Original article

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Prone imaging allows efficient radiopharmaceutical usage by obviating the necessity of a rest study in Tc-99m-methoxyisobutylisonitrile myocardial perfusion scintigraphy

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Objective In myocardial perfusion single-photon emission computed tomography studies, diaphragmatic attenuation of the inferior wall is a common artifact, which can be minimized by prone imaging. The aim of this retrospective study was to validate the impact of stress–prone imaging on the necessity of a rest perfusion study with a final goal of effective radiopharmaceutical usage.

Methods The findings of 98 patients who had been examined by a combined supine and prone imaging were retrospectively evaluated. Prone acquisition was performed only when reduced perfusion was observed in the inferior wall on the stress supine images. The reconstructed images were evaluated both visually and quantitatively. Rest myocardial single-photon emission computed tomography study was omitted in patients with complete normalization of uptake in the prone images. Results obtained were also compared with the clinical data and follow-up.

Results Prone imaging obviated the necessity of a rest perfusion study in 76 of 98 patients (77.5%). Among normally reported patients ($n=89$), 76 (85.4%) were saved from a rest study due to the prone study results. Prone study provided improved results in quantitative analysis as well. The difference between the mean summed stress scores of supine and prone studies was statistically significant in normally reported patients ($P=0.013$). However, no significant difference was observed in scores of ischemic patients ($P=0.341$).

Conclusion Adding prone imaging to a post-stress Tc-99m-methoxyisobutylisonitrile myocardial perfusion study not only minimizes the inferior wall attenuation, but also reduces the need for a rest test, particularly in low-risk or intermediate-risk patients. Thus, prone imaging seems to be both safe and effective. *Nucl Med Commun* 32:284–288 © 2011 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Introduction

Myocardial perfusion single-photon emission computed tomography (SPECT) is a very effective noninvasive method, which provides valuable information in clinical practice whereas artifacts may reduce the clinical value of this technique [1,2]. Soft tissue attenuation is a major source of artifact. Attenuation of emission photons passing through tissues produces artifacts, which degrades the image obtained in myocardial SPECT studies; this can result in apparent perfusion defects. Breast fixation, prone acquisition, attenuation correction, or gated-SPECT studies have been used to overcome this effect on SPECT studies.

One of the most common artifacts is observed in the inferior wall as a result of diaphragmatic attenuation, which is more common in men [3,4]. The clinical use of prone imaging is widely accepted to minimize the diagnostic impact of the artifacts [5,6]. Patients with inferior wall defects on supine myocardial perfusion scintigraphy (MPS), that are not present on prone MPS, have a low risk of subsequent cardiac events, similar to that of patients with normal supine studies [7]. The mechanism responsible for the improvement in prone imaging is the movement of the heart relative to the diaphragm.

When a 2-day protocol is preferred in MPS, the stress study is usually carried out first, as the rest study can be omitted if the stress study is interpreted as normal [8–10]. A recent report by Duvall *et al.* [11] pointed out the excellent short-term prognosis of a normal stress-only MPS comparable with that of a normal rest–stress MPS. Patients with a stress defect in MPS should always undergo a resting SPECT study. As a normal stress study would eliminate subsequent rest imaging, radiation dose, investigation time, and radiopharmaceutical doses used would

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decrease. In the case of diaphragmatic attenuation, absence of perfusion defects in a stress–prone study may help to rule out ischemic heart disease while decreasing the need for rest imaging, especially when combined with a supine study.

Considering the reliability of prone imaging, we developed a retrospective analysis to validate the impact of the stress-prone imaging on the necessity of a rest perfusion study in a 2-day protocol with a final goal of effective radiopharmaceutical usage in addition to lowering the radiation dose delivered to the patients.

Materials and methods

Study population

Data of 98 patients (94 male, four female) who had been imaged both in the supine and prone positions between June 2009 and May 2010 were retrospectively evaluated. The mean age was 59 years and ranged between 25 and 86 years. The likelihood of coronary artery disease (CAD) has been documented based on age, sex, symptoms, and other coronary risk factors such as hypertension, diabetes, smoking, hypercholesterolemia, and family history of CAD (Table 1).

Clinical history showed known CAD and previous stenting in 18 patients, noncritical coronary stenosis in two patients, whereas 78 patients were referred for suspected CAD with no history of myocardial infarction (MI) with low or intermediate pretest probability.

