PROCEEDINGS OF THE SOCIETY FOR EXPERIMENTAL BIOLOGY AND MEDICINE **147**, 137–139 (1974)

The Effect of Aortic Coarctation on the Concentrations of Water and Electrolytes in Cardiac Muscle (38297)

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(Introduced by Abraham G. White)

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Arterial concentrations of water and electrolytes are altered in animals suffering from various forms of experimentally induced hypertension (1–3), including hypertension resulting from the administration of deoxycorticosterone, adrenal regeneration, renal artery constriction, and the infusion of Angiotensin II (4).

Since previous studies have suggested that the level of arterial blood pressure may influence water and electrolyte metabolism (5, 6), it seemed of interest to investigate the ionic and water concentrations of heart muscle in experimentally induced aortic coarctation, a condition in which arterial blood pressure is elevated in the segment of the thoracic aorta proximal to the constriction.

The results of the present investigations indicate that elevations of aortic blood pressure increase cardiac concentrations of water and calcium.

Materials and Methods. The thoracic aorta was constricted in seven mongrel dogs under sodium pentobarbital anesthesia (30 mg/kg). During surgery, pulmonary ventilation was maintained by means of an endotracheal tube and a mechanical insufflator. Incision was made anteriorly and laterally along the fifth left intercostal space. The thoracic aorta was constricted by sutures for a distance of about 3 cm, immediately distal to the arch. A Dacron band was drawn around the constricted portion and sutured, without further constriction of the vessel. Approximately 70–80% of the cross-sectional area of the aorta was constricted.

Blood pressure was determined in the forelimbs by the cuff method of Wilson and Clark (7), both preoperatively and postoperatively.

On the day of sacrifice of each animal, 6 weeks after coarctation had been produced, intra-arterial blood pressures were measured, by means of a mercury manometer, in the carotid and femoral arteries, as well as in the thoracic aorta (immediately proximal and distal to the experimental constriction).

Samples of cardiac tissue, 60–80 mg, were obtained under pentobarbital anesthesia (30 mg/kg) from the left ventricle. Similar samples of cardiac tissue were obtained from matched control animals.

All tissue samples were analyzed, in duplicate, for water content and for concentrations of sodium, potassium, chloride, calcium, and magnesium.

Water content and electrolyte concentrations were determined as follows: Pieces of heart tissue were gently blotted on Whatman filter paper No. 50, until dry. Afterwards, the pieces were placed in tared stoppered tubes, and weighed. Water content was determined by drying the tissue overnight at 105°. Thereafter, the samples were extracted for 24 hr at room temperature with 0.2 ml/mg wet wt of modified Cotlove's reagent (8), containing 10% acetic acid, 100 m*M* HNO_3, and 7.5 m*M* $LiSO_4$. Complete extraction was ensured by continuous rotation.

Sodium and potassium concentrations were read directly in an IL internal standard flame photometer, and chloride was titrated in a Buchler–Cotlove chloridometer. Standards were prepared in the aforementioned Cotlove reagent, containing sodium and potassium in approximately the same concentration as those of the sample.

Calcium and magnesium concentrations were determined in a Perkin–Elmer atomic absorption

spectrophotometer. Aliquots of the original samples were diluted 1:5 with deionized water and 1% lanthanum. Standards contained calcium and magnesium in approximately the same concentrations as the samples. They also contained the same concentrations of lanthanum and acetic–nitric–lithium mixture. This procedure has the advantage of permitting the determination of water and electrolytes in the same sample.

Results. Blood pressure. After the coarctation was produced, the cuff systolic blood pressure in the forelegs progressively rose to a hypertensive level by the fourth postoperative day, 186 ± 3.8, as compared with a preoperative value of 120 ± 2.0 mm Hg ($P < 0.001$). On the day of sacrifice, a gradient of 40 mm Hg across the aortic constriction was observed.

Body weight. Body weights averaged 22.4 ± 2.5 kg for control dogs, and 24.1 ± 1.8 kg for dogs with experimental aortic coarctation ($P > 0.4$).

Serum electrolytes. Serum sodium, potassium, and calcium concentrations (mEq/l) were also not significantly altered, averaging: Na, 143 ± 2.1; K, 4.6 ± 0.3; Ca, 2.1 ± 0.08 in the control dogs, and Na, 144 ± 1.1; K, 4.6 ± 0.2; and Ca, 2.2 ± 0.03 in the coarcted dogs ($P > 0.5$).

Electrolyte and water concentrations of left ventricular muscle. The concentrations of sodium, potassium, magnesium, and chloride of heart muscle following experimental aortic coarctation were not significantly different from those in control animals (Table I). In contrast, the concentration of calcium increased significantly to 22.5% above control values, and the concentration of water also increased significantly to 3.9% above control values in the heart muscles of dogs experiencing aortic coarctation.

Discussion. The present demonstration that experimental aortic coarctation does not significantly alter the concentrations of sodium, potassium, and chloride confirms the results of previous studies (9).

Increases in the concentrations of calcium and water following aortic coarctation suggest that elevation of arterial blood pressure may influence the metabolism of calcium and water in ventricular muscle. Mechanisms underlying these observed changes remain unknown.

Increases in the concentrations of calcium and water in left ventricular muscle also have been observed by Tobian and Duke in rats, 11 mo after hypertension had been induced by narrowing one renal artery and removing the opposite kidney (10). These authors speculate that the hypertrophied hypertensive heart may be associated with an increased distance for diffusion of calcium from the extracellular space into the center of the thickened muscle fiber. They suggest the possibility that increased intracellular calcium in the hypertrophied heart may result in increased release of calcium sufficient to compensate for the overlong aforementioned diffusion distances and also to maintain normal contractility or to increase contractility (10).

Finally, presently reported values for calcium (m*M*/kg wet wt) agree with previously reported data (11).

We have previously reported on the calcium and water concentrations of aortic samples taken proximally or distally to the area of experimental aortic coarctation (12). Proximal to the coarctation, the aorta showed an increase in water concentration of 28.2 ± 3.2 ml/kg tissue wet wt over that of the aorta distal to the constriction. However, calcium concentrations of the aorta were

TABLE I. Effect of Aortic Coarctation on the Concentrations of Water and Electrolytes in Left Ventricular Muscle Tissue of Dogs.

Per kg tissue wet wt	Normal[a] ($N=7$)	Coarctation[a] ($N=7$)	P
Na (mEq)	42.5 ± 1.2	46.1 ± 1.7	> 0.1[b]
K (mEq)	80.3 ± 3.8	84.1 ± 3.8	> 0.5[b]
Ca (m*M*)	2.04 ± 0.05	2.5 ± 0.13	< 0.005[c]
Mg (m*M*)	9.8 ± 0.2	8.87 ± 0.5	> 0.2[b]
Cl (mEq)	35.1 ± 1.0	36.6 ± 2.5	> 0.5[b]
H_2O (ml)	745 ± 6	774 ± 5	< 0.005[c]

[a] Mean value ± SEM.

[b] Not significantly different from normal.

[c] Significantly different from normal.

equal on either side of the constriction.

Summary. Experimentally produced aortic coarctation resulted in increased concentrations of calcium and water in cardiac ventricular muscle, but did not alter the ventricular concentrations of sodium, potassium, and chloride.

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Received March 13, 1974. P.S.E.B.M., 1974, Vol. 147.