Original Research

The Role of Myocardial Perfusion Imaging in the Evaluation of Patients Undergoing Percutaneous Transluminal Coronary Angioplasty

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Key words:
Percutaneous transluminal coronary angioplasty (PTCA), myocardial perfusion imaging (MPI), Tc-99m sestamibi.

Introduction: We studied the value of myocardial perfusion imaging (MPI) for the evaluation of improvement in myocardial perfusion in patients with successful percutaneous transluminal coronary angioplasty (PTCA).
Methods: Sixty patients (10 women, 50 men) aged 54.18 ± 11.71 years were analyzed. MPI was performed before PTCA, 6-10 days (16 cases), 1-3 months (21 cases), and then 3-6 months (23 cases) after the procedure. In all patients repeated coronary angiography was done at least once after PTCA. Statistical analysis of the numbers of segments with various degrees of perfusion (normal, ischemia, fixed segment), before and after PTCA, was performed for three groups (6-10 days, 1-3 months and 3-6 months after PTCA) separately, using paired T and also ANOVA tests. A p-value <0.05 was considered to be statistically significant.
Results: Improvement, defined as a decrease in the number of ischemic or fixed segments, was observed in 13 of 16 patients at 6-10 days after PTCA, in 18 of 21 cases 1-3 months after PTCA, and in 20 of 23 patients 3-6 months after PTCA. The sensitivity and specificity of MPI calculated before PTCA and at the 3 subsequent time points, using angiography as the gold standard, were 80/81, 100/35, 90/100, and 76/100 percent, respectively.
Conclusion: Our results confirm the necessity for an assessment of perfusion both before and shortly after angioplasty, since it provides the best documentation of the changes in myocardial perfusion.

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The impact of coronary artery disease (CAD) on the health of individuals in the developed world has declined over the past three decades as a result of the identification of modifiable risk factors and the introduction of new primary and secondary prevention strategies, such as percutaneous transluminal coronary angioplasty (PTCA). Nonetheless, CAD continues to be a major public health problem.[1] PTCA is an effective method of revascularization in patients with coronary artery disease and was first performed successfully in 1977.[2] Although repeated arteriographic studies permit direct visualization of the ongoing changes in the treated vessels, certain risks and discomfort for the patient limit its serial use. In contrast, even though myocardial scintigraphy does not reveal morphologic changes in the vascular wall, it can be used to assess the functional capacity of the vessel and to demonstrate changes in myocardial perfusion after PTCA. In addition, it has been proposed as an accurate method for the detection of restenosis and prognostic determination after a previous coronary angioplasty. Nevertheless, the selection of the best protocol for an assessment of perfusion, the detection of restenosis and also the best time for post-angioplasty scintigraphic evaluation are still controversial. This study was undertaken to analyze the

scintigraphic images in patients who underwent PTCA. Specifically, we examined the patterns obtained before PTCA, within 6-10 days after PTCA, as well as at 1-3 and 3-6 month intervals after PTCA. In addition, this study aimed to determine the sensitivity and specificity of each scintigraphic interval using angiography as the gold standard.

Methods

The study included 10 women and 50 men (mean age 54.18 ± 11.71 years). The patients were recruited from the cardiology clinic at Shariati Hospital in Tehran from January 2003 to may 2005. Sixty patients who had undergone successful coronary angioplasty were included in this study. Patients without successful PTCA and without coronary angiography after PTCA were excluded from our study. Angioplasty success was defined as a residual stenosis of ≤50% in diameter, with a gain of ≥20% compared to pre-angioplasty values and without major complications (death or myocardial infarction). One vessel in 52 and 2 vessels in 8 patients were dilated during angioplasty. The left anterior descending artery was dilated in 32 patients, the right coronary artery in 22 patients, and the left circumflex artery in 14 patients. In cases with 2-vessel angioplasty, the left anterior descending and left circumflex arteries were dilated in 3 patients, the left anterior descending and right coronary arteries were dilated in 2 patients, and the right coronary and left circumflex arteries were dilated in 3 patients. MPI was performed 4-58 days (30.32 ± 17.33) before PTCA (perfusion before PTCA, Pb). According to the timing of post-PTCA MPI (perfusion after PTCA, Pa), the patients were divided into three subgroups: 6-10 days (8.29 ± 1.31 days), 1-3 months (1.95 ± 0.67 months) and also 3-6 six months (4.68 ± 0.89 months) after PTCA.

This study was approved by the Tehran University of Medical Sciences ethics committee, and written informed consent was obtained from all the patients.

