which produces an MR value in Eq. 4 of virtually 1.0; i.e. both systems, under these conditions, have equal detection merit.

The fact that a reduction in resolution area by a factor 2.2 $[(R_2/R_1)^2 = 2.2]$ requires an increase in counting time by a similar factor $T_1/T_2 \simeq 2.2$ is particular to these two systems with sensitivity ratio $S_1/S_2 = 4$ since on substituting into Eq. 4 we get

$$\begin{aligned} MR &\simeq 1/4 \times 2.2 \times 2.2 \\ &\simeq 1.0 \end{aligned}$$

which satisfies our equal perception probability criterion. In general, $T_1/T_2 \neq (R_2/R_1)^2$ for equal perception, the required value of T_1/T_2 depending on both $(R_2/R_1)^2$ *and* S_1/S_2.

Turning now to Westerman's clinical example and taking the data from the text (which unfortunately varies slightly from that given in the figure caption), we have:

$$\begin{aligned} S_1/S_2 &= 1/4 \\ T_1/T_2 &= 2/1.5 \\ R_2/R_1 &= 2.2/1.5. \end{aligned}$$

Again substituting into Eq. 4 we get a merit ratio MR of 0.73 which then indicates System 2 (coarse collimator) to be superior in detection ability, as borne out by Westerman's experimental findings.

In summary, Eq. 2 affords us a very simple figure of merit for radioisotope imaging systems which can be almost mentally applied in practice. It is particularly useful when considering the use of a high-resolution collimator to attempt to image detail since a simple comparative test using Eq. 4 tells us how much more exposure time is required, compared with a coarser collimator, just to obtain the same detection probability.

W. G. WALKER
Intertechnique S.A.,
78-Plaisir, France

A REPLY: DETECTING ABILITY OF RADIOISOTOPE IMAGING DEVICES

We are interested in Dr. Walker's suggestion of the factor S/R^2 as a simple figure of merit related to detecting ability (R and S are the resolution diameter f.w.h.h. and sensitivity for point sources). His concept is entirely in agreement with—although less exact in its relationships than—the concept developed in a full analysis by one of us (Sharma, 1969).

The parameter that is proportional to S/R^2 is found to be the "detecting ability, D," or reciprocal of the time required to achieve a given level of statistical confidence (say n standard deviations) in the expression

$$n = \frac{\text{Difference in no. of counts between "suspect" area and "normal" area}}{\text{Standard deviation of this difference}}. \quad (1)$$

The full equation relating detecting ability to the other parameters is, for a Gaussian point spread curve, given by:

$$D = \frac{\mu v^2 C_N S (1 - p/100)^2 (f - 1)^2 e^{-2\mu d}}{n^2[v(1 - p/100)(f - 1) e^{-\mu d} + 1.44 \pi R^2 (\log_e 10 - 1/2 \log_e p)(1 - e^{-\mu l})]} \quad (2)$$

in which

D = reciprocal of time required to achieve a critical level of significance (i.e. any given value of n in Eq. 1)
v = volume of source to be detected
f = ratio of concentration in source to that in the surrounding medium
C_N = concentration of radioisotope in surrounding medium
μ = total linear attenuation coefficient of the photons by the medium
d = depth of source in medium
l = thickness of patient or phantom
p = percent isocount contour defining the test area.

At the condition of threshold detection, the second term in the denominator (representing background counts from the surrounding tissue) is predominant, and $D \alpha v^2 C_N S/R^2$, for given values of f, μ, d, p, l and n.

Walker's factor S/R^2, being proportional to D in certain conditions and thus inversely proportional to the critical time required for threshold detection of a small source, is indeed useful. It can of course only be used for limited comparisons under comparable conditions unless the coefficient in Eq. 2 is evaluated. A corresponding equation has been derived for a triangular point spread curve (Sharma, 1969).

These formulations are quite valid for both moving (e.g. rectilinear) and stationary (e.g. camera) imaging devices, but not for the stationary focusing-collimator head of a moving scanner; Walker's letter is not clear on this point. Detecting ability is, however, only proportional to S/R^2 for point sources or for sources smaller than the resolution diameter R.

We have also considered the variation of R^2/S

with R for an imaging system. It was found that the value of R^2/S and hence of detecting ability D was independent of R for a spherical source of diameter less than R (Sharma, 1969). This finding has the important consequence that, as the resolution diameter R of an imaging system is increased from zero, the detecting ability increases until R is equal to the source diameter, and then further increases in R *do not alter* the detecting ability. In the presence of significant inherent resolution (Anger, 1964) the detecting ability does increase slightly as R is increased further. The penalty for increasing resolution diameter is therefore not any loss of detecting ability; it is simply loss of positional accuracy.

Correspondingly, detecting ability is rapidly lost if the resolution diameter is made smaller than the diameter of the source it is desired to detect by approximately a factor of R^2. It may be noted that if R is kept matched to the source diameter, D decreases with the 4th power of R for a focused-collimator system and with the 6th power of R for multiparallel hole collimators (Sharma and Fowler, 1969).

These are the factors controlling detecting ability with respect to resolution diameter for small sources. The theoretical analyses (Sharma, 1969) are in agreement with experimental results and with Dr. Walker's suggestion to use R^2/S as a figure of merit for simple comparisons for small sources only and involving no change of depth, volume, radioisotope or counting time. The counting time for a stationary scanner (camera) is equal to the exposure time. For a moving scanner, however, it is the time required to scan over an area enclosed by the contour enveloping the peripheral holes on the collimator face (Sharma, 1969). For sources larger than R, a parameter which includes effective "collecting time" must be used, such as the merit-time-product defined by two of us earlier (Westerman, Stead and Fowler, 1969).

R. R. SHARMA
Postgraduate Institute of Medical Education and Research,
Chandigarh, India
B. R. WESTERMAN
Chicago Wesley Memorial Hospital,
Chicago, Ill.
J. F. FOWLER
Royal Postgraduate Medical School,
Hammersmith Hospital,
London, England

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ASSAY OF RADIOACTIVE MATERIALS

We would like to take this opportunity to thank Dr. Herbert Vetter for his kind words about our article, "Assays of Radioactive Materials for Use in Patients—a Five Year Study" (*J. Nucl. Med.* **9**:236, 1938). However, one point in Dr. Vetter's letter deserves clarification. He described an instance in which a patient experienced untoward symptoms following injection of ^{32}P as a "sterile pyrogen-free solution for intravenous use." The pH of this material was 1, and Dr. Vetter says correctly that this error would have escaped the scrutiny of the NIH Radiation Safety Office.

The original article dealt solely with the responsibilities of the NIH Radiation Safety Office, i.e., identification and quantification of the principle radionuclide and of any radioactive contaminants present in materials intended for use in patients. The NIH Radiopharmaceutical Service is responsible for a wide variety of biological and chemical testing procedures which would include pH measurements and adjustments.

Testing such as that done by *both* the NIH Radiopharmaceutical Service and the NIH Radiation Safety Office should prevent the errors described by Dr. Vetter.

PATRICIA A. CLIGGETT
JOSEPH M. BROWN, JR.
National Institutes of Health
Bethesda, Maryland