Comparison of Single-Detector and 90°-Angled Two-Detector Cameras for Technetium-99m-Sestamibi Cardiac SPECT

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Purpose: This paper evaluates the utility of a new 90°-angled two-detector (2-DT) camera for ^{99m}Tc-sestamibi imaging.
Materials and Methods: SPECT acquisitions obtained on a single-detector camera (1-DT) were repeated with a two-detector camera (2-DT) with similar performance characteristics in 30 patients studied using different combinations of 1-DT and 2-DT protocols. Acquisition time for the 2-DT was half that for the 1-DT for 29 studies (12 stress, 17 rest) yielding similar image count density. For another 21 studies (11 stress, 10 rest) 2-DT acquisition time was equal to that for 1-DT scans, yielding double the 1-DT count density. Defect extent and severity were quantified by comparison to normal limits.
Results: By blinded qualitative analysis, 2-DT 12.5 min scans identified perfusion defects better than 1-DT 25 min scans in 6 out of 29 cases (21%, $p = 0.13$). Twenty 5-min 2-DT scans identified defects better than 25-min 1-DT scans in 5 out of 21 cases (24%, $p = 0.017$). In all cases image quality was best for 25-min 2-DT, double-count density scans. In patients scanned by all three methods, defect extent and severity correlated well ($r = 0.90$ to 0.96). Defect extent and severity were slightly less with the two-detector half-time acquisition than with the single-detector acquisition ($p = 0.0006$ and 0.005, respectively). Otherwise, no differences in defect extent or severity were demonstrated using the acquisition techniques described.
Conclusion: We conclude that the new 90°-angled 2-DT camera provides sestamibi SPECT images of diagnostic quality equivalent to those of a 1-DT camera using half the acquisition time. Image quality can be substantially improved using an acquisition time equal to 1-DT SPECT.
Key Words: SPECT; myocardial perfusion imaging

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There are now several commercially available multiheaded scintillation camera detector systems for cardiac SPECT. Three-headed cameras were developed first, but more recently dedicated cardiac cameras with two 90°-angled detectors have become available. The purpose of this study was to determine if image quality and diagnostic accuracy of one such 90°-angled detector system (Optima, General Electric Medical Systems, Milwaukee, WI) was equivalent to, or possibly superior to, conventional cardiac SPECT using a single-detector system.

METHODS

Using a 90°-angled two-detector camera for a 180° cardiac SPECT acquisition each detector rotates 90°: detector 1 from the 45° right anterior oblique to 45° left anterior oblique position, and detector 2 from the 45° left anterior oblique to 45° left posterior oblique position (Fig. 1). With this configuration, two imaging options are most readily available. First, with a SPECT acquisition time equivalent to that used

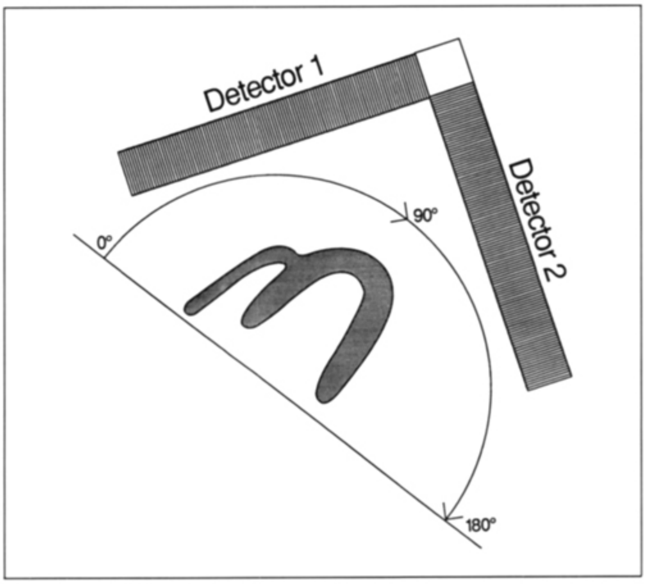

FIGURE 1. Geometry of a scintillation camera with two perpendicular detects for 180° cardiac SPECT. In this image the patient is viewed from the feet, thus the heart is viewed from below.

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TABLE 1
Comparison of Single-Detector and Two-Detector Acquisitions

Number of patients	Studies: Stress	Studies: Rest	Camera/detector system used: One-Detector 25 min	Two-Detector 25 min	Two-Detector 12.5 min
20	10	10	X	X	X
1	1	0	X	X	—
9	2	7	X	—	X
30	13	17	30	21	29

for a single-detector system, the resultant image count density is doubled. Alternately, using an acquisition time which is half that for a conventional single-detector study, an equivalent image count density can be obtained. The first option potentially enhances image quality, whereas the second option potentially improves patient tolerance and increases throughput.

