*Original Paper*

Perfusion

# The utility and prognostic value of dipyridamole technetium-99m sestamibi myocardial perfusion imaging SPECT in predicting perioperative cardiac events following non-cardiac surgery

Perfusion
28(4) 333–339

DOI: 10.1177/0267659113481398
prf.sagepub.com
SAGE

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**Abstract**

*Objective*: A perioperative cardiac events is one of the most important medical concerns for both surgeons and patients. The purpose of the current study was to determine the prognostic value of myocardial perfusion imaging (MPI), using dipyridamole 99m Tc-MIBI, for the prediction of perioperative cardiac events.

*Materials and methods*: This study included 253 patients who were candidates for non-cardiac elective surgery and underwent scanning with dipyridamole 99m Tc-MIBI. Based on normal or abnormal MPI, patients were divided into two groups and all preoperative cardiac events were recorded. Risk factors, including diabetes mellitus, dyslipidemia, hypertension, smoking and age ≥70 years, were compared between patients with normal and abnormal MPI and, also, in patients with or without cardiac events.

*Results*: There were 197 patients with normal and 56 patients with abnormal MPI. In total, 14 patients had perioperative cardiac events, which included myocardial infarction (MI), hypotension, arrhythmia and death; of the 14 patients with perioperative cardiac events, 12 had abnormal and two had normal MPI. There were statistically meaningful differences between the two groups ($p<0.001$). Based on these findings, we determined that MPI had a sensitivity of 85.7%, a specificity of 81.6%, an accuracy of 81.8%, a positive predictive value of 21.4 % and a negative predictive value of 98.9%.

*Conclusion*: The incidence of perioperative cardiac events is higher in patients with abnormal MPI. Dipyridamole 99m Tc-MIBI myocardial perfusion imaging can accurately detect the preoperative cardiac risk of patients undergoing major non-cardiac surgery. Based on these findings, the occurrence of perioperative cardiac events in patients with abnormal MPI should be considered, especially in the older age population (age ≥70).

**Keywords**

myocardial perfusion imaging; 99 Tc-MIBI scan; perioperative cardiac event

## Introduction

The number of patients undergoing non-vascular surgery is rising and a remarkable number of these subjects experience cardiac events, including cardiac death and non-fatal myocardial infarction (MI), or non-fatal cardiac arrest.[1] Although, the value of medical consultation in preoperative risk evaluation seems to be imperative, investigations have nevertheless questioned the effectiveness of preoperative assessment.[2] Therefore, the development of an accurate and practical test that will provide timely assistance to surgeons, cardiologists, anesthesiologists and patients is necessary. Currently, the American College of Cardiology/American Heart Association (ACC/AHA) Guidelines recommends the

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implementation of non-invasive testing for preoperative risk stratification only for high-risk surgical procedures.[3]

The application of myocardial perfusion imaging in preoperative risk evaluation has been assessed in many studies, with controversial results. Although the majority of studies demonstrated a positive role,[4-9] the outcome of myocardial perfusion imaging (MPI) SPECT in the prediction of perioperative cardiac events is not well understood and requires further assessment for its application in clinical practice. In addition, some issues, such as the type of radiotracer, coronary artery disease (CAD) risk factors and type of perfusion defect, as well as the stress type of MPI, are not clearly elucidated.

The aim of this study was to evaluate the usefulness of dipyridamole technetium-99m sestamibi MPI SPECT for the prediction of perioperative cardiac events in patients undergoing elective non-vascular surgery. Furthermore, the association of cardiac events with some clinical parameters was also investigated.

## Materials and Methods

### *Participants and study design*

Three hundred and twelve patients were referred for preoperative, pharmacologic stress, myocardial perfusion imaging from September 2005 to September 2011. Stress testing was carried out within three weeks prior to non-vascular surgery requiring general anesthesia.[7] Planned surgery was suspended for 59 patients due to high risk prognostic findings observed on MPI, such as a large defect size, defects in more than one coronary artery supply region, reversible defects in multiple myocardial scan segments, a large number of non-reversible defects and transient or persistent left ventricular cavity dilation.[10] The remaining 253 participants, who gave informed consent, were enrolled in the study. None of the participants had a history of coronary revascularization (coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI)), valvular heart disease, congestive heart failure (CHF), congenital heart disease (CHD), cardiomyopathy or serious life-threatening illnesses. All patients were candidates for elective operations and surgery was carried out in the departments of surgery, urology, orthopedics, gynecology, neurosurgery and ophthalmology.

