Preventing Patient Motion during Tomographic Myocardial Perfusion Imaging

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We evaluated whether use of a device that positions and supports the upper extremities and back during tomographic myocardial perfusion imaging reduces the incidence and severity of patient motion and patient motion artifact. **Methods:** We enrolled 190 patients referred for stress/redistribution myocardial perfusion imaging. All patients were imaged once with the patient support device (PSD) and once without it. Patients were randomly assigned to use the PSD either during poststress or redistribution imaging. The presence and severity of patient motion was determined by visual inspection and quantitative motion detection. The presence of reconstruction artifact due to motion was detected visually and confirmed by motion correction. **Results:** Use of the PSD reduced the incidence of motion from 38% ± 3.7% to 26% ± 3.3% ($p < 0.05$) and reduced the amount of motion by 5.3 ± 2.2 mm ($p < 0.05$). Patients who did move, moved less when using the PSD by both visual ($p < 0.02$) and quantitative criteria ($p < 0.05$). Use of the PSD reduced the incidence of reconstruction artifacts to one third of control ($p < 0.05$). **Conclusion:** The use of this positioning and support device during tomographic myocardial perfusion imaging reduces the incidence and severity of patient motion and motion artifact.

Key Words: single-photon emission computed tomography; thallium-201; patient motion

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Patient motion during tomographic myocardial perfusion imaging is one of the most common causes of image artifact (*1–4*). Quality assurance of tomographic imaging requires examining the image data for patient motion, either by visual inspection of a cinegraphic display of the raw data (*1,5*) or by computer assisted methods (*5–9*). Patient motion produces characteristic artifacts (*5,7*) that can be minimized by correction of the raw data (*3,8,9*) or by temporal image fractionation (*10*). These methods, however, are not always satisfactory (*3,5,8–10*). Because of the limitations of motion detection and correction, the best approach to patient motion is prevention.

Patients have difficulty lying still during tomographic imaging for multiple reasons (*1,11*). Patients commonly complain that their arms and shoulders ache from being held in a fixed position over the head and that their backs hurt from lying flat on a hard surface. This discomfort may be exacerbated by fatigue from recent exertion and by co-morbid conditions such as congestive heart failure or arthritis. Discomfort in the arms or legs may provoke movement as a patient attempts to readjust to relieve focal pressure and muscle tension. Placing patients in a comfortable position and maintaining that posture may reduce the probability of patient motion.

Devices designed to limit movement of the upper extremities have been used to decrease patient motion (*11*). These devices restrain the hands or require the patient to hold hand grips. We have found these devices ineffective or counterproductive in minimizing arm and shoulder discomfort. In addition, they do nothing to prevent back discomfort.

Recently, a new device has become available that positions and supports both the upper and lower extremities. This device supports the arms in a passive position over the head and maintains the knees and hips in a flexed position, thereby firmly apposing the lumbar spine to the imaging table pad and supporting the back. We undertook a randomized controlled trial to evaluate the effect of this device on the incidence and severity of patient motion and patient motion artifact.

MATERIALS AND METHODS

Patients

We prospectively recruited 190 consecutive patients referred for stress/redistribution tomographic myocardial perfusion imaging with ^{201}Tl. Patients undergoing either dipyridamole stress testing and exercise/stress testing were allowed to participate. The Human Studies Committee of Albany Medical Center, Albany, NY approved the investigation and all subjects gave written informed consent.

Study Protocol

We randomly assigned patients to use the positioning and support device (PSD; Patient Support System I™, R-Made, Inc., Royal Oak, MI) during poststress or redistribution tomographic acquisitions. Each patient had one of the two acquisitions performed with the PSD and the other acquisition performed without the PSD. The PSD consisted of two components: (a) a rigid multi-angled plastic device that passively supports the arms and (b) a firm, contoured foam support under the legs that flexes the knees and hips (Fig. 1). The PSD was designed to allow small

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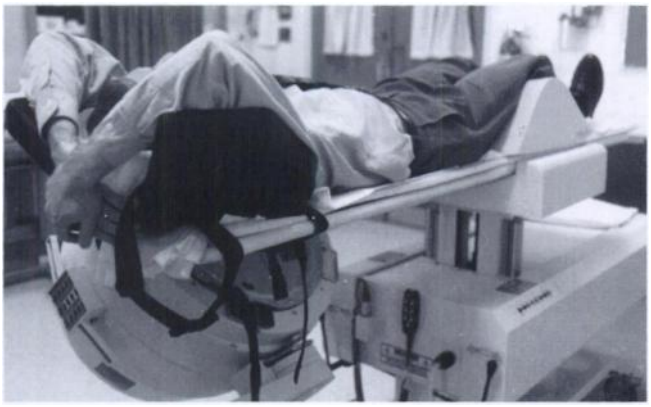

