may be clinically detectable, but is unlikely to cause quantitatively important image artifacts. Movement of greater than 6.5 mm can cause clinically important image artifacts and must be considered as a potential source of error in ^{201}Tl tomographic myocardial perfusion studies.

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EDITORIAL
Sensitivity of SPECT Thallium-201 Myocardial Perfusion Imaging to Patient Motion

In this month's issue, Cooper et al. have simulated both vertical and horizontal patient motion during SPECT ^{201}Tl myocardial perfusion imaging and they determined the relationship between the amount and timing (frame at which motion occurred) of patient motion and false-positive SPECT ^{201}Tl images (1). As our group had done, studies were read normal or abnormal based on quantitative criteria applied to bull's-eye analysis. In comparison to our findings, the results of Cooper et al. show a markedly decreased sensitivity to patient motion. Table 1 summarizes the disparate results on the frequency of false-positive findings for patient scans with simulated motion, which occurred half-way through the SPECT scan.

Previously, our group described a technique which detects and corrects for vertical (i.e., head-to-foot) patient motion during SPECT ^{201}Tl myocardial perfusion imaging (2,3). We also evaluated the sensitivity of SPECT ^{201}Tl to patient motion by quantitative bull's-eye analysis of (low probability of disease) patient data sets with simulated patient motion (2). Motion was simulated by "moving" the SPECT view data from ± 0.5 to ± 3.0

pixels for views 17-32 of a 32 view/180° SPECT acquisition. The SPECT data then were reconstructed, and reformatted into short-axis slices. The short-axis slices were processed through our own version of the bull's-eye program [REV 3.0 on the General Electric STAR system, and later used on other General Electric computer systems (4)] using a gender-matched normal file consisting of 50 females and 50 males (5). Each simulated data set was processed as an independent study so that slice selection, angle se-

TABLE 1
Comparison of False-Positive Findings for Motion That Occurred in the Middle of the SPECT Scan

Degree of motion (mm)	Eisner et al. (2)	Cooper et al. (1)
3.25	15%	2.9%
6.5	40%	4.8%
13	80%	20%
26	80%	55%

lection for short-axis slice reformatting and bull's-eye parameters were not biased by previous selections.

Prior to our motion study, we had developed and published quantitative criteria for detection of coronary artery disease using the same bull's-eye processing program and normal files employed for the simulation study (6, 7). It is important to note that the bull's-eye program, processing methodology, criteria for abnormal scan and so forth that we developed and use are different from the Cedars-Sinai bull's-eye program (8).

What factors can account for the difference between the results of Eisner and those of Cooper for an abnormal versus normal study?

Table 2 presents a comparison of the acquisition and processing protocols presented in the two papers (and from private communication from Dr. Cooper) from which we conclude items 1–4.

1. The bull's-eye program used by Cooper et al. (1) is not the Cedars-Sinai program (8), does not use the Cedars-Sinai normal files, and has not been validated clinically. Therefore, the sensitivity/specificity values for detection of coronary artery disease using Cedars-Sinai bull's-eye analysis in the multicenter trial are not appropriate for the Cooper et al. study.

2. Perhaps the decreased sensitivity to motion compared to the results of Eisner et al. (2) is a reflection of an overall decreased sensitivity of the program to patients with disease. Indeed, the sensitivity of the Cooper et al. bull's-eye program to motion (4.8% false-positive rate for 1.0 pixel shift) is much lower than the rate of motion-related artifacts that were detected visually by Cooper et al. (greater than 60% detection rate for 1.0 pixel shift).

2. Data filtering before SPECT reconstruction differs in the two reports (two dimensional Hanning (2) versus two-dimensional Metz (1)). Perhaps the particular type of Metz filter used by Cooper et al., which enhances different and lower spatial frequencies than the SPECT reconstruction filter of Eisner et al., produces decreased sensitivity to both motion effects and coronary artery disease detection.

3. There is a difference in the methodology to produce the simulated motion effect. For example, to simulate a one pixel nonreturning upward motion in the middle of the scan, Cooper et al. (1) shift views 1–16 one-half pixel down and views 17–32 one-half pixel up. Eisner et al. shift views 17–32 one pixel

up. Moreover, compared to the procedure of Eisner et al. (2), the Cooper et al. (1) shift procedure produces enhanced smoothing of the view data, which could produce SPECT reconstructed images with less motion artifact for a given magnitude pixel shift.

In summary, the apparent discrepancy in the motion-related false-positive rates appears to be related to the processing techniques, processing filters and protocols, and the quantitative definition of abnormal resulting from the use of different bull's-eye programs. The readers of the *Journal of Nuclear Medicine* should be aware that "bull's-eye programs" are not generic (4). The use of different SPECT processing techniques and quantification methodologies suggests that each clinical laboratory has to evaluate its own sensitivity to motion-related effects. I would suggest that the reader can simply perform his/her own simulation study following the technique of Eisner et al. (2) and Cooper et al. (1). Data from normal patients without any evidence of motion should be motion-shifted in the middle of the SPECT study and processed through normal clinical protocols to determine an institution-specific false-positive rate.

In our institution, we employ cross-correlation program analysis (3) to

TABLE 2
Comparison of Acquisition and Processing Protocols

	Eisner et al. (2)	Cooper et al. (1)
^{201}Tl dose (mCi)	3.0–3.5	3.0
Collimator	LEGP	LEHR
Views/Arc	32/180	32/180
Starting angle	45 RAO	45 RAO
Pixel size (mm)	6.0	6.5
Technique to simulate 1 pixel shift in view 17 and all subsequent frames	+1 pixel (views 17–32)	−0.5 pixel (views 1–16) +0.5 pixel (views 17–32)
Pre-SPECT filter	2D Hanning (goes to zero at ½ sampling frequency)	2D Metz
Bull's-eye program	References 2, 4	Cedars-Sinai like (8)
Normal file	Ref. 5 (50 males; 50 females)	Cooper et al. (1)
Criteria for abnormal SPECT ^{201}Tl myocardial perfusion scan	References 6, 7	Cedars-Sinai (8)
Sensitivity/Specificity SPECT ^{201}Tl myocardial perfusion imaging	References 6, 7	Unknown

quantitate the amount of patient motion in both the horizontal and vertical direction. It takes little time to correct for y-motion (threshold = 0.5 pixels) and to confirm through the rotating cine display of the view data that the y-direction motion has decreased following correction. With this quality control check, we see no reason not to motion-correct SPECT data. Without the degrading effects of motion, the shifted data set has greater integrity than the uncorrected data.

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