

A COMPARISON OF $^{82}\text{Rb}^+$ AND $^{13}\text{N}_3$ FOR MYOCARDIAL POSITRON SCINTIGRAPHY

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Rubidium-82 (75-sec half-life) is eluted from a ^{82}Sr (25-day half-life) generator and infused into phantom and dog to show that it gives images of myocardial accumulation comparable to ^{13}N -ammonia with the positron camera.

Radionuclides of the chemically related alkaline elements, potassium, rubidium, cesium, and their analogs, have been shown to be of clinical value in the direct assessment of the distribution of myocardial blood flow using noninvasive scintigraphic techniques. High-resolution positron scintigraphic techniques appear particularly attractive not only for localization and sizing of myocardial infarctions but for direct assessment of the distribution of regional myocardial blood flow. The purpose of this paper is to demonstrate the feasibility of positron imaging of the myocardium in patients with ^{82}Rb and a high-speed positron camera as an alternate to imaging the myocardium with ^{13}N -ammonia.

Of the many radioisotopes of potassium analogs, relatively few are positron emitters. Among these are: ^{38}K , 7.7 min; ^{79}Rb , 21 min; ^{81}Rb , 4.6 hr; ^{82}Rb , 1.2 min; $^{82\text{m}}\text{Rb}$, 6.3 hr; ^{84}Rb , 33 days; and ^{13}N -ammonia, 10 min. Of these nuclides, ^{38}K , ^{79}Rb , ^{82}Rb , and ^{13}N -ammonia are relatively free from other gamma rays and are sufficiently short lived to be useful in acute clinical situations in which the patient's condition is changing rapidly, thus enabling repeated studies to assess the efficacy of various modes of therapy. Studies using most of these radionuclides require a charged-particle accelerator near the hospital or clinic. An exception is ^{82}Rb , which can be obtained from a long-lived ^{82}Sr generator (25-day half-life) and is therefore available at will for application in acute clinical situations. In addition, its short half-life offers low radiation exposure to the patient.

METHODS

The comparison of ^{82}Rb and ^{13}N -ammonia for myocardial scintigraphy was carried out using a

resolution phantom and multiple intravenous injections in a dog. A multicrystal positron camera was used to image the distribution of positron-emitting radioactivity following intravenous injection of these two agents (1). Rubidium-82 was obtained by continuous elution of a generator containing the parent isotope ^{82}Sr .

The ^{82}Sr - ^{82}Rb generator previously developed (2) was modified and miniaturized to provide an easily transportable source of 75-sec ^{82}Rb , which is obtained by elution from the 25-day ^{82}Sr parent. The dimensions of the semiautomated generator system (Fig. 1) are $60 \times 22 \times 18$ cm. The ^{82}Sr parent, which was produced at the LBL 88-in. cyclotron, was placed on weakly acidic cation-exchange resin retained in a stainless steel column fitted with a fine mesh screen and Luer-lok connections. Intramedic polyethylene tubing and adapter fittings were used to provide a closed system for the intravenous infusion of the ^{82}Rb in 2–3% saline solution. Every 5–10 min about 0.8 mCi pure $^{82}\text{Rb}^+$ can be injected automatically with about 7 cc eluant. Nitrogen-13-ammonia was obtained by deuteron irradiation of methane in the MGH cyclotron by a procedure similar to that employed by Tilbury, et al (3). A comparison of the spatial resolution and the sensitivity of the camera for each of the two agents was carried out using a line phantom constructed of tubing for introduction of isotope (Fig. 2). The phantom consists of eight 2-cm lines separated by distances of 5.0, 2.5, 2.0, 1.5, 1.1, 0.75, and 0.5 cm. This phantom was loaded with about 0.7 mCi of ^{13}N -ammonia and ^{82}Rb and 1.9×10^5 events were accumulated during 200 sec in each case. Images of ^{82}Rb were obtained with no motion of the positron camera. Images obtained with ^{13}N -ammonia employed a linear scanning motion of the positron camera perpendicular to the direction of the phantom lines to improve spatial sampling (4).

