

The Distribution of Rb^{86} in the Dogs Heart¹

B. Malamos, S. Mouloupoulos, P. Kostamis, E. Paraschou and K. Elias

Athens, Greece

The regional uptake of Rb^{86} by the heart muscle has been studied by several authors (Love *et al* (6), Sapirstein (8), Levy *et al* (3)). The isotope was administered either by continuous infusion or by a single intravenous injection. The Rb^{86} uptake was measured in specimens taken from several parts of the myocardium (Levy *et al* (3)). The uptake of Rb^{86} by the left ventricle exceeded by 45 per cent (Love *et al* (6)), 23 per cent (Sapirstein) (8) or 50 per cent (Levy *et al*) (3) the uptake of the right ventricle.

The determination of the Rb^{86} distribution *in vivo* might offer a possibility to follow the uptake of the isotope by the functioning heart muscle under several experimental conditions of normal or abnormal heart activity. Such a measurement presents some difficulties, in that there is not, as yet, a method equally accurate to the one available for the post mortem studies.

During this investigation, an attempt was made to measure the regional Rb^{86} uptake during open chest experiments in the dog and to follow it under several experimental conditions.

METHOD

A small Geiger-Müller counter,² with a diameter of 0.8 cm (window thickness 1.5 mg/cm², operating voltage 725 volts, plateau length 100V) was initially tried in a wax model. A cylinder was made up of wax, whose internal diameter was 4 cm. The thickness of the wall ranged from 3 to 20mm (Fig. 1). Several solutions of Rb^{86} , from 0.5 to 3 μC per ml, were introduced into the cylinder. The counter was placed outside the cylinder, at a distance between 0 and 1 cm from the cylinder's wall and was then rotated around the cylinder. With this setup the absorption of radiation by a wall of changing thickness, coming from solutions of different concentrations, could be measured.

Rubidium-86 is a radioactive isotope with a half-life of 18.7d. It emits β -particles of 1.77 MeV (91.5%), and 0.68 MeV (8.5%), as well as γ -rays of 1.08 MeV (8.5%).

¹Department of Clinical Therapeutics, University of Athens Medical School, (Chairman: Prof. B. Malamos), Alexandra Hospital, Athens, Greece.

²Aston Electronics, T-222-A, for ophthalmic use.

The absorption of $\text{Rb}^{86}\beta$ -radiation by the heart muscle itself was also investigated. Specimens of the left and right ventricular myocardium, of different thickness, recently cut out of a functioning heart, were interposed between the counter and a source of Rb^{86} .

After the preliminary testing of the method, 20 mongrel dogs, weighing 6-16 Kgs, were anesthetised with sodium pentothal (20 mg per Kg). Following intubation of the trachea, the chest was opened on the left side. A catheter (size No 7 F) was introduced into the left auricular appendix. The same counter used for the experiment in vitro, was placed alternatively at four different points of the anterior surface of the ventricles, namely at the base and apex of the right and left ventricle (Fig. 3). While the counter was over each one of these positions, a rapid injection of $1 \mu\text{c}$ Rb^{86} per Kg of body weight, in 1 ml of isotonic glucose was given through the catheter. After the four injection-one for each position of the catheter-the Geiger-Müller was "walked" over each one of the four points and a continuous recording was obtained.

Subsequently, the infusion of Rb^{86} was started through the same catheter, at a rate of $0.1 \mu\text{c}$ in 1 ml of isotonic glucose per minute, per Kg of body weight. Readings were obtained from the same points at 5 minutes intervals, for 1 hour. Several readings were obtained each time and the average value was considered.

The activity over the left atrium and the aorta was checked with the same counter. The activity of blood samples, taken every 20 minutes was determined in a well-type counter.

In a group of 10 animals the Rb^{86} uptake was followed at the 4 points mentioned until the death of the animal. This occurred either by inducing respiratory anoxia (3 experiments) or after intravenous infusion of large amount of fluids (7 animals).

