

# The Utility and Potential Cost-Effectiveness of Stress Myocardial Perfusion Thallium SPECT Imaging in Hospitalized Patients with Chest Pain and Normal or Non-Diagnostic Electrocardiogram

Tuvia Ben-Gal MD and Nili Zafrir MD

Nuclear Cardiology Unit, Rabin Medical Center (Beilinson Campus), Petah Tiqva, and Sackler Faculty of Medicine, Tel Aviv University, Israel

**Key words:** in-hospital chest pain, thallium-201 SPECT, cardiac event, non-diagnostic electrocardiogram, cost-effectiveness

## Abstract

**Background:** The evaluation of hospitalized patients with chest pain and non-diagnostic electrocardiogram is problematic and the optimal cost-effective strategy for their management controversial.

**Objectives:** To determine the utility of myocardial perfusion imaging with thallium-201 for predicting outcome of hospitalized patients with chest pain and a normal or non-diagnostic ECG.

**Methods:** On pain cessation, 109 hospitalized patients, age  $61 \pm 14$  years (mean  $\pm$  SD), with chest pain and non-diagnostic ECG underwent stress myocardial perfusion SPECT imaging with thallium-201. Costs related to their management were calculated. The occurrence of non-fatal myocardial infarction or cardiac death was recorded at  $12 \pm 5$  months follow-up.

**Results:** A normal SPECT was found in 84 patients (77%). During one year follow-up, only 1 (1.2%) compared to 7 (28%) cardiac events (6 myocardial infarctions, 1 cardiac death) occurred in patients with normal versus abnormal scans respectively ( $P < 0.0001$ ). Negative predictive value and accuracy of the method were 99% and 83% respectively. Multivariate regression analysis identified an abnormal SPECT as the only independent predictor of adverse cardiac event ( $P = 0.0016$ ). Total cost from admission until discharge was 11,193 vs. 31,079 shekels ( $P < 0.0001$ ) for normal and abnormal scan. Considering its high negative predictive value, shortening the hospital stay from admission until scan performance to 2 days would result in considerably reduced management costs (from NIS 11,193 to 7,243) per patient.

**Conclusion:** Stress SPECT applied to hospitalized patients with chest pain and a normal or non-diagnostic ECG is safe, highly accurate and potentially cost effective in distinguishing between low and high risk patients.

*IMAJ 2001;3:725-730*

The accurate evaluation of chest pain is made difficult by the low specificity of standard clinical and electrocardiographic variables [1-4]. The optimal clinical and cost-effective strategy for the management of patients who present to the emergency department with chest pain and non-diagnostic ECG is controversial [5-7]. Because of the limited diagnostic accuracy of clinical and ECG data [2], and considering the serious consequences of inappropriate emergency room discharge of patients with true myocardial ischemic event [8], most emergency room physicians adopt a liberal admission policy. The appropriate management of those patients is a major clinical and economic issue [9].

Patients with typical anginal chest pain and ischemic ECG changes considered at high risk for acute myocardial ischemic event are usually admitted to the coronary care unit [10,11]. Patients considered at intermediate risk – as determined by angina-like chest pain and a normal or non-diagnostic ECG – are usually admitted to an internal medicine department. During hospital stay, patients refractory to the initial medical therapy commonly undergo coronary angiography and a revascularization procedure if indicated. For those patients who do respond to the medical therapy and for those in whom the diagnosis of an acute ischemic event is still uncertain, a risk stratification protocol is required. The Duke treadmill score [12], Holter ST segment monitoring [13,14], two-dimensional echocardiography [15], computerized algorithms [16] and myocardial perfusion with thallium-201 [17-20] or with technetium-99m sestamibi [6,21-23] are all methods previously used in order to improve the diagnostic accuracy in this group of patients.

Recently, in an attempt to address this unsettled clinical and economic issue, different types of protocols were tested for the evaluation of chest pain in "Chest Pain Units." Emergency department "chest pain units" have been developed in 520 (22% of total) medical centers in the USA [24]. The cost-effectiveness of the "chest pain unit" has not yet been determined and the concept has not been adopted by most medical centers around the world. The diagnostic and predictive usefulness of initial SPECT myocardial perfusion imaging with technetium-99m sestamibi in the emergency room has been confirmed in previous studies but the cost-effectiveness of those protocols is still under evaluation [25]. In the present study we sought to determine whether stress myocardial perfusion imaging with

SPECT = single-photon emission computed tomography

ECG = electrocardiogram

NIS = shekels; NIS 4.33 = \$1.00 (13 September 2001).

thallium-201 could safely distinguish patients hospitalized with angina-like chest pain and non-diagnostic ECG from those at low and high risk for developing an acute myocardial ischemic event. We evaluated the short and long-term prognostic significance of thallium scanning in this group of patients and calculated the cost-effectiveness of performing the thallium scan earlier.