The follow-up period for each patient was defined as the length of time from scintigraphic evaluation until the last known contact as documented by medical records or telephone interviews for events such as MI hospitalization for chest pain, cardiac catheterization for chest pain, or revascularization. The mean follow-up time was 10.6 months and ranged between 6 and 16 months.

Myocardial perfusion scintigraphy

A total of 83 patients underwent Tc-99m-methoxyisobutylisonitrile (MIBI) myocardial perfusion SPECT after exercise on a treadmill, following a modified Bruce protocol, and achieved at least 85% of their age-predicted maximal heart rate. Fifteen patients with movement limitation or left bundle brunch block received pharmacological stress with dipyridamole.

Table 1 **Characteristics of patients**

Parameter	Data (n = 98; %)
Age	59 (mean)
Male/female	94/4
Known CAD	20 (20.4)
Risk factors	
Hypertension	51 (52)
Diabetes	23 (23.5)
Hypercholesterolemia	34 (34.7)
Family history	38 (38.8)
Smoking	56 (57)
Stress protocol	
Treadmill	83 (84.7)
Dipyridamole	15 (15.3)

CAD, coronary artery disease.

Before the radionuclide study, all patients had fasted for at least 4 h and cardiac medication was stopped. Thirty minutes after intravenous injection of 740 MBq Tc-99m-MIBI, myocardial imaging was acquired by a 90°-configuration dual-detector γ camera (E-cam, Siemens Medical Systems, Illinois, USA), equipped with low-energy high-resolution collimators. The acquisition protocol included 64 projections (25 s/projection, 32 per detector, matrix size 64×64) over a 180° arc beginning in the 45° right anterior oblique position to the left posterior oblique. The zooming factor was 1.45. Images were reconstructed using a back projection algorithm and a Butterworth filter with a cutoff frequency of 0.45 cycles per pixel and order 5.

Rest myocardial SPECT images on supine and prone positions were taken on another day if needed. Rest study was omitted in patients with complete normalization of uptake in stress-prone images.

Data analysis

Processing and visual evaluation were completed immediately after the acquisition of the stress supine study. The final evaluation of the reconstructed images of supine and prone SPECT studies was made both visually and quantitatively by an experienced nuclear medicine physician.

The Software program used for the quantitative analysis was quantitative perfusion SPECT (Cedars Cardiac Quantification 6.0.14.1; Cedars-Sinai Medical Centre, Los Angeles, California, USA). Analysis of perfusion was expressed as summed stress score (SSS), in a 20-segment model, on a five-point scale for each segment. Database used for the automated scoring was selected according to the imaging position.

The data are presented as proportions or mean values when appropriate. The ratio of stress-only imaging provided by combining prone and supine studies has been documented.

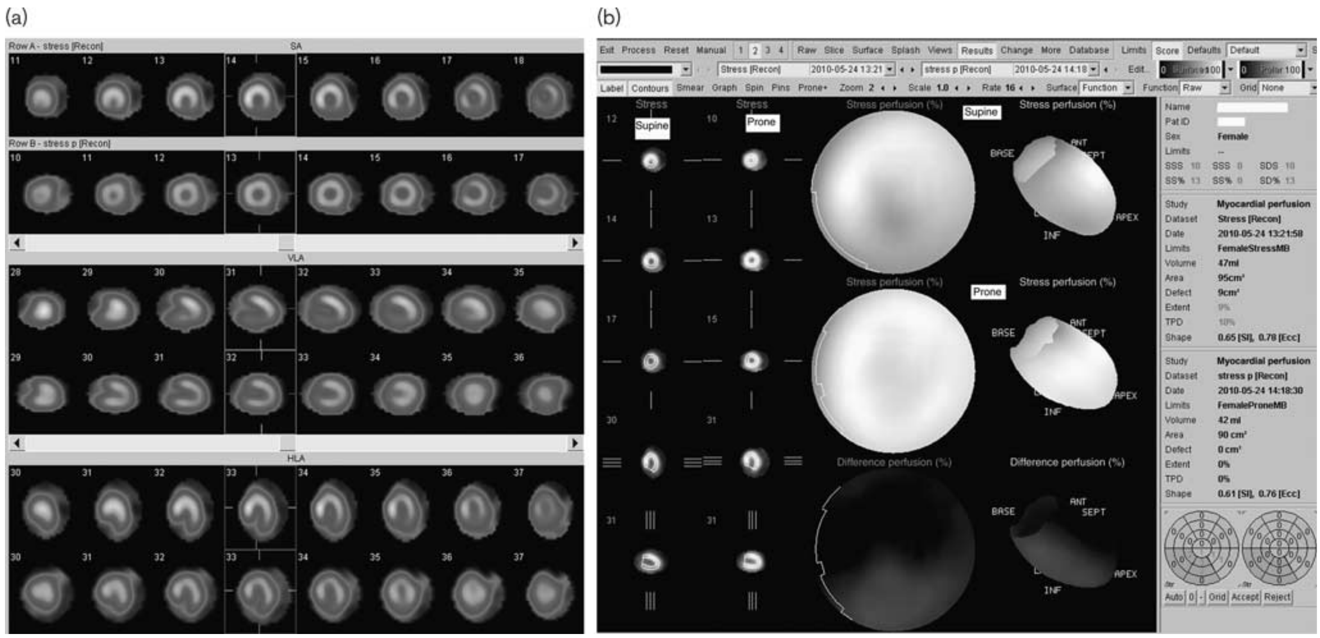
Scores derived in supine and prone studies were compared with each other using the paired t-test. (SPSS 16.0 Software; SPSS Inc., Chicago, Illinois, USA). A significant difference was considered to be present when the P value was less than 0.05.

