	18.6	1.40	0.262	0	0	No cardiac disease
R. D.	Brain tumor	20.5	1.30	0.267	0	0	
J. S.	Carcinoma of esophagus	21.0	1.21	0.254	0	0	
J. F.	Syphilitic myocarditis	19.6	1.10	0.216	0	0	Cardiac failure; never received potassium dibasic phosphate
J. J.	Syphilitic aortic insufficiency	18.7	0.95	0.177	0	0	
J. B.	Chronic nephritic hypertension	18.5	0.94	0.172	0	0	
E. R.	Cardiac hypertrophy	17.5	0.97	0.170	0	0	
F. H.	Hypertension	18.6	0.95	0.177	0	0	
J. R.	Hypertension	19.9	0.85	0.148	0	0	
E. H.	Mitral stenosis	18.3	1.13	0.206	0	0	
G. H.	Hypertension	17.6	0.95	0.168	12	2.5	Cardiac failure; received potassium dibasic phosphate
H. M.	Mitral stenosis	19.2	1.12	0.215	6	6.3	
F. D.	Syphilitic aortic insufficiency	17.6	1.00	0.176	6	22.0	
B. P.	Hypertension	20.3	1.12	0.228	6	28.7	
A. D.	Hypertension	18.6	1.03	0.192	6	42.3	
A. A.	Coronary arteriosclerosis	17.5	0.92	0.161	6	55.3	

TABLE 3

The solids and potassium content of left ventricle

Subject	Chief diagnosis	Solids	Potassium in dry tissue	Potassium in wet tissue	Daily dose of K_2HPO_4	Duration of administration of potassium	Remarks
		per cent	*per cent*	*per cent*	*grams*	*weeks*	
E. A.	Lymphosarcoma	22.4	1.29	0.289	0	0	No cardiac disease
R. D.	Brain tumor	23.0	1.19	0.274	0	0	
J. S.	Carcinoma of esophagus	19.9	1.47	0.292	0	0	
J. F.	Syphilitic myocarditis	19.5	1.02	0.200	0	0	Cardiac failure; never received potassium dibasic phosphate
J. J.	Syphilitic aortic insufficiency	20.4	0.98	0.199	0	0	
J. B.	Chronic nephritic hypertension	19.9	1.02	0.203	0	0	
E. R.	Cardiac hypertrophy	18.6	1.07	0.199	0	0	
F. H.	Hypertension	19.4	0.83	0.162	0	0	
J. R.	Hypertension	19.9	1.10	0.221	0	0	
E. H.	Mitral stenosis	17.6	1.02	0.180	0	0	
G. H.	Hypertension	19.9	1.05	0.208	12	2.5	Cardiac failure; received potassium dibasic phosphate
J. C.	Syphilitic aortic insufficiency	19.2	1.12	0.215	6	5.0	
H. M.	Mitral stenosis	21.6	1.05	0.227	6	6.3	
F. D.	Syphilitic aortic insufficiency	19.3	1.16	0.224	6	22.0	
B. P.	Hypertension	22.0	1.24	0.274	6	28.7	
A. D.	Hypertension	18.4	1.12	0.206	6	42.3	
A. A.	Coronary arteriosclerosis	18.4	0.96	0.177	6	55.3	

TABLE 4

The solids and potassium content of liver

Subject	Chief diagnosis	Solids	Potassium in dry tissue	Potassium in wet tissue	Daily dose of K_2HPO_4	Duration of administration of potassium	Remarks
		per cent	*per cent*	*per cent*	*grams*	*weeks*	
E. A.	Lymphosarcoma	20.3	1.20	0.244	0	0	No cardiac disease
J. D.	Carcinoma of gallgladder	23.1	1.07	0.248	0	0	
J. F.	Syphilitic myocarditis	25.2	0.69	0.174	0	0	Cardiac failure; never received potassium dibasic phosphate
J. J.	Syphilitic aortic insufficiency	20.7	0.72	0.148	0	0	
J. B.	Chronic nephritic hypertension	21.5	0.80	0.173	0	0	
E. R.	Cardiac hypertrophy	18.1	1.11	0.201	0	0	
G. H.	Hypertension	20.5	0.77	0.158	12	2.5	Cardiac failure; received potassium dibasic phosphate
J. C.	Syphilitic aortic insufficiency	22.2	0.88	0.196	6	5.0	
H. M.	Mitral stenosis	21.7	0.72	0.155	6	6.3	
F. D.	Syphilitic aortic insufficiency	22.2	0.86	0.191	6	22.0	
B. P.	Hypertension	25.0	1.18	0.296	6	28.7	
A. D.	Hypertension	23.1	1.06	0.244	6	42.3	
A. A.	Coronary arteriosclerosis	23.0	1.27	0.291	6	55.3	

