Gross and Subcellular Distribution of Cesium-137 in Pigeon (Columbia livia) Tissues with Special Reference to Muscles

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ABSTRACT

A study on the gross distribution of $^{137}$Cs in pigeon tissues showed that initially cardiac muscle acquired the maximum amount of the radionuclide followed by pancreas, liver, gizzard, red muscle and white muscle in that order. Over a period of time white muscle showed more radioactivity than the other tissues because it accumulated $^{137}$Cs steadily and lost the radionuclide more slowly. Among the subcellular fractions, the supernatant had 65-80 %, nuclear fraction 12-21 %, mitochondria 1.1-10 % and microsomes 0.45-3.4 % radioactivity indicating that the major portion of $^{137}$Cs in cells occurs in soluble form.

INTRODUCTION

The metabolism and distribution of $^{137}$Cs is of interest because it is one of the most important long-lived components of radioactive fallout. Cesium and potassium, both alkali metals, are chemically similar and under appropriate conditions may displace each other in biological systems. Potassium is well known to be essential in maintaining membrane potential, in muscular contraction and relaxation and in conduction of nervous impulses. The effect of cesium, in place of potassium or otherwise, on such systems is not known. Earlier studies have shown high levels of cesium accumulation in the muscles of rats, dogs and mice, chicks, and rainbow trouts. However, only scant information is available on the distribution of the radionuclide in different types of muscles despite the fact that skele-
tal muscle is known to be histophysiologicaly heterogeneous\textsuperscript{6,7,8,9}. This paper deals with the differential distribution of \textsuperscript{137}Cs in muscles and liver of pigeons and in their subcellular fractions.

**MATERIALS AND METHODS**

Pigeons (*Columba livia*) weighing 250-300 g were used. Approximately 10 \( \mu \text{Ci} \) \textsuperscript{137}CsCl was injected intramuscularly through one of the wings and the birds were sacrificed 1 hour, 1, 5, 10 and 15 days after injection. Samples of *M. pectoralis* (red muscle), leg muscles (white muscle), heart (cardiac muscle), gizzard (smooth muscle), liver and pancreas were collected for direct radioanalysis. Duplicate samples were counted in all cases. The radionuclide was assayed by gamma-ray spectrometry which measured the characteristic \textsuperscript{137}Cs peak at 0.662 Mev using a Nuclear Data model ND 120, 512 channel pulse-height analyzer in conjunction with a well-type 3" \( \times \) 3" NaI (Tl) crystal. The counts recorded under the peak were taken as the measure of \textsuperscript{137}Cs. The radioactivity was computed as "relative activity".

\[
\frac{\text{cpm/g tissue}}{\text{cpm/g body weight (dose)}}
\]

Subcellular fractions were prepared from *M. pectoralis*, leg muscles, heart, gizzard and liver of pigeons 24 hours after \textsuperscript{137}Cs injection. The tissues were minced in a blender and homogenized in a Potter-Elvehjem homogenizer in 9-10 volumes of 0.25 M sucrose in the cold. Fractionation was carried out \textsuperscript{10,11} using Sorvall RC-2B and VAC-60 centrifuges and 4 subcellular fractions were isolated as follows:

1. 600\( \times \)g, 10 min. (nuclei, myofibrils, cell membranes and any undisrupted cells),
2. 8,000\( \times \)g, 10 min. (muscle mitochondria),
   10,000\( \times \)g, 20 min. (liver mitochondria),
3. 30,000\( \times \)g, 30 min. (muscle microsomes),
   105,000\( \times \)g, 60 min. (liver microsomes),
4. Supernatant from (3). These fractions were made up to known volumes and 2 ml aliquots in duplicate were counted as described earlier. The activity was expressed as follows.

\[
\frac{\text{cpm of fraction}}{\text{cpm of sum fractions}} \times 100
\]

**RESULTS**

The distribution of radiocesium in pigeon tissues as a function of time is shown in Table 1. One hour after administration heart showed the maximum radioactivity followed by pancreas, liver, gizzard, red muscle and white muscle. Twenty four hours after injection the pattern of distribution was different, pancreas showing the maximum \textsuperscript{137}Cs concentration and liver the least. On the 5th day, there was a reduction in radioactivity of all the tissues as compared with the data one hour after injection, except that white muscle which had twice that observed one hour after
Table 1. Distribution of $^{137}$Cs in pigeon tissues as a function of time after intramuscular injection. "relative activity": \[
\text{cpm/g tissue} / \text{cpm/g body weight (dose)}
\]

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Time of sacrifice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 hour</td>
</tr>
<tr>
<td>Red muscle</td>
<td>1.54*</td>
</tr>
<tr>
<td>White muscle</td>
<td>0.46</td>
</tr>
<tr>
<td>Heart</td>
<td>4.34</td>
</tr>
<tr>
<td>Gizzard</td>
<td>2.39</td>
</tr>
<tr>
<td>Liver</td>
<td>2.63</td>
</tr>
<tr>
<td>Pancreas</td>
<td>4.06</td>
</tr>
</tbody>
</table>

* Each figure is the average of experiments on 4 animals.