Each patient completed a questionnaire, providing information on risk factors. We investigated the relationship between clinical risk factors and the occurrence of perioperative cardiac events. Clinical factors considered included age ≥70 years, sex, hypertension, dyslipidemia, diabetes mellitus and smoking. Risk factors encountered during the study included: (1) hypertension (self-reported history of hypertension and/or use of antihypertensive medication or a blood pressure >140/90 mmHg); (2) smoking and (3) dyslipidemia (high-density lipoprotein cholesterol <40 mg/dl, low-density lipoprotein cholesterol >100 mg/dl or antihypercholesterolemic treatment). Pretest likelihood of coronary artery disease (CAD) was estimated by consideration of age, the ratio of cholesterol to HDL, gender and smoking.[11]

The study complies with the Declaration of Helsinki and this was confirmed by the institutional ethics committee of Shahid Beheshti University of Medical Sciences.

### *Perioperative cardiac events*

Perioperative cardiac events were assessed during the period of surgery and for 72 hours following surgery. The clinicians were blinded to the clinical variables and scintigraphic data. Events included cardiac death (sudden death and death resulting from MI or CHF), non-fatal MI (distinguished by an increase in cardiac enzymes and the progression of either new Q waves or constant ST-T wave changes), CHF (presence of pulmonary edema sign and symptoms), unstable angina (development of ≥2 episodes of ischemic electrocardiographic changes with a succeeding resolution), cardiac arrhythmia that necessitated antiarrhythmic drugs and, also, severe hypotension requiring inotropic support to maintain blood pressure.

### *Dipyridamole technetium 99m-sestamibi SPECT protocol*

All subjects underwent a two-day stress SPECT protocol. Technetium-99m sestamibi (740 MBq) was intravenously infused at rest and during pharmacologic stress.

All cardiovascular drugs were stopped for at least two days and the patients fasted overnight before the study. Intravenous normal saline solution was connected to an antecubital vein, using a 20-gauge cannula. Dipyridamole (0.56 mg/kg) was administered over four minutes. The patients' symptoms and 12-lead ECG were monitored constantly. A dose of 740 MBq of Tc-99m Sestamibi, as a compact bolus, was injected four minutes after the start of the infusion. Twenty minutes later, the patients were asked to eat a fatty meal to accelerate hepatobiliary clearance of Tc-99m sestamibi and imaging was carried out 90 minutes after the initial infusion of dipyridamole. The rest phase was performed the next day.

### *Acquisition and processing protocols*

A double-head SPECT scintillation camera (ADAC Genesys, Malpitas, CA, USA) was used to acquire 32 views over 180°, using a step-and-shoot method, progressing from 45° right anterior oblique to 45° left posterior

oblique projections. A symmetric 20% energy window over the 140 keV Tc-99m photopeak and a low energy all-purpose (LEAP) collimator were used and the data were stored in 64 x 64 matrices. Acquisition time was 25 seconds per projection during rest and stress studies. An expert nuclear medicine specialist used the cine display of the rotating planar projections to evaluate sub-diaphragmatic activities, attenuations, and patient motion to optimize the quality of the images. Processing was performed using a two-dimensional Butterworth prefilter and a ramp filter for back projection to transaxial tomographic images. The reorientations of images were performed along the vertical long axis and the horizontal and short axes of the left ventricle. Acquisition parameters were similar for the rest and stress studies. For each image, all three stress image sets were interpreted discretely in comparison with the same rest image.

### *Visual SPECT analysis*

For assessment, MPIs were divided into 17 segments, corresponding to the locations of the territories of the various coronary arteries. For the assessment of the segments, a three-grade scale was used: normal perfusion, and reversible and fixed segments. A reversible defect was defined as the presence of a region with decreased or absent myocardial activity on stress scans which improved in the rest stage images. A fixed segment was defined as a region of decreased or absent myocardial activity in both the stress and rest sets. Image interpretation was performed by two nuclear medicine specialists without knowledge of the patients' data.