TABLE 5

The solids and potassium content of the kidney

Subject	Chief diagnosis	Solids	Potassium in dry tissue	Potassium in wet tissue	Daily dose of K_2HPO_4	Duration of administration of potassium	Remarks
		per cent	*per cent*	*per cent*	*grams*	*weeks*	
W. S.	Acute peritonitis	19.3	1.13	0.215	0	0	No cardiac disease
E. A.	Lymphosarcoma	16.6	1.76	0.292	0	0	
E. H.	Eclampsia	17.5	1.20	0.208	0	0	
J. D.	Carcinoma of gallbladder	20.4	0.83	0.170	0	0	
J. F.	Syphilitic myocarditis	16.6	0.68	0.114	0	0	Cardiac failure; received no potassium dibasic phosphate
J. J.	Syphilitic aortic insufficiency	17.8	1.00	0.178	0	0	
J. B.	Chronic nephritic hypertension	17.0	0.91	0.154	0	0	
E. R.	Cardiac hypertrophy	14.2	0.88	0.125	0	0	
G. H.	Hypertension	15.4	0.87	0.135	12	2.5	Cardiac failure; received potassium dibasic phosphate
J. C.	Syphilitic aortic insufficiency	17.2	0.99	0.170	6	5.0	
H. M.	Mitral stenosis	18.2	0.89	0.163	6	6.3	
F. D.	Syphilitic aortic insufficiency	15.3	0.91	0.144	6	22.0	
B. P.	Hypertension	18.7	1.13	0.212	6	28.7	
A. D.	Hypertension	16.1	1.09	0.176	6	42.3	
A. A.	Coronary arteriosclerosis	13.3	0.97	0.129	6	55.3	

TABLE 6

Average values for the solids and potassium content

Tissue	Solids			Potassium in dry tissue			Potassium in wet tissue		
	Subjects without cardiac disease	Subjects with cardiac failure, not receiving K_2HPO_4	Subjects with cardiac failure, receiving K_2HPO_4	Subjects without cardiac fatigue	Subjects with cardiac disease not receiving K_2HPO_4	Subjects with cardiac disease receiving K_2HPO_4	Subjects without cardiac disease	Subjects with cardiac disease not receiving K_2HPO_4	Subjects with cardiac disease receiving K_2HPO_4
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Skeletal muscle.....	24.8	20.3	22.4	1.35	0.98	1.26	0.335	0.199	0.297
Right ventricle.....	20.0	18.8	18.5	1.30	0.98	1.02	0.261	0.181	0.190
Left ventricle.....	21.8	19.3	19.8	1.32	1.01	1.10	0.285	0.195	0.219
Liver.....	21.7	21.4	22.5	1.13	0.83	0.96	0.246	0.174	0.219
Kidney.....	18.4	16.4	16.3	1.23	0.87	0.96	0.221	0.143	0.161

