jnm / PRELIMINARY NOTE

RADIOPOTASSIUM-38 FOR IN VIVO STUDIES OF DYNAMIC PROCESSES

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Rapid uptake of ^{42}K by the myocardium indicates that 7.7-min ^{38}K may be advantageous over 22.4-hr ^{43}K for in vivo imaging. The two 511-keV "annihilation" photons, which are emitted at 180 deg to each other incidental to the decay of ^{38}K by positron emission, furnish inherent directionality and high sensitivity when they interact with appropriate detectors. The 2.17-MeV gamma ray emitted in each disintegration usually is disadvantageous.

The 11-min average life of ^{38}K ideally matches the duration of processes involving rapid turnover of potassium. And it provides greatly reduced radiation exposures, improved statistics, and frequent repeatability in obtaining multiple views and in studies of pathological, physiological, and pharmacological variations.

Bombardment of calcium carbide with deuterons from a small biomedical cyclotron, followed by simple and rapid chemical manipulations, furnishes ^{38}K in high specific activity in the $^{40}_{20}Ca(^{2}_{1}H,^{4}_{2}He)^{38}_{19}K$ nuclear reaction.

Potassium-38 decays by emitting 2.68-MeV (max) positrons with a 7.7-min $T_{1/2}$. Thus, 200% of 511-keV annihilation $\pm\gamma$-rays (*1*) become available for imaging. The calculated "narrow-beam" half-thicknesses of these are: water, 7.2 cm; NaI, 2.1 cm; lead, 0.42 cm. The calculated (*2*) probability of photopeak interactions with the 1.3-cm-thick NaI(Tl) of the Anger camera is ~17%. Unfortunately, a 2.17-MeV gamma ray accompanies each disintegration; but the half-thickness of it in NaI is large (~4.7 cm).

Poe (*3*) effectively compared precordial uptake and clearance characteristics of ^{42}K and ^{131}Cs after administering them simultaneously to dogs. The ^{42}K reaches plateau concentration in the heart within 5–20 min when injected into a jugular vein. Only 22% remains in the blood at 2 min and scanning may commence immediately. After bolus injection into the anterior descending coronary artery, 71% is extracted during the first circulation through the coronary capillary bed. The amount of ^{42}K for recirculation is inconsequential and it clears quickly from the heart with a 78-min $t_{1/2}$. Hence, immediate rapid imaging is indicated.

Poe studied the prospect of using ^{43}K "for quantitative measurements of regional myocardial blood flow and function" because of its relatively short $T_{1/2}$, its "dominant gamma emissions in the ^{131}I range," and its producibility in the UCLA Biomedical Cyclotron. Actually, ^{43}K emits 96 gamma rays per 100 disintegrations, having energies in the range of 0.59–1.01 MeV (*1*). Calculated "narrow-beam" half-thicknesses of these in lead exceed 0.5 cm; thus, resolution may be degraded because of septal or edge penetrations. Moreover, the calculated (*2*) probability of photopeak interactions with the NaI(Tl) of the Anger camera is only ~13% for the 0.619-MeV gamma rays emitted 81% of the time by ^{43}K.

Radiopotassium-38 would seem to be a better choice than ^{43}K for imaging the heart in view of Poe's findings because its 7.7-min $T_{1/2}$ closely matches the time of maximum uptake in contrast with the 175-fold longer 22.4-hr $T_{1/2}$ of ^{43}K (*1*). Advantages of ^{38}K over ^{43}K for rapid imaging stem principally from the superior resolution achievable as well as from improved statistics obtainable because of greatly reduced radiation. Despite the more energetic beta particles of ^{38}K, the radiation absorbed doses from it will not exceed a few percent of those from ^{43}K.

Use of the Anger camera in the positron mode

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to achieve directionality by means of the two back-to-back $\pm\gamma$-rays of ^{38}K, which are emitted 180 deg to each other, should make this instrument at least ten times more sensitive for imaging the heart and other small structures than when transmission through apertures in metal collimators is used (*4*). When computer-processed data from two opposite Anger-type cameras (operated in positron-coincidence mode) are used to study three-dimensional resolution, it is found to be 1.5 cm laterally and 3.5 cm axially (*4*). Tomographic capabilities (*4*) should be adequate to improve images of ^{38}K in the heart while discriminating against accumulations in chest and back muscles and other tissues. Particularly attractive is the potential for making absolute activity determinations (*4*) of ^{38}K in the heart and other structures in health or disease as well as in studies of physiological variances or of responses to drugs.

The new MGH positron camera (*5*) may be used advantageously with ^{38}K when sequential images of very rapid dynamic processes involving potassium are desirable.

The 11-min average life of ^{38}K facilitates repetitive and multiple views since residual activity from a previous dose may disappear largely during procedural manipulations. This convenient but appropriately short average life of ^{38}K makes it the *ideal* (*6*) potassium radionuclide here, because it is comparable to the duration of many physiological and pharmacological phenomena. Use of it for studies of potassium metabolism in cancer is inviting since many workers report high concentrations in tumors (*7*).

Generation of ^{38}K in small biomedical cyclotrons now available in many medical centers might best be achieved in the nuclear reaction (*1*) discovered in 1937, viz., $^{40}_{20}Ca(^{2}_{1}H,^{4}_{2}He)^{38}_{19}K$. The Coulomb barrier is ~4.3 MeV and the Q-value is strongly positive at 4.6 MeV. Natural calcium contains 97% of the target ^{40}Ca.

A convenient compound of calcium for a cyclotron target is calcium carbide because its high melting point of 2,300° and good thermal conductivity permit the use of high-beam currents (*8*).

Simply adding water to the bombarded target rapidly rids it of the carbon as acetylene, little of which should be ^{11}C-HCCH when the deuteron energies are kept below ~12.5 MeV. The 7.7-min ^{38}K, present in the supernate in no-carrier-added specific activity, should be separable quickly by filtration or centrifugation to remove the insoluble $Ca(OH)_2$ residue.

Nitrogen-13 ($T_{1/2}$ = 10 min) may be generated simultaneously (*1*) in the $^{12}_{6}C(^{2}_{1}H,^{1}_{0}n)^{13}_{7}N$ reaction (Q = −0.3 MeV). It may be liberated as ^{13}N-ammonia under the strongly basic and reducing conditions prevailing during simultaneous release with the acetylene (*8*). If desired for use as a vital biomolecule (*5,9*), the ^{13}N-NH_3 is readily separable from the acetylene.

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