## Materials and Methods

### Study population

The study group consisted of 109 consecutive patients (52% males, mean age  $60.7 \pm 13.7$  years) admitted to the internal medicine departments at the Rabin Medical Center, Israel, between July 1996 and September 1997 [Table 1]. Patients were admitted due to angina-like chest pain and a normal or non-diagnostic 12 lead ECG. All the patients underwent stress thallium-201 myocardial perfusion imaging during the current hospitalization when requested by the attending physician. Excluded from the study were patients with suspected acute MI, known previous MI, percutaneous transluminal coronary angioplasty or coronary artery bypass graft. Patients were treated with anti-anginal agents including heparin (n=53), aspirin (n=84), nitrates (n=57), and a combination of nitrates with calcium channel or beta-blocking agents (n=36). The following characteristics were recorded: gender, age, hospital stay until scanning and from then until discharge, and the prevalence of risk factors for coronary artery disease.

### Stress testing

On a 6 hours fasting state, patients underwent stress testing using the symptom-limited treadmill exercise test (37 patients). For patients unable to exercise, under a beta-blocking agent or with bundle branch block the pharmacological stress test with dipyridamole was performed (72 patients). The dipyridamole was administered intravenously at a dose of 0.56 mg/kg of body weight (maximum 60 mg) over 4 minutes followed by low grade exercise as allowed by the patient. Intravenous aminophylline was administered at the supervising physician's discretion for symptoms related to the dipyridamole administration. Throughout the stress test the patients' symptoms, heart rate, blood pressure and 12 lead ECG were monitored continuously. A positive stress ECG was defined as 1 mV of horizontal or downsloping ST segment depression that persisted for 80 msec after the J point.

### Single-photon emission computed tomographic imaging protocol

At maximum stress (symptom limited or at target heart rate) or at 4 minutes from completion of the dipyridamole injection, 2.5–3.5 mCi of thallium-201 was injected intravenously with exercise continuing for 1 minute after the injection. SPECT imaging was begun 5–10 minutes after stress. Step and shoot

**Table 1.** Clinical characteristics of 109 study patients with and without "hard" cardiac event

	Cardiac event ("hard")	No cardiac event	P value
No. of patients	8	101	
Age (yr)	$60 \pm 14$	$67 \pm 9$	NS
Gender (male)	3 (37%)	51 (50%)	NS
Hypertension	7 (88%)	51 (50%)	0.04
Diabetes mellitus	3 (37%)	15 (15%)	NS
Smoking	3 (37%)	27 (27%)	NS
Hyperlipidemia	5 (63%)	40 (40%)	NS
Family history	1 (12%)	22 (22%)	NS
Anti-anginal therapy	20 (80%)	34 (40%)	0.005
Abnormal stress ECG	5 (63%)	19 (19%)	0.01
Abnormal thallium scan	7 (83%)	18 (18%)	<0.0001
No. of segments involved	$6.7 \pm 3.2$	$2.7 \pm 2.3$	<0.001

Values presented are mean values  $\pm$ SD or percent of patients.

acquisition using digital gamma camera (Apex SP 4-HR, Elscint Haifa, Israel) for 20 minutes was done with images, from 45 right anterior oblique to 135 left anterior oblique. The images were stored at 6 intervals in a  $64 \pm 64$  matrix. Imaging was repeated 4 hours after stress. All the imaging sets (horizontal long, vertical long, and short axis planes) were normalized to the maximal myocardial activity in that set.

### SPECT image interpretation

All scans were reviewed on a computer monitor display by two experienced observers without knowledge of patient identity. Final segmental interpretation of all scans was achieved by consensus. Stress images obtained after exercise testing were examined for the presence of perfusion defects and compared with the rest images. Fourteen segments were analyzed: from 3 sets of short axis views at apical, mid and basal levels (4 segments each) and 2 apical segments from vertical view. Defects in at least two consecutive images that were present and unchanged on both stress and rest scans were defined as fixed defects. If a defect seen on the stress images was absent or less prominent on the rest images it was considered as a reversible defect. Scans were considered normal or abnormal based on the presence of any kind of perfusion defect.