FIGURE 1. A patient being imaged with a PSD. The device consists of two parts: multi-angled plastic wings under the patient's head that support the arms in a comfortable and secure position over the head and a firm foam support under the legs that postures the knees and hips in a flexed position.

pillows to be placed between its lateral wings and the patient's arms, so that the patient's shoulders could be maintained at a comfortable angle. During control acquisitions, patients did not use the PSD and placed their left arm over their head and were asked to position their right arm either at their side or over their head, depending upon which position was most comfortable.

We instructed the technologists to provide equal attention to minimizing patient motion and maximizing patient comfort in both groups. Technologists made all patients as comfortable as possible before and during acquisitions by offering small pillows to both groups to maximize comfort. In the PSD group, technologists placed the pillows between the patient's arms and the lateral wings of the PSD. In the control group, technologists placed the pillows under the patient's head. Pillows were not used under the legs or back. Both groups were continuously monitored during image acquisition for the presence of motion or discomfort, and provided extra assistance as needed. Extra assistance included verbal encouragement to remain still, supporting a patient's arm or hand or repositioning of the arms or pillows.

Both groups were imaged with a single-head camera that acquired 32 images over 180° for 25 sec per stop. Total acquisition time was 16 min. Images were acquired onto a 64 × 64 matrix with 7.5 mm/pixel.

If a study was stopped and restarted because of observed motion, only the first acquisition attempt was analyzed and the need to restart a study was recorded. This avoided a potential bias for patients who moved, but could be prevented from moving on a subsequent acquisition by coaxing, direct restraint or closer observation.

Comfort Assessment

At the end of the redistribution study, we asked patients to compare their comfort with and without the PSD. Patients scored their comparison on a five-point scale, ranging from greatly preferring to greatly disliking the PSD.

Visual Analysis

An observer experienced in interpreting thallium scans who was blinded to the randomization status viewed a cinegraphic loop of the raw projection data. The images were displayed in alternating forward and reverse sequence on a video display with adjustable window, level and cine framing rate. Discontinuity of the heart's position between two successive images was scored as patient motion. "Upward creep," the gradual upward motion of the heart within the thorax during the poststress images (*12*), was not scored as patient motion. If an acquisition could not be completed because of gross motion, the images were scored as having motion.

If either the poststress or redistribution scan for a patient contained motion, then side-by-side comparisons of the two datasets were made. The observer compared the severity of motion in each dataset based on a subjective impression of the distance, direction and number of episodes of motion and the camera angle at which motion occurred in each dataset (*4,7*). Scan pairs were scored as: poststress scan motion more severe, less severe or equal to redistribution scan motion. If one of the scans could not be completed because of gross motion, that set was scored as having more severe motion.

Quantitative Anaylsis

We calculated a quantitative patient motion score using the two-dimensional fit method for motion detection (*5*). This method provides a measure of the distance of axial motion between successive images in a tomographic dataset. The motion score was defined as the sum of the absolute values of all axial interframe shifts greater than 0.5 pixels (3.75 mm). We used this threshold to minimize the measurement noise in motion-free data and chose the value of 3.75 mm because a motion artifact is very unlikely below this distance (*4,9*). Patient motion in poststress/redistribution scan pairs was compared quantitatively by calculating the difference in the paired motion scores.

Evaluation of Motion Artifact in Reconstructed Images

If a study contained visually detectable motion, we examined the reconstructed images for artifacts before and after motion correction. Visually detectable motion was used as the criterion for motion correction because visually detectable motion inspection is approximately 100% accurate in detecting clinically important motion (*5*). Motion correction was performed by shifting all projection images according to the distance of motion measured by the two-dimensional fit method (*5,13*). Linear interpolation was used for fractional pixel shifts. Projection data with and without motion correction were reconstructed identically.

Motion artifact was defined as any streaking, smudging, defects or hot spots unexplained by physiology or pathology that was improved by motion correction. An observer classified the motion artifact as minor (not enough to interfere with the diagnostic quality) or major (interfering clinically with the diagnostic quality). If an acquisition could not be completed because of gross motion, the images were scored as having major artifact.

Data Analysis

The frequency of motion was tabulated and the standard deviation calculated (*14*). The significance of differences in distributions was determined by chi square analysis. The significance of differences of means and incidences was determined by analysis of variance and, where appropriate, the Student t-test.