Study protocol

Dipyridamole technetium 99m-sestamibi SPECT protocol

Patients fasted overnight and all cardiovascular medications were discontinued at least 2 days before the study. An intravenous line of normal saline solution was connected to an antecubital vein using a 20-gauge cannula. Dipyridamole (0.56 mg/kg) was infused over 4 min. Patients' symptoms and three-lead ECG were monitored continuously. A dose of 740 MBq of Tc-99m sestamibi as a compact bolus was injected 4 min after initiation of the infusion. Sixty minutes later, the patients were asked to eat a fatty meal to accelerate hepatobiliary clearance of Tc-99m sestamibi and imaging was performed 90 minutes after initial infusion of dipyridamole. The rest phase was performed on 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 * 64 matrices. Acquisition time was 25 s per projection during rest and stress studies. Processing was performed using a two-dimensional Butterworth prefilter and a ramp filter for back projection to transaxial tomographic images. The transaxial images were reoriented along the vertical long axis, the horizontal axis and the short axis of the left ventricle. For each patient, all three stress images were interpreted separately in comparison with same rest image.

Visual SPECT analysis

Visual analysis of short and long axis slices on both computer screen and film reproductions of Tc-99m sestamibi SPECT was performed by two experienced readers who had no information about medical history or coronary angiograms. For assessment, scans were divided into 17 segments, corresponding to the location of the territories of the various coronary arteries (Figure 1).[3] For the evaluation of the segments a three-grade scale was used: normal perfusion, ischemic and fixed segments.[4] Ischemia was considered as the presence of a region with decreased or absent myocardial activity on exercise scans, which was improved on the rest stage images. A fixed segment was defined as a region of decreased or absent myocardial activity both on exercise and rest sets.

Coronary arteriography

Coronary arteriography was performed with a monoplane imaging system and recorded on DVD. Angiographic images were visually assessed by two readers who were blind to the MPI data.

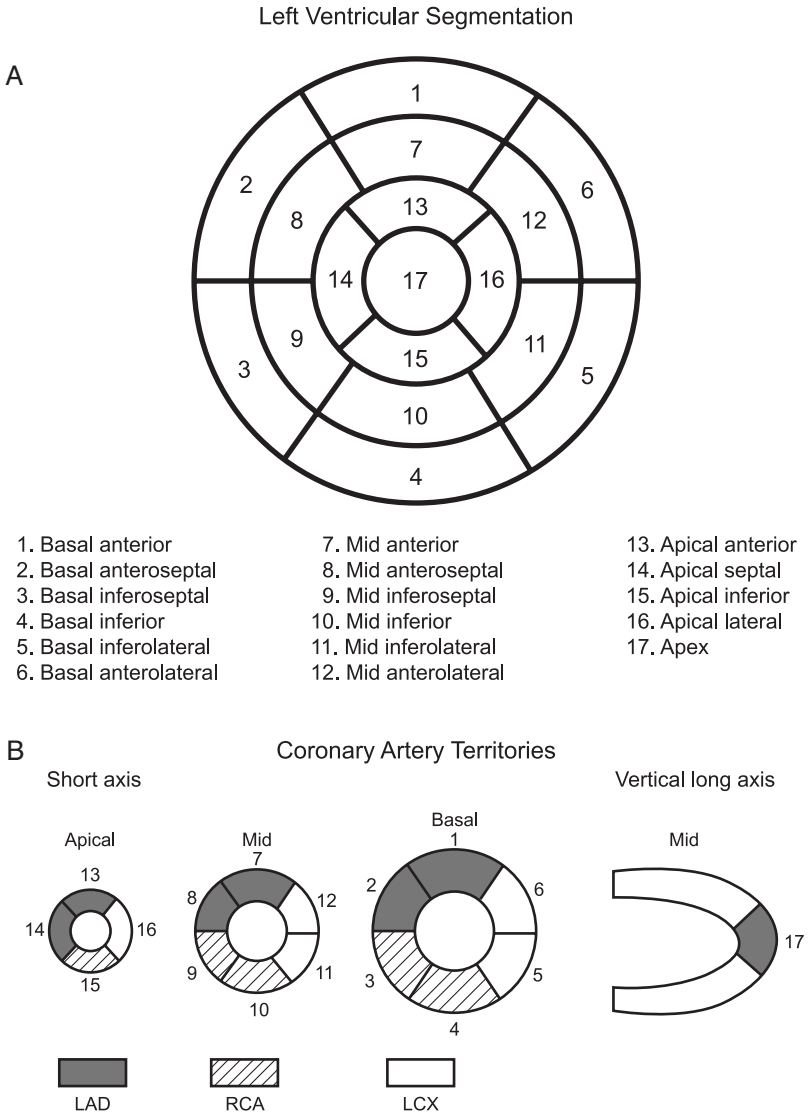

Figure 1. A. A polar-plot depiction of the left ventricular segmentation according to the 17-segment model. The recommended nomenclature is noted for each segment below. B. The 17-segment model, obtained by three individual short-axis slices as well as one mid-cavity vertical long-axis slice. A depiction of the coronary artery distribution is also noted.