### ECG interpretation

The rest ECG was categorized as normal or abnormal. Most abnormal ECGs had baseline non-specific ST-T segment abnormalities or bundle branch blocks. Patients with specific ischemic ECG at rest were excluded from the study.

### Coronary angiographic evaluation

Selective coronary cine-angiography was performed with the Judkins technique. Cine recordings of the left coronary system

MI = myocardial infarction

were made in at least four projections: right anterior oblique, left anterior oblique, antero-posterior cranial, and caudal. The right coronary system was screened in the RAO and LAO projections at least.

### Clinical endpoints

Endpoints were defined as "Hard events" – i.e., pre- and post-hospital discharge cardiac death and non-fatal myocardial infarction, or "Soft events" – coronary revascularization procedures (PTCA or CABG). The performance of coronary angiographies was also recorded. Follow-up data (mean  $11.7 \pm 5.3$  months) were collected using telephone interviews, physician's office records, hospital records, and were 100% completed. The occurrence of any of the clinical endpoints defined above was recorded.

### Cost calculations

The cost of different procedures was determined from the official prices published by the Israeli health authorities. The official price of one hospital day stay is 1,317 New Israeli Shekels; this price was considered as one cost unit. The price of coronary angiography, PTCA and CABG is 8,560 NIS (6.5 CU), 20,150 NIS (15.3 CU), and 44,514 NIS (33.8 CU) respectively, whereas the price of a thallium SPECT imaging scan (using either exercise or pharmacological stress test) is 2,012 NIS (1.5 CU). Costs related to the management of every patient were calculated, including costs of hospital stay from admission until scan performance and from then until discharge, costs of the thallium scan itself, and costs of any invasive procedure performed. Cost savings by the potential earlier performance of the thallium scan were calculated by subtracting the average potential costs from the average actual costs.

### Statistical analysis

Pearson correlation coefficients ( $r$ ) and its significance ( $P$ ) were calculated between the parameters. In order to analyze statistical significant difference of continuous parameters (expressed as means  $\pm 1$  SD) between ischemic and non-ischemic groups, the two-tail Student  $t$ -test was applied. In order to analyze statistical significant relationships between categorical parameters (like cardiac events, positive thallium scan, etc.), chi-square test was used or Fisher's exact test if required. In order to predict the occurrence of cardiac events, logistic regression models were fitted to the data. Odds ratio and confidence intervals were also calculated. A  $P$  value  $< 0.05$  was considered significant. The sensitivity, specificity, positive and negative predictive values of thallium stress SPECT for the prediction of cardiac events in hospitalized patients with chest pain and non-diagnostic ECG were calculated.

RAO = right anterior oblique

LAO = left anterior oblique

PTCA = percutaneous transluminal coronary angioplasty

CABG = coronary artery bypass graft

CU = cost unit

## Results

### Clinical and ECG characteristics

There was no statistically significant difference in the prevalence of coronary artery disease risk factors (excluding hypertension) between patients with or without cardiac events [Table 1]. Patients with abnormal scan were older ( $67 \pm 12$  vs.  $59 \pm 14$  years) and more hypertensive: 18 (72%) vs. 40 (48%) patients ( $P = 0.02$ ). The presence of a non-diagnostic rest ECG was demonstrated in 74 patients: 52 (62%) and 22 (88%) from the group of patients with normal and abnormal scans respectively ( $P = NS$ ).

### Thallium scanning

Of the 109 patients, 84 (77%) had a normal thallium myocardial perfusion scan; among them, 34 patients performed the symptom-limited Bruce protocol and the other 50 patients were stressed pharmacologically. Twenty-five patients (23%) had an abnormal stress thallium scan, among whom 3 patients performed Bruce stress test and the other 22 were stressed pharmacologically. No major complications resulted from the stress tests. Fixed and reversible defects were found in 2 and 21 scans respectively. Two equivocal defects were also considered as abnormal. In the abnormal scans, the mean number of involved segments was  $4.0 \pm 2.6$  per patient. Abnormal stress ECG was found in 13 (16%) and 11 (44%) patients with a normal and abnormal thallium scan respectively ( $P = 0.001$ ) [Table 2].