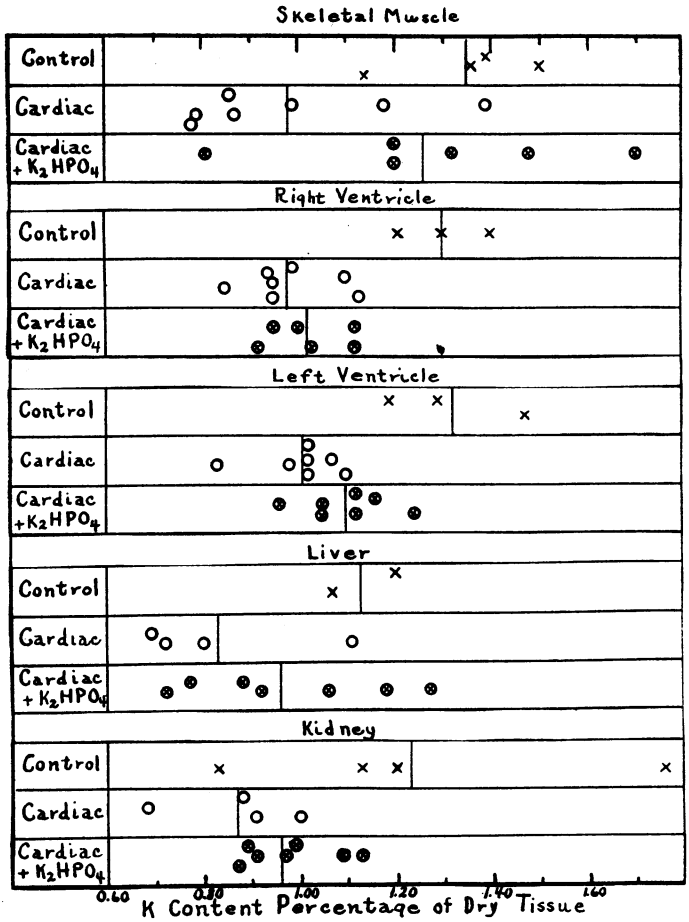

FIG. 1. POTASSIUM CONTENT IN DRY TISSUE
Vertical lines indicate average value for each type of tissue

DISCUSSION

Skeletal Muscle

Total solids. In the control subjects the percentage of total solids varied between 22.2 and 27.1 per cent with an average of 24.8 per cent. Most of the subjects with cardiac disease had lower solids, although three of them had values within, and one had a value above the control range. The average values for solids were higher in the subjects who did than in those who did not receive potassium phosphate but were below the controls in both groups. Two of the subjects (J. R. and M. H.) had had marked edema previously but at the time of death had no "pitting." The water content of their muscles was definitely high, low total solids indicating that moderate edema of the muscles may be present without demonstrable signs. The reverse situation, i.e., a high percentage of total solids in the muscle with "pitting" of the subcutaneous tissues, did not occur in this series. It seems that the presence of "pitting" may usually be interpreted as meaning that the regional muscles as well as the subcutaneous tissues are edematous, but the absence of pitting does not mean that the muscles of the legs are not edematous. When diuresis occurs and all evidence of edema disappears the muscles may (as in J. R. and M. H.) still be rich in water, or (as in F. H. and B. P. both of whom had been edematous in the past) their water content may diminish to normal.

Potassium. Inspection of figure 1 shows definitely that the potassium content of the skeletal muscle of patients with cardiac failure tends to run much lower than in the control. As is to be expected, the range is greater, and in the present series two of the seven cases fall within the control range. Administration of K_2HPO_4, with one exception, restored the potassium content of skeletal muscle to the level of the controls. That this is a restoration of potassium seems most probable since the clinical history, treatment other than K_2HPO_4 administration, and the autopsy findings were similar in the two groups.

Cardiac Muscle

Total solids. The ventricles of the control subjects contained, as an average, about ten per cent more total solids than did those of the patients with cardiac disease. The content of solids in the patients

with heart disease who received potassium was approximately the same as in those who did not.

Potassium. It is evident from Figure 1 that the potassium content of both right and left ventricle is markedly lower in the group of cardiac patients than in the controls. Administration of K_2HPO_4 did not restore the potassium content of the right ventricle, and apparently restored the potassium content of the left ventricle only slightly. This difference between the response of right and left ventricle to K_2HPO_4 treatment is probably too small to be considered significant.

Liver and kidney

Liver. In the majority of instances the potassium content of the liver of the subjects with cardiac disease was less than that of the control subjects. The livers of the patients who received potassium salts had, on the average, about fifteen per cent more potassium in the dry tissue than was found in the cardiac patients who did not receive potassium salts (tables 4 and 6).

Kidney. The findings in the kidneys were extremely variable. The average content of solids was about twelve per cent greater in the control subjects than in those with cardiac disease. The latter subjects usually had considerably less potassium in the wet and dry tissue than did the controls. The kidneys of those subjects who were given potassium salts contained about ten per cent more potassium than did the kidneys of the cardiac patients who were not given potassium (fig. 1).

SUMMARY

The total solid and potassium content of skeletal muscle, of cardiac muscle from both ventricles, and of liver and kidney have been determined in (*a*) subjects dying without cardiac disease; (*b*) individuals dying of congestive cardiac failure, who did not receive potassium salts, and (*c*) patients dying of congestive cardiac failure, who were given potassium dibasic phosphate during life. All the subjects with cardiac disease had had edema, although some of them had none at the time of death.

The organs of the "control" cases contained, as an average, more

potassium in both the wet and dry tissues than was found in the subjects with cardiac disease.

Among the subjects with cardiac disease, the average content of tissue potassium was greater in the subjects who received the potassium salt than in those who did not. The difference was most striking in the skeletal muscle and least marked in the heart.

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