To compare the performance of this new two-headed detector to conventional single-headed SPECT, 30 patients with historical and/or electrocardiographic evidence of prior myocardial infarction were studied with ^{99m}Tc-sestamibi SPECT myocardial perfusion imaging. Each SPECT dataset was interpreted by a single, experienced observer without knowledge of quantitative results or the corresponding study obtained using a different detector geometry. Twenty-seven of the 30 patients had perfusion defects as determined by single-headed SPECT. Thirteen defects were large (greater than one half of a major vascular territory), 7 were of moderate size (one quarter to one half of a vascular territory) and 7 were small (less than one quarter of a vascular territory).

Twenty-two patients underwent sestamibi imaging using the single-day protocol, with a 9 mCi (333 MBq) rest dose followed by a 31-mCi (1147 MBq) stress dose. The separate-day protocol was used in 8 patients, who received 22 mCi (814 MBq) for both the stress and rest SPECT studies.

Because ^{99m}Tc-sestamibi does not appreciably wash out of the myocardium or redistribute, patients could be imaged two or three times after a single injection to compare single-detector and two-detector imaging. Ten stress studies were acquired with the single-detector system and with both the full-time 25 min and also the half-time 12.5 min two-detector acquisitions. Ten resting studies were also acquired using all three modes of acquisition. One stress study was acquired with the single-detector system and the full-time two-detector protocol. Finally, two stress studies and seven rest studies were acquired with the single-detector and half-time, two-detector protocols. Thus, we were able to compare single-detector acquisitions with the two-detector full-time protocol for 21 studies and with the two-detector half-time protocol for 29 studies (Table 1).

For purposes of comparison, SPECT images were displayed as 6 mm-thick short-axis, vertical long-axis and horizontal long-axis slices and evaluated qualitatively by an experienced nuclear medicine physician with regard to count density, myocardial-to-background contrast and perfusion defect contrast. To better assess defect extent, images were also displayed in polar map format. To more objectively compare these cameras and acquisition protocols, we performed quantitative analysis of SPECT sestamibi perfusion scans using commercially available software (CEqual, General Electric Medical Systems, Milwaukee, WI). By this method, image pixels significantly below gender-matched normal limits are identified and blackened (*1*). The number of contiguous blackened pixels is termed the defect extent. The number of standard deviations below normal limits of each of these abnormal pixels is then summed to determine the defect severity.

The acquisition and processing protocols for the various options are summarized in Table 2. The basic principle adopted in adjusting the processing of higher count density two-detector imaging was to increase the filter cutoff frequency. For instance, for high-dose stress single-day studies and separate-day studies, the Butterworth filter cutoff frequency was increased from 0.52 to 0.65. For low-dose single-day rest studies, the cutoff frequency was increased from 0.40 to 0.45.

TABLE 2
Imaging Parameters

Protocol	Acquisition time	Collimator	Stops	Filter	Cutoff	Power
One-detector stress, two-day rest	25 min	HRP	64	Butterworth	0.52	5
Two-detector stress, two-day rest	12.5 min	HRP	64	Butterworth	0.52	5
One-detector, one-day rest	30 min	HRP	64	Butterworth	0.40	10
Two-detector, one-day rest	15 min	HRP	64	Butterworth	0.40	10
Two-detector stress, two-day rest	25 min	HRP	64	Butterworth	0.65	10
Two-detector, one-day rest	30 min	HRP	64	Butterworth	0.45	10

RESULTS

Comparing the one-detector acquisition with the two-detector half-time acquisition, yielding equivalent image count density, images were judged by blinded, subjective visual assessment to be equivalent in 21 of 29 patients (72%). In 6 of 29 patients (21%), the two-detector system defined defects more clearly, whereas in 2 of 29 cases (7%) the single-detector camera was judged superior. This difference between qualitative visual assessment in the single-detector (1-DT) and two-detector cameras (2-DT) half-time acquisition was statistically analyzed by chi square testing:

	1-DT 25 min	2-DT 12.5 min	Total
Method better	2	6	8
Method not better	27	23	50
Total	29	29	58

The chi square value was 2.32, $p = 0.13$, not a statistically significant (ns) difference (*2*).

Comparing the one-detector acquisition with the two-detector full-time acquisition, yielding double the count density, images were equivalent in 16 of 21 cases (76%). The two-detector full-time acquisition better defined abnormalities (i.e., provided better apparent contrast resolution) in 5 of 21 cases (24%). In no case did we judge the one-detector camera to be superior.