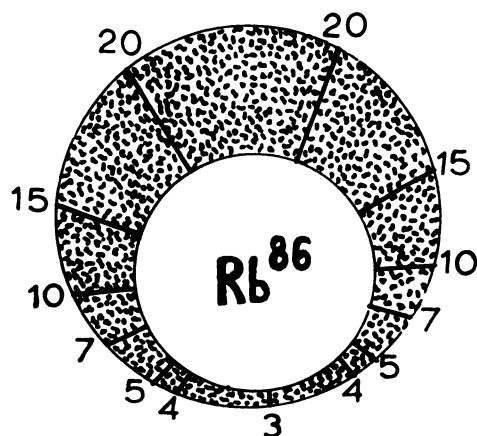


Figure 1

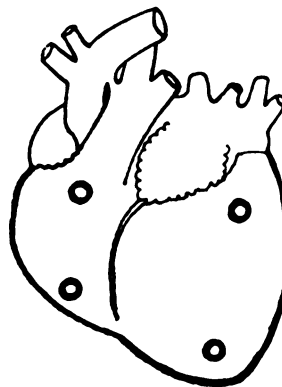


Figure 2

Fig. 1. Transverse section of the cylindrical wax model. Numbers indicate the thickness of the wall of the cylinder in mm.

Fig. 2. Diagram indicating the four points in the anterior surface of the dog's heart, over which the Rb^{86} uptake was followed.

In the other group of 10 animals, the anterior surface of the heart was scanned with the counter before and after ligation of the descending branch of the left coronary artery. Unipolar epicardial electrocardiographic leads were recorded from the same area.

In 7 animals specimens of ventricular myocardium were obtained from the four points mentioned, immediately after the death of the animal. They were weighed and measured in a well-type counter before and after washing them with isotonic NaCl solution.

RESULTS

The experiments with the wax model showed the following:

1. The positioning of the counter from the wall of the cylinder up to a distance of 1 cm does not reduce the number of counts more than 10 per cent in comparison to the reading obtained when the counter is in contact with the wall.

2. Changes in thickness of the wall from 3 to 10 mm shows an almost linear relationship to the number of counts. A change over 1 cm does not substantially affect the reading (Fig. 3). The rate of change in counts for different concentrations of the isotope is high enough when the thickness of the wall is less than 1 cm. It is very low for a wall thickness of more than 1 cm (Fig. 4).

The radioactivity of a source of $20\mu\text{C Rb}^{86}$ was absorbed over 80 per cent by a piece of myocardial tissue over 0.5 cm thick. During the animal experiments, the activity of the blood, measured over the aorta, was giving readings of 10 to 20 per cent of the readings obtained from the ventricular wall at the same time. The activity of the atria ranged between 10 and 40 per cent of the activity simultaneously recorded.

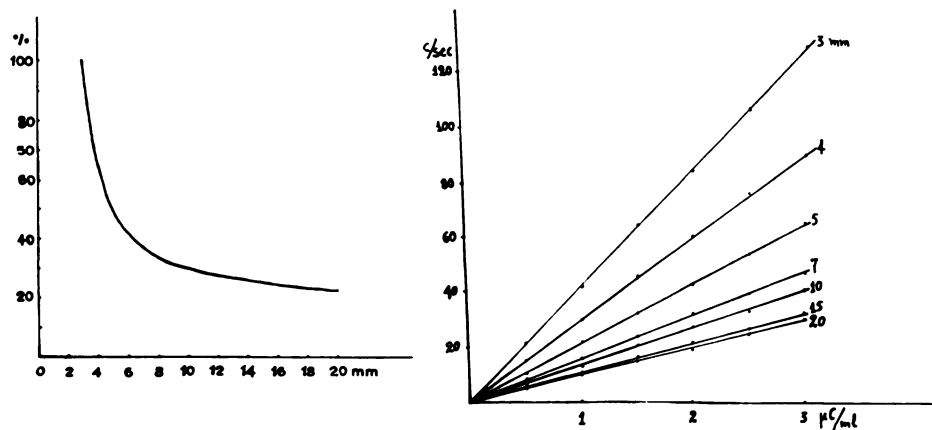


Fig. 3. Diagram indicating the relationship between the number of counts recorded from the outside of the cylinder and the thickness of the cylinder's wall, for one given Rb^{86} concentration inside the cylinder.

Fig. 4. Diagram indicating the number of counts recorded from the outside of the cylinder, versus different Rb^{86} concentrations inside the cylinder, for various diameters of the wall.

After a single injection, the uptake of Rb^{86} by the ventricular myocardium was higher on the left side of the heart than on the right one (Fig. 5). Furthermore, the uptake at the base of the left ventricle was the highest of all, no matter whether this area was measured during the first or during the subsequent injections. The difference was statistically significant ($p < 0.01$). When the counter was walked over the ventricular myocardium, the same distribution pattern was observed (Fig. 6). During continuous infusion, the same pattern was also observed (Fig. 7).