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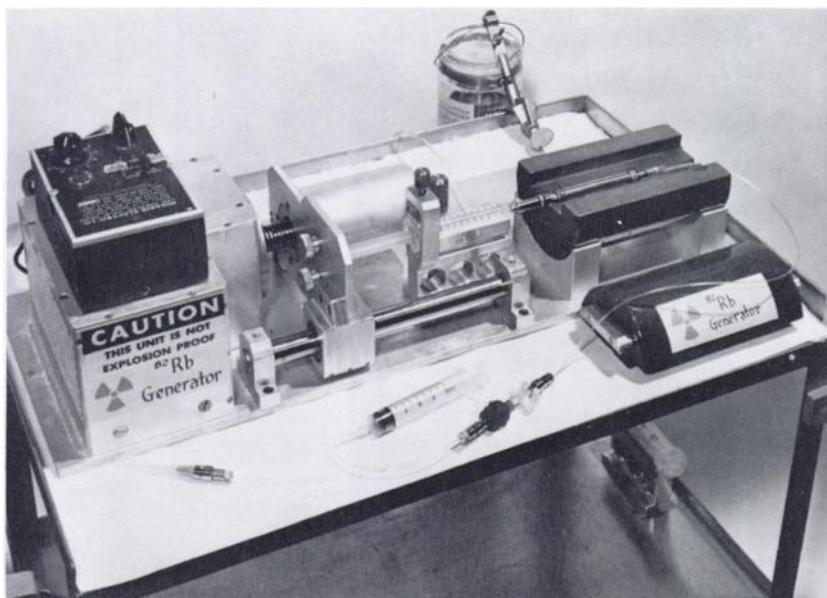


FIG. 1. Rubidium-82 generator is capable of delivering 0.8 mCi in 7 sec with 7 cc of 2–3% sodium chloride.

A 27-kg mongrel dog anesthetized with sodium pentobarbital was positioned such that the myocardium was viewed in the left lateral projection on the 0.4 focal plane of the camera. Rubidium-82 was introduced through an indwelling catheter in a rear leg vein by continuous elution of the ^{82}Sr generator with 10 cc of 3% NaCl over a period of 15 sec. Approximately 0.6–1.0 mCi of ^{82}Rb was introduced in this manner. Imaging commenced at periods ranging from 30 to 90 sec after the end of infusion using one-dimensional scanning motion of the camera for a period of at least two ^{82}Rb half-lives. Multiple injections were made with 5–10-min intervals between injections. Immediately following the ^{82}Rb scans, 1–2 mCi ^{13}N -ammonia in physiologic saline, prepared in the MGH cyclotron, was introduced by bolus injection. Scanning commenced at about 5 min after introduction of the activity; scan times were on the order of 200 sec, again using one-dimensional scanning motion of the camera.

RESULTS AND DISCUSSION

Rubidium-82 spatial resolution is comparable to that of ^{13}N -ammonia (Fig. 2). The two phantom images afford a direct comparison of the use of scanning motion as opposed to static imaging with the positron camera. The spatial resolution obtained with ^{13}N -ammonia is approximately 20–30% higher than that obtained with ^{82}Rb , whose end-point positron energy is nearly three times that of ^{13}N . In both cases the lines separated by 1.5 cm are well resolved. No correction was made for random coincidence background or for nonuniform distribution of sensitivity over the face of the camera. The average random coincidence count background over the

face of the camera is approximately 15–20% of the total coincidence count at the average counting rates employed ($\sim 10^3$ cps). The overall detection sensitivity is approximately 10^3 coincidence counts per minute per microcurie in the camera's field of view in air at a spacing of 50 cm between detector faces.