	1-DT 25 min	2-DT 25 min	Total
Method better	0	5	5
Method not better	21	16	37
Total	21	21	42

The chi square value was 5.68, $p = 0.017$, indicating that the 2-DT full-time method was statistically significant in preference over the 1-DT.

In Figure 2 quantitative analysis of the one-detector acquisitions is compared to that of the two-detector half-time acquisitions with regard to defect extent scores (Fig. 2A) and defect severity scores (Fig. 2B). By linear regression analysis the scores correlate closely, with r values of 0.94 and 0.96, respectively. Using a t-test for paired samples, defect extent and severity were slightly less with the single-detector acquisition than with the two-detector half-time acquisition ($p = 0.0006$ and $p = 0.005$, respectively). This observation corroborates our impression that defects were visually detected slightly better using the latter technique.

Comparing one-detector acquisitions with two-detector full-time acquisitions, the correlation is also good (Fig. 3A, B). The r values for extent and severity are 0.90 and 0.96, respectively. No significant differences were statistically demonstrated for defect extent ($p = 0.10$) or defect severity ($p = 0.08$) as determined by these two methods.

The correlation between the half-time and full-time acquisition protocols for the two-detector system with regard to defect extent and severity scores also was good. In 16 patients imaged using both protocols, correlation coefficients were 0.92 and 0.96 for defect extent and severity, respectively (Fig. 4A, B). Again, there was no significant difference demonstrable for defect extent ($p = 0.61$) or defect severity ($p = 0.44$) as determined by these two methods.

CASE EXAMPLES

Case 1: Inferior Myocardial Infarction

In this patient with an inferior myocardial infarction (Fig. 5), the stress and rest studies performed using both the single-detector (Fig. 5A) and two-detector half-time (Fig. 5B) acquisition protocols demonstrate the marked inferior perfusion defect equally well. To provide a three-dimensional assessment of the inferior perfusion defect in this patient with an inferior infarct, stress and rest polar map displays for both acquisition protocols (Fig. 6C, D) are shown for the stress and rest studies. For the stress and rest studies, both acquisition protocols demonstrate a nearly identical inferior fixed defect. Quantitative extent and severity plots demonstrate similar findings.

Case 2: Multivessel Coronary Artery Disease

This is an exceptional case example of a patient with two-vessel coronary disease involving the left anterior descending and right coronary arteries (Fig. 6). The single-detector stress and rest studies (Fig. 6A) appear entirely normal. However, stress and rest acquisitions using the two-detector camera and full-time acquisition, yielding double the count density, (Fig. 6B) demonstrate mild, reversible anteroseptal and inferior perfusion defects, consistent with the patient's known coronary disease. Thus, in this unusual case only the higher count density two-detector study was diagnostically accurate.

The quantitative plots in this patient demonstrate only equivocal abnormalities with the single-detector acquisition (Fig. 6C) but more definitive evidence of multivessel disease with the two-detector full-time acquisition (Fig. 6D).

DISCUSSION

One would anticipate that SPECT imaging time could be decreased with a multidetector camera with no loss in image count density or diagnostic accuracy (*3,4*). Specifically, acquisition time should be halved with a 90°-angled two-detector system. During the past two years sales of multiheaded detectors have been brisk, and laboratories have readily adopted more rapid acquisition protocols to increase patient throughput efficiency. However, to our knowledge such abbreviated imaging protocols have not been validated. In this study we have demonstrated both qualitatively and quantitatively that with the 90° opposed two-detector system and half the acquisition time, SPECT image quality and diagnostic accuracy are not compromised.

In fact, by visual scan analysis, we observed that image quality was superior with the two-detector half-time protocol in 21% of cases, whereas it was inferior in only 7% ($p = 0.13$, ns). Also, by quantitative analysis defect extent and severity