### *Statistical analysis*

A two-tailed t-test was used to compare the mean values between the groups. The continuous variables are expressed as the mean ± SD and categorical variables as the absolute values and percentages. Student's t-test was used to compare differences between continuous variables and the Chi-square test was used for categorical variables. The MPI findings compared to cardiac events were categorized as true positive (TP), true negative (TN), false positive (FP) or false negative (FN). Thereafter, the statistical parameters were determined as follows: specificity [TN/(TN+FP)], sensitivity [TP/(TP+FN)], PPV [TP/(TP+FP)], NPV [TN/(TN+FN)] and accuracy [(TP+TN)/(TP+TN+FN+FP)]. Multiple logistic regression analysis was applied to evaluate the association of cardiac event as a dependent variable with other variables, including MPI results, diabetes mellitus (DM), hypertension, dyslipidemia, smoking, age and gender. The statistical analysis was carried out using the Statistical Package for the Social Science (SPSS) version 18 (SPSS Inc., Chicago, IL, USA). A $p<0.05$ was considered to be statistically significant.

## Results

A total of 253 patients (169 males and 84 females) with a mean age 55.8± 9.43 years were included in the study. Thirty (11.8%) patients had diabetes mellitus (DM), 65 (25.7%) had hypertension, 102 (40.3%) had dyslipidemia and 93 (36.7%) were smokers.

The pretest likelihood of CAD was low in 158 patients, intermediate in 31 patients, high in five and very high in 59 patients. Thirteen cardiac events occurred in patients in the very high group and one occurred in the high group. No cardiac events occurred in patients with low or intermediate pretest likelihood of CAD.

Of the total 253 patients, 56 patients (22.1%) had perfusion abnormalities in pharmacologic stress myocardial perfusion SPECT and the remaining 197 patients (77.9%) had no perfusion abnormalities. In 56 patients with abnormal MPI, 36 patients (64.3%) had reversible perfusion defects, 12 patients (21.4%) had fixed defects and eight patients (14.3%) had both reversible and fixed defects.

Perioperative cardiac events occurred in 14 patients (5.5%). Six of the 14 patients had ventricular tachycardia during surgery and required a continuous administration of anti-arrhythmic drugs. Three cases had non-fatal MIs and two cases died. Two of the patients who died from cardiac arrest included a 78-year-old man with a history of dyslipidemia and hypertension and a 90-year-old man with a history of smoking and dyslipidemia.

In addition, three patients exhibited severe hypotension and required inotropic support to maintain blood pressure following surgery.

Five of the 158 patients with low pretest likelihood of CAD, three of the 31 patients with intermediate pretest likelihood of CAD, two of the five patients with high pretest likelihood of CAD and 46 of the 59 patients with very high likelihood of CAD had abnormal MPI.

In 14 patients with cardiac events, 12 cases (21.4%) had abnormal MPI and the remaining two cases (1.01%) had normal MPI. There was a significant difference in the number of cardiac events between patients with normal and abnormal MPI ($p<0.001$) (Figure 1).

In 12 patients with cardiac events who had abnormal MPI, seven cases had both reversible and fixed defects, three cases had reversible perfusion defects and two patients had fixed defects. The location of the perfusion defects was in the inferoapical region in three patients, in the apicoseptal region in five patients, in the anterior and septal regions in two patients and in the inferior and inferolateral regions in two patients.

The sensitivity, specificity and accuracy of MPI for predicting perioperative cardiac events were 85.7%,