There was no statistically significant difference in the hospital stay from admission until scan performance (period of time needed for achieving clinical stabilization) between patients with normal and abnormal scans ( $5.0 \pm 2.7$  and  $4.3 \pm 2.2$  days, respectively). Patients with normal scan had shorter hospital stay from the scan performance until discharge ( $1.1 \pm 2.4$  vs.  $6.8 \pm 6.5$  days respectively,  $P < 0.00001$ ).

**Table 2.** Comparison of clinical characteristics of 109 study patients with normal and abnormal thallium scans

	Abnormal scan	Normal scan	<i>P</i> value
No. of patients (%)	25 (23%)	84 (77%)	
Age (yr)	$67 \pm 12$	$59 \pm 14$	0.009
Gender (male)	13 (52%)	44 (52%)	NS
Hypertension	18 (72%)	40 (48%)	0.02
Diabetes mellitus	7 (28%)	10 (12%)	NS
Smoking	8 (32%)	24 (29%)	NS
Hyperlipidemia	11 (44%)	35 (42%)	NS
Family history	3 (12%)	19 (24%)	NS
Abnormal stress ECG	11 (44%)	13 (16%)	0.001
<b>Stress test</b>			
Treadmill	3 (12%)	34 (40%)	
Dipyridamole	22 (88%)	50 (60%)	

Values presented are mean values SD or percent of patients.

## Cardiac events

Among the 109 study patients, 8 (7%) had "hard" cardiac events: non-fatal myocardial infarction in 7 patients and cardiac death in one. "Soft" cardiac events occurred in 8 (7%) patients (all with abnormal scan): PTCA was performed in 4 (3.5%) and CABG in another 4 (3.5%) patients. Only one of the 84 patients with a normal thallium scan had an adverse cardiac event: a non-fatal myocardial infarction [Figure 1]. This patient was a 56 year old woman with typical anginal chest pain and a non-diagnostic rest ECG at admission. During dipyridamole injection she experienced marked chest pain and the ECG showed ST segment depression. The patient responded to anti-anginal therapy. Two days later, she had a small inferior wall acute myocardial infarction. Pre-hospital discharge PTCA was successfully performed to a totally occluded right coronary artery. During hospital stay, non-fatal MI occurred in four patients: in three patients with abnormal and in one with normal scans. One patient with an extremely abnormal scan and severe stenosis in three coronary arteries was referred for CABG but died 2 days after the operation. The other three MIs, all in the group of patients with abnormal scan, occurred  $4 \pm 2$  months after hospital discharge. An abnormal scan had positive and negative predictive values of 28% and 99% respectively in the prediction of adverse "hard" cardiac events. The mean number of abnormal segments in patients with no cardiac event and in those with "hard" cardiac event was  $2.7 \pm 2.3$  and  $6.7 \pm 3.2$  segments respectively ( $P < 0.001$ ) [Table 1]. At a mean follow-up of  $11.7 \pm 5.3$  months, no late cardiac events occurred in the group of patients with normal thallium scan, including those patients with abnormal coronary angiography.

## Coronary angiography

Coronary angiography was performed in 11 (13%) and 14 (56%) patients with normal and abnormal scan respectively. Among the 11 patients with the normal scan, 7 (64%) had no significant