The follow up until the death of the animal showed a change in the distribution of the Rb^{86} during the last minutes. The difference between base and apex readings became larger in 7 experiments, smaller in 8 and remained unchanged in 2. The remaining 3 animals were sacrificed. The cause of death did not seem to affect the pattern.

The radioactivity measured in the myocardial specimens showed a similar difference per gram of weight between base and apex of the left ventricle and between the bases of the left and right ventricles ($p < 0.01$). The washing of the specimens with an isotonic NaCl solution did not change the findings consid-

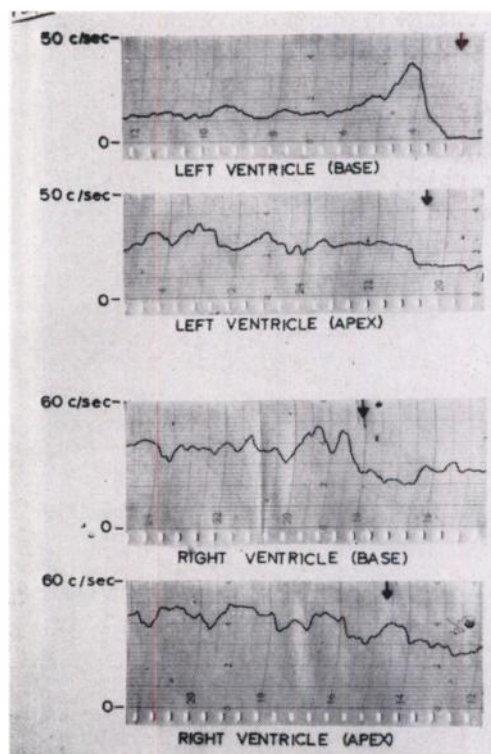


Fig. 5. Radioactive curves recorded from the base and apex of the left ventricle and the base and apex of the right ventricle, following each one a rapid single injection of Rb^{86} at the time indicated by the arrows. The curves should be read from right to left. Paper speed: 12" per minute.

erably. The results of the comparison between right ventricular base and apex were not statistically significant.

Following the ligation of the artery, the uptake of the corresponding area remained almost equal to the pre-ligation level. (Fig. 8). A constant relationship was observed between the regional S-T segment changes in the epicardial electrocardiogram and the number of counts recorded from the same areas. (Fig. 9). These results are reported in detail elsewhere.

DISCUSSION

Before the main experiments of this study, the validity of the β -counting had to be investigated under similar conditions. The amount of β -radiation measured with a small counter across a myocardial layer could only be counted when the thickness of the layer was less than 1 cm. Thicker myocardial layers were absorbing the whole amount of β -radiation, which could no more be traced by the counter. Hence the radioactivity of the blood and the posterior wall of the heart should not interfere with the readings over the anterior wall, provided that the thickness of the anterior wall exceeds 1 cm.

It was also found that there is no need to keep the counter in touch with the myocardium. The change in distance between the counter and the myocardial surface did not usually exceed 1 cm and the movements of the functioning heart could not affect the reading for that particular reason. Longer time constants in the ratemeter helped to integrate instant changes and obtain a more accurate average reading.

These and other observations during the "*in vitro*" experiment indicated that the determination of the regional radiation could be achieved with a certain degree of accuracy. However, there are some inherent disadvantages to this method. The radioactivity that mostly affects the counter is coming from the

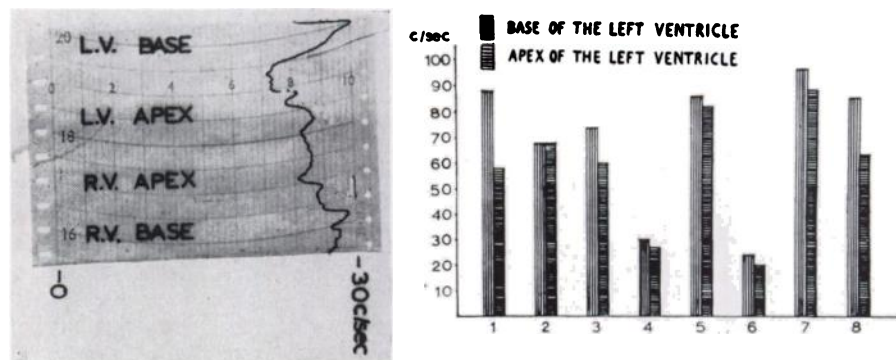


Fig. 6. Continuous recording of the radioactivity over the anterior surface of the heart. The counter was "walked" over the base of the right ventricle, the apex of the right ventricle, the apex of the left ventricle and the base of the left ventricle (right to left in the recording). The highest peak is recorded over the base of the left ventricle.