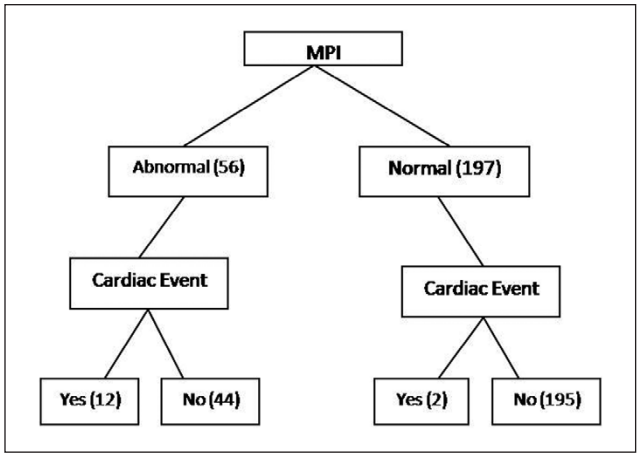


**Figure 1.** The result of MPI in patients with and without cardiac event.

**Table 1.** Comparison of CAD risk factors in patients according to cardiac events and the results of MPI.

| Risk factor \ Cardiac event | No(239) | Yes(14) | P-value |
|---|---|---|---|
| DM | 23 | 7 | <0.001 |
| Dyslipidemia | 93 | 9 | 0.06 |
| Hypertension | 50 | 10 | <0.001 |
| Smoking | 82 | 11 | <0.001 |
| Age≥70 years | 26 | 8 | <0.001 |

CAD: coronary artery disease; MPI: myocardial perfusion imaging; DM: diabetes mellitus.

81.6%, and 81.8%, respectively, in all patients operated on. The positive predictive value (PPV) and negative predictive value (NPV) were 21.4% and 98.9%, respectively, in all patients.

The comparison of various CAD risk factors in patients with and without cardiac events showed a significant difference ($p<0.05$) (Table 1). The distribution of CAD risk factors also showed a significant difference in patients with normal and abnormal MPI ($p<0.05$) (Table 2). In addition, comparison of various CAD risk factors in patients with abnormal MPI who did and did not have cardiac events showed a significant difference in age ≥70 years ($p=0.013$) (Table 3).

According to multiple regression analyses with cardiac event as a dependent variable, the MPI (Odds Ratio = 23.118; 95% CI: 1.65- 323.95; $p=0.02$), diabetes mellitus (Odds Ratio = 7.021; 95% CI: 1.49- 33.087; $p=0.01$) and age (Odds Ratio =1.083; 95% CI: 1.023-1.147; $p=0.00$) were significantly associated.However, hypertension, dyslipidemia and gender did not show such a correlation.

**Table 2.** Comparison of CAD risk factors in patients with and without cardiac events.

| Risk factor \ MPI | Normal (197) | Abnormal (56) | P value |
|---|---|---|---|
| DM | 11 | 19 | <0.001 |
| Dyslipidemia | 55 | 47 | <0.001 |
| Hypertension | 23 | 42 | <0.001 |
| Smoking | 46 | 47 | <0.001 |
| Age≥70 years | 22 | 12 | 0.04 |

CAD: coronary artery disease; MPI: myocardial perfusion imaging; DM: diabetes mellitus.

## Discussion

Coronary artery disease is a main reason for morbidity and mortality among patients undergoing elective non-cardiac surgery; cardiac deaths comprise nearly one-half of perioperative deaths.[8] Consequently, the preoperative identification and determination of the extent of ischemic heart disease can be vital for the accurate management of patients undergoing non-cardiac surgery in order to decrease the likelihood of unfavorable perioperative cardiac events.[12]

Myocardial perfusion imaging seems to be a favorable modality for preoperative risk assessment.[12,13] For the reason that many preoperative individuals are not capable of exercising, pharmacological MPI, such as dipyridamole, plays an important role in the assessment and risk stratification of these patients,[8,14], which is well tolerated and has few side effects.[15,16] The present study verifies the previous reports that revealed preoperative MPI to be a useful predictor of cardiac events in patients undergoing non-cardiac surgery.[12,17] The occurrence of all cardiac events was 5.5% and the rate of death only 0.79% in our study patients. These results are similar to previous studies in which the death rate ranged from 0.6% to 3.6%.[12,18]

In the present study, the sensitivity and specificity of dipyridamole 99mTc-MIBI SPECT were 85.7% and 81.6%, respectively, for all cardiac events. The negative predictive value (NPV) was 98.9%, which means that the incidence of perioperative cardiac events is extremely low. In contrast, the positive predictive value (PPV) was 21.4%, for which further correlation with other modalities, such as angiography, is needed. Similar statistical parameters were reported in prior studies.[8,19-21]

Similarly, we found a significantly higher incidence of cardiac events (21.4%) in patients with abnormal MPI compared with those without. In our study, the prevalence of patients with abnormal MPI had a significantly greater prevalence of all risk factors than patients with normal MPI. In addition, the prevalence of patients with cardiac events had a significantly greater prevalence of

