Pulmonary Radiation Microemboli

It was with great interest that we read this journal's recent article on "Pulmonary Radioactive Microemboli following Radionuclide Venography" (*1*).

Since 1974 our department has used a method of venography slightly modified from Henkin et al. (*2*), using MAA from various manufacturers. Shortly after this procedure was adopted, some of our patients developed small, pulmonary emboli with concentrated radioactivity (Fig. 1). In some of the injected veins, a persistent streak could be seen to extend from the injection site up through the lower third of the calf. We concluded that the sluggish blood flow diluted the injectate too slowly, with resulting i.v. clotting. We believe that the observed pulmonary microemboli could originate from such radioactive clots in the legs. We also think that spots of increased radioactivity in the veins of the lower extremities could result from entanglement of radioactive microemboli in pre-existing thrombi.

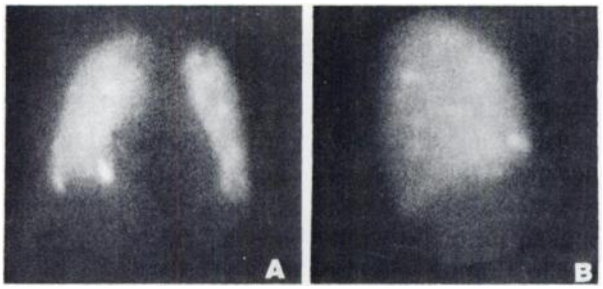

FIG. 1. "Radioactive" pulmonary microemboli in peripheral lung vessels as a result of i.v. blood coagulation caused by slow dilution of Tc-99m MAA. (A) anterior view and (B) right lateral view.

By way of prevention, 2 yr ago we started to mix 2,000 units of heparin into each prepared suspension of Tc-99m before injection. Since that time we have seen neither local thrombosis nor "radioactive" pulmonary emboli. There may be modest uptake in the thrombosed legs, but at most it is transitory, lasting 1 min or less.

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Human Reaction to Bovine TSH

The readership is in debt to Dr. Krishnamurthy for his recent article showing the relationship between dosage and human reaction to Bovine TSH (*1*). This report lends support for the attitude of those of us who advise allowing the patients to produce their own endogenous TSH by permitting them to be off thyroid hormone 6 wk before imaging procedures are employed. This will generally permit endogenous serum TSH levels to reach a maximum. Under these circumstances, supplemental exogenous TSH adds nothing. If this period of withdrawal from thyroid hormone does not result in high levels of endogenous TSH, one could conclude that there is a substantial amount of functioning thyroid tissue remaining. Under these circumstances, the radioactive iodine uptake will be adequate for therapeutic purposes without stimulation in most instances. In some cases one can employ a period of treatment with antithyroid drugs, taking advantage of the rebound increase in radioiodine uptake after their withdrawal, or the diuretic regimen I reported several years ago (*2*).

Utilizing these techniques will make it seldom necessary to employ exogenous TSH in the treatment of thyroid cancer patients.

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Coincidence Assay Techniques—Hg-197

We have read with interest the correspondence on the coincidence summing technique applied to the absolute calibration of I-125 (*1,2*). It seems useful to draw attention to limitations in the validity of the present techniques, but it is also necessary to demonstrate the significance of the correction terms under the conditions of practical measurement typically employed.

We have recently applied the coincidence-summing assay technique to Hg-197 (*3*). This nuclide shows a decay scheme closely analogous to that of I-125 (Fig. 1), since the 192-keV and 268-keV gamma photons have an intensity $<2\%$ of that of the 77-keV gamma (*4*). The K x-rays range in energy from 67 keV to 81 keV, and thus as with I-125 the gamma photon and the K x-rays will be detected with almost equal efficiency by a NaI(Tl) well crystal.

Figure 2 shows spectra for a sample of Hg-197 of ~2 kBq (2,000 d/sec) counted outside and inside the well of a NaI(Tl) crystal. The upper spectrum shows one peak from the gamma and the K x-rays, whereas the coincidence spectrum (lower) shows a second peak at the sum of the x-ray and gamma energies.

Eldridge and Crowther (*5*) developed the earlier work of Harper et al. (*6*) to show that the activity N of a sample of I-125 is related to the counts per second in the singles and coincidence peaks, A_s and A_c, by the equation

$$N = \frac{P_1 P_2}{(P_1 + P_2)^2} \cdot \frac{(A_s + 2A_c)^2}{A_c} \text{ Bq.},$$

where P_1 and P_2 are the emission probabilities for the gamma and x-ray photons, respectively. This is effectively the same equation as quoted by Harper and Lathrop (*2*). With their intensity data for I-125, the coefficient takes the value 0.240 and is insensitive to small changes in P_1 and P_2.

