Impact of Smoking on Health-Related Quality of Life After Percutaneous Coronary Revascularization

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Background—PTCA is performed primarily to improve health-related quality of life (HRQOL) in patients with symptomatic coronary artery disease. In patients undergoing PTCA, smoking has been shown to increase risks of late myocardial infarction and death. Whether smoking also affects HRQOL after PTCA is currently unknown.

Methods and Results—We examined the relation between smoking status and HRQOL among 1432 patients who underwent PTCA as part of 2 multicenter clinical trials. HRQOL was assessed with the use of the Medical Outcomes Study SF-36 questionnaire. Patients were classified as smokers (n=301), quitters (n=141), or nonsmokers (n=990) on the basis of their smoking status at the time of their index procedure and during the first year of follow-up. For the overall population, HRQOL improved significantly after PTCA for all scales except general health perception, with improvements ranging from 5.5 points for mental health to 23.2 points for role-physical functioning. After adjustment for baseline characteristics and initial HRQOL, nonsmokers had gains at 6 months that were larger than those of smokers for all health domains: physical function (15.4 versus 10.4 points), role-physical (24.5 versus 13.9), pain (18.4 versus 13.3), general health perception (1.7 versus −4.5), vitality (11.0 versus 4.7), social function (12.8 versus 3.5), role-emotional (13.5 versus 6.7), and mental health (6.8 versus 0.8; P<0.02 for all comparisons). Quitters had 6-month HRQOL improvements that were greater than those in smokers for all domains as well. Findings were similar at 1 year.

Conclusions—Quality-of-life benefits of PTCA are diminished by continued smoking. Efforts to promote smoking cessation at the time of PTCA may substantially improve the health outcomes of these procedures. (Circulation. 2000;102:1369-1374.)

Key Words: angioplasty • smoking • trials

More than 500,000 percutaneous coronary interventions are performed annually in the United States, at a cost of >$5 billion. Although they are life-saving in selected cases, the main benefits of these procedures are relief of angina and improved quality of life. Although considerable research has been directed at improving the outcomes of percutaneous coronary revascularization, these studies have generally focused on “hard” end points such as procedural complications or angiographic restenosis. Few studies have examined factors that influence health-related quality of life after PTCA, however. This is unfortunate because identification of modifiable factors that influence quality-of-life outcomes after PTCA would provide an opportunity to substantially improve clinically meaningful outcomes for a large patient population.

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One factor that might influence quality of life after percutaneous coronary revascularization is smoking. In the United States, ≈25% of all patients who undergo PTCA are smokers. Several studies have shown that long-term risks of myocardial infarction and death are higher for smokers than for nonsmokers after both percutaneous and surgical coronary revascularization. Moreover, smoking is associated with microvascular endothelial dysfunction that may limit the ability of epicardial revascularization to restore normal coronary blood flow. Finally, recent studies have shown that smoking is associated with reduced exercise capacity after PTCA and impaired functional capacity after bypass surgery. Little is known, however, about the specific effects of smoking on overall health-related quality of life after PTCA.
The goal of this study was to examine the relation between cigarette smoking and changes in health-related quality of life at 6 months and 1 year after percutaneous coronary revascularization.

Methods

Patient Population

The population for this study was drawn from patients who underwent percutaneous coronary revascularization as part of 2 multicenter clinical trials: the Balloon versus Optimal Atherectomy Trial (BOAT) and the ACS Multi-Link Stent System Trial (ASCENT). As previously described, BOAT was a randomized trial (n=989) comparing the angiographic and clinical outcomes of directional atherectomy with conventional balloon angioplasty, whereas ASCENT was a randomized trial (n=1040) comparing the ACS Multi-Link stent with the Palmaz-Schatz stent. This quality-of-life substudy was restricted to those patients who completed a baseline quality-of-life assessment at the time of their index revascularization procedure (n=1789).

Inclusion and exclusion criteria for the two trials were similar. All patients had symptomatic coronary artery disease requiring revascularization of a single coronary lesion <25 mm long in a native coronary artery with reference vessel diameter ≥3.0 mm by visual estimate. Exclusion criteria included myocardial infarction within 5 days of treatment, stroke within the preceding 3 months, bifurcation lesions, and excessive proximal tortuosity believed to preclude treatment with either stenting or directional atherectomy.

Data Collection

Detailed case report forms concerning baseline demographic and clinical data, procedural details, and clinical events during the initial hospitalization and follow-up were completed by a research coordinator at each site and submitted to the data coordinating center (Cardiovascular Data Analysis Center, Beth Israel Deaconess Medical Center, Boston, Mass). All patients underwent clinical follow-up at 1, 6, and 12 months after randomization to determine their symptomatic and clinical status. All end points (death, myocardial infarction, repeat revascularization) were entered on the basis of information provided by the patients at the time of their index revascularization and at 1-year follow-up. Patients who did not smoke during the year before their index revascularization procedure but who did not smoke during the follow-up year were considered nonsmokers (n=141). Patients who smoked during the year preceding their procedure as well as at any time during the follow-up period were considered persistent smokers (n=301). No patients in the study group began smoking after the index revascularization procedure.

Health-Related Quality-of-Life Assessment

Health-related quality of life was assessed at baseline, 6 months after treatment, and 1 year after treatment with the use of a written, self-administered questionnaire. The 36-item Medical Outcomes Study Short-Form health status questionnaire (SF-36) was used to measure overall health according to 8 subscales (physical function, role functioning-physical, pain, general health perception, vitality, social function, role functioning-emotional, and mental health) and 2 summary scales (physical health and mental health). Each scaled score may range from 0 to 100 points, with higher scores indicating better health status. The SF-36 has undergone extensive validity and reliability testing and has been shown to be responsive to clinically meaningful changes in quality of life among patients undergoing percutaneous coronary revascularization.