**Table 3.** Comparison of CAD risk factors in patients with normal and abnormal MPI.

| Risk factor | Normal MPI (197 cases) | | | Abnormal MPI (56 cases) | | | Total |
|---|---|---|---|---|---|---|---|
| | Cardiac event | | | Cardiac event | | | |
| | No(195) | Yes(2) | P-value | No(44) | Yes(12) | P-value | |
| DM | 10 | 1 | 0.00 | 13 | 6 | 0.18 | 30 |
| Dyslipidemia | 55 | 0 | 0.38 | 38 | 9 | 0.34 | 102 |
| Hypertension | 21 | 2 | 0.00 | 34 | 8 | 0.45 | 65 |
| Smoking | 45 | 1 | 0.37 | 37 | 10 | 0.94 | 93 |
| Age≥70 years | 20 | 2 | 0.89 | 6 | 6 | 0.01 | 34 |

CAD: coronary artery disease; MPI: myocardial perfusion imaging; DM: diabetes mellitus.

all risk factors, except for dyslipidemia, than patients without events.

In the literature, many studies, mostly using thallium-201 as the imaging agent, have suggested that pharmacologic MPI was helpful for preoperative risk assessment in non-cardiac surgery.[4,5] Boucher et al., for the first time, demonstrated the utility of MPI for preoperative cardiac risk assessment with DIP Tl-201 MPI in vascular surgeries.[22] In one study, Chen et al. showed that a reversible defect was helpful for predicting perioperative cardiac events in patients, even in low-risk patients.[12]

The cardiac event rate was 1% in the 225 subjects with a normal dipyridamole 201 Tl MPI, 8% in patients with ischemic defects restricted to one vessel, 20% in those with ischemia in two vessels and 52% in those with wide-ranging ischemic changes.[23] Brown and Rowan reported that the likelihood of a perioperative cardiac event was 1% in patients with only one segment with reversible 201 Tl defect, 8% in those with four segments involved and 49% in those with seven segments with reversible defects.[19]

In a review article, Yao and Rozanski summed up the results of 15 prognostic studies and demonstrated that a very low frequency of perioperative cardiac events (9/750, 1.2%) existed among patients who had a normal 201 Tl MPI study, similar to our findings (2/197, 1.01%). The frequency of major cardiac events was 15.6% (114/730) in patients with reversible defects and 5.1% (14/277) in subjects with fixed defects.[21]

Furthermore, some studies assessed this issue using 99mTc-sestamibi as the imaging agent. Bry et al. assessed the positive predictive value and cost-effectiveness of dipyridamole myocardial scintigraphy in 237 patients undergoing vascular surgery.[24] The large sample-size studies using dipyridamole 99mTc-sestamibi SPECT MPI before non-vascular surgery were mentioned by Stratmann et al.[25,26] Cardiac event rates were 4% for a normal MPI, 27% for an abnormal MPI, 24% for an ischemic defect and 37% for a fixed defect ($p<0.01$). In Hendel et al.'s study, patients with ischemic defects had a significantly higher incidence of death or MI than patients with other test results ($p<0.001$).[27]

On the other hand, our present findings do not match with some investigations that showed no relationship between ischemic defects and cardiac outcomes.[7,28] In addition, Davidson et al. tested the prognostic value of MPI in candidates for liver transplant. The sensitivity and specificity of dipyridamole 201 Tl-SPECT were 37% and 63%, respectively. The positive predictive value (PPV) and negative predictive value (NPV) of MPI compared with angiography were 22% and 77%, respectively, in all patients. The authors concluded that there was a low prognostic value of MPI in these patients and further imaging modalities, such as angiography, should be applied.[6] The reasons for this discrepancy lie in the differences in the study population, acquisition protocol and technical limitations in these studies.[18]

Furthermore, the current study depicted that patients with an abnormal MPI who had a cardiac event were older than patients without a cardiac event and neither diabetes mellitus, dyslipidemia, hypertension nor smoking were significantly different in the two subgroups.