RESULTS

Of the 190 patients who consented to participate, eleven patients were dropped from the study: five because of subsequent cancellation of the study, three because the imaging protocol was changed to planar imaging, two because of failure to return for redistribution imaging and one because of lost data. Patients were 61 ± 13 yr of age (mean

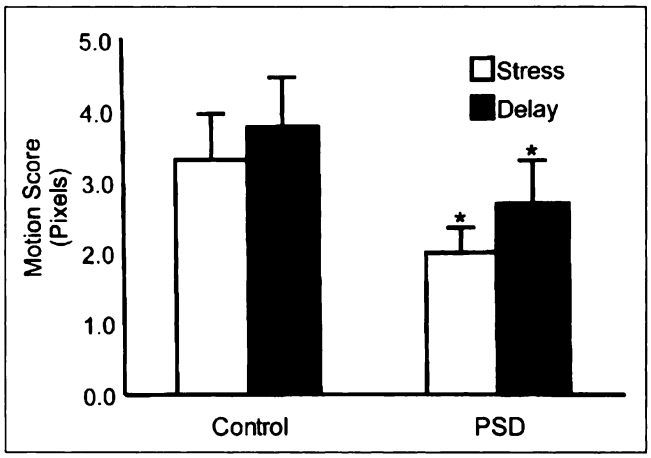

FIGURE 2. Quantitative motion score (mean ± s.d.) for patients with visually detectable motion, defined as the sum of the absolute values of all axial interframe shifts greater than 0.5 pixels (3.75 mm). Among patients with visually detectable motion, the PSD reduced the distance of motion measured by the motion score (*$p < 0.05$).

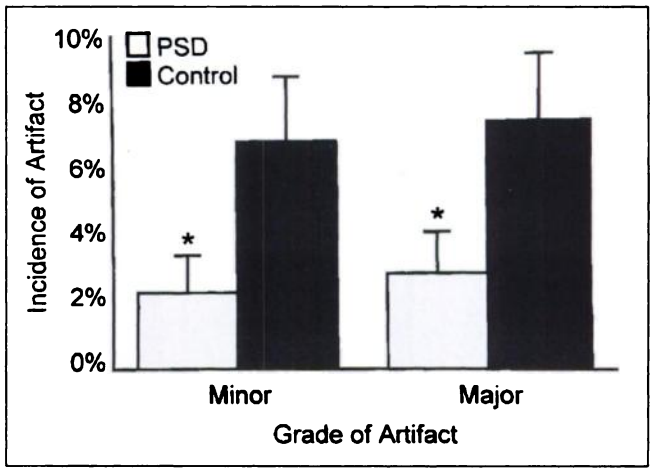

FIGURE 3. Incidences (±s.d.) of minor and major motion artifacts in patients studied with and without the PSD and control studies. Minor artifact was defined as artifact that did not limit the diagnostic usefulness of the study. Major artifact was defined as artifact that limited the diagnostic usefulness of the study (*$p < 0.05$ different form control).

± s.d.; range: 32 to 92 yr). Stress protocols used included: treadmill exercise (63% of studies), combination dipyridamole and low-level treadmill exercise (21%) and dipyridamole alone (16%). Ninety of the evaluated patients were randomized to use the PSD during poststress imaging and 86 were randomized to use the PSD during redistribution imaging.

The incidence of motion was 26% ± 3.3% in the PSD group versus 38% ± 3.7% in the control group ($p < 0.05$). The incidence of motion in both groups was 32% ± 2.5% and 15% ± 2.7% of patients moved both with and without the PSD. There were no statistically detectable differences in the incidences of motion between poststress and redistribution images for either group, regardless of the stress protocol.

Use of the PSD decreased the quantitative motion score by 5.3 ± 2.2 mm ($p < 0.05$). The quantitative motion scores for the subset of patients with visually detectable motion is shown in Figure 2. In this group of patients, use of the PSD decreased the quantitative motion score by 9.0 ± 3.8 mm ($p < 0.05$).

The incidence of motion artifact was 5% ± 3.8% in the PSD group and 14% ± 6.0% in the control ($p < 0.05$). The incidence of motion artifact was less than the incidence of detectable motion, because not all patient motion results in a detectable artifact (*4,7*). Among the patients who had severe motion, the severe motion occurred more frequently during the control acquisition (68% ± 5.1% versus 32% ± 5.1%; $p < 0.02$). Motion caused an artifact that limited the diagnostic usefulness of 5% ± 1.1% of studies. Use of the PSD reduced the number of major motion artifacts from 13 to 5 and the number of minor artifacts from 12 to 4 (Fig. 3).

