jnm / PRELIMINARY NOTE

^{134m}Cs, A NEW MYOCARDIAL IMAGING AGENT

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Myocardial imaging is presently restricted by the unavailability of a suitable radiopharmaceutical. Cesium-134m, which has a 2.9 hr half-life and emits a gamma-ray of 128 keV, is easily available and appears promising for this purpose. In three dogs with induced myocardial infarctions, we could easily distinguish infarcted areas from the normal myocardium in images obtained with an Anger camera.

Effective myocardial imaging can often be a useful aid to clinical medicine in the detection and management of myocardial infarcts especially where surgery is involved or contemplated. So far, attempts at finding a suitable radionuclide for this purpose have been only partially successful. Agents such as ^{43}K, ^{129}Cs, and ^{131}Cs have been used to this effect (*1–3*).

These all possess certain disadvantages, which have limited their use. Potassium-43 and ^{129}Cs, which have only recently become available, are expensive and do not possess an ideal gamma-ray energy for efficient in vivo imaging. Cesium-131 emits an x-ray of low energy (30 keV), which is not desirable for in vivo imaging. Thallium-199 and ^{201}Tl have also been proposed for possible myocardial imaging by Kawana, et al (*4*) and Chandra, et al (*5*). Of these, the radionuclide ^{201}Tl possesses physical properties that would make it a suitable choice for myocardial imaging. However, because of several problems in its production, it is not available at present. Another radiopharmaceutical that is currently of interest is $^{13}NH_3$ (*6,7*). Its use is limited to a small number of hospitals which possess their own cyclotron.

This report concerns the investigation of another

Received Aug. 8, 1972; revision accepted Nov. 11, 1972.

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TABLE 1. PHYSICAL PROPERTIES AND COMPARISON OF RADIOISOTOPES USED OR PROPOSED FOR MYOCARDIAL SCANNING

Radionuclide and half-life	Gamma-ray energy (keV)	% emission	Radiation dose rad/mCi	Relative radiation dose per detected photon for the same resolution: Anger camera	Relative radiation dose per detected photon for the same resolution: Rectilinear scanner	Comments*
^{134m}Cs 2.9 hr	128	14	.24	1	1	(1)
^{134m}Cs 2.9 hr	128	14	.48	2	2	(2)
^{43}K 22.4 hr	380	103	.62	3	2.0	(3)
^{129}Cs 32 hr	375	45	.24	2.6	1.7	(3)
^{131}Cs 9.7 d	30	88	.31	—	—	
^{199}Tl 7.4 hr	455	16	.045	1.8	1.2	(3,4)
^{201}Tl 73 hr	167	10	.14	1.5	1.4	(4)

* (1) One half-life (0.34% ^{134}Cs) after production. (2) Two half-lives (6 hr —0.68% ^{134}Cs) after production. (3) Has high-energy gamma-rays. (4) Not yet available.

radioisotope of cesium, ^{134m}Cs, which has previously received little attention. Cesium-134m is commercially available and can be produced in a reactor in large quantities at a reasonable cost. It has desirable physical properties as an in vivo scanning agent. Its half-life of 3 hr and single gamma emission of 128 keV are optimal for in vivo imaging. However, inevitable contamination with ^{134}Cs (0.18% at the time of production) is a limiting factor because of its 2.05-year half-life. The proportion of ^{134}Cs, relative to ^{134m}Cs, increases with shelf-time. Because of the significant radiation dose to the whole body from ^{134}Cs (.062 rad/μCi as calculated by us), this contamination must be kept as low as possible to minimize the radiation burden to the patient. In effect, the agent must be used within 3–4 half-lives (9–12 hr) after production. Because there is very little pharmaceutical preparation time involved, the use of the radionuclide at reasonable distances from the reactor is quite feasible.

In the present studies, ^{134m}Cs was produced in the Union Carbide reactor at Tuxedo, New York. Typically, 10–15 mg of cesium carbonate were irradiated for approximately 3 hr in a neutron flux of 6.7×10^{13} neutrons/cm^2/sec and were dissolved in 5 ml of pyrogen-free water. This produced about 50 mCi of ^{134m}Cs at the end of irradiation. The toxicity of cesium compounds (*8,9*) has been reported to be relatively low ($LD_{50/30} = 1.33$ gm/kg). Therefore, the administration of 5–10 mg of stable cesium to a standard 70-kg man would seem safe.

Table 1 shows the radiation dose to the whole body for 1 and 2 half-lives after production of ^{134m}Cs in comparison to other radionuclides used or proposed for myocardial scanning. Ammonia (13N) has been omitted from Table 1 because the radiopharmaceutical at this time cannot be used generally because of its very short half-life. The radiation dose to the whole body was calculated by using the absorbed-fraction method, and assuming that the radionuclides were distributed uniformly in the whole body. The biological half-lives in the human for these radionuclides were taken from published literature. The details of these calculations will be published separately. Radiation dose to the whole body per millicurie from this agent compares favorably with that of the other radionuclides. For a more meaningful comparison of radiopharmaceuticals, however, one should compare the radiation dose to the patient for each detected photon with either an Anger camera or a rectilinear scanner of a given spatial resolution. This compares the radiation burden per unit information obtained (*10*) as shown in Table 1, columns 6 and 7. It can be seen that ^{134m}Cs is preferable to ^{129}Cs and ^{43}K, and it compares favorably with ^{201}Tl.