In a study of more than 1,300 patients, Bai et al. demonstrated that age was an independent predictor of cardiac events in patients with abnormal SPECT studies, but, in individuals with normal MPI, perioperative risk was independent of age.[29]

Currently, the ACC/AHA guidelines recommend non-invasive preoperative testing, such as MPI, for the evaluation of cardiac function only in high-risk surgical procedures.[5] The 2009 ACCF/AHA Guideline concluded that three factors, including the patient's specific clinical variables, exercise capacity and surgery-specific risk, must be assessed to determine the risk of cardiac events.[30]

There is remarkable indecision regarding the predictive accuracy of non-invasive preoperative cardiac tests and the ACC/AHA algorithm for cardiac risk evaluation.[31-33]

Meanwhile, some new non-invasive modalities have been developed for the diagnosis of coronary artery disease (CAD), including a fast growing multi-detector computed tomography (MDCT) technology which provides rapid and trustworthy contrast-enhanced imaging

of coronary arteries and coronary plaque.[34] The high negative predictive value of this technique can exclude the existence of hemodynamically significant CAD.[34]

Coronary computed tomography angiography (CTA) seems to be helpful for the management of patients with acute chest pain. Other potential usages include preoperative risk assessment and evaluation of revascularization. It may also provide valuable information for short- and long-term risk assessment as well as stratification of cardiovascular disorders.[35] Like MPI, patients with an intermediate pretest likelihood of CAD may benefit from coronary CTA.[34]

In terms of radiation exposure, the mean effective dose with CTA, using 64-slice MDCT, is approximately 11–22 mSv,[36] whereas this value for myocardial perfusion imaging with SPECT is about 15–20 mSv.[37]

In comparison to MPI, coronary CTA directly visualizes the atherosclerotic plaques with a short procedure and no specific preparation; however, data on clinical utility and cost-effectiveness are lacking and this requires further investigation.[34]

Finally, these findings support the claim that preoperative dipyridamole 99mTc-MPI SPECT may be useful for predicting perioperative cardiac events in patients with non-cardiac surgery, although further evidence needs to be found. Also, this study depicted that, with the possibility of perioperative cardiac events in patients with a higher pretest likelihood of CAD, accurate risk stratification of perioperative cardiac events is imperative to allocate informed patients and to help surgeons, cardiologists and anesthesiologists in decision-making.

It should be mentioned that our study has some limitations. We did not perform gated SPECT imaging and semi-quantitative SPECT analysis, because these methods are not routine in our center. The next limitation is the lack of precise surgical risk estimation and evaluation of cardiac event and MPI in each group.

It is noteworthy that this non-randomized study may have selection bias with heterogeneous groups which could add some co-founding variables and have an impact on the results. Furthermore, some cardiac events may occur over a prolonged time course. Although most perioperative cardiac events occur during the first three days after surgery,[38,39] extended monitoring should be taken into account in future studies.

## Conclusion

Dipyridamole 99m Tc-MIBI myocardial perfusion imaging can accurately detect the preoperative cardiac risk of patients undergoing major non-cardiac surgery. Based on the findings, the occurrence of perioperative cardiac events in patients with abnormal MPI should be considered, especially in advanced age. However, further well-designed investigations that follow patients for a longer period of time are needed to evaluate these results.

### Acknowledgements

This study was the postgraduate thesis of Dr Reza Shahoseini and was supported by Shahid Beheshti University of Medical Sciences (grant no. 2678). We extend our thanks to colleagues at our institutes for their help in data acquisition.

### Conflict of interest statement

The authors declare that there are no conflicts of interest.