We have applied this equation to Hg-197 using the decay data given in the M.I.R.D. tables (*4*), which give the intensity of the 77-keV gamma photon to be 0.253 and the total intensity of the K x-rays to be 0.717. These give a

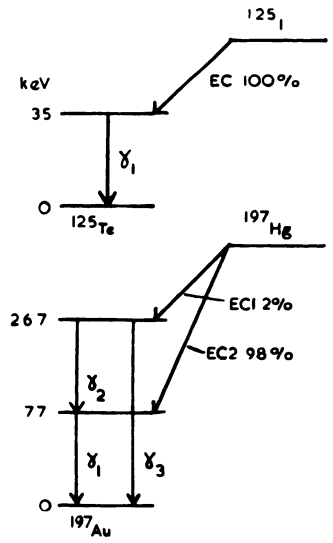

FIG. 1. Decay schemes of I-125 and Hg-197.

value of 0.190 for the intensity coefficient. Samples of Hg-197, obtained as chlormerodrin, were prepared in four activities and counted to test the validity of this approach. To test the effects of sample volume, the last sample was recounted after dilution.

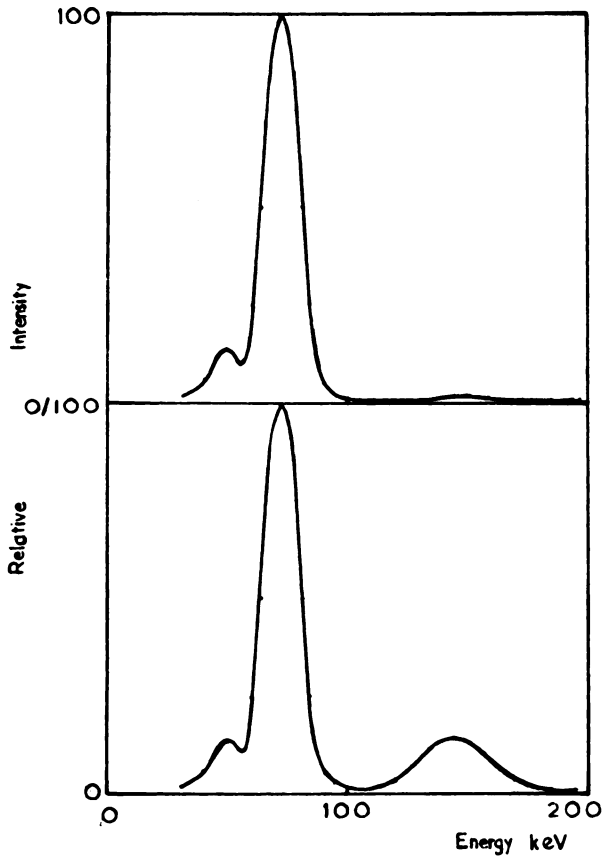

FIG. 2. Spectra of a Hg-197 sample counted in low geometry (upper) and in high geometry (lower).

Comparison of the radioactivities with those obtained for these samples from the National Physical Laboratory, Radiation Sciences Division, showed a small but consistent difference between the coincidence result and the N.P.L. calibration. A review of the literature on Hg-197, however, showed that whereas the latest data quoted in the M.I.R.D. Tables dates from 1965, Martin and Blickertoft reviewed Hg-197 in Nuclear Data Tables in 1970 (*7*). They give the gamma intensity as 0.195 and the K x-ray intensity as 0.718. Thus whereas the intensity of the x-rays remains unaltered, that of the 77-keV gamma is reduced from 0.25 to 0.19.

The new data give a value of 0.168 for the intensity coefficient, and the full expression for the activity of a sample is then

$$N = 0.168 \cdot (A_s + 2A_c)^2/A_c \quad \text{Bq}.$$

Figure 3 shows that this expression gives excellent agreement with the results of the National Physical Laboratory's standard ionization chamber. Checks showed that the results are insensitive to minor changes in peak definition or to changes in sample volume until the sample virtually fills the well.

The large variations in the quoted intensity of the strongest gamma photon of a common radionuclide reflect the difficulty found in separating the gamma from the K x-rays in many experiments. They may also have contributed to the large errors for Hg-197 calibrations (up to ~30%) found by Hare et al. (*8*) in their survey of well ionization-chamber calibrators.

In the literature on Hg-197, an abstract of a coincidence study was found (*9*). This appears to have contained a detailed study of intensities and an activity calibration, but we have not been able to obtain the original paper.