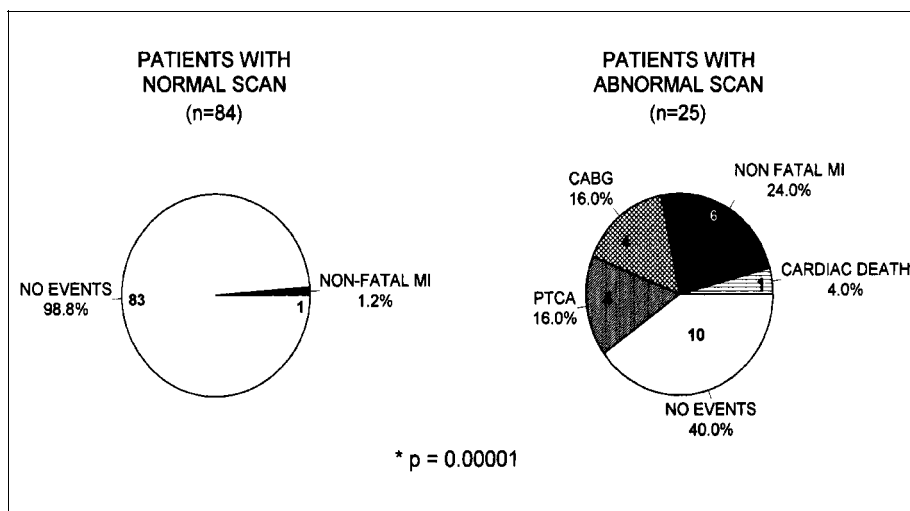
coronary artery stenosis, 2 (18%) had one-vessel disease (one of whom was the patient with the acute MI), one (9%) patient had two-vessel disease and one (9%) had three-vessel disease. Except for the patient who developed the acute MI, all the other patients with angiographically proven coronary artery disease and a normal scan were treated conservatively (mainly because of good collateral flow). Among the 14 patients with abnormal scan who underwent coronary angiography, coronary artery stenosis was absent in only 2 (14%). One, two and three-vessel disease was seen in 6 (43%), 2 (14%) and 4 (29%) patients respectively. Among the group of patients with abnormal scan (excluding the procedures performed on the patients with "hard" cardiac events), PTCA was performed in 4 (16%) and CABG in another 4 (16%).

## Multivariate analysis

In the univariate analysis, hypertension, abnormal stress ECG, treatment with anti-anginal therapy, and abnormal thallium perfusion scan were found to be predictors of adverse cardiac events. All parameters were entered into a multivariate regression model to assess their independent predictive value. Abnormal thallium myocardial perfusion scan was identified as the only independent predictor of adverse cardiac event ( $P = 0.0016$ , odds ratio = 32.3, confidence interval = 3.7–279).

## Costs

The mean cost per patient including hospital stay from admission until thallium scan and the thallium scan itself was 8,560 NIS (6.5 CU) vs. 7,639 NIS (5.8 CU) for those with normal and abnormal scan respectively ( $P = \text{NS}$ ). The mean total cost per patient including hospital stay from admission until discharge (for those not undergoing any further invasive procedure) and invasive procedures (not including hospital stay costs from the procedure day until discharge) was 11,193 NIS (8.5 CU) and 31,079 NIS (23.6 CU) for patients with normal and abnormal scans respectively. For the group of patients with a normal scan, shortening hospital stay from admission until scan performance to 2 days would result in reduced management costs (including the scan itself) from 11,193 NIS (8.5 CU) to 7,243 NIS (5.5 CU) per patient. The high prognostic accuracy of thallium SPECT has been proven previously and was confirmed in the present study. Omitting the unneeded coronary angiographies would result in further reducing the total costs for the management of hospitalized patients with chest pain and a non-diagnostic ECG to 6,058 NIS (4.6 CU) per patient [Table 3].



**Figure 1.** Adverse cardiac events and revascularization procedures in hospitalized patients with normal and abnormal scan.

**Table 3.** Management costs of patients hospitalized with chest pain: potential cost savings by earlier thallium scan (in NIS)

Total costs	Present	Proposed	P value
Normal scan (n=84)	11,193	6,058	<0.05
Abnormal scan (n=25)	31,079	28,052	NS

## Discussion

We found that performing stress myocardial perfusion SPECT imaging with thallium-201 in patients hospitalized with angina-like chest pain and a normal or non-diagnostic ECG can accurately and safely identify those at increased risk for adverse cardiac events. In multivariate analysis, positive thallium scan was the only independent predictor of an acute non-fatal myocardial infarction and cardiac death. The sensitivity for predicting adverse cardiac events and the negative predictive value for excluding them were very high. During the study period, coronary angiography was performed in 25 patients (11 and 14 with normal and abnormal scans respectively). Of interest are the 11 patients with normal scan who were referred for coronary angiography on clinical grounds disregarding the scan results: no coronary lesion was found in 7 patients (64%) and only 1 of the remaining 4 patients with normal scan was sent for a revascularization procedure. The uneventful course of those patients at late follow-up suggests that the absence of jeopardized viable myocardium as shown by the thallium-201 redistribution defects may be more valuable than coronary angiographic findings for predicting future adverse cardiac events.