Results were also compared with the coronary angiography results or the final clinical data on the basis of the number of cardiac events observed during the follow-up period.

Results

The activity in the inferior wall was much greater when patients were imaged in the prone position as opposed to the supine position. Prone images obviated the necessity of a subsequent rest perfusion study in 76 of 98 patients (77.5%). Without additional radiopharmaceutical administration for

Fig. 1



(a) Stress images of a 75-year-old female patient showing inferior wall perfusion defect on supine position images (upper line), which normalize on prone study (lower line). (b) Quantitative evaluation in a 20-segment model showing improvement of stress scores in the prone study compared with the supine study.

a rest study, the absence of perfusion defects in the inferior wall had been shown by prone imaging in these 76 patients. The attenuation artifacts caused by the diaphragm were severe enough to require rest imaging if prone study was not carried out (Fig. 1a and b).

Twenty-two of 98 patients (22.5%) underwent rest perfusion study, as the abnormality in the inferior wall did not completely disappear in the prone study or for the additional defects in the other walls. Myocardial ischemia was detected in nine patients in the inferior or inferolateral wall accompanying anteroseptal defect in two of them confirmed by coronary angiography.

The number of normally reported MPS (with or without rest imaging) was 89. Among normally reported patients, 76 of them (85.4%) were saved from a subsequent rest study due to the results of prone imaging.

There was no cardiac or noncardiac death or MI during the follow-up. The accuracy of normally reported combined supine and prone stress-only MPS was 97% depending on the final clinical diagnosis and outcome of patients. Angiography showed coronary stenosis in two patients with normally reported MPS. One of the patients had 40% stenosis in the left anterior descending artery and 100% chronical stenosis in the right coronary artery. The other patient had severe stenosis in the right coronary artery. However, the inferior myocardial wall was perfused by collaterals in both patients. Both of them received medical treatment afterwards.

Table 2 Mean values of summed stress scores and *P* values of the comparison of supine versus prone study

	SSS		
MPS results	Supine	Prone	*P* value
Overall	4.38	3.70	0.027
Normal	3.83	3.02	0.013
Ischemia	11.0	11.86	0.341

MPS, myocardial perfusion scintigraphy; SSS, summed stress scores.

Mean SSS of supine and prone studies derived in quantitative analysis were 4.38 and 3.70 overall, 11 and 11.86 in ischemic patients, and 3.83 and 3.02 in patients with normally reported MPS, respectively. There was no difference between SSS of supine and prone studies in ischemic patients ($P = 0.341$); however, it was significant overall ($P = 0.027$) and in patients with normally reported MPS ($P = 0.013$). In addition to the visual evaluation, quantitative analysis of prone imaging increased the accuracy of MPS by providing improved stress scores in quantitative perfusion SPECT (Table 2).

