Electrolyte Content of Rat Heart Atria and Ventricles

By J. A. Barclay, M.A., M.B., E. J. Hamley, Ph.D., and Helga Houghton, B.Sc.

The peculiar property of the heart, its spontaneous beating, makes it one of the few tissues easily studied when isolated and perfused artificially. The rhythmic beat provides a reliable and immediate check of normal activity since any change in periodicity can be assumed to reflect changes in metabolism. Furthermore, any variation in the pattern of the beat can be studied electrically and provides a correlation with changes in electrolyte content. The small size of the rat heart also provides a link with the tissue-slice preparation which has usually been used for electrolyte studies. In spite of these points the electrolyte data available in the literature on the rat heart do not present the different chambers, i.e., atria and ventricles, as separate entities except for a few estimations referring to the atria used as tissue-slice preparations. The whole heart used as a perfused preparation has shown its distinct differences in the extracellular space and, therefore, the ionic intracellular concentration of each chamber.

If the electrolyte content of a tissue is to be studied in any detail, it is imperative that extracellular space be measured accurately. Several materials may be used. The most reliable is inulin, but sucrose, chloride and sodium have been used frequently in the past. Data on these 4 materials are presented in the literature on the rat heart. The problem here is to determine the amount of each chamber, i.e., atria and ventricles, as separate entities except for a few estimations referring to the atria used as tissue-slice preparations. The whole heart used as a perfused preparation has shown us distinct differences in the extracellular space and, therefore, the ionic intracellular concentration of each chamber.

In view of the very high chloride and sodium values found in the perfused hearts, values are also given from a sample of fresh, unperfused heart. Furthermore, the work has been extended to include similar data from perfused rabbit hearts so that a comparison may be made with data in the literature and to illustrate species differences.

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Methods

The rats were males, weighing 270 to 330 Gm., derived originally from Wistar strain albino rats, killed by concussion. The hearts were removed with utmost speed and mounted on a cannula for perfusion by Langendorff's method.1 Perfusate was oxygenated (100 per cent O₂) Ringer-Locke solution2 with 0.2 per cent glucose, having a pH 7.2 to 7.4 due to the sodium bicarbonate of the solution (150 mEq./L. Na and 6.25 mEq./L. K). Analytic grade reagents were used throughout with fresh glass-distilled water. The perfusion pressure was 30 to 33 cm. solution, temperature 30 to 35 C. The hearts were removed for analysis after 2 hours perfusion.

Samples of tissue for assay were the whole atria or pieces cut from the ventricles, dried quickly on "ash-free" filter paper, weighed and deposited in 0.9 per cent saline. After 45 minutes the saline was analyzed for inulin or sucrose (a similar procedure was applied to control blanks). Other samples were digested in 0.13SF HNO₃ solution for 24 hours and analyzed for sodium and potassium by flame photometer. The same digest was analyzed for chloride by Sanderson's method.3 Dry weights were obtained by dehydrating samples of tissue on aluminum pans in an oven at 105 C. until constant weights were reached after 12 hours. Since it is impractical to assay inulin and sucrose simultaneously, 2 series of preparations were run; inulin, Cl and Na were analyzed on one and sucrose, Cl and Na on the other, the results for Cl and Na being grouped. The number of estimations was limited by the amount of material available in each atrium or ventricle.

The rabbits were males weighing 2.5 Kg., from common, mixed laboratory stock. The procedures used were identical to those described above.

Results

The data summarized in tables 1 through 4 include the mean values ± standard error of the mean, followed by the number of samples (shown in parentheses).

