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. PTCA is an effective method of revascularization in patients with coronary artery disease and was first performed successfully in 1977. 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 after angioplasty, 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 (1.95 ± 0.67 months) and 3-6 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.

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.
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. 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 non-invasive method, as well as the ability to assess a margin-
Reversible perfusion defects were seen in 18% to 45% of asymptomatic patients using planar MPI 1 day to 7 weeks after coronary angioplasty, and in 35% of patients undergoing dipyridamole SPECT within 19 days of coronary angioplasty. Rodés-Cabau et al 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 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. These observations support the idea of obtaining a perfusion study in patients with PTCA. In a similar investigation, Kostkiewicz et al performed a study in 53 patients using exercise TI-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 TI-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. The aforementioned differences are probably because of the different myocardial imaging methods (99m-Tc sestamibi versus TI-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, 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.

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

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

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

Acknowledgement

This research was supported by Tehran University of Medical sciences & Health Services grant no. 2090. The authors would like to express their sincere thanks to the technologists of the Research Institute for Nuclear Medicine and also the staff of the angiography department of Shariati Hospital of Tehran University of Medical Sciences for their fruitful cooperation.

References