Discussion

MPS has a highly negative predictive accuracy for ruling out ischemic heart disease and future cardiac events [12]. However, distinction between attenuation artifacts and true perfusion abnormalities should be provided to increase the accuracy of the scintigraphic evaluation. Several studies have shown that prone imaging assists the discrimination of true perfusion abnormality from artifact, particularly in case of inferior wall defects especially in men [4,7,13]. In patients who have inferior wall perfusion defects and normal prone images, the prognosis is excellent with a low event rate and is equal to that observed in a cohort of patients with normal MPS using supine imaging alone [7].

Prone position imaging is suggested to be applied to a patient with inferior wall-fixed defect on conventional imaging [13,14]. In our study, we combined prone imaging with supine imaging at the time of the stress study and validated the impact of stress–prone imaging on the necessity of a rest imaging. The good prognostic value of a normal scan has been well documented earlier [15,16]. Stress-only imaging is also dedicated as a safe protocol depending on the low cardiac event rates reported in the literature [8,9,11]. The major factor contributing to the reduced specificity is the attenuation artifacts. The results of this study show that prone imaging increases the number of stress scans that can be interpreted as normal without a concomitant rest scan in MPS performed with Tc-99m-MIBI.

To overcome attenuation problems, gated imaging and attenuation correction are other methods that have been used. The addition of gating provides increased specificity and helps in the discrimination of infarct from attenuation artifact, especially when wall motion and wall thickening are preserved in apparently fixed perfusion defects. In contrast, true myocardial perfusion defect due to subendocardial infarction that is associated with a normal contraction pattern might be falsely attributed to soft tissue attenuation [17]. It should also be remembered that preserved wall motion and thickening in a stress-induced perfusion defect with Tc-99m-MIBI does not prove it to be an artifact, as functional parameters reflect cardiac function during imaging, whereas Tc-99m-MIBI imaging reflects the perfusion after tracer injection [5]. Although an improvement in the diagnostic accuracy in case of attenuation problems is provided with gated imaging, two sets of images (stress and rest) are usually required and eliminating the necessity of rest imaging may not be possible.

Attenuation correction also assists the recognition of artifacts. For this purpose, an auxiliary transmission scan with a radiation source outside the patient or an X-ray tube with an opposing detector that form a CT system is required [5]. Diminished effect of soft tissue attenuation is provided by these techniques. Improved sensitivity, specificity, and accuracy of myocardial perfusion imaging as a result of attenuation correction techniques have been reported in the literature [4,9,18]. Hence, this approach does not always provide accurate correction [19]. Sometimes, overcorrection of the inferior wall may lead to lowered sensitivity for the detection of true perfusion defects [20]. Furthermore, many of the existing systems used in centers still do not include the option of well-functioning attenuation correction. Prone imaging can be performed in any SPECT camera without the need for specialized hardware of software and seems to provide a useful alternative in centers, which are not equipped for routine attenuation correction procedures.

Deciding on stress–prone imaging after supine study requires a rapid accurate analysis of the images. However, withholding further imaging at rest needs adequate decision making. At this point, quantification programs enhance the objectivity of interpretation and improve confidence in evaluation. In contrast, quantitative analysis may not be helpful in differentiating between true disease and artifactual defects when dealing with a wide spectrum of findings in the inferior wall [13]. According to the results of the studies by Slomka *et al.* [21] and Nishina *et al.* [22], the combined prone–supine quantification technique improves the diagnostic performance of quantitative SPECT specificity, and normalcy rates increases without altering sensitivity. In our study, we observed that quantitative values of patients with diaphragm attenuation were also improved in the prone study apart from visual analysis. Summed stress scores of supine and prone studies were not different in patients with true perfusion defects.

The prone acquisition has been reported to produce artifactual anteroseptal defects, probably due to the closer position of the heart to the bony structures of the anterior chest wall [14,23]. Nevertheless, earlier reported high specificity and normalcy rates suggest that this is not common [24]. Segall and Davis documented that sensitivity and specificity for left anterior descending artery and circumflex were not significantly affected by patient position [13].

Attenuation artifacts in supine SPECT imaging commonly affect the anterior myocardial wall in female patients and the inferior wall in male patients. The diaphragmatic attenuation of the inferior wall in supine SPECT imaging is more common in men [3,4]. The unproportional number of male and female patients (94 male, four female) in our study was a limiting factor, as we were not able to analyze the data separately according to sex and compare the findings of the male and female patients.