Figure 3 shows examples of left lateral position scintigrams obtained with the two agents in the 27-kg dog. The ^{82}Rb image was obtained beginning about 75–90 sec after the infusion of activity. Images

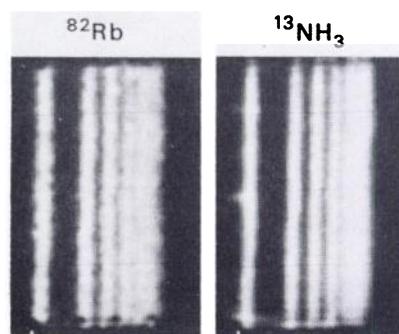


FIG. 2. Positron imaging of phantom with 0.2 cm i.d. tubing separated by distances of 5.0, 2.5, 2.0, 1.5, 1.1, 0.75, and 0.5 cm. Linear scanning was employed to improve spatial sampling for ^{13}N -ammonia image.

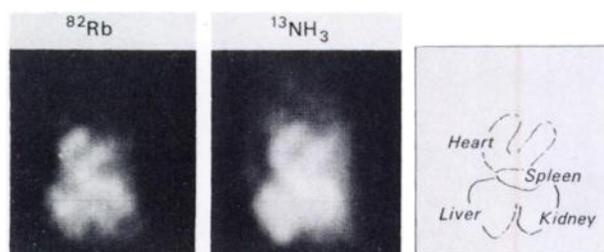


FIG. 3. Comparison of ^{82}Rb with ^{13}N -ammonia myocardial imaging in dog.

obtained at earlier times exhibited activity still present in the blood. Thus adequate myocardial images were obtained at times greater than about one ^{82}Rb half-life after the end of infusion. The ^{13}N -ammonia image was obtained between 5 and 8 min after introduction of activity.

The quality of images in Fig. 3 is comparable for both of the agents except that there is a greater tissue background activity in the ammonia image relative to that of the rubidium image. This is probably a result of the passive diffusion of ^{13}N -ammonia into muscle tissues other than the myocardium whereas the ^{82}Rb behaves largely as a monovalent cation. An interesting feature of the two images is that the ^{82}Rb image defines the intraventricular cavity less sharply than the ammonia, suggesting, in part, the effect of the higher positron energy emitted in the decay of ^{82}Rb as well as a gradient of activity distribution increasing from epicardial to endocardial surface as reported with other monovalent cation distributions in the myocardium (5). In both cases activity taken up in the spleen, liver, and kidney are approximately equivalent and do not interfere with the quality of the myocardial image.

These studies suggest that ^{82}Rb may be a good radionuclide for positron imaging of the myocardium, particularly in acute clinical situations where myocardial scintigraphy can be done in an intensive care unit at bedside using a positron scintigraphic device. Previous work with ^{82}Rb using the Anger positron camera was unsatisfactory (6) because that camera saturates below the activity level necessary for adequate statistics considering the physical half-life. Gamma-mode imaging of the human myocardium using ^{82}Rb in two patients shows this isotope will give good images if 5 mCi are injected. Coincidence-mode imaging will undoubtedly provide comparable human images as well in a positron camera designed to operate with these high activities. Because of the short half-life, ^{82}Rb is ideal for resting and stress studies at the same sitting in patients. Furthermore, dogs with coronary artery occlusions could be studied under stress such as produced by ventricular pacing, hypoxia, isuprel, or contrast infusion. A program for positron imaging of normal and ischemic myocardium is presently under way at the Massa-

chusetts General Hospital for which a dedicated positron camera is being designed to be located in the myocardial intensive care unit. A ^{82}Sr - ^{82}Rb generator of 3-mCi output will complement this program. For 1 mCi the radiation dose is 1.7 mrads to the whole body and 10 mrads to the heart.

SUMMARY

A comparison of ^{82}Rb and ^{13}N -ammonia for myocardial scintigraphy has been carried out in a dog. Images obtained with both agents are of uniform high quality. A relatively high uptake is obtained in heart muscle for both agents compared with skeletal muscle although the relative skeletal muscle uptake of ^{82}Rb appears to be somewhat less than that for ^{13}N -ammonia. The clearest ^{82}Rb myocardial images with the positron camera were obtained at times after about 1 min after the end of infusion when the activity has cleared from the blood. Some activity appears in spleen, liver, and kidneys but does not affect the quality of the myocardial images.

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