nm/PRELIMINARY NOTE

A DUAL-SPECTROMETER SYSTEM FOR HIGH-EFFICIENCY IMAGING OF MULTI-GAMMA-EMITTING NUCLIDES WITH THE ANGER GAMMA CAMERA

D. A. Goodwin, D. Menzimer and R. DelCastilho

Veterans Administration Hospital and Stanford University School of Medicine, Palo Alto, California

In spite of the fact that many gamma-emitting nuclides have more than one useful gamma energy, it is impossible in imaging with the Anger camera system to include more than one photopeak within the window, unless the two peaks are very close together. In radionuclide imaging we are often faced with a severe photon limitation, especially in cases in which the administered dose is limited by a long effective half-life, such as with ^{75}Se-selenomethionine, and when one is imaging a radionuclide distribution over a period of 24 hr or longer. One way of attacking the problem of photon limitation is by using very short-lived radionuclides and administering a very large dose. This approach has worked extremely well when the data can be collected soon after injection. Brain scanning with ^{99m}Tc-pertechnetate immediately after a 10-mCi injection is an example of this type of study. This approach is not feasible, however, in other types of studies where the observation time is prolonged due to slow biological processes such as uptake of colloid by lymphatics or uptake of radionuclides by tumors or blood clots (*1–3*). These studies can only be completed over a period of 24–48 hr or longer, and a large amount of radionuclide can not be administered due to the radiation hazard to the patient. Here another solution must be sought to the photon-limitation problem by usefully increasing the detection efficiency of the instrument. The following discussion will be illustrated with the radionuclide ^{111}In, which has an ideal pair of gamma photons for this application (173 keV and 247 keV), as well as a physical half-life (2.8 days) well suited to studies carried out over a period of 24 hr to 1 week (*4*). The following techniques can be applied, however, to any radionuclide with two or more useful gamma emissions.

METHOD

The Anger gamma camera uses a system in which four separate coordinate signals are developed in the detector from a single event in the crystal (*5*). These signals are then sent to the console where pulse-height and positioning information are developed. The dual-spectrometer system we describe here requires the addition of a second summing network and pulse-height analyzer to the standard Nuclear-Chicago Pho/Gamma system. If one has the positron gamma camera (*6*), it already contains these components, which can be "tapped" as we describe in this paper; if not, then the modules can be added to the standard Pho/Gamma system. The additional spectrometer is referred to in this discussion as Spectrometer B and is set to pass only the pulses from the high-energy range of the pair (247 keV in the case of ^{111}In). The spectrometer already contained in the standard Pho/Gamma console is referred to as Spectrometer A and is set to pass only the pulses from the low-energy range of the pair (173 keV in the case of ^{111}In). In the case of ^{111}In, the x and y pulses associated with the 247-keV photopeak are 247/173 times as large as those associated with the 173-keV photopeak. The former must be attenuated by a factor of 173/247 for the images associated with the two photopeaks to be the same size and to add together effectively. As will be seen from the following discussion Spectrometer A handles all the events; the high-energy ones are attenuated by special gain gates to match exactly the low-energy pulses. The final common pathway of all pulses, whether originating from a high- or low-energy event, is therefore through Spectrometer A and the console positioning circuitry; both these components are standard equipment with the Pho/Gamma system.

In the dual-spectrometer system (see block diagram, Fig. 1), a 1-μsec delay is added in each coordinate line. The delayed information is then sent through the gain gates and on to the console in the conventional manner. The undelayed coordinate sig-

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For reprints contact: David A. Goodwin, Nuclear Medicine Service, Veterans Administration Hospital, 3801 Miranda Ave., Palo Alto, Calif. 94304.

nals are summed and analyzed by Spectrometer B and, if they are from a high-energy event, are passed and the resultant output sent to trigger the gain gates. The spectrometer in the Pho/Gamma system, Spectrometer A, is set in the normal manner so that the gamma analyzer window encompasses the lower energy photopeak (173-keV in the case of ^{111}In). Spectrometer B is provided with a special set of attenuators so that the window encompasses the higher energy peak (247 keV for ^{111}In). Both Spectrometers A and B are set with a 20% window width.

The sequence of events is as follows: An event is seen by the detector and, from this, four coordinate signals are developed. These signals are delayed by 1 μsec allowing Spectrometer B to determine whether the signal was from the higher or lower energy event. If the signal was from the lower energy event, it will be rejected by Spectrometer B, and after 1 μsec the information will continue through the delay circuit unchanged to be handled in the usual way. The resultant z pulse formed from the addition of the coordinate signals will fall within the window of Spectrometer A and place the information at the proper location on the display. If, however, the signal was from a high-energy event, it will be passed immediately by Spectrometer B, and the gain gates will be triggered, which changes the gamma system gain by a precise and predetermined amount depending on the difference in the two gamma-energy ranges being looked at (173/247 for ^{111}In) before the coordinate information passes through. The individual coordinate signals formed from the high-energy event are each attenuated equally and separately by the gain gates so that z pulse formed by their sum will also fall within the Spectrometer A window, and the information on the display will be in exactly the same location as that from the low-energy event, providing the transfer took place at the same location in the crystal.