Most patients preferred using the PSD (Fig. 4), but 13 patients disliked or greatly disliked the PSD. The incidence of motion among these 13 patients was greater than among the remaining patients (42% ± 9.7% versus 31% ± 2.5%), but the difference was not statistically significant. The incidence of motion artifact in the reconstructed images, however, was greater in patients who disliked the PSD ($p < 0.05$; Fig. 5). There was one minor motion artifact when using the PSD versus one minor and three major artifacts when not using the PSD. There was no statistically detectable difference in patient scores between patients using the PSD on the poststress or redistribution acquisition.

DISCUSSION

Use of the PSD reduced the incidence and severity of patient motion. Most importantly, use of the PSD reduced the incidence of motion artifacts that interfered with the diagnostic usefulness of the study. Although use of the PSD did not completely eliminate patient motion, it reduced the magnitude of motion in patients who did move. The importance of the use of the PSD is further emphasized by the common occurrence of patient motion.

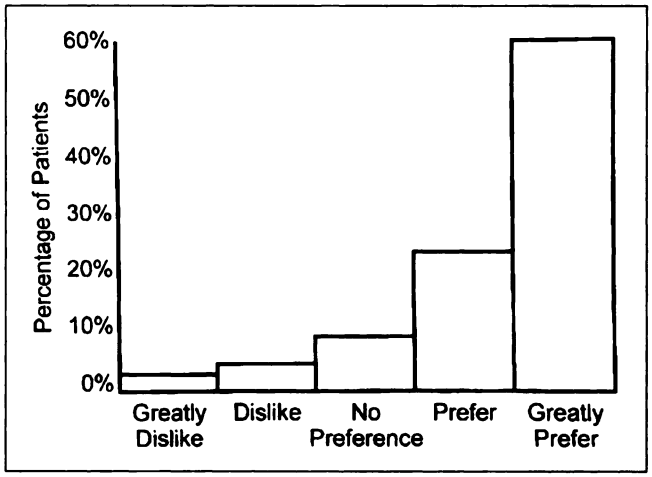

FIGURE 4. Distribution of patient preference scores for the PSD.

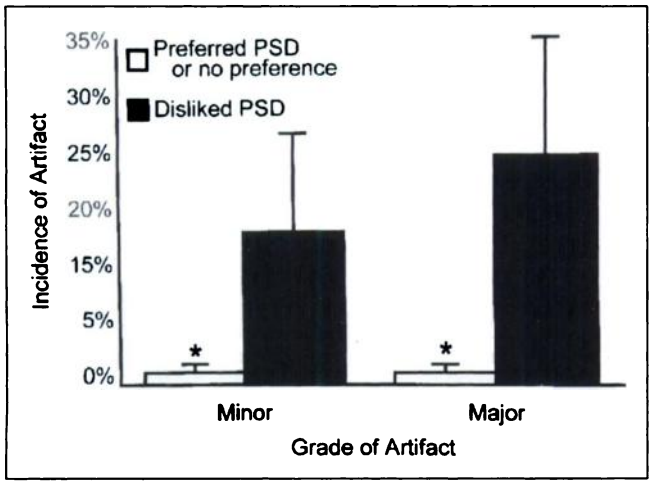

FIGURE 5. Incidence (±s.d.) of minor and major motion artifact according to patient preference for the PSD (*$p < 0.05$ versus controls).

Many laboratories use SPECT acquisition times of 25 min or longer, which is longer than the 16-min acquisition time used in the current study. During longer acquisition times, patient motion may be more frequent than in the current study. This further supports the importance of the use of the PSD to reduce patient motion.

These results are free of several potential biases. The observers who scored patient motion and motion artifact were unaware of the patient's randomization status. Although quantitative motion detection is less accurate than visual inspection (*5*), the quantitative results support the visual findings. The two groups were well matched since each patient was imaged with and without the PSD. One potential bias of this study was that the technologists knew the randomization status of a patient, and therefore could have elicited more cooperation from the PSD group. They, however, provided equal attention to both groups.

A small group of patients felt less comfortable when using the PSD. This group had a greater incidence of motion artifact than patients who preferred using the PSD or had no preference, yet they seemed to benefit by using the PSD. This finding suggests that patient motion may not always correspond to the perception of comfort. Other factors, such as reducing the amount of voluntary muscle activity needed to maintain a fixed body position or increasing the amount of force required to move the arms or knees, may be important. This hypothesis is supported by evidence that the incidence of patient motion is reduced in the prone position (*15*). Although postexercise fatigue has been suggested as a factor in patient motion, our study suggests that this may not be a major factor because the incidence of motion between poststress and redistribution imaging were not different among patients who exercised.