The long-term prognosis of patients with a normal thallium-201 stress SPECT is excellent and there is no need for further cardiac evaluation after hospital discharge. During the first 48 hours after admission an acute MI can be ruled out. Considering the safety of early stress thallium SPECT (exercise or pharmacological) in clinically stable patients as shown in our study and in view of the high negative predictive value of the test, an effort should be made to reduce the length of hospital stay from admission until scan performance. Referring a clinically stable patient with a normal thallium scan to an aggressive evaluation has no additive prognostic value and is not justified. Thus, a patient hospitalized with chest pain and non-diagnostic ECG who undergoes a stress thallium-201 SPECT 48 hours after admission can be safely discharged with no need for further inpatient or outpatient cardiac evaluation. Reducing hospital length of stay from admission until scan performance and avoiding the unnecessary coronary angiograms in patients with a normal scan are two practical means for lowering management costs of patients hospitalized with chest pain. This last statement is limited by the true costs of the management of those patients, which depend on the form of billing in different medical systems (globally by "diagnosis" or by costs of hospital stay and procedures done separately).

## Limitations of the study

The primary limitation of the study is the sample size (although it is larger than most studies performed previously). Only one

event occurred among the patients with normal scan, which could result in statistical error. The study cohort represented the general group of patients with diagnostic uncertainty. Patients with known coronary artery disease considered by their physicians at high risk for adverse cardiac event, and patients considered at low risk for adverse cardiac event (with non-specific chest pain and a normal ECG) were excluded from the study. Some selection bias of the study cohort might still be present and it depends on the clinical judgment of the referring physician. The awareness of the attending physician (and the angiographer) of the results of the scan could affect the decisions made regarding the coronary angiography but the present study was not designed to address this issue.

## Conclusions and clinical implications

Stress thallium-201 myocardial perfusion SPECT imaging has a significant prognostic value in patients hospitalized with angina-like chest pain and a normal or non-diagnostic ECG. The presence of thallium-201 distribution defects identifies patients at higher risk for adverse cardiac events; such patients may be referred for further invasive evaluation. Patients with normal thallium scan are candidates for early hospital discharge and should not be referred to any invasive procedures, thereby improving utilization of hospital resources.

## References

1. Brush JE, Brand DA, Acampora D, Chalmer B, Wackers FJ. Use of the initial electrocardiogram to predict in-hospital complications of acute myocardial infarction. *N Engl J Med* 1985;312:1137-41.
2. Villanueva FS, Sabia PJ, Afrookteh A, Pollock SG, Hwang LJ, Kaul S. Value and limitations of current methods of evaluating patients presenting to the emergency room with cardiac-related symptoms for determining long term prognosis. *Am J Cardiol* 1992;69:746-50.
3. Lee TH, Rouan GW, Weisberg MC, Brand DA, Cook EF, Acampora D, Goldman L. Sensitivity of routine clinical criteria for diagnosing myocardial infarction within 24 hours of hospitalization. *Ann Intern Med* 1987;106:181-6.
4. Hilton TC, Thompson RC, Williams HJ, Saylor R, Fulmer H, Stowers SA. Technetium-99m sestamibi myocardial perfusion imaging in the emergency room evaluation of chest pain. *J Am Coll Cardiol* 1994;23:1016-22.
5. Einsenstein EL, Wackers FJ, Wagner GS, Natale D, Lam LC, Stowers SA. The cost-effectiveness of an aggressive diagnostic strategy with SPECT myocardial perfusion imaging and early exercise stress testing in emergency department patients who present with chest pain and non-diagnostic ECGs [Abstract]. *Circulation* 1998; 98(Suppl):3055.
6. Kontos MC, Jesse RL, Schmidt KL, Ornato JP, Tatum JL. Value of acute rest sestamibi perfusion imaging for evaluation of patients admitted to the emergency department with chest pain. *J Am Coll Cardiol* 1997;30:976-82.
7. Hamm CW, Goldman BU, Heecheen C, Kreyman G, Berger J, Meinertz T. Emergency room triage of patients with acute chest pain by means of rapid testing for cardiac troponin T or troponin I. *N Engl J Med* 1997;337:1648-53.

8. McCarthy BD, Beshansky JR, D'Agostino RB, Selker HP. Missed diagnosis of acute myocardial infarction in the emergency department: results from a multicenter study. *Ann Emerg Med* 1993;22:579-82.
9. National Heart Attack Alert Program Coordinating Committee. Emergency Department: Rapid Identification and Treatment of Patients with Acute Myocardial Infarction. NIH Publication No.93-3278. September 1993.
10. Lee TH, Goodman L. The coronary care unit turns 25: historical trends and future directions. *Ann Intern Med* 1988;3:21-4.
11. Mulley AG, Thibault GE, Hughes RA, Barnett GO, Reder VA, Sherman EL. The course of patients with suspected myocardial infarction; the identification of low-risk patients for early transfer from intensive care. *N Engl J Med* 1980;302:943-8.
12. Mark DB. An overview of risk assessment in coronary artery disease. *Am J Cardiol* 1994;73:19-25B.
13. Marmur JD, Freeman MR, Langer A, Armstrong PW. Prognosis in medically stabilized unstable angina: early holter ST segment monitoring compared with pre-discharge exercise thallium tomography. *Ann Intern Med* 1990;113:575-9.
14. Nixon JV, Brown CN, Smitherman TC. Identification of transient and persistent segmental wall motion abnormalities in patients with unstable angina by two-dimensional echocardiography. *Circulation* 1982;65:1497-503.
15. Amanullah AM, Lindvall K. Prevalence and significance of transient-predominantly asymptomatic-myocardial ischemia on Holter monitoring in unstable angina pectoris and correlation with exercise test and thallium-201 myocardial perfusion imaging. *Am J Cardiol* 1993;72:144-8.
16. Goldman L, Cook FF, Brand DA, Lee TH, Rouan GW, Weisberg MC, Acampora D, Stasiulewicz C, Walshon J, Terranova G, Kobernick M, Goldstein-Wayne B, Copen D, Daley K, Brandt AA, Jones D, Mellors J, Jakubowsky R. A computer protocol to predict myocardial infarction in emergency department patients with chest pain. *N Engl J Med* 1988;318:797-80.
17. Brown K, Okada RD, Boucher CA, Philips HR, Strauss HW, Pohost GW. Serial thallium-201 imaging at rest in patients with unstable and stable angina pectoris: relationship of myocardial perfusion at rest to presenting clinical syndrome. *Am Heart J* 1983;106:70-7.
18. Freeman MR, Williams AE, Chisholm RJ, Patt NL, Greyson ND, Armstrong PW. Role of resting thallium-201 perfusion in predicting coronary anatomy, left ventricular wall motion, and hospital outcome in unstable angina pectoris. *Am Heart J* 1989;117:306-14.
19. Madsen JK, Stubgaard M, Utne HE, Hansen JF, van Duijvendijk K, Reiber JH, Christoffersen K. Prognosis and thallium-201 scintigraphy in patients admitted with chest pain without confirmed acute myocardial infarction. *Br Heart J* 1988;59:184-9.
20. Brown KA. Prognostic value of thallium-201 myocardial perfusion imaging in patients with unstable angina who respond to medical treatment. *J Am Coll Cardiol* 1991;17:1053-7.
21. Stramann HG, Younis LT, Wittry MD, Amato M, Miller D. Exercise technetium-99m myocardial tomography for the risk stratification of men with medically treated unstable angina pectoris. *Am J Cardiol* 1995;76:236-40.
22. Gregoire J, Theroux P. Detection and assessment of unstable angina using myocardial perfusion imaging: comparison between technetium-99m sestamibi SPECT and 12-lead electrocardiogram. *Am J Cardiol* 1990;66:42-6E.
23. Bilodeau L, Theroux P, Gregoire J, Cragnon D, Arsenault A. Technetium-99m sestamibi tomography in patients with spontaneous chest pain: correlation with clinical electrocardiographic and angiographic findings. *J Am Coll Cardiol* 1991;18:1684-91.
24. Zalenski RJ, Rydman RJ, Ting S, Kampe L, Selker HP. A national survey of emergency department chest pain centers in the United States. *Am J Cardiol* 1998;81:1305-9.
25. Radensky PW, Hilton TC, Fulmer H, McLaughlin BA, Stower SA. Potential cost effectiveness of initial myocardial perfusion imaging for assessment of emergency department patients with chest pain. *Am J Cardiol* 1997;79:595-9.

---

**Correspondence:** Dr. N. Zafrir, Director, Nuclear Cardiology Unit, Rabin Medical Center (Beilinson Campus), Petah Tiqva 49100, Israel. Phone: (972-3) 937-7279, Fax: (972-9) 9560-390, zafrirmd@isdn.net.il