Table 2. Subcellular distribution of $^{137}$Cs in pigeon tissues 24 hours after intramuscular injection: Per cent of combined activity of all the fractions.

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Supernatant</th>
<th>Subcellular fractions</th>
<th>Microsomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red muscle</td>
<td>79.2*</td>
<td>19.4</td>
<td>1.2</td>
</tr>
<tr>
<td>White muscle</td>
<td>80.8</td>
<td>17.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Heart</td>
<td>76.5</td>
<td>21.6</td>
<td>1.3</td>
</tr>
<tr>
<td>Gizzard</td>
<td>65.0</td>
<td>21.4</td>
<td>10.0</td>
</tr>
<tr>
<td>Liver</td>
<td>80.6</td>
<td>12.6</td>
<td>6.5</td>
</tr>
</tbody>
</table>

* Each figure is the average of 6 experiments.

injection.

The subcellular distribution of $^{137}$Cs in pigeon tissues is shown in Table 2. The supernatant fraction had the maximum activity followed by the nuclear, mitochondrial and microsomal fractions of all the tissues studied.

DISCUSSION

The distribution of $^{137}$Cs in tissues and its eventual excretion have been investigated in a number of laboratory and farm animals$^{12-13}$. The soft tissues have been shown to have relatively high levels of the radionuclide. Rosoff et al$^{14}$ have also reported comparatively large amounts of $^{137}$Cs in human muscle and liver. Our results are in general agreement with those findings.

The cardiac muscle of pigeon acquires $^{137}$Cs faster and in greater amounts than the other tissues but it loses the radionuclide rapidly. Nelson et al$^{15}$ found that mice myocardium also did not retain radiocesium in spite of high initial concentrations. However, a recent study on rats$^{16}$ has shown a high initial uptake of $^{134}$Cs by heart muscle followed by a more gradual rate of elimination than what we have observed in pigeons. This disparity may be due to differences in computation.
White muscle shows a slow but steady accumulation of radiocesium with the result that at longer time intervals this muscle has the highest radioactivity. This is similar to what has been reported for rainbow trout white muscle\(^5\) and rat gastrocnemius (white muscle)\(^6\). Red muscle and smooth muscle fall between the cardiac muscle and white muscle with respect to accumulation as well as retention. Our data on \(^{137}\text{Cs}\) retention in pigeon liver, heart and white muscle are comparable to those obtained by Ballou and Thompson\(^2\) for the tissues of rats.

Sreter and Woo\(^7\) reported low potassium and high sodium content in mammalian red muscle and vice versa in the white muscle. Since potassium and cesium share many physical and chemical properties\(^1\) the uptake of cesium by muscle is probably by the displacement of K\(^+\). The fact that red muscle initially accumulates more cesium than white muscle would seem to be linked with higher oxidative metabolism of the former. The suggestion of Sjödin and Beauge\(^8\) that cesium transport into muscle is energy-dependent supports this assumption. There are also indications that inhibition of oxidative metabolism adversely affects cesium entry into muscles\(^9\).

The pattern of subcellular distribution of \(^{137}\text{Cs}\) is similar in all the tissues assayed though characteristic differences exist in the actual amount present in individual fractions. The supernatant fractions of all the tissues show the highest amount of the radionuclide with 65 to 80 % of the total activity. A similar observation has been made by Wester\(^20\) in the case of beef heart. The nuclear fraction (with myofibrils) is next with 12–21 % activity. The other two fractions have comparatively insignificant radioactivity except the mitochondrial fraction of the gizzard and liver and the microsomal fraction of the gizzard. It is noteworthy that the subcellular fractions of red muscle and cardiac muscle show great similarity in the distribution of \(^{137}\text{Cs}\). Cassens et al\(^21\) showed that the largest amount of muscle zinc is found in the heavy fraction (nuclei and myofibrils). This fraction of red muscle has three times as much zinc as that of white muscle whereas the supernatants from the two muscles have the same zinc content. Hermann and Kun\(^22\) have shown that copper is highest in the mitochondrial fraction of rat liver. It is apparent that the subcellular fractions have specific affinities towards the cations. Our results indicate that the major proportion of cesium remains in soluble form in pigeon tissues.

REFERENCES