Baseline quality of life was assessed at the time of the initial revascularization procedure. Follow-up quality of life was assessed by mailed surveys at 6 months and 1 year after initial treatment. Those patients who did not respond to the mailed survey within 2 weeks were administered the same instrument by telephone, when possible.

Smoking Status

We classified patients as nonsmokers, quitters, or persistent smokers on the basis of information provided by the patients at the time of their index revascularization and at 1-year follow-up. Patients who did not smoke during the year before their index revascularization procedure or during the follow-up period were considered nonsmokers (n=990). Patients who smoked during the year before their

Statistical Analysis

All analyses compared nonsmokers with quitters and persistent smokers. Continuous variables are described as means ± SD and were compared by paired or unpaired t tests, as appropriate. Categoric variables are described as frequencies and were compared by Fisher’s exact tests. Ordinal variables were compared by Wilcoxon rank-sum tests. Probability values refer to 2-tailed significance tests and were not adjusted for multiple comparisons.

We used multivariable linear regression models to determine whether the mean change in health-related quality of life of persistent smokers differed from that of either nonsmokers or quitters. Each regression model adjusted for demographic characteristics (age, sex, education level, race, marital status), comorbid medical conditions (hypertension, congestive heart failure, cancer, chronic allergies, arthritis, back problems, visual impairment, chronic obstructive pulmonary disease, deafness, limitations in the use of an arm or leg, ulcer, and psychiatric conditions), other clinical factors (number of diseased vessels, ejection fraction, history of myocardial infarction or coronary artery bypass surgery, baseline Canadian Cardiovascular Society anginal class), type of treatment performed (PTCA, atherectomy, stenting), and the baseline SF-36 score for the specific scale. Baseline scores were included to account for the fact that those who entered the trial with a higher level of functioning had less room for improvement (ceiling effect) and to control for regression to the mean. To examine whether our results were sensitive to differences between respondents and nonrespondents, we imputed the change scores of nonrespondents by using multiple imputation techniques and reestimated the models for the full study population. Since the results of these sensitivity analyses were similar to our primary results, only the primary results are reported.

Results

Patient Population

Of the 1789 patients who completed the baseline quality-of-life instrument, 1432 (80%) completed the 6-month quality-of-life assessment and constituted the analytic cohort for our study. There were several minor differences in baseline characteristics and 6-month clinical outcomes between respondents and nonrespondents. Fourteen of the nonrespondents died (3.9%) before the 6-month time point. Compared with respondents, nonrespondents tended to be slightly younger (60 versus 58 years, P=0.001), to be less likely to graduate from high school (77% versus 67%, P<0.001), and to have lower ejection fractions (58% versus 56%, P=0.03) and were less likely to be white (91% versus 86%, P=0.005) and married (80% versus 72%, P=0.002). During the 6-month follow-up period, rates of myocardial infarction and repeat revascularization by PTCA did not differ between the two groups, but nonrespondents were more likely to have undergone bypass surgery than respondents (4.8% versus 1.4%).

Baseline Characteristics

Baseline demographic and clinical characteristics of the analytic cohort are described in Table 1. Smokers were significantly younger than nonsmokers and less likely to have graduated from college. Smokers were also less likely than nonsmokers to have a history of bypass surgery or diabetes mellitus. On the other hand, smokers were more likely to
have had a prior myocardial infarction than nonsmokers. The only significant difference in baseline characteristics between quitters and persistent smokers was age, with quitters being 2 years older on average.

**Clinical and Angiographic Outcomes**

There were no significant differences in initial procedural success or the incidence of myocardial infarction, repeat PTCA, or major vascular complications according to smoking status during the initial hospitalization or the 1-year follow-up period (Table 2). Smokers had a slightly higher rate of bypass surgery than nonsmokers during the index hospitalization (1.5% versus 0.3%, \( P = 0.02 \)), but by 1-year follow-up, this difference was no longer statistically significant (3.0% versus 1.8%, \( P = 0.21 \)). For the subset of patients who had protocol-directed angiographic follow-up at 6 months (\( n = 1052 \)), rates of angiographic restenosis (defined as >50% diameter stenosis) did not differ between groups at 6 months (28.2% for nonsmokers, 31.0% for quitters, and 28.1% for current smokers, \( P = 0.92 \)).

**Changes in Health-Related Quality of Life**

For the overall study population, quality-of-life scores at 6 months were significantly higher than baseline scores for 7 of 8 SF-36 subscales, with improvements ranging from 5.5 points for mental health to 17.3 points for bodily pain and

### Table 1. Baseline Demographic and Clinical Characteristics According to Smoking Status

<table>
<thead>
<tr>
<th>Smoking Status</th>
<th>Persistent Smokers ( (n=301) )</th>
<th>Nonsmokers ( (n=990) )</th>
<th>Quitters ( (n=141) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>55±9</td>
<td>62±10*</td>
<td>57±10*</td>
</tr>
<tr>
<td>Female sex, %</td>
<td>25.9</td>
<td>27.8</td>
<td>22.7</td>
</tr>
<tr>
<td>White race, %</td>
<td>89.7</td>
<td>90.8</td>
<td>90.1</td>
</tr>
<tr>
<td>Multivessel disease, %</td>
<td>20.8</td>
<td>25.1</td>
<td>19.4</td>
</tr>
<tr>
<td>Prior myocardial infarction, %</td>
<td>45.7