Although rare, one of the limiting factors of prone imaging is the inability of some patients to lie in the prone position. Another point is that, the combined supine and prone approach in stress study may be applicable only with Tc-99m-labeled myocardial perfusion tracers that do not rapidly distribute. Sequential supine and prone imaging during stress imaging with Tl-201 is not proper, because improvement in the prone position compared with supine images might be a consequence of redistribution within true defects [25]. Another limiting factor of combining prone study with supine is the extra time required for imaging. The unpredictable need for the additional prone acquisition may cause disruption of the imaging schedule. In our center, additional imaging time (approximately 15 min) was not a major limiting factor especially when compared with difficulties in radiopharmaceutical supply. On account of serious Tc-99m shortage affecting most of the countries including ours, there had been times that we had to cancel the appointment of some of our patients, as we were not able to receive the amount of technetium we needed. In such a period, adding prone imaging to supine in stress study in selected cases provided availability of stress-only imaging in more patients than expected in routine workup and led to an increased convenience for an important subset of patients. Waiting list was available to reduce for other patients even for MPS or other examinations. Combining supine and prone imaging seems to increase the duration of overall study, but the possibility of obviating a rest SPECT compensates the situation. Moreover, a combined approach would not always be necessary in routine workup.

Stress-only imaging seems to be patient convenient. However, this approach may be acceptable only for patients without stress defects at Tc-99m-MIBI myocardial perfusion SPECT. There are reports in the literature about the safety of stress-only imaging or usefulness of prone imaging in diaphragmatic attenuation. Our results suggest that visual and quantitative evaluation of prone imaging is very efficacious on deciding the necessity of a rest SPECT. If a normal stress imaging without rest confers good prognosis, fewer rest images could be necessary by the aid of visual and quantitative evaluation of combined supine and prone imaging. The benefits of this approach can be summarized as follows: (i) using technetium doses efficiently, (ii) lowering radiation dose delivered to the patients, (iii) reducing patient time to reach the results, and (iv) improving the laboratory throughput.

In conclusion, adding prone imaging to post stress Tc-99m-MIBI myocardial perfusion study in selected cases with inferior wall defects seems to be both safe and effective, as it reduces the need for a rest study, particularly in low-risk or intermediate-risk patients.