Like many departments performing tomographic imaging of the heart, we have informally tried many devices to restrict patient movement. Most positioning and support devices maintain the arms above the head by actively securing the patient's hands or providing hand grips for the patient to hold (*11*). These devices fail to provide anatomic support for the shoulders, elbows and arms or they require sustained muscular exertion. These problems are not present with the PSD used in this study. In addition, the PSD we used also positions the hips and knees in slight flexion. This rotates the pelvis and apposes the lumbar spine to the imaging table pad. This may limit rotational and translational motion by providing stable back support.

The PSD did not eliminate all patient motion. There are two possible reasons. First, the PSD is not a restraining device and therefore patients who attempt to move either from discomfort or lack of cooperation will be free to do so. Second, patients may have involuntary motion, such as coughs or hiccoughs, that will not be prevented with a support device. In the current study, we could not determine the relative incidence of voluntary versus involuntary motion.

CONCLUSION

Our data support the routine use of the PSD. The PSD reduced patient motion and clinically important motion artifact. In addition, the device was accepted by almost all patients. One could withhold the PSD from patients made less comfortable with its use, or use the PSD selectively in patients who feel more comfortable with its use. We do not know, however, whether selective use of the PSD would result in further reductions in patient motion. Patient motion and resultant patient motion artifact can be substantially reduced through the routine use of the PSD. Even with routine use, surveillance for patient motion should be continued since some patients will move.

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FIRST IMPRESSIONS:
Anterior View from SPECT Analog Acquistion of Stress Thallium-201 Perfusion Studies in Two Patients

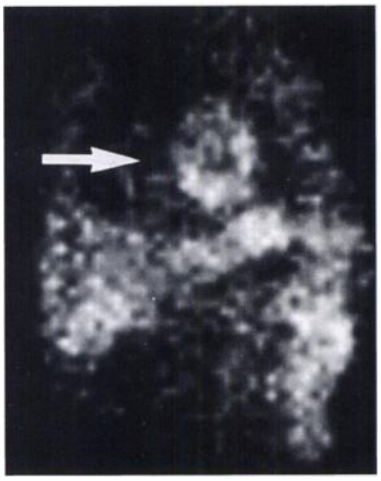

Figure 1.

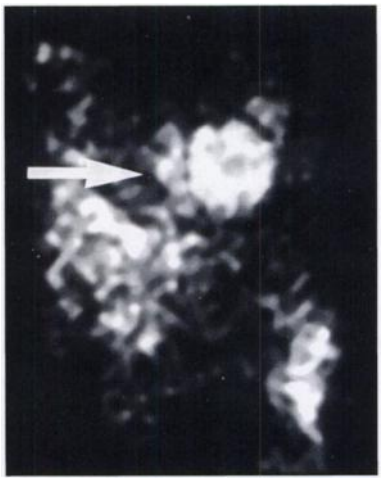

Figure 2.

PURPOSE
Patient 1, a 5'7", 167 lb, 48-yr-old man (Fig. 1), diagnosed with scleroderma, presented with an 11-mm circumcardiac pericardial effusion without signs of tamponade as demonstrated on echocardiogram. The left ventricle was normal in size with mild left ventricular hypertrophy. Pericardiac photopenia was due to a large collection of pericardial fluid. Patient 2, a 5' 4" 50-yr-old woman who weighed 275 pounds, had large breasts that caused soft-tissue attenuation on the cine projection image. In Figure 2, the shape of the photopenic defects seen in Patient 1 resemble those in Patient 2 due to breast attenuation on the still-frame analog images. On cine review of Patient 1's images, photopenia did not extend beyond the chest wall, as is usually the case for large breast attenuation, especially in the lateral views. This patient's condition emphasizes the superficial (single plane) resemblance of different causes of apparent circumcardiac attenuation, which can only be distinguished by careful review of the cine (multiplane) images. Both cases illustrate the merit and need for analog cine review of images to identify the location of soft-tissue attenuation in ^{201}Tl myocardial perfusion scans.

TRACER
Thallium-201 (111 MBq)

ROUTE OF ADMINISTRATION
Intravenous

TIME AFTER INJECTION
Ten minutes

INSTRUMENTATION
ADAC Dual-Head Vertex SPECT camera, Pegasys Computer System (64 × 64 × 16 matrix, 64 views at 20 sec/view)

CONTRIBUTORS
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