Regional Distribution of Myocardial Blood Flow in the Dog as Determined by Rb$^{86}$

By MATTHEW N. LEVY, M.D., AND JORGE MARTINS DE OLIVEIRA, M.D.

Two different techniques have been devised in which the radioactive isotope of rubidium, Rb$^{86}$, has been employed to assess the rate and distribution of myocardial blood flow. In the method developed by Love and Burch, a constant arterial plasma level of this isotope is maintained by a continuous infusion. Data obtained in this manner revealed that in the dog the mean rate of Rb$^{86}$ uptake by the left ventricle was 45 percent greater than by the right ventricle. The method contrived by Sapirstein, on the other hand, involves the rapid intravenous administration of isotope and the determination of its fractional uptake by the tissues shortly after injection. By means of this technique, results were obtained in the rat which indicated that right ventricular blood flow exceeded left ventricular flow by 23 percent. In the present study, the single injection method was applied to the canine myocardium to determine whether the reported disparities in relative perfusion rates of the two ventricles are dependent upon dissimilarities between species or upon differences in the experimental methods employed.

Methods

Twenty-six mongrel dogs of both sexes, weighing from 7.7 to 20.5 Kg., were anesthetized by intravenous injection of sodium pentobarbital (30 mg./Kg.). A left thoracotomy was performed, and artificial respiration was administered. Three μc./Kg. of rubidium$^{86}$ chloride (Abbott Laboratories; specific activity, 1.4 to 1.7 mc./mg.) were injected rapidly into a femoral vein. In 12 dogs, ventricular fibrillation was induced 20 seconds after injection; in 9 other dogs, the heart was fibrillated after 10 minutes. In the remaining 5 dogs, the Rb$^{86}$Cl was given 19 hours prior to opening the chest and stopping the heart. The heart was immediately removed after fibrillation was induced. It was washed briefly in running tap water and weighed. The cardiac chambers were then opened, and the remaining blood was removed by blotting lightly with filter paper. Specimens of approximately 1 Gm. were taken from several regions of the myocardium. The samples were then placed in previously tared lusteroid tubes and weighed on an analytical balance. The Rb$^{86}$ content of these tissues, as well as of an aliquot of the solution injected into the animal, was determined in a well-type scintillation detector (NRD Radimax scintillation counter). The Rb$^{86}$ content of each specimen was computed on the basis of counts per minute (CPM) per 100 Gm. tissue. This in turn was expressed as “fractional uptake,” or per cent of the total CPM injected.

Results

In table 1, the fractional uptake (mean ± S.E.) are presented for the left and right atria (LA and RA), the lateral wall of the right ventricle (RV), the interventricular septum (IVS), and the following regions of the left ventricle: anterior superior wall (ASW), diaphragmatic wall (DW), apex, anterior papillary muscle (APM), and posterior papillary muscle (PPM). Twenty seconds after administration of the isotope, the atrial contents tend to be somewhat less than that of the right ventricle, but the differences are of borderline statistical significance ($P = .06$ for the difference between uptakes by LA and RV). The fractional uptake by the right ventricle is, however, significantly less than that of the left ventricle, where the Rb$^{86}$ content is fairly homogeneous for the various regions studied. For example, the lowest value observed in the left ventricle was 6.01 ± 0.31 per cent in the anterior superior wall as compared to 4.26 ± 0.23 per cent for the right ventricle ($P < .001$).

Ten minutes after injection of Rb$^{86}$Cl, all values tend to be higher than those for the corresponding regions after only 20 seconds.
However, only in the case of the anterior papillary muscle is this difference statistically significant \((P = .01)\).

When 19 hours had elapsed, the fractional content of each region has considerably diminished. It may be noted that the difference in content between right and left ventricular regions has disappeared.

**Discussion**

Table 1 reveals that 20 seconds after the injection of Rb\(^{86}\)Cl the uptake per 100 Gm. of left ventricle varied from 6.01 to 6.60 (mean 6.41) per cent of the injected dose. These values were significantly greater than the fractional uptake observed for the lateral wall of the right ventricle (4.26 per cent) or for the right or left atrium (3.82 and 3.67, respectively). Thus, the mean value for the left ventricle in this study was 50 per cent greater than that for the right ventricle. This corresponds very closely with the results reported by Love and Burch.\(^1\) These investigators measured the clearance of Rb\(^{86}\) by the myocardium of the dog under conditions in which the plasma Rb\(^{86}\) level was maintained constant by a continuous infusion. They reported that the clearance of this isotope by the left ventricle exceeded that by the right ventricle by an average of 45 per cent. Also, they found that the clearance by the atria was slightly lower than that by the right ventricle, just as in the present report.

The relative distribution of Rb\(^{86}\) in the rat ventricular myocardium is reversed, on the other hand. Hershgold, Steiner, and Sapirstein\(^2\) reported that 10 to 20 seconds after a single injection of isotope the fractional uptake by the right ventricle is significantly greater than by the left ventricle. Since the method used in the present study was also modeled after that devised by Sapirstein,\(^2\) the disparities in results clearly represent species differences between the rat and dog.

