safety only encourage misunderstanding and distrust of those professionals responsible for the safe use of radiation and radioactive materials.

Educated and responsible physicians are not afraid of radiation or its invisible boogieman, nor are they casual or uncaring about the real associated risk. If physicians, radiation safety officers and other professionals behave incorrectly towards the real radiation risk, then it is your fault and my fault for not educating them.

I have never (in 30 yr) met a physician that was any more knowledgeable about the realistic dangers of medical radiation uses than a member of the general public, unless that physician had specific radiation training. Again, this is not their fault, and their fear is consistent with what they do not know. Again, this is OUR fault as supposedly the knowledgeable experts. Indeed, we have actually profited upon this fear.

I emphasize "OUR" fault because your editorial tries to place blame on the regulatory agencies. Agencies such as the NRC, OSHA, EPA and the FDA are not the cause of difficulty involved in radiation uses in the medical field. It is not the regulation that causes difficulty, but ignorance that is the boogieman. You and I are the cause of its existence. Shame on us.

If the NRC deletes its control over medical use of radioactive material, you will surely have some of these uneducated physicians regulating your activities through the advisory body of "experts." You do not actually think that the SNM and ACNP will always pick the controlling body, do you? I think not. In the last 22 yr of working with radioactive materials, I have *never* experienced the NRC hindering the responsible medical use of byproduct materials.

If control is left up to the states, more restrictions will surely result. Most states cannot even agree on who is a physician much less an authorized user. What makes you think they can be realistic and consistent in their regulations? Do not forget, each state will need the funds to operate this new section. For current agreement states, the expense will certainly not be less. Decentralization usually (almost always) costs more. We will pay dearly to spite the NRC.

Be careful SNM and ACNP, you may get your wish!

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REPLY: About the only thing that makes me feel good about your letter is that you read my column "Scatter," entitled, "Invasion from Mars," and felt moved enough to write to me about it. I am disappointed that I apparently communicated so ineffectively that you think that our thoughts are not compatible.

I am gravely concerned about the lack of understanding of radiation effects among the public, regulators and physicians, including many radiologists, possibly nuclear medicine physicians and, certainly, radiation safety officers and health physicists. Several years ago, one of my mentors, Dr. Roslyn Yalow, in an editorial published in *Health Physics*, castigated the health physics community for its failure to educate and, in fact, for taking advantage of radiation phobia. Of course, as a presumably knowledgeable nuclear medicine physician activist and editor, I blame myself (in part) for this problem.

"Invasion from Mars" was a somewhat lighthearted but nonetheless serious description and criticism of the sad state of insight and understanding throughout the United States. I share your notion that this situation would worsen if the states directly control radiation safety issues. Please notice that I was previously quoted in *Newsline* concerning this matter specifically. I disagree strenuously that fewer problems would exist *without* the NRC. Additionally, I am distressed when knowledgeable health physicists and cancer epidemiologists admit the lack of evidence regarding adverse effects at radiation levels below 10 cGy per annum but say that we have to maintain almost *draconian* control because the United States Congress or the public expects us to do this. The best hope, I believe, is for an informed NRC to mandate national regulations in this regard.

Once again, I wonder what the Martians think about this?

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Don't Forget MERiT

TO THE EDITOR: We read with great interest the article of O'Donoghue et al. (*1*) concerning the relationship between tumor size and predicted curability for radiopharmaceutical therapy with beta-emitting radionuclides: a logical extension of their previous report (*2*). The data presented demonstrate the reduced effectiveness of targeted therapies of small metastatic lesions treated with high-energy beta-emitting radionuclides due to the long path lengths of the energetic particles relative to the size of the tumors. The authors cogently argue for the use of a multiradionuclide therapeutic approach to enhance curability. A low-energy beta-emitting radionuclide (^{199}Au for example) would be utilized to effectively irradiate small lesions, and a radionuclide which emits more penetrating beta particles (such as ^{90}Y) would be used to deposit much greater absorbed radiation doses in larger primary tumors and circumvent nonuniform tracer distribution.

Our group has also recognized the limitations of high-energy beta-emitters for treating small tumors. We have proposed the use of magnetic fields to confine high-energy beta particles to trajectories that promote increased energy deposition in small metastatic lesions (*3*). This technique, which we call magnetically enhanced radionuclide therapy (MERiT), utilizes magnetic fields to curve the paths of energetic beta-particles; confining them, to a certain extent, close to their point of emission. Thus, increasing the amount of energy deposited within the tumor and concurrently reducing radiation exposure from tracer in the tumor to surrounding normal tissues. This approach changes the character of the absorbed energy distribution in the tumor; MERiT can, for small lesions, increase the amount of deposited energy per unit volume of tumor.