Discussion

The extracellular tissue spaces of the right and left atria and right and left ventricles are all statistically different, irrespective of
the method of estimation, and the data clearly indicate that ventricular tissue spaces are very much smaller than auricular tissue spaces. There is no statistical significance between estimations of tissue spaces by inulin and by sucrose except in the left ventricle. The left ventricle in the adult rat has markedly smaller tissue space than the right. It is a histologic fact that vascularization is good, and in 2 hours perfusion time, equilibration of inulin with the tissue spaces should have occurred easily. Trial runs showed no increase in inulin space after the first 20 minutes of perfusion, and Bleehen and Fisher have shown that in the rat heart the rate of turnover of inulin has a diffusion half-life of 3 to 5 minutes, indicating that 2 hours perfusion time is more than adequate to allow equilibrium to be reached. Further support for the difference between right and left ventricles can be found from the other methods of estimation; the chloride spaces in both perfused and unperfused preparations confirm that the right ventricular space is larger than the left. The rabbit data substantiate this difference between right and left, and if one concedes that data from the whole minced heart will give values that reflect the large anatomic size of the left ventricle, the sucrose space of the cat myocardium seems to be even smaller than the rat's.

The data for intracellular ionic contents of the perfused hearts clearly exhibit that migration of ions across the cell membrane during perfusion is great. This is not in itself remarkable and may be due to the very high chloride and sodium content of the perfusing fluid when compared to blood. What is remarkable is that unperfused hearts examined immediately after removal from the thorax show high intracellular chloride and sodium values, and these values are highest in the auricles. This cannot be explained as a part of a special mechanism of contraction in view of the low values known for skeletal muscle but may possibly be associated with specialized myocardial mechanisms of conduction since even higher values have been reported for A-V bundle.

**Table 1**

<table>
<thead>
<tr>
<th>Chamber</th>
<th>Perfusion in Ringer-Locke solution</th>
<th>Fresh, unperfused</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inulin</td>
<td>Sodium</td>
</tr>
<tr>
<td>Right atrium</td>
<td>84.2 ± 2.7 (13)</td>
<td>38.3 ± 1.6 (15)</td>
</tr>
<tr>
<td>Left atrium</td>
<td>83.9 ± 3.8 (14)</td>
<td>38.0 ± 0.7 (11)</td>
</tr>
<tr>
<td>Right ventricle</td>
<td>85.4 ± 2.5 (15)</td>
<td>38.5 ± 2.3 (11)</td>
</tr>
<tr>
<td>Left ventricle</td>
<td>93.8 ± 2.4 (10)</td>
<td>47.0 ± 1.3 (51)</td>
</tr>
</tbody>
</table>

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The increase of intracellular sodium during perfusion with Ringer-Locke solution appears to coincide with migration of potassium that maintains the total intracellular concentration of Na plus K unchanged over a period of 2 hours. Similarly, increase in intracellular water is significant in all chambers and is the prime effect of perfusion. It may be that the reciprocal relationship of sodium and potassium is part of a simple mechanism by which electrolytes and water invade the cell. This is not necessarily in the form of isotonic solution uptake as suggested by Leaf, since similar calculations applied to our data for the heart do not confirm his results which refer to brain and kidney tissue slices.

It is hoped that these data will show the specificity of the tissue spaces and ionic contents of the different chambers of the heart and thus aid in the elucidation of the mechanisms of myocardial function.

**Summary**

Extracellular tissue spaces are compared using inulin, sucrose, chloride and sodium in hearts perfused with Ringer-Locke solution by Langendorff's method. Also chloride and sodium spaces are given for unperfused, fresh hearts. From the inulin spaces the intracellular chloride, sodium, potassium and water concentrations in both perfused and unperfused heart chambers have been calculated. Data showing the specificity of the
ELECTROLYTE CONTENT OF HEART

atrium and ventricles of the heart are presented.

**Summario in Interlingua**

Spatios tissiilar extracellular esseva comparate, utilisante inulina, sucrora, chioruro, e natrium in cordes perfundite con solution do Ringer-Locke secundo le metodo do Langendorff. Etiam le spatios de chloruro e de natrium es date pro non-perfundite cordes fresc. Ab le spatios de inulina, le concentrations intracellular de chloruro, natrium, kalium, e aqua osseva calculate. Datos demonstrante le specificitate del atrio e del ventriculos del corde es presentate.

**References**

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