Statistical analysis

A statistical analysis of the numbers of segments with various degrees of perfusion (normal, ischemic, fixed) before and after PTCA was performed for the three groups, separately, using paired T and ANOVA tests. SPSS version 13 was used for these analyses. A p-value <0.05 was considered to be statistically significant.

Results

Myocardial perfusion defects on scintigraphy were observed in all the patients before PTCA. Nineteen cases had atypical and 12 cases typical chest pain during history taking before scanning, while the remaining 29 patients were asymptomatic.

Assessment of perfusion in the territory of the dilated vessels revealed, on average, 1.33 fixed segments, 2.30 segments with ischemia and 2.30 normal segments per patient. The imaging performed 6-10 days, 1-3 months and 3-6 months after PTCA showed total normalization of the scintigraphic picture in 2, 4 and 5 patients, respectively. Improvement, characterized as a decrease in the number of ischemic or fixed segments, was observed in 13 of 16 patients at 6-10 days following PTCA, in 18 of 21 cases 1-3 months

after PTCA, and in 20 of 23 patients 3-6 months after PTCA. Comparative analysis between before and after PTCA in the three groups revealed an increase in the number of segments normally perfused ($p<0.05$), and a significant decrease in ischemic segments ($p<0.05$) (Table 1). The number of fixed segments decreased only insignificantly. Scans performed 3-6 months after PTCA as compared to two earlier MPI examinations showed an increase in the number of ischemic segments and a decrease of normal perfused segments, but the changes did not reach statistical significance. The sensitivity and specificity before PTCA and at the four subsequent time points, using angiography as reference examination, were 80/81, 100/35, 90/100 and 76/100 percent, respectively (Table 2).

Discussion

Our study showed good segmental correlation between Tc-99m sestamibi SPECT and angiography both before and after PTCA. Both before and after PTCA, the sensitivity and specificity of our MPI was within the ranges noted in previous studies, which reported that the sensitivity is 39-100% and its specificity is 46-100%, improving with time after PTCA.[5,6] The myocardial perfusion scan has been useful for the assessment of coronary artery disease and the identification of critical stenoses before angioplasty, as well as for the follow-up evaluation of patients after the intervention.[7] In the age of multi-vessel PTCA and partial revascularization, the possibility of localizing ischemia by a noninvasive method, as well as the ability to assess a marginal angiographic finding of functional importance, is of great significance for patient care. Also, SPECT imaging allows the determination of whether clinical ischemia is caused by restenosis at the site of angioplasty or by progression of disease in other coronary arteries.[8] Therefore, it is beneficial for patients who are being prepared for revascularization procedures to undergo myocardial perfusion imaging to document the presence, extent, and reversibility of myocardial ischemia before and during follow up.

Table 1. Comparative analysis of the numbers of segments with various degrees of perfusion calculated per patient in three groups of patients undergoing percutaneous transluminal coronary angioplasty (PTCA).

Time post PTCA	Perfusion type	Pb	Pa
	Normal	2.75	3.93
6-10 days	Ischemic	2.18	1.06
	Fixed	1.5	1.46
	Normal	2.09	4.09
1-3 months	Ischemic	2.52	0.80
	Fixed	1.33	1.25
	Normal	2.39	4.26
3-6 months	Ischemic	2.17	0.56
	Fixed	1.17	1.06

Pb – perfusion before PTCA; Pa – perfusion after PTCA.

In our study, scans performed 3-6 months after PTCA as compared to two earlier scans demonstrated an increase in the number of ischemic segments and a decrease in normal perfused segments, but these changes, which could be due to the restenosis phenomenon, did not reach statistical significance. According to various authors, restenosis occurs in 20% to 30% of patients.[9,10] The sensitivity of exercise electrocardiography in restenosis detection ranges from 24% to 52%, and the specificity does not exceed 64%.[11,12] Also, the usefulness of exercise electrocardiography in patients with partial revascularization is questionable, because a positive test may result from non-revascularized areas. Even in patients with dilation of all the stenotic vessels, a positive response may be indicative of disease progression rather than restenosis.[11,12] More recently, the introduction of stents has led to a dramatic decline in acute complication rates after angioplasty. Nevertheless, after coronary stent implantation the restenosis rate is reported to be 25% to 39%, mainly because of lumen encroachment by intimal hyperplasia within the stent.[13] The value of MPI in the detection of restenosis is also a widely discussed issue in the literature, and several studies, using exercise planar thallium-201 scintigraphy, thallium-201 SPECT imaging, and dipyridamole thallium-201 tomography have investigated the value of MPI in this setting.[14,15]