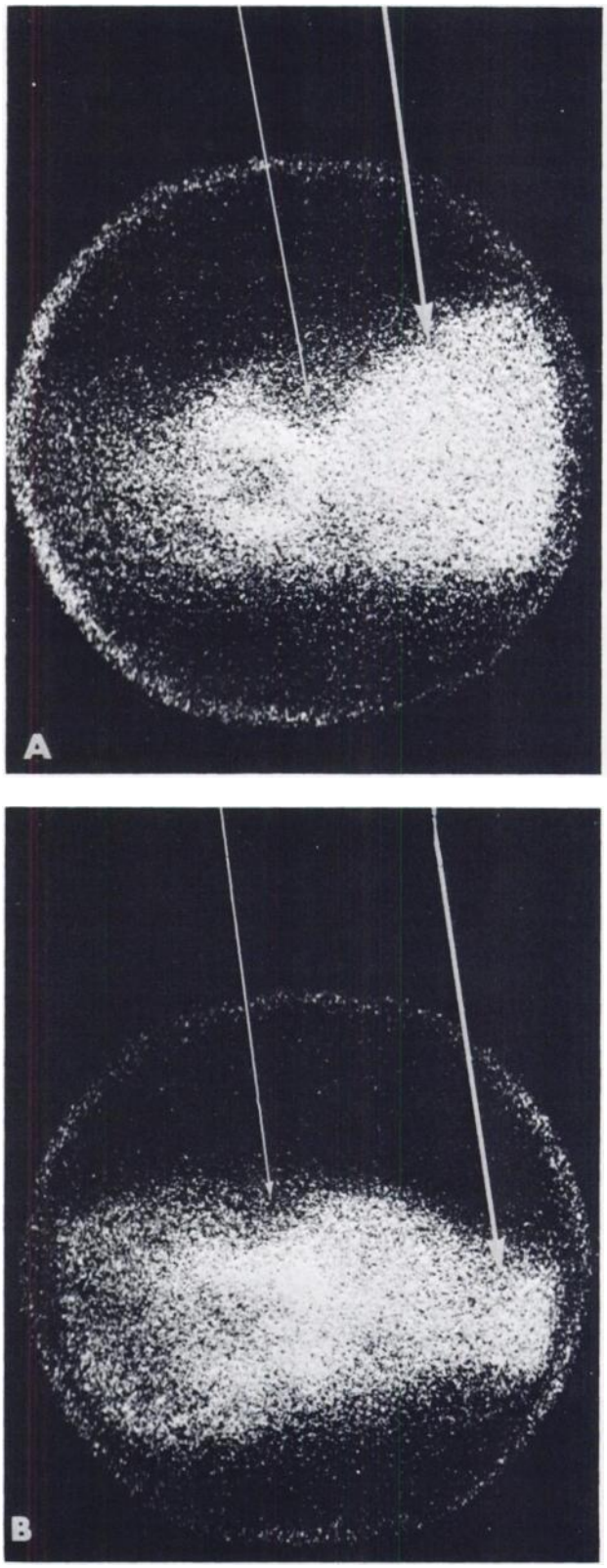

FIG. 1. Anger camera images of infarcted heart 25 min post 3 mCi injection of ^{134m}Cs. Large arrows indicate radioactivity in liver; small arrows indicate area of infarct in left ventricular wall. In A, detector is angled slightly from left to right as well as caudad. In B, detector is somewhat cephalad and points slightly from right to left. Heart specimen showed infarct about 1 × 3 cm in anterior left ventricular wall near apex.

The radiation dose due to ^{134m}Cs + ^{134}Cs can be further reduced by a factor of 2–3 with oral administration of Prussian blue, which inhibits the reabsorption of cesium from the gut, and therefore reduces the biological half-life of cesium (*11*).

The behavior and distribution of cesium in animals and humans has been studied in detail by other researchers (*12,13*). It is known that, cesium, in its initial distribution, largely mimics potassium, and therefore, a relatively large concentration is found in living myocardial cells.

We have studied ^{134m}Cs in three dogs with acute myocardial infarctions. We used an intra-arterial wire electrode that was placed under fluoroscopic control to induce electrothrombotic occlusion of the left anterior descending coronary artery or one of its major branches. The myocardial infarctions were documented by EKG monitoring. The following day the dogs were injected with 3 mCi of ^{134m}Cs, and myocardial imaging was performed in multiple projections using an Anger camera with a pinhole collimator. Simultaneously, blood was sampled by an indwelling catheter at 1–5 min intervals for 2 hr to determine the clearance of ^{134m}Cs from the blood. This clearance had two exponential components, one with a half-life of approximately 3 min and the other about 25 min. The best images were obtained between 25 and 60 min after injection. The dogs were then sacrificed, and the Anger camera images were correlated with the distribution of infarcted areas as seen in the heart. In the in vivo images, infarcted areas were clearly delineated as were the cardiac chambers and walls (Figs. 1A, 1B). The details obtained from these images compare favorably with previously published myocardial images. We feel that the easy availability, suitable physical characteristics, and good image quality obtained justify evaluating the use of ^{134m}Cs in human myocardial studies.

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