A THIRD CONTRIBUTION REGARDING THE INFLUENCE OF THE INORGANIC CONSTITUENTS OF THE BLOOD ON THE VENTRICULAR CONTRACTION.

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In a previous communication (*Journal of Physiology*, Vol. IV. No. I.) I showed, that without the presence of a lime salt in the circulating fluid, the contractility of the ventricle cannot be supported. I also showed that lime salts greatly delay diastolic dilatation, and that this effect of a physiological quantity of lime is obviated by a physiological quantity of a potash salt.

I further showed that a solution containing sodium chloride and a lime salt only will not sustain contractility so long as a mixture containing a potash salt in addition. For operating with saline solution and lime only, the characteristic lime effects appear, in about half to three quarters of an hour, i.e. the ventricular contractions grow weak and contractility soon ceases; but if in addition to the saline solution containing a calcium salt, a physiological quantity of potassium chloride is superadded, then good contractility will persist for an hour to two hours with only slightly weakened contractions, being about a third less strong.

We see then that a potassium salt by its influence on dilatation is essential to the maintenance of contractility.

I showed too that when fed with a neutral fluid the ventricle will contract well for ninety minutes or longer.

Moreover I demonstrated that sodium bicarbonate added to saline solution will not sustain contractility, nor will saline solution with sodium bicarbonate and potassium chloride. Yet sodium bicarbonate

or rather an alkaline state of the fluid does favour contractility as the following experiments show.

A ventricle fed with the neutral solution, 100 c.c. saline, 2·5 c.c. $CaCl^2$ solution 0·5%, and 0·75 c.c. of 1% potassium chloride solution, in the course of an hour to an hour and a half grows weaker, and becomes reduced by one-third its original strength. At this point on the addition of 5 c.c. of a 1% solution of sodium bicarbonate the strength of the contractions becomes notably improved; sometimes indeed the contractions are as good as at the beginning of the experiment.

On another occasion, I replaced blood solution by 100 c.c. saline containing 2 c.c. of 0·5% solution of calcium chloride. The characteristic lime effect on diastolic dilatation ensued. In about forty-five minutes the contractions grew weaker, and when reduced to about one-third their original height I added seven minims of 1% potassium chloride solution. In nine minutes the contractions being still feebler I added 5 c.c. 1% solution of sodium bicarbonate. The spontaneous contractions, which on the addition of potassium chloride stopped, soon recommenced, their strength increased, and thirty-six minutes after adding the sodium salt the spontaneous contractions became equal to the blood mixture standard.

In a similar experiment, extended over a shorter time (about thirty-six minutes), spontaneous contractions restored by sodium bicarbonate became even stronger than with the blood used at the beginning of the experiment.

To what is this improvement due? Is an alkaline solution necessary to the production of muscular contraction? or is the weakening which sodium bicarbonate removes, really due to the developement of acid by the muscular contractions? It can scarcely be maintained that an alkaline fluid is necessary seeing that, though weakened, yet fairly good contractions persist after feeding the ventricle with a neutral solution for ninety minutes and more.

It is more probable I think that the acid developed in the muscles under contraction gradually weakens and at last suspends contractility.

This much at least is certain that the sodium bicarbonate acts by virtue of its alkalinity and not as a soda salt, for the addition to the circulating fluid of calcium hydrate or ammonium carbonate will produce the same restoration of the beats.

I replaced blood solution by 100 c.c. saline containing 2·5 c.c. of 0·5% solution of calcium hydrate. When the contractions became weak I

added a small quantity of potassium chloride and the contractions became weaker still. I then added to the 100 c.c. of circulating fluid 1 c.c. of lime water and the contractions quickly improved.

On another occasion I replaced blood mixture by 100 c.c. saline, 2 c.c. calcium chloride ·5%, and 0·75 c.c. potassium chloride 1%. In about twenty-five minutes the contractions were reduced to about ⅓ their original amount. Then I added 1 c.c. lime water and the contractions quickly improved, and became as good as with blood mixture; subsequently the lime caused much persistent spasm.

Carbonate of ammonia also improves the contractions.

I replaced blood mixture by 100 c.c. saline with 5 c.c. calcium chloride ·5%. In forty minutes the contractions became very weak with marked lime effect. I added 0·75 c.c. of 1% of potassium chloride and the contractions became still weaker. In eight minutes after adding the potassium chloride I added in successive doses 10 c.c. carbonate of ammonia solution ·5%; the contractions improved greatly but did not become quite so good as when operating with blood mixture.

We see then that the amount of contraction, the duration of the contraction, the breadth of the trace, and the rapidity of diastolic dilatation, depend entirely on the relative quantity of the normal saline constituents of the blood.

With calcium chloride added to saline, if the rhythmic contractions retain their normal frequency, we get increased breadth with rounding of the top of the trace, which leads to fusion of the beats and the trace rises high above the base line. A physiological quantity of a potash salt added to the circulating fluid, quickly removes all the lime effects and restores good normal contractions.

If the contractions are less frequent or occur only with an excitation the calcium chloride like other lime salts at first broadens the trace, rounding its top and then greatly retards diastolic dilatation. Potassium chloride obviates these effects.

The retardation of dilatation may be removed, but a little larger dose makes the beat quite normal, sharpening the top of the trace and decreasing its breadth. If a larger quantity is added, the height of the trace becomes reduced. If when the trace is somewhat weakened by potash, 5 c.c. of 1% solution of sodium bicarbonate is added to 100 c.c. of circulating fluid, the contractions regain their full strength but again become broadened and their tops rounded; but this broadening is again removable by a further dose of potassium chloride, which if large enough will again weaken the contraction. The addition of

another 2·5 c.c. of 0·5% solution of calcium chloride to the 100 c.c. of circulating fluid will again reproduce complete contractions and the trace may again become broadened; but the addition of more calcium chloride, even 10 c.c. of 0·5% solution, will not prolong diastolic dilatation; in fact with a sufficient quantity of potassium chloride, no quantity of calcium chloride is capable of retarding diastolic dilatation.