Our comparative analysis of the segments before, and 6-10 days, 1-3 months and 3-6 months after PTCA, demonstrated a statistically insignificant decrease of fixed segments, suggesting that the fixed abnormality was caused by severe resting hypoperfusion ("hibernating" myocardium) rather than by scarring.[16,17] A decrease in the number of fixed segments after PTCA was also noticed by Eichorn et al.[18]

The timing of perfusion scintigraphy after PTCA remains a controversial issue.[14] A decrease in specificity has been observed when MPI is performed within two months of PCI. This phenomenon was initially noted in the early days of PCI,[19] and has been observed more recently in studies using MPI shortly after coronary

Table 2. Sensitivity and specificity of myocardial perfusion imaging (MPI) before and during follow up of percutaneous transluminal coronary angioplasty (PTCA) in the main three territories.

Time	MPI parameter (%)	LAD	RCA	LCX	Total
Before PTCA	Sensitivity	100	80	60	80
	Specificity	63.6	80	100	81
6-10 days post PTCA	Sensitivity	100	100	100	100
	Specificity	20	66.66	20	35
1-3 months post PTCA	Sensitivity	88	83	100	90.33
	Specificity	100	100	100	100
3-6 months post PTCA	Sensitivity	87.5	75	66	76
	Specificity	100	100	100	100

LAD – left anterior descending artery; LCX – left circumflex artery; RCA – right coronary artery.

stenting.[20] Reversible perfusion defects were seen in 18% to 45% of asymptomatic patients using planar MPI 1 day to 7 weeks after coronary angioplasty,[19] and in 35% of patients undergoing dipyridamole SPECT within 19 days of coronary angioplasty.[21] Rodés-Cabau et al[22] detected reversible defects in 17% of patients who underwent exercise stress SPECT within one week of stenting. Four days after stenting using adenosine SPECT, Nagaoka et al[23] observed reversible defects in 36% of patients, which persisted in 50% of patients who underwent repeat imaging at 1.5 months. Our study suggests that approximately one month post PTCA may be a good time for scanning.

According to our results, most of the patients were asymptomatic or had atypical chest pain. Therefore, the presence or absence of symptoms after PTCA is not a good indication of vascular condition. A similar study showed that 30 percent of patients with recurrent symptoms had no restenosis, while 25 percent of patients with restenosis may be asymptomatic.[15] These observations support the idea of obtaining a perfusion study in patients with PTCA. In a similar investigation, Kostkiewicz et al[24] performed a study in 53 patients using exercise Tl-201 scintigraphy before, 6 to 10 days after, and 3 to 6 months after PTCA. The imaging performed 6 to 10 days after PTCA showed an improvement, seen as a decrease in the number of ischemic segments in 36 patients (67.9%). On exercise Tl-201 scintigraphy performed 3 to 6 months after PTCA a normalized scan was observed in 20 patients; recurrence of stenosis was found only in 2 (10%) of those patients. The positive predictive value of the study performed 6 to 10 days after PTCA was 56%, while the negative predictive value of such a study was 91%. Similarly, for detection of restenosis in a scan performed 3 to 6 months after PTCA there was a strong negative predictive value (90%) and a weak positive predictive value (63%). Although there were minor differences between our study and those mentioned above, the results were overall rather similar.[24] The aforementioned differences are probably because of the different myocardial imaging methods (99m-Tc sestamibi versus Tl-201), population differences, and also because of the intervening time between angioplasty and angiographic reevaluation.

In our study, we showed improvement in coronary blood supply in 51 (85%) patients, with full normalization of the scintigraphic image in 11 (18.33%) of those patients. Similar results were reported by Okada et al,[25] who noticed improvement in perfusion in 14 of 20 patients after PTCA, with full normalization in eight of those patients. The high incidence of false-positive results in the present study may be explained by several factors, such as incomplete revascularization, previous myocardial infarction and abnormal coronary function, due either to platelets, endothelial function, or other factors which prevent normal coronary flow reserve after angioplasty.[26]

Finally, it should be emphasized that our study is not free of drawbacks. The studied group was actually heterogeneous and the results must be interpreted with this consideration in mind. In addition, we did not address the prognostic value of MPI in patients with recurrent angina, or in those with positive or inconclusive results from an exercise ECG and also positive MPI testing after successful PTCA. However, further studies with a larger patient population are required to investigate these issues.

Conclusions

Our results confirm the necessity for an assessment of perfusion both before and shortly after angioplasty, which appears to provide the best documentation of

continuing changes in myocardial perfusion after coronary artery dilation. Furthermore, this study demonstrated that approximately one month after PTCA there is a good correlation between stress-induced myocardial perfusion abnormalities and the presence or absence of restenosis, independently of clinical symptoms, and suggests that this is the optimal time for such an evaluation.

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