Fig. 7. Difference in counts between base and apex of the left ventricle during continuous infusion of Rb^{86} .

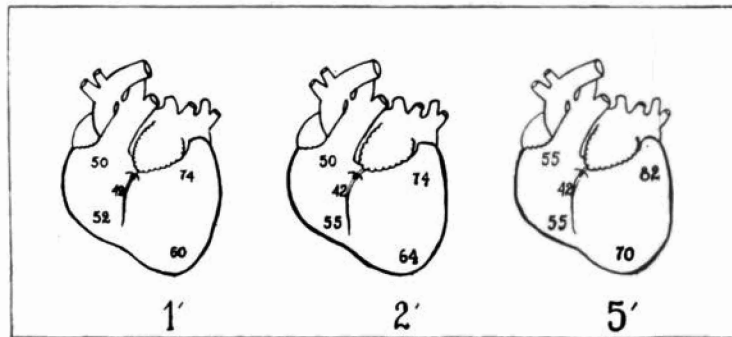


Fig. 8. The number of counts per second at different points of the anterior surface of the heart, 1, 2 and 5 minutes after ligation of the descending branch of the left coronary artery, during a constant continuous infusion of Rb^{86} . Near the ligation point, the number of counts remains the same, while the other points show a continuous increase.

outer layers of the myocardium. Thus, any discrepancy between the inner and outer layers of the myocardial wall will tend to complicate the results. A second factor affecting the readings is certainly the different thickness of the myocardial wall. Under these limitations the results may be valid for serial determinations over any particular area. The comparison between several areas needs subsequent confirmation by measuring specimens in the well-type counter.

In vivo and *in vitro* measurements showed a constant difference in the Rb^{86} uptake between areas near the apex and areas near the base of the left ventricle. There is no first hand explanation for this phenomenon. Large arteries were not included at the basal areas measured, but even if this happened the activity of

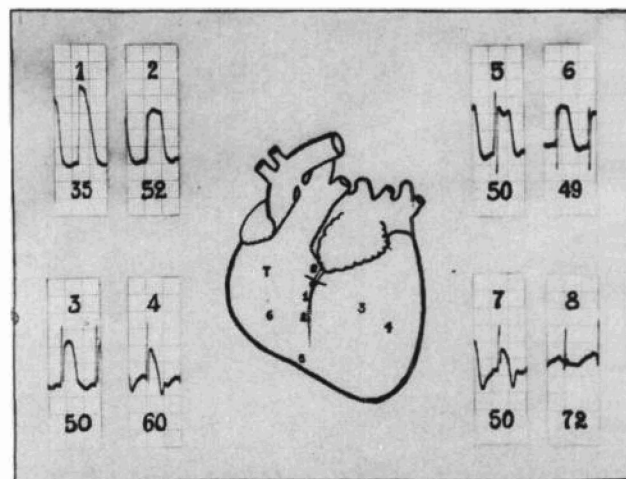


Fig. 9. Unipolar epicardial electrocardiograms recorded from several points of the anterior surface of the heart, (indicated with numbers) following ligation of the descending branch of the left coronary artery. The numbers below the ECG tracings indicate the counts over the same areas and at the same time.

the blood was not high enough to affect the reading. It can only be stated at the moment, that for unknown reasons—mechanical or biochemical—there is a higher uptake by the heart muscle at the base of the left ventricle than at the apex of the same.

The difference found between the right and left ventricle agrees with the observations of Levy *et al* (3), Sapirstein (8), Love *et al* (6), and others.

An interesting change in the distribution between base and apex of the left ventricle was seen in premortal stages, before the appearance of either ventricular fibrillation or cardiac arrest. The direction of this change was not uniform. The change may be due among other reasons to a different degree of dilatation of the ventricles, affecting the thickness of the underlying myocardial wall.

SUMMARY

In vivo measurements of the regional myocardial Rb^{86} -uptake were performed in dogs with the chest open, using a small ophthalmic-counter. Myocardial tissue specimens from several regions of the ventricular wall were also measured in a well-type counter. The preponderance of the left ventricular uptake against that of the right ventricle was confirmed.

Furthermore, a significant difference was observed between the base and the apex of the left ventricle, with a higher uptake at the basal regions. No satisfactory explanation of this finding can be given.

There was no uniform premortal change in the distribution of the isotope over several regions of the ventricular wall.

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