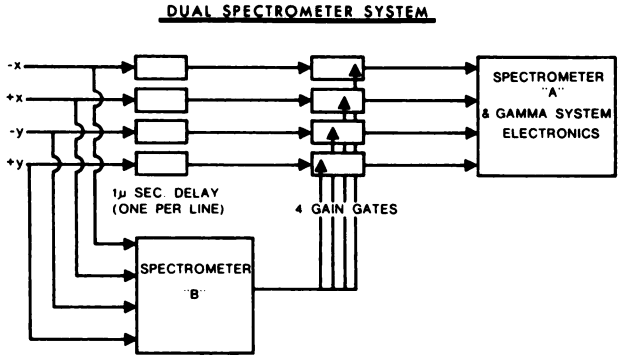

FIG. 1. Dual-spectrometer circuit uses two addition circuits and two pulse-height analyzers for counting both energy peaks of ^{111}In.

By changing Spectrometer B gain and the attenuator values on the gain gates, the system can be adapted to handle gamma energies (or groups of gamma energies that fall within a 20% window) from multi-gamma-emitting radionuclides other than ^{111}In over the entire useful gamma-energy range of the gamma camera.

With this dual-spectrometer system only the photo-

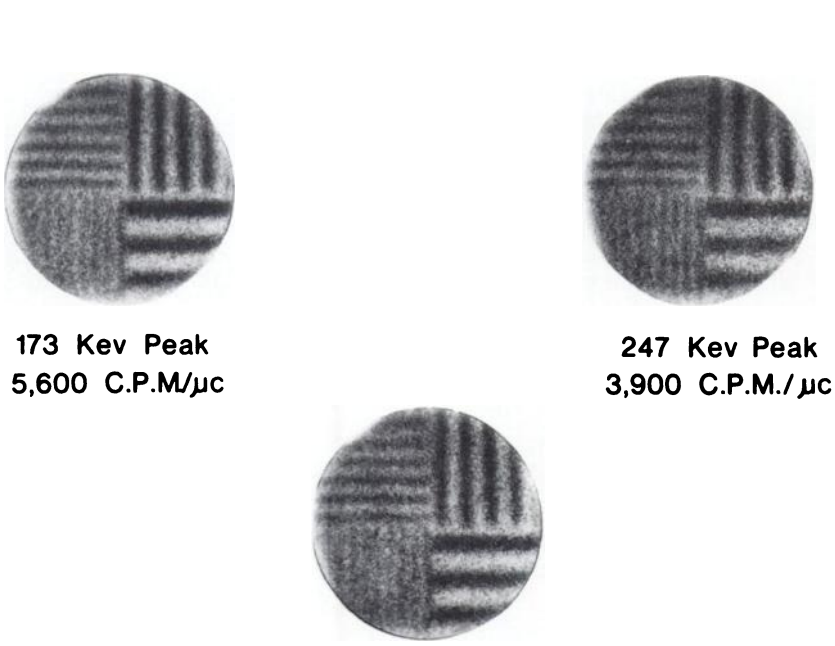

FIG. 2. ^{111}In phantom study shows resolution obtained using combined peaks is comparable to that using 173-keV peak alone. Resolution is slightly better using 247-keV peak alone. Studies were done with 20% windows.

peaks are counted, eliminating scattered photons lying outside the photopeaks which would degrade resolution. A single switch returns the system to single-channel function. An alternative circuit is currently being tested which would eliminate many of the added components described here and use those modules already present in the standard Pho/Gamma III console.

RESULTS

The sensitivity of the Anger gamma camera for ^{111}In without the collimator in place was approximately 9,000 cpm/μCi on the 173-keV peak and approximately 5,500 cpm/μCi on the 247-keV peak; calculated total counts per minute per microcurie were 14,500. Thus the 173-keV peak accounted for approximately 60% and the 247-keV peak approximately 40% of the total available counts. With the dual spectrometer in operation the observed counts were 13,900 cpm/μCi or 96% of the calculated sum value. Therefore one can obtain approximately a 40–60% increase in counting rate with the dual-spectrometer system using ^{111}In depending on whether the high- or low-energy peaks were being counted initially. Phantom studies carried out accumulating 500,000 counts with Spectrometer A, first set on the low-energy peak and then on the high-energy peak and then both peaks (using Spectrometers A and B) are shown in Fig. 2. Slightly better resolution is obtained using the 247-keV peak alone; however, the ¼-in. strips are still plainly visible using the 173-keV peak. The resolution when both peaks are used is comparable to the resolution obtained with the 173-keV peak. Thus there is no significant loss in resolution when both photopeaks are counted. The resolution is identical to that obtained with ^{99m}Tc which has a single 140-keV gamma; however, 30–40% higher counting rates are obtainable with ^{111}In using the dual spectrometer.

DISCUSSION

In nuclear medicine the problem of photon limitation in imaging has been attacked in one of two ways: first, by using radionuclides with shorter and shorter physical half-lives to enable larger and larger doses to be administered without radiation hazard to the patient; and second, by increasing the useful detection efficiency of the instrument as one does with stationary gamma-camera devices. It is apparent that the first method is limited to those studies in which the data can be collected in a time period compatible with the physical half-life of the radionuclide, which in some cases is measured in seconds.

In studies that require longer periods of observation such as bone scanning, cysternography, lymphography or tumor localization, the physical half-life of the radionuclide label must be matched to the observation time and is usually measured in days. This limits the amount of radioactivity that can safely be administered to the patient. Photon limitation in these studies can only be overcome by increasing the useful detection efficiency of the instrument. In the case of ^{111}In, detection efficiency has been increased 40–60% without degrading resolution by using the dual-spectrometer system. Efficiency for other radionuclides with more than one useful gamma energy such as ^{67}Ga, ^{75}Se and ^{169}Yb can also be significantly increased by this technique.

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