The relative distribution of isotope in this study in the periods from 20 seconds to 10 minutes after administration is probably closely related to the relative distribution of myocardial blood flow. The initial distribution of tracer is controlled by circulatory factors and by individual exchange rates.\(^4\) It is likely that the exchange rates for the various regions of the myocardium are quite similar, although at present data are not available on this point. One variable which may affect the relative exchange rates for the two ventricles is the relative rate of blood flow in each region. It has been shown that in the canine myocardium the tissue extraction of Rb\(^{86}\) is inversely related to the rate of blood flow.\(^5,6\) Since it may be inferred from the present data, as well as from those of Love and Burch,\(^1\) that the blood flow per gram of tissue is greater in the left ventricle than in the right, the actual differences in blood flow may be somewhat greater than indicated by the relative fractional uptakes.

Sapirstein\(^2\) was unable to detect any differences in fractional uptake of K\(^{42}\) by the myocardium of the dog over a time range of from 20 to 120 seconds. In the present study, the myocardial uptake of rubidium, which biologically behaves similarly to potassium,\(^7\) tended to be greater 10 minutes after injection than after only 20 seconds. This difference was statistically significant \((P = .01)\) for the anterior papillary muscle and approached significance \((P = .07)\) for the right ventricle. This finding is in accord with the data of Love, Romney, and Burch,\(^3\) which revealed that Rb\(^{86}\) attained its maximum concentration in the canine myocardium from 15 to 45 minutes following a single intravenous injection of this isotope.

**Table 1**

<table>
<thead>
<tr>
<th>Region</th>
<th>20 seconds</th>
<th>10 minutes</th>
<th>19 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA</td>
<td>3.37 ± 0.18*</td>
<td>3.94 ± 0.28</td>
<td>1.74 ± 0.19</td>
</tr>
<tr>
<td>RA</td>
<td>3.82 ± 0.22</td>
<td>4.97 ± 0.29</td>
<td>2.34 ± 0.27</td>
</tr>
<tr>
<td>RV</td>
<td>4.26 ± 0.23</td>
<td>7.22 ± 0.28</td>
<td>2.62 ± 0.31</td>
</tr>
<tr>
<td>DW</td>
<td>6.54 ± 0.36</td>
<td>7.70 ± 0.28</td>
<td>2.34 ± 0.29</td>
</tr>
<tr>
<td>APM</td>
<td>6.60 ± 0.33</td>
<td>7.04 ± 0.28</td>
<td>2.34 ± 0.29</td>
</tr>
<tr>
<td>PPM</td>
<td>6.60 ± 0.33</td>
<td>7.04 ± 0.28</td>
<td>2.34 ± 0.29</td>
</tr>
<tr>
<td>ASW</td>
<td>6.01 ± 0.31</td>
<td>6.33 ± 0.32</td>
<td>6.39 ± 0.30</td>
</tr>
<tr>
<td>IVS</td>
<td>6.33 ± 0.32</td>
<td>6.39 ± 0.30</td>
<td>6.39 ± 0.30</td>
</tr>
<tr>
<td>Apex</td>
<td>6.39 ± 0.30</td>
<td>6.39 ± 0.30</td>
<td>6.39 ± 0.30</td>
</tr>
</tbody>
</table>

*Values (mean ± S.E.) represent the per cent of the injected dose per 100 Gm. tissue.
Many hours after the administration of isotope, equilibrium is approached in which uniform specific activity is attained throughout the body. Since rubidium behaves similarly in many respects to potassium, at equilibrium its distribution should resemble that of potassium. The potassium concentration of the myocardium is fairly uniform in the right and left ventricles, and is significantly lower in the atria. As table 1 shows, Rb\(^{86}\) is also distributed rather homogeneously in the ventricular myocardium 19 hours after injection; the difference in Rb\(^{86}\) content between the right and left chambers has disappeared. Furthermore, in conformity with the potassium distribution, the atrial Rb\(^{86}\) content is appreciably less. Finally, the higher fractional uptakes observed shortly after injection as compared to the values after many hours are simply a reflection of the higher ratio of blood flow to potassium content for the myocardium than for the average for the rest of the body.

**Summary**

The distribution of Rb\(^{86}\)Cl in the canine myocardium was determined at 20 seconds, 10 minutes, and 19 hours after administration of isotope. The uptake of Rb\(^{86}\) 20 seconds after injection is related to blood flow, and the myocardial distribution of isotope probably closely reflects the apportionment of coronary blood flow. The isotope was uniformly divided between the various regions of the left ventricle and averaged 6.4 per cent of the injected dose per 100 Gm. of tissue. This value exceeded the fractional uptake of 4.3 per cent for the right ventricle and 3.7 per cent for the atria.

After 19 hours, the Rb\(^{86}\) content serves virtually as a tracer for potassium. After this interval, the myocardial distribution of Rb\(^{86}\) closely followed previously published reports of the relative potassium contents of the various myocardial regions.

**References**

1. **Love, W. D., and Burch, G. E.:** Differences in the rate of Rb\(^{86}\) uptake by several regions of the myocardium of control dogs and dogs receiving norepinephrine or pitressin. J. Clin. Invest. 36: 479, 1957.


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