References

1 DePuey EG III. How to detect and avoid myocardial perfusion SPECT artifacts. *J Nucl Med* 1994; **35**:699–702.
2 Aktaş A, Yalcin H, Koyuncu A, Aydinalp A, Müderrisoglu H. The influence of post-exercise cardiac changes on thallium-gated myocardial perfusion scintigraphy findings in normal subjects. *Nucl Med Commun* 2005; **26**:109–114.
3 Hedén B, Persson E, Carlsson M, Pahlm O, Arheden H. Disappearance of myocardial perfusion defects on prone SPECT imaging: comparison with cardiac magnetic resonance imaging in patients without established coronary artery disease. *BMC Med Imaging* 2009; **10**:9–16.
4 Malkerneker D, Brenner R, Martin WH, Sampson UK, Feurer ID, Kronenberg MW, *et al.* CT-based attenuation correction versus prone imaging to decrease equivocal interpretations of rest/stress Tc-99m tetrofosmin SPECT MPI. *J Nucl Cardiol* 2007; **14**:314–323.
5 Hesse B, Lindhardt TB, Acampa W, Anagnostopoulos C, Ballinger J, Bax JJ, *et al.* EANM/ESC guidelines for radionuclide imaging of cardiac function. *Eur J Nucl Med Mol Imaging* 2008; **35**:851–885.
6 Peterson PN, Parker JA, Tepper MR, Hauser TH, English J, Danias PG. Prone SPECT myocardial perfusion imaging is associated with less cardiac drift during the acquisition duration than imaging in the supine position. *Nucl Med Commun* 2005; **26**:115–117.
7 Hayes SW, De Lorenzo A, Hachamovitch R, Dhar SC, Hsu P, Cohen I, *et al.* Prognostic implications of combined prone and supine acquisitions in patients with equivocal or abnormal supine myocardial perfusion SPECT. *J Nucl Med* 2003; **44**:1633–1640.
8 Schoroeder-Tanka JM, Tiel-van Buul MM, Van der Wall EE, Roolker W, Lie KI, Van Royen EA. Should imaging at stress always be followed by imaging at rest in Tc-99m MIBI SPECT? *Int J Card Imaging* 1997; **13**:323–329.
9 Gibson PB, Demus D, Noto R, Hudson W, Johnson LL. Low event rate for stress-only perfusion imaging in patients evaluated for chest pain. *J Am Coll Cardiol* 2002; **39**:999–1004.
10 Hesse B, Tägil K, Cuocolo A, Anagnostopoulos C, Bardiés M, Bax J, *et al.* EANM/ESC procedural guidelines for myocardial perfusion imaging in nuclear cardiology. *Eur J Nucl Med Mol Imaging* 2005; **32**:855–897.
11 Duvall WL, Wijetunga MN, Klein TM, Razzouk L, Godbold J, Croft LB, *et al.* The prognosis of a normal stress-only Tc-99m myocardial perfusion imaging study. *J Nucl Cardiol* 2010; **17**:370–377.
12 Marcassa C, Bax JJ, Bengel F, Hesse B, Petersen CL, Reyes E, *et al.* Clinical value, cost effectiveness, and safety of myocardial perfusion scintigraphy: a position statement. *Eur Heart J* 2008; **29**:557–563.
13 Segall GM, Davis MJ. Prone versus supine thallium myocardial SPECT: a method to decrease artifactual inferior wall defects. *J Nucl Med* 1989; **30**:548–555.
14 Dogruca Z, Kabasakal L, Yapar F, Nisil C, Vural VA, Onsel C. A comparison of Tl-201 stress-reinjection-prone SPECT and Tc-99m-sestamibi gated SPECT in the differentiation of inferior wall defects from artifacts. *Nucl Med Commun* 2000; **21**:719–727.
15 Brown KA, Altland E, Rowen M. Prognostic value of normal technetium-99m-sestamibi cardiac imaging. *J Nucl Med* 1994; **35**:554–557.
16 Hachamovitch R, Berman DS, Kiat H, Cohen I, Cabico JA, Friedman J, *et al.* Exercise myocardial perfusion SPECT in patients without known coronary artery disease: incremental prognostic value and use in risk stratification. *Circulation* 1996; **93**:905–914.
17 DePuey EG. Artifacts clarified by and caused by gated myocardial perfusion SPECT. In: Germano G, Berman DS, editors. *Clinical gated cardiac SPECT.* New York, NY: Futura Publishing Co.; 1999. pp. 183–237.
18 Ruiz Solís S, Rodado Marina S, Soriano Castrejón A, Cortés Romera M, Poblete García VM, García Vicente AM, *et al.* Clinical and prognostic value of X-ray-based attenuation correction in post-stress myocardial perfusion SPECT. *Rev Esp Med Nucl* 2007; **26**:77–89.
19 Almquist H, Arheden H, Arvidsson AH, Pahlm O, Palmer J. Clinical implication of down-scatter in attenuation-corrected myocardial SPECT. *J Nucl Cardiol* 1999; **6**:406–411.
20 Harel F, Génin R, Daou D, Lebtahi R, Delahaye N, Helal BO, *et al.* Clinical impact of combination of scatter, attenuation correction, and depth-dependent resolution recovery for (201)Tl studies. *J Nucl Med* 2001; **42**:1451–1456.
21 Slomka PJ, Nishina H, Abidov A, Hayes SW, Friedman JD, Berman DS, *et al.* Combined quantitative supine-prone myocardial perfusion SPECT improves detection of coronary artery disease and normalcy rates in women. *J Nucl Cardiol* 2007; **14**:44–52.
22 Nishina H, Slomka PJ, Abidov A, Yoda S, Akincioglu C, Kang X, *et al.* Combined supine and prone quantitative myocardial perfusion SPECT: method development and clinical validation in patients with no known coronary artery disease. *J Nucl Med* 2006; **47**:51–58.
23 Kiat H, Van Train KF, Friedman JD, Germano G, Silagan G, Wang FP, *et al.* Quantitative stress–redistribution thallium-201 SPECT using prone imaging: methodologic development and validation. *J Nucl Med* 1992; **33**:1509–1515.
24 Shin JH, Pokharna HK, Williams KA, Mehta R, Ward RP. SPECT myocardial perfusion imaging with prone-only acquisitions: correlation with coronary angiography. *J Nucl Cardiol* 2009; **16**:590–596.
25 Katayama T, Ogata N, Tsuruya Y. Diagnostic accuracy of supine and prone thallium-201 stress myocardial perfusion single-photon emission computed tomography to detect coronary artery disease in inferior wall of left ventricle. *Ann Nucl Med* 2008; **22**:317–321.