We feel that the successful application of this approach to Hg-197 supports the validity of the technique when used in appropriate conditions. These appear to be met satisfactorily when the sample activity is low—say, <10 kBq—

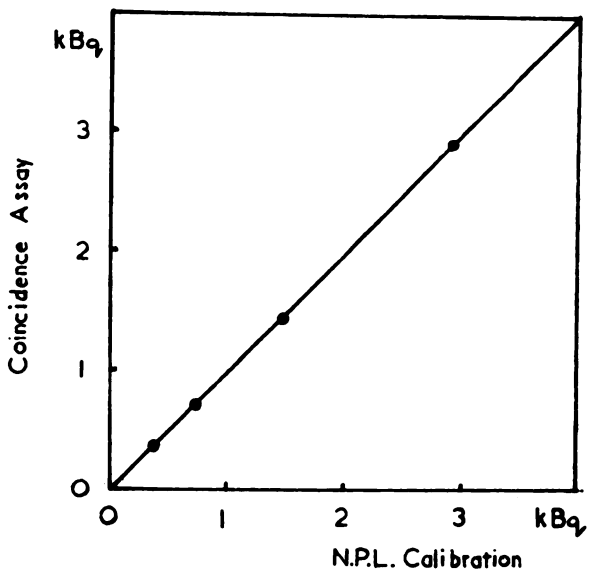

FIG. 3. Comparison of coincidence summing assay results with those of the National Physical Laboratory's standard ionization chamber.

and when the sample volume is such that close to 4π geometry is obtained.

The consideration of the decay of Hg-197 is also made somewhat simpler, since there are no K x-rays produced from internal conversion of the 77 keV gamma, and angular correlation effects must be minimal.

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Reply

In my letter to the editor (*1*) I pointed out a fundamental error in a formula by Harper et al. Although their expressions (a) and (b) are correct, expression (c) is not.

This is demonstrated in the special case of 4π geometry, 100% photoelectric detection efficiency, no attenuation, and all photons occurring in pairs cascaded, γ_1 and γ_2, with abundances $\eta_1 = \eta_2 = \eta_{12}$. This means that in formulae (a) and (b) of the referenced paper, $\epsilon_i = \eta_i$ (i = 1,2). For the counting rate in the coincidence peak, however, the following expression holds: $N_{12} = A.\ \eta_{12}$ and *not* according to (c) $N_{12} = A.\ \eta_1 \times \eta_2$, where A is the source activity.

It will be the task of Hudson, Waters, and Davis to explain their procurement of satisfactory results while using an erroneous equation.

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Coincidence-Counting Techniques

A number of letters have recently appeared in this journal (*1–3*) discussing the basis of the coincidence technique as applied to the absolute assay of I-125, I-123, and Hg-197. Van Damme (*1*) has questioned the validity of the use of a random coincidence term in calculating the sum-peak intensity, and has drawn attention to the possibility of angular correlation effects.

Harper and Lathrop (*2*) and Hudson, Waters, and Davis (*3*) have justified the application of their approach to I-125 and to Hg-197, but there appears to be value in amplifying their comments to draw particular attention to the physical situation met in x — γ and in x — x coincidence summing and to contrast this with γ — γ cascade summing.

We may do this by considering the decay of Hg-197 (Fig. 1). More than 98% of the disintegrations proceed via EC_1 to the 77.3-keV level of Au-197. Thus, to an acceptable degree of accuracy, those transitions proceeding via EC_2 may be ignored. Considering the electron-capture process that occurs in EC_1, we should note that this may proceed *either* by K capture, subsequently yielding a K x-ray, *or* by other modes such as L capture, which do not yield a K x-ray. Nonetheless, all these disintegrations lead to the 77-keV level whether or not a K x-ray was emitted in the process. The fraction yielding K x-rays, $\eta_1 = 0.72$.

The decay of the 77-keV state of Au-197 proceeds by the emission of γ_1, which may be internally converted so that the yield of externally detectable gamma photons *per disintegration* is reduced to $\eta_2 = 0.195$. The probability of internal conversion is clearly independent of whether or not a K x-ray was emitted in the previous electron-capture process.

The probability, per disintegration, for the detection of

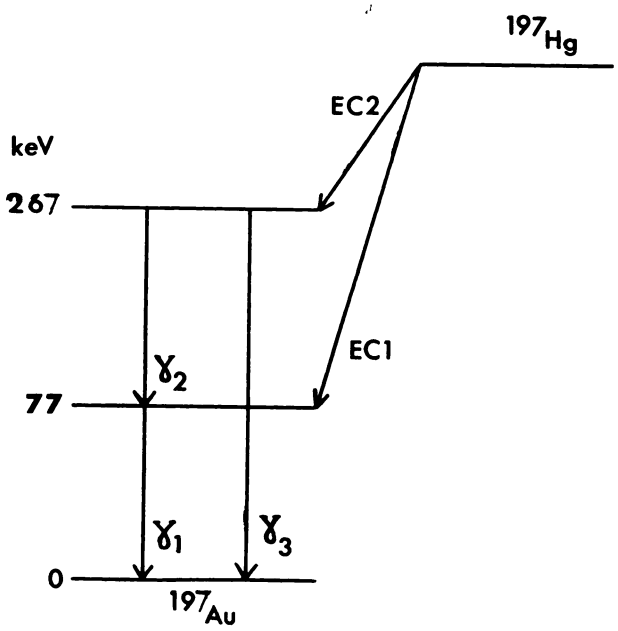

FIG. 1. The decay scheme of Hg-197.