### References

1. Fathala A, Hassan W. Role of multimodality cardiac imaging in preoperative cardiovascular evaluation before noncardiac surgery. *Ann Card Anaesth* 2011; 14: 134–145.
2. Katz RI, Cimino L, Vitkun SA. Preoperative medical consultations: impact on perioperative management and surgical outcome. *Can J Anaesth* 2005; 52: 697–702.
3. Eagle KA, Berger PB, Calkins H, et al. ACC/AHA guideline update for perioperative cardiovascular evaluation for noncardiac surgery---Executive Summary. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1996 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery). *Circulation* 2002; 105: 1257–1267.
4. Weinstein H, Steingart R. Myocardial perfusion imaging for preoperative risk stratification. *J Nucl Med* 2011; 52: 750–760.
5. Kayano D, Nakajima K, Ohtake H, Kinuya S. Gated myocardial perfusion SPECT for preoperative risk stratification in patients with noncardiac vascular disease. *Ann Nucl Med* 2009; 23: 173–181.
6. Davidson CJ, Gheorghiade M, Flaherty JD, et al. Predictive value of stress myocardial perfusion imaging in liver transplant candidates. *Am J Cardiol* 2002; 89: 359–360.
7. Baron JF, Mundler O, Bertrand M, et al. Dipyridamole-thallium scintigraphy and gated radionuclide angiography to assess cardiac risk before abdominal aortic surgery. *N Engl J Med* 1994; 330: 663–669.
8. Papaioannou GI, Heller GV. Risk assessment by myocardial perfusion imaging for coronary revascularization, medical therapy, and noncardiac surgery. *Cardiol Rev* 2003; 11: 60–72.
9. Assadi M, Nabipour I, Saghari M, Eftekhari M, Pourbehi MR, Afrasiabi K. The role of myocardial perfusion imaging in the screening of silent ischemia in diabetic patients. *ISMJ* 2010; 13: 59–71.
10. Beller GA, Zaret BL. Contributions of nuclear cardiology to diagnosis and prognosis of patients with coronary artery disease. *Circulation* 2000; 101: 1465–1478.
11. 1996 National Heart Foundation clinical guidelines for the assessment and management of dyslipidaemia. Dyslipidaemia Advisory Group on behalf of the scientific committee of the National Heart Foundation of New Zealand. *N Z Med J* 1996; 109(1024): 224–231.