To assess the effectiveness of MERiT in extending the size range of curable tumors in the context of the work of O'Donoghue et al. (*1*), the model of cure probability reported in this work was used. The only deviation from the model was the use of a Monte Carlo software package to calculate the absorbed fraction (φ). This simulation allows for the effects of magnetic confinement to be included in the calculation of φ. Results from this analysis for ^{90}Y are shown in Figure 1. The base values as reported by O'Donoghue et al. (*1*) for all model parameters such as tumor cell diameter, clonogenic fraction, packing factor, radiosensitivity, biological half-life and tumor population doubling time were used. In addition,

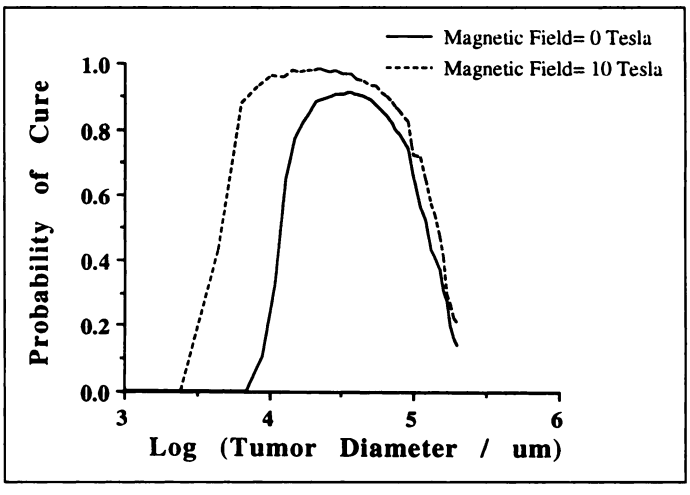

FIGURE 1. Probability of cure plotted versus tumor size. Effects of a 10-Tesla (1 Tesla = 10,000 Gauss) on predicted tumor curability is compared to the standard case when no field is present.

the initial activity per unit mass of tumor (C_0) reported to produce 0.9 cure probability at the optimal size was used. Cure probability with no magnetic field present is compared to the result when a 10-Tesla magnetic field is applied.

The two curves shown in Figure 1 clearly illustrate that the application of the magnetic field extends the range of potentially curable tumors significantly. Submillimeter lesions, however, are predicted to be incurable. What is not shown is the up to 80% reduction in absorbed radiation dose to adjacent normal tissues from radiopharmaceutical accumulated in the tumor, which in some applications, can limit the injected amount of radionuclide and therefore the effectiveness of the treatment. Hence, the use of magnetic confinement allows for more efficient utilization of emitted beta particles. The length of time a patient must spend in the magnet basically depends on the physical half-life of the radionuclide and localization time of the radiopharmaceutical. Therefore, ^{90}Y may not be the optimal choice as a MERiT radionuclide, instead a beta-emitter with a shorter half-life such as ^{188}Re might be more appropriate, if rapid localization is achieved.

Undeniably, the use of a multiradionuclide regimen is presently the most feasible way to target treatment to both primary and metastatic tumors. Future advancements in the fields of magnet design and radiopharmaceuticals may allow MERiT to become a useful technique in the treatment of cancer. Perhaps MERiT could be utilized in tandem with multiradionuclide approaches to maximize therapeutic effectiveness for a wider range of tumor sizes compared to the conventional approach. Regardless, discussion of the limitations of curability due to tumor size should include a mention of MERiT, even if it is currently impractical and expensive.

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Angular Sampling Necessary for Clinical SPECT

TO THE EDITOR: The recent article by Rosenthal et al. (*1*) provides a useful overview of quantitative SPECT, which undoubtedly will be used as a valuable educational reference. The article includes description and discussion of several important basic aspects of SPECT, including essential practical considerations. One important consideration is the choice of the number of projection angles for data acquisition which is often poorly understood. Unfortunately, the description of angular sampling provided by Rosenthal et al. (*1*) is in some respects ambiguous, such that readers are likely to derive an incorrect conclusion as to the required number of detector positions for SPECT acquisition. I hope that the following description may clarify the ambiguities related to angular sampling requirements and provide an intuitive basis for practical use.

As pointed out by Rosenthal et al. (*1*), the matrix size should be chosen so that the pixel size is less than half the resolution expected (essentially ensuring that the sampling theorem is satisfied and that the maximum spatial frequency in a study is preserved). It is then reasonable to suggest that the same sampling distance be preserved in the angular direction for any point in the reconstructed matrix. Consider Figure 1, which illustrates the gamma camera's position for two adjacent angular projections. The sampling distance can be considered as the arc (A in Fig. 1) subtended by

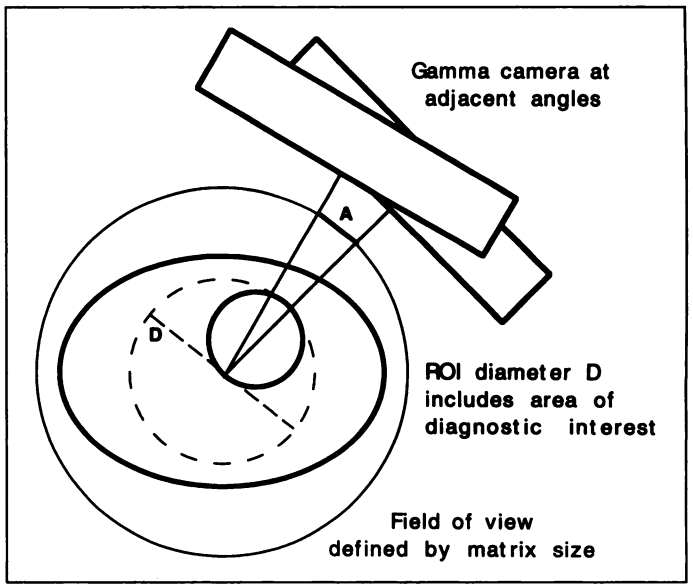

FIGURE 1. SPECT acquisition for a study of the thorax. Necessary angular sampling for complete reconstructed field of view requires that arc A be less than $\delta x/2$ (where δx is the resolution distance). For a cardiac study, however, it is sufficient for angular sampling to be satisfied on the circumference of the ROI diameter D, which encloses the region of diagnostic interest.

the angle between adjacent projections at any radius. The maximum arc is at the edge of the matrix; so if this arc is less than half the resolution distance, the complete matrix will be sufficiently well sampled. This would suggest an equation for the necessary number of separate angles over 360 degrees (N) to be:

$$N = \pi D/(\delta x/2)$$

using identical notation to Rosenthal et al's. article, where D is the field size and δx is the resolution distance. Note that the resultant equation is different to that provided by Rosenthal et al. (*1*) by a factor of two. N refers to the number of individual projections or detector positions over 360° rather than the number of projection angles over 180°. Some authors define the number of projection angles as that required over 180°, on the basis that opposite views can be considered "at the same angle." Of course, in the absence of attenuation, as for CT scanning, sampling over 180° is sufficient with opposite views being identical. This may contribute to the ambiguity.

Several authors have related N directly to the matrix size with particular concern for reconstruction streak artifacts that occur with poor angular sampling (*2–5*). In the case where the whole field is sampled at exactly $\delta x/2$, $D/(\delta x/2)$ corresponds to the matrix size (M) and $N = \pi M/2$ over 180°, approximated by some to 1.5 M. These formulae have fairly wide acceptance (*6*) but tend to suggest a higher number of angles than is used in clinical practice. It is reasonable to suggest that sampling be sufficient over all parts of the images that have diagnostic information and thus it is possible to relax the requirement that the complete matrix area be sufficiently sampled. Rosenthal et al. (*1*) recognize this and point out that D can be considered the "diameter of a circle enclosing the region of interest." The diameter (D), however, must refer to a circle centered on the axis of rotation. This is illustrated in Figure 1 for a cardiac study, in which D clearly exceeds the minimum diameter circle which could enclose the cardiac region.

It is useful to consider typical clinical examples to illustrate the correct choice of number of angles:

1. For cardiac studies acquired over 180° using a camera of 400-mm field size, reconstructed resolution is typically around 16 mm. The linear sampling therefore requires a pixel size of less than 8 mm corresponding to a matrix size typically 64 × 64. The centre of rotation is typically towards the posterior wall of the heart and the heart diameter is of the order of 100 mm. Use of the revised equation