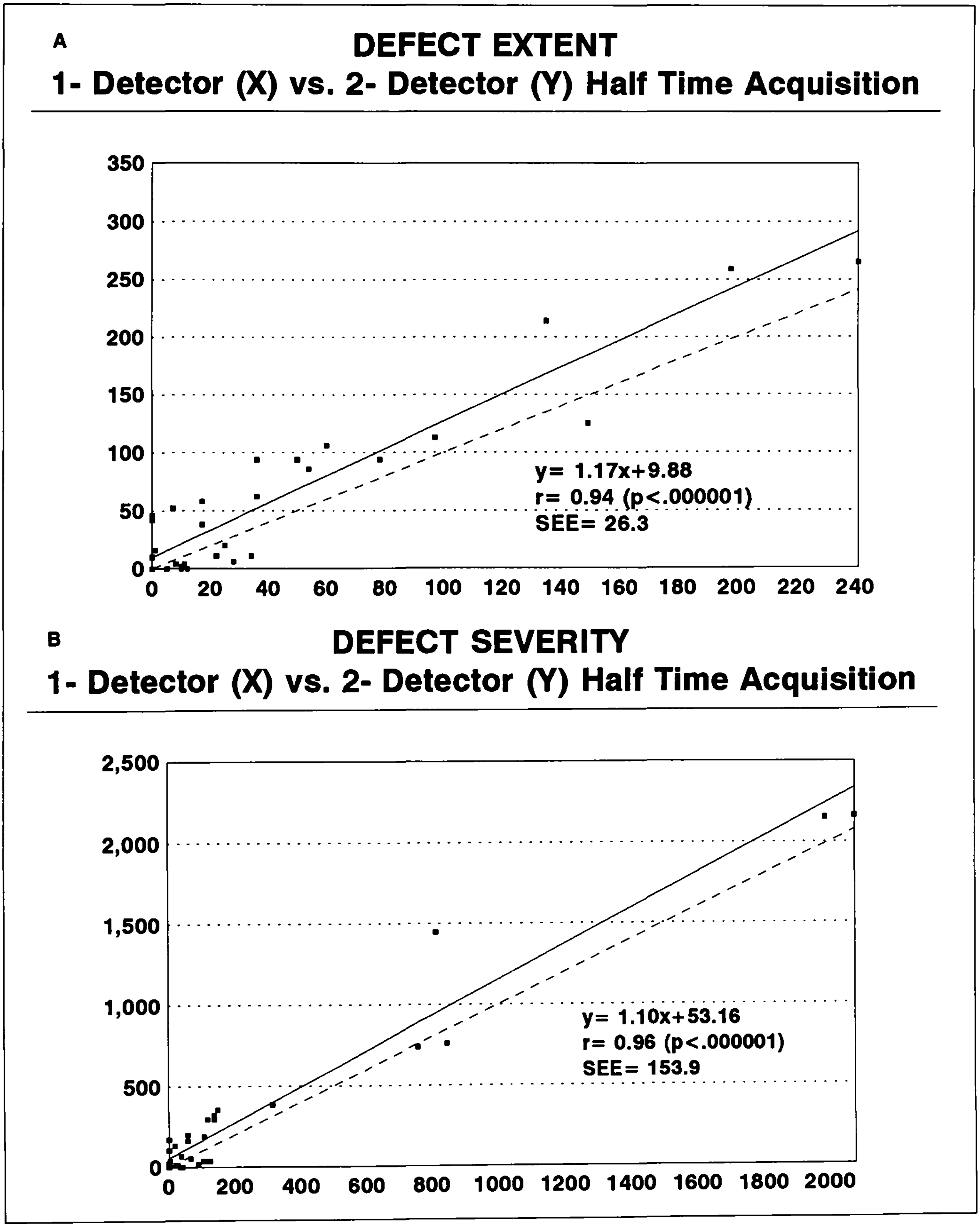

FIGURE 2. Comparison of (A) defect extent scores and (B) severity scores for the single-detector camera (x-axis) and the two-detector camera using a half-time acquisition (y-axis) on 29 patients.

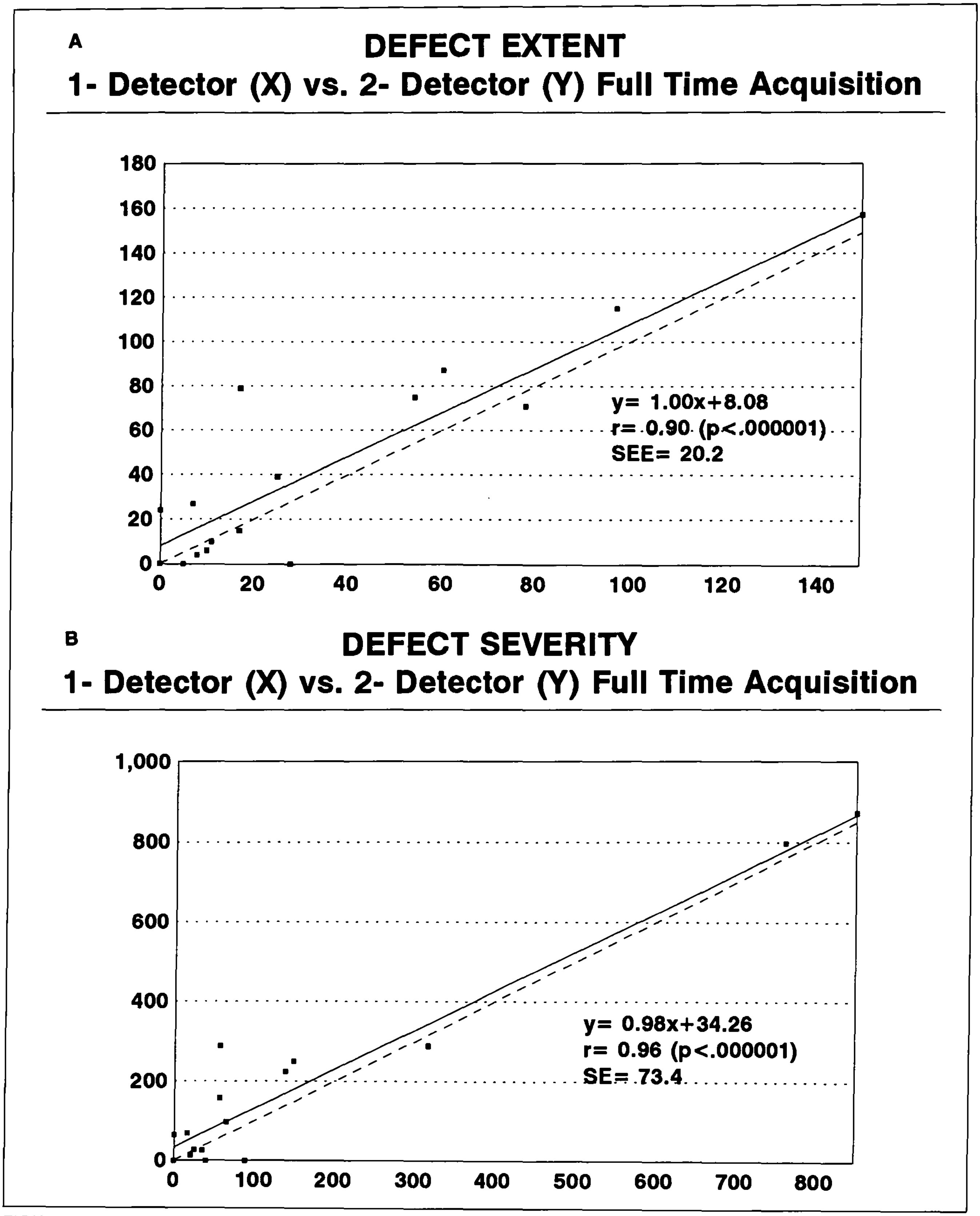

FIGURE 3. Comparison of (A) defect extent scores and (B) severity scores for the single-detector camera (x-axis) and the two-detector camera using a full-time acquisition (y-axis) on 16 patients.

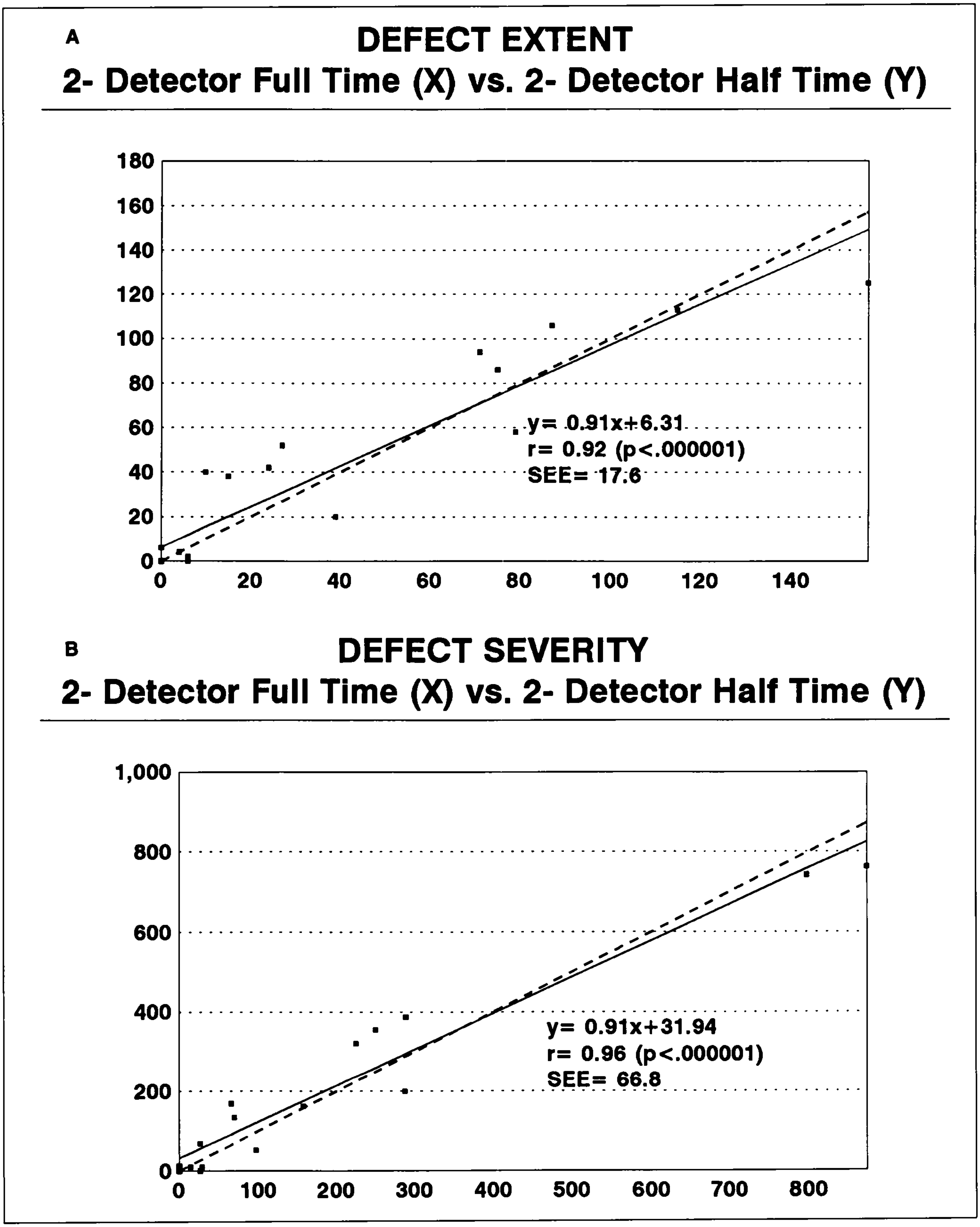

FIGURE 4. Comparison of (A) defect extent scores and (B) severity scores using the two-detector camera with full-time (x-axis) and half-time (y-axis) acquisitions on 16 patients imaged using both two-detector protocols.

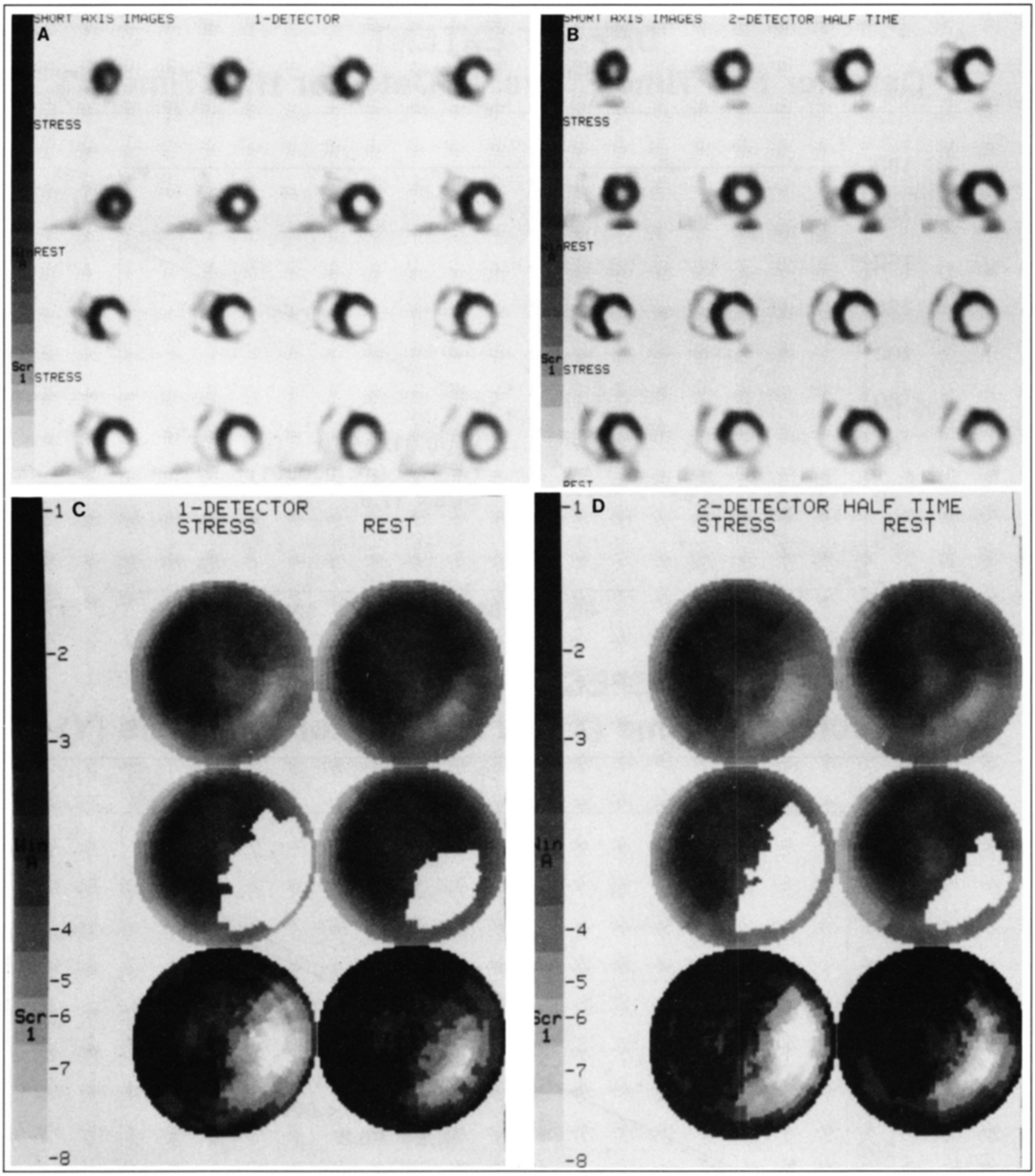

FIGURE 5. Patient with inferior myocardial infarction imaged using a single-detector camera and the two-detector camera with a half-time acquisition. (A) Short-axis stress/rest and tomograms with single-detector camera. (B) Short-axis stress/rest tomograms with two-detector camera, half-time acquisition. (C) Polar plots from a single-detector acquisition. The stress/rest raw polar plots (top row) demonstrate a very minimally reversible, essentially fixed, inferolateral perfusion defect. The extent plots (middle row) identify (whiten) all pixels significantly below gender-matched normal limits. The severity plots (bottom row) code abnormal pixels according to the number of standard deviations below normal limits (see gray scale on left hand border of image). (D) Polar plots from the two-detector camera using half the SPECT image acquisition time. Format same as (C).

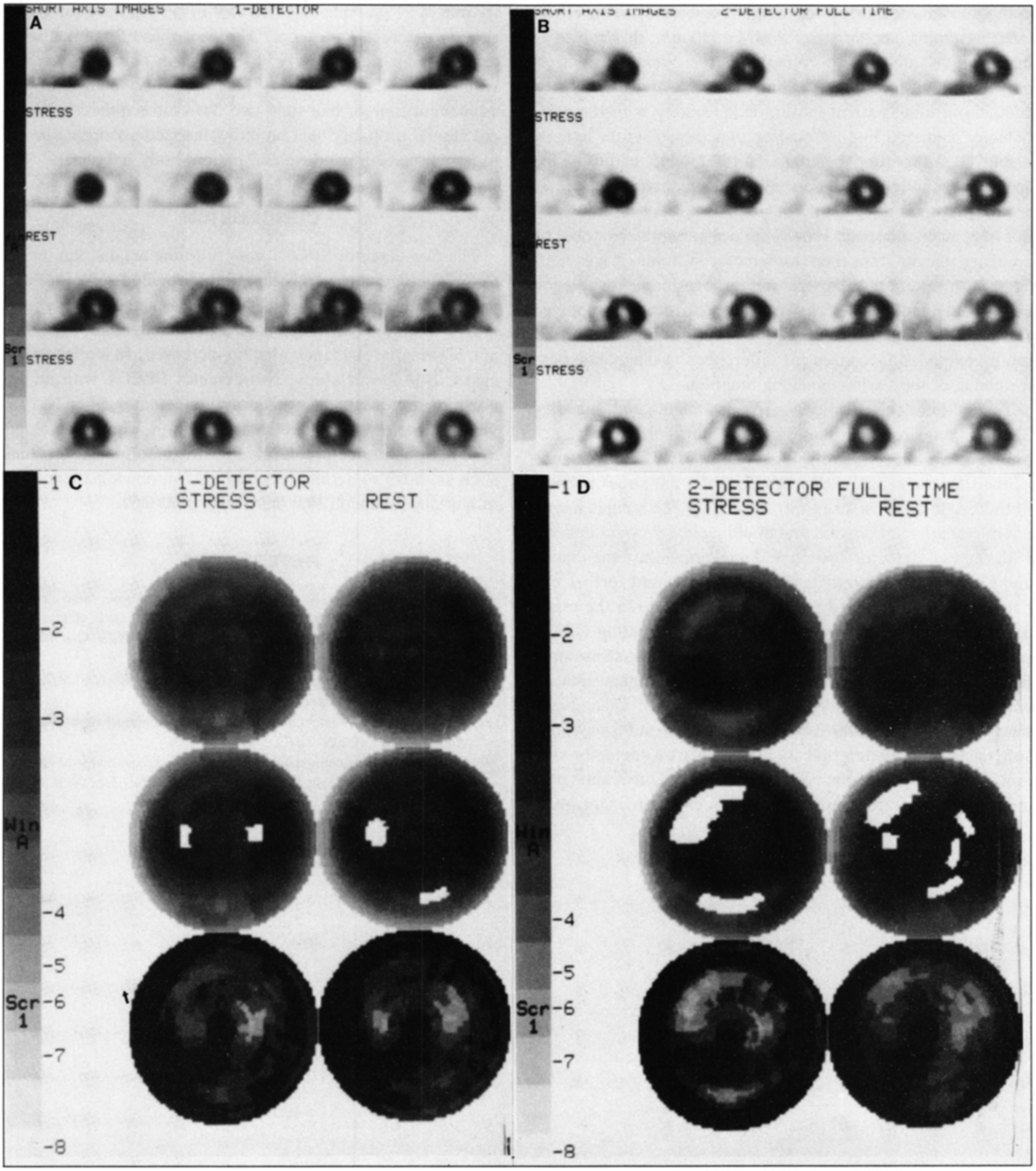

FIGURE 6. Patient with stenoses of the left anterior and right coronary arteries, documented by contrast angiography undergoing both stress/rest SPECT using the single-detector camera and the two-detector camera, full-time acquisition. (A) Short-axis stress and rest tomograms from the single-detector study. (B) Short-axis stress and rest tomograms from the two-detector full-time study. (C) Raw polar coordinate plots (top row), extent maps (middle row) and severity maps (bottom row) from the single-detector study. Only questionable abnormalities are identified. (D) Same as (C), but for the two-detector, full-time study. Two-vessel ischemia is more readily apparent.

were slightly greater using the two-detector half-time method ($p = 0.0006$ and 0.005, respectively). This marginal improvement could possibly be explained by several factors. First, the image resolution of each of the detectors of the two-headed camera we evaluated is slightly superior to that of the single-detector camera, manufactured two years earlier by the same manufacturer. The intrinsic full width at half maximum (FWHM) of each of the two detectors is ≤3.2 mm compared to 4.0 mm for the single-detector camera. However, assuming a collimator FWHM of 10 mm, this improvement in intrinsic resolution improves the overall resolution only from 10.5 mm to 10.7 mm. Secondly, with a shorter acquisition time, patient motion is less likely with the two-detector camera. For all studies planar projection images displayed in rotating cinematic format were carefully inspected. Although we did not observe significant (>1 pixel) motion in any study, subtle degrees of patient motion may not have been detected. Finally, in designing the protocol to compare images from the two-detector systems, it was necessary to alter filtering parameters to compensate for changes in image count density. These adjustments in power and cutoff frequency are fairly standard, but they cannot be totally excluded as causes for differences in diagnostic performance of the various imaging techniques.

Technetium-99m-sestamibi provides high count density SPECT myocardial perfusion images, particularly those acquired using the relatively high, 22 to 31 mCi doses prescribed for the separate-day protocol and the stress portion of the single-day rest/stress protocol. In these studies it was not necessarily anticipated that doubling image count density with the two-detector system and an acquisition time equivalent to that for the one-detector system would further enhance image quality and diagnostic accuracy. On the other hand, using the relatively low (8 to 9 mCi) resting ^{99m}Tc-sestamibi dose prescribed for the single-day rest/stress protocol, we anticipated some improvement in image quality with the equivalent-time two-detector protocol. This advantage should be particularly evident in obese patients in whom soft tissue attenuation and increased heart-to-detector distance further decrease image count density. Our results did, in fact, demonstrate a subjective improvement in image quality in 5 of 21 patients (24%) ($p = 0.017$) with the equivalent-time two-detector protocol. Three of these 5 studies were resting scans performed with 8 mCi, all of which were in women with large breasts. Therefore, the choice of the equivalent-time or half-time two-detector acquisition protocol should probably best be individualized according to the radiopharmaceutical dose and patient body habitus.

CONCLUSION

The two-detector SPECT with full-time acquisition (equal to the one-detector acquisition time) provided superior quality images in 5 out of 21 (24%) of the cases in our study ($p = 0.017$). With the half-time imaging protocol patient tolerance and laboratory efficiency may be increased. In a minority of cases, 24% in our study, two-detector SPECT with an acquisition time equal to that for one-detector SPECT provided superior diagnostic image quality. This equivalent-time option may be preferable for low count density studies such as those sometimes encountered in obese patients and in one-day protocol, low-dose resting studies.

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