12. Chen T, Kuwabara Y, Tsutsui H, et al. The usefulness of dipyridamole thallium-201 single photon emission computed tomography for predicting perioperative cardiac events in patients undergoing non-cardiac vascular surgery. *Ann Nucl Med* 2002; 16: 45–53.
13. Beattie WS, Abdelnaem E, Wijeysundera DN, Buckley DN. A meta-analytic comparison of preoperative stress echocardiography and nuclear scintigraphy imaging. *Anesth Analg* 2006; 102: 8–16.
14. Navare SM, Mather JF, Shaw LJ, Fowler MS, Heller GV. Comparison of risk stratification with pharmacologic and exercise stress myocardial perfusion imaging: a meta-analysis. *J Nucl Cardiol* 2004; 11: 551–561.
15. Javadi H, Shariati M, Mogharrabi M, et al. The association of dipyridamole side effects with hemodynamic parameters, ECG findings, and scintigraphy outcomes. *J Nucl Med Technol* 2010; 38: 149–152.
16. Poldermans D, Bax JJ, Boersma E, et al. Guidelines for pre-operative cardiac risk assessment and perioperative cardiac management in non-cardiac surgery. *Eur Heart J* 2009; 30: 2769–2812.
17. Maunoury C, Stone DA, Chen CC, Plotnick GD, Holder LE. Preoperative cardiac risk assessment with adenosine stress dual-isotope myocardial single-photon emission computed tomography. *Clin Cardiol* 1996; 19: 488–490.
18. Leppo JA, Dahlberg ST. The question: to test or not to test in preoperative cardiac risk evaluation. *J Nucl Cardiol* 1998; 5: 332–342.
19. Brown KA, Rowen M. Extent of jeopardized viable myocardium determined by myocardial perfusion imaging best predicts perioperative cardiac events in patients undergoing noncardiac surgery. *J Am Coll Cardiol* 1993; 21: 325–330.
20. Vanzetto G, Machecourt J, Blendea D, et al. Additive value of thallium single-photon emission computed tomography myocardial imaging for prediction of perioperative events in clinically selected high cardiac risk patients having abdominal aortic surgery. *Am J Cardiol* 1996; 77: 143–148.
21. Yao SS, Rozanski A. Principal uses of myocardial perfusion scintigraphy in the management of patients with known or suspected coronary artery disease. *Prog Cardiovasc Dis* 2001; 43: 281–302.
22. Boucher CA, Brewster DC, Darling RC, Okada RD, Strauss HW, Pohost GM. Determination of cardiac risk by dipyridamole-thallium imaging before peripheral vascular surgery. *N Engl J Med* 1985; 312: 389–394.
23. Lette J, Waters D, Cerino M, Picard M, Champagne P, Lapointe J. Preoperative coronary artery disease risk stratification based on dipyridamole imaging and a simple three-step, three-segment model for patients undergoing noncardiac vascular surgery or major general surgery. *Am J Cardiol* 1992; 69: 1553–1558.
24. Bry JD, Belkin M, O'Donnell TF Jr., et al. An assessment of the positive predictive value and cost-effectiveness of dipyridamole myocardial scintigraphy in patients undergoing vascular surgery. *J Vasc Surg* 1994; 19: 112-121; discussion 121–114.
25. Stratmann HG, Younis LT, Wittry MD, Amato M, Miller DD. Dipyridamole technetium-99m sestamibi myocardial tomography in patients evaluated for elective vascular surgery: prognostic value for perioperative and late cardiac events. *Am Heart J* 1996; 131: 923–929.
26. Stratmann HG, Younis LT, Wittry MD, Amato M, Mark AL, Miller DD. Dipyridamole technetium 99m sestamibi myocardial tomography for preoperative cardiac risk stratification before major or minor nonvascular surgery. *Am Heart J* 1996; 132: 536–541.
27. Hendel RC, Whitfield SS, Villegas BJ, Cutler BS, Leppo JA. Prediction of late cardiac events by dipyridamole thallium imaging in patients undergoing elective vascular surgery. *Am J Cardiol* 1992 70: 1243–1249.
28. Mangano DT, London MJ, Tubau JF, et al. Dipyridamole thallium-201 scintigraphy as a preoperative screening test. A reexamination of its predictive potential. Study of Perioperative Ischemia Research Group. *Circulation* 1991; 84: 493–502.
29. Bai J, Hashimoto J, Nakahara T, Suzuki T, Kubo A. Influence of ageing on perioperative cardiac risk in noncardiac surgery. *Age Ageing* 2007; 36: 68–72.
30. Fleisher LA, Beckman JA, Brown KA, et al. 2009 ACCF/AHA focused update on perioperative beta blockade incorporated into the ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American college of cardiology foundation/American heart association task force on practice guidelines. *Circulation* 2009; 120(21): e169–276.
31. Devereaux PJ, Goldman L, Cook DJ, Gilbert K, Leslie K, Guyatt GH. Perioperative cardiac events in patients undergoing noncardiac surgery: a review of the magnitude of the problem, the pathophysiology of the events and methods to estimate and communicate risk. *CMAJ* 2005; 173: 627–634.
32. Kertai MD, Boersma E, Bax JJ, et al. A meta-analysis comparing the prognostic accuracy of six diagnostic tests for predicting perioperative cardiac risk in patients undergoing major vascular surgery. *Heart* 2003; 89: 1327–1334.
33. Etchells E, Meade M, Tomlinson G, Cook D. Semiquantitative dipyridamole myocardial stress perfusion imaging for cardiac risk assessment before noncardiac vascular surgery: a meta-analysis. *J Vasc Surg* 2002; 36: 534–540.
34. Hoffmann U, Ferencik M, Cury RC, Pena AJ. Coronary CT angiography. *J Nucl Med* 2006; 47: 797-806.
35. Mowatt G, Cummins E, Waugh N, et al. Systematic review of the clinical effectiveness and cost-effectiveness of 64-slice or higher computed tomography angiography as an alternative to invasive coronary angiography in the investigation of coronary artery disease. *Health Technol Assess* 2008; 12(17): iii-iv, ix–143.
36. Hundt W, Rust F, Stabler A, Wolff H, Suess C, Reiser M. Dose reduction in multislice computed tomography. *J Comput Assist Tomogr* 2005; 29: 140–147.
37. Morin RL, Gerber TC, McCollough CH. Radiation dose in computed tomography of the heart. *Circulation* 2003; 107: 917–922.
38. Badner NH, Knill RL, Brown JE, Novick TV, Gelb AW. Myocardial infarction after noncardiac surgery. *Anesthesiology* 1998; 88: 572–578.
39. Fleischmann KE, Goldman L, Young B, Lee TH. Association between cardiac and noncardiac complications in patients undergoing noncardiac surgery: outcomes and effects on length of stay. *Am J Med* 2003; 115: 515–520.