TABLE 1
COR Offset Measurements

	COR Offset		
	Radius = 16 cm	Radius = 32 cm	%Increase
Defective GP Collimator	0.36 pixels	0.62 pixels	72%
New GP Collimator	0.43 pixels	0.50 pixels	16%

The first problem is sensitivity loss with increasing source-to-collimator distance. A defective general-purpose (GP) collimator showed a continuous decrease in sensitivity with source-to-collimator distance. Sensitivity loss appeared to be 6% with a rotation radius of 60 cm, and 10% or greater with a radius of 60-70 cm. This is clearly a potentially serious problem, which may go unnoticed during routine clinical work with short object-to-collimator distances, such as in SPECT brain imaging. With whole-body SPECT imaging, this sensitivity loss can lead to longer acquisition time.

The second problem is a center of rotation (COR) offset variation with a different COR radius. Table 1 shows the offset data taken at two COR radii. As seen, the offset value with a defective collimator is increased by 72% with an increase of COR radius from 16 cm to 32 cm. Ideally, there should be no offset radius variations with different COR radii. This offset variation with COR radius is a problem and may lead to errors in image reconstruction.

Figure 1 shows two comparative transverse images of the Carlson phantom: one obtained with a defective collimator and the other with a new parallel-hole collimator. As seen, image quality is essentially equivalent at short source-to-collimator distances (Fig. 1A). Clearly, a phantom study alone can be misleading in evaluating the integrity of the collimator.

In our estimation, defective GP collimator holes were slightly slanted, causing (a) sensitivity loss with source-to-collimator distances, and (b) variation in offset values in the COR calibration measurements. In general, parallel-hole collimator angulation defects may lead to artifacts and sub-optimal image quality as well as sensitivity loss with source-to-collimator distance.

A variety of source and image parameters influence SPECT image quality. Although defective collimators are infrequently encountered, we recommend that every new collimator be evaluated and checked for the following:

1. Collimator Angulation Test. Image a point source on the floor at two vertical distances, one at the lowest position and the other at the maximum gantry height. Check the point source image symmetry and coincidence of two images. If images are skewed and/or the two images do not coincide (this is a quick method often employed by field service engineers), suspect collimator hole angulation.
2. Sensitivity Constancy Test. Measure the point source sensitivity as a function of distance. The sensitivity should be constant with distance.
3. COR Variation Test. Measure the COR offsets with two extreme radii. Ideally, there should be no offset variations.

We believe that it is sufficient to perform the above tests during initial acceptance testing, however, retesting on an annual basis is also recommended.

Currently, no collimator performance specifications and standards for SPECT exist in the nuclear medicine industry or in professional associations such as NEMA, AAPM, and SNM. We would like to see this situation remedied.

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The Expected Value of Cash Flows in the Economic Analysis of Clinical Positron Emission Tomography of the Heart

TO THE EDITOR: The Special Contribution by Gould, Goldstein, and Mullani (*1*) can be expected to serve as a framework for a variety of future economic analyses of diagnostic procedures and technology. Unfortunately, there is an error in the analytical process. Although the error is not

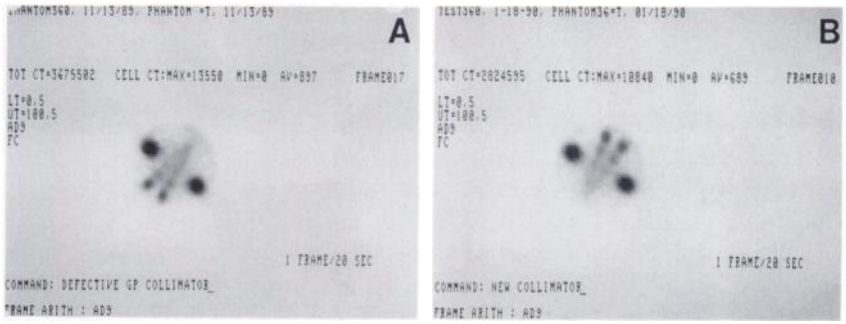

FIGURE 1
(A) Carlson phantom with defective GP collimator and (B) Carlson phantom with new GP collimator.

systemic in nature (that is, it does not impact on numerous aspects of the analysis), it is of such significance that, in some cases, it could affect the ultimate decision regarding the economic benefit of one type of test (or technology) versus another.

In analyzing the potential economic impact resulting from thallium imaging versus positron emission tomography (PET), it was determined that 3.75 (of the 25) patients with coronary artery disease (CAD) would have normal thallium tests (based on a sensitivity of 85%) and would not be further studied. Similarly, 1.25 patients with CAD would be "missed" based on the 95% sensitivity of PET. Taking into account a mortality rate of 7% per year for those "missed" patients, it was determined that (35%) (3.75) = 1.31 deaths/5 yr would occur in the "missed" thallium cases, and (35%) (1.25) = 0.44 deaths/5 yr would occur in the "missed" PET cases. These 5-yr death rates were then multiplied by the total expense of $155,000 (yearly lost wages of $30,000 per year for 5 yr plus the cost of mortality of $5,000) per deceased person, to determine the loss of wages and productivity over a five-year period due to mortality in the "missed" cases. Thus, for "missed" thallium cases the cost was (1.3) ($155,000) = $201,500; and for "missed" PET cases the cost was (0.44) ($155,000) = $68,200.

Note that these calculations implicitly assume that all the deaths related to the 7%/yr mortality rate occur at the beginning of the first year; that is, each of the deaths is assumed to incur the entire 5-yr loss of wages ($150,000). More specifically, the calculations implicitly assume a 35% mortality at the beginning of the first year!

It is important, therefore, that the effect of the 7%/yr mortality rate over the 5-yr period be properly evaluated from an expected value perspective. Based on a 7%/yr mortality rate, the "missed" thallium cases would result in (0.07) (3.75) = 0.2625 deaths per year, and the "missed" PET cases would result in (0.07) (1.25) = 0.0875 deaths per year. These death figures may then be used as weights for the potential economic loss in each year of the five-year period. Now, for each death in the first year, the cost of lost wages ($150,000) and mortality ($5,000) result in a total cost of $155,000 over the five-year period. This total cost decreases by $30,000/yr for each of the following years (that is, a death in the second year will result in lost wages of only $125,000, not $155,000). Thus, total cost for years 2 through 5 are $125,000, $95,000, $65,000, and $35,000, respectively. The expected cost over the five-year period for the "missed" thallium cases is then:

(0.2625) ($155,000) + (0.2625) ($125,000) + (0.2625) ($95,000) + (0.2625) ($65,000) + (0.2625) ($35,000) = $124,688.

Similarly, the expected cost over the five-year period for the "missed" PET cases is:

$$(0.0875)(\$155,000) + (0.0875)(\$125,000) + (0.0875)(\$95,000) + (0.0875)(\$65,000) + (0.0875)(\$35,000) = \$41,563.$$

Notice that the differences in cost between thallium and PET is $124,688 − $41,563 = $83,125, using the expected value approach, versus $201,500 − $68,200 = $133,300 based on the erroneous approach which effectively uses a 35% mortality rate the first year, rather than a 7% rate in each of five years. The difference in the results ($133,300 − $83,125 = $50,175) between the two approaches is substantial, and, while the difference does not affect the ultimate total cost advantage (medical costs plus lost productivity costs) of PET versus thallium in this instance, the use of the erroneous procedure certainly could lead to improper decisions in other cases.

Three related issues should also be noted. First, the expected value process discussed herein adopts an assumption implicit in the analysis of the original article: It is assumed that the mortality each year is a constant derived from the application of the 7%/yr rate to the size of the original group subject to future year mortality. In reality, the size of the group subject to mortality in a given year is smaller than that in the previous year, due to the previous year's mortalities. If this factor were to be included in the analysis, it would lead to different results. Second, lost wages are treated herein as losses of total annual salary, as they were treated in the original article. It would be better to use an average based upon the assumption that the mortality could occur on any day of the year. Third, it should be noted that, in practice, it would be advisable to use a procedure that discounts the future year costs to yield a more meaningful present value for the five-year costs.

The framework presented by Gould, Goldstein, and Mullani should prove to be useful in dealing with issues of health care economics, and the procedures suggested herein will provide a valid determination of cost in one part of that framework.

REFERENCE

1. Gould KL, Goldstein RA, Mullani NA. Economic analysis of clinical positron emission tomography of the heart with rubidium-82. *J Nucl Med* 1989; 30:707–717.

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REPLY: The comments by Dr. John M. Gleason on our paper, "Economic Analysis of Positron Emission Tomography of the Heart with Rubidium-82" (*1*), were gratifying in that they acknowledge our identification of the substantial medical cost to society of definitive coronary arteriography in individuals with false-positive thallium treadmill tests. Dr. Gleason's criticisms of our methodologic details to further refine the concept are quite appropriate. Since the concept of these hidden costs had not been previously published, we chose to simplify the analysis as much as possible. We agree that these more refined calculations should be used.

We would also point out several other assumptions which need to be adjusted for a more realistic analysis of the economic impact of PET with rubidium-82 (^{82}Rb) compared to thallium exercise testing. The actual total cost of thallium exercise testing in most major American cities is in fact $1,200 per study. The actual total cost for cardiac catheterization is $10,000-$14,000 per individual. Both figures are higher than our original estimates of the hidden costs from false-positive tests.

Additionally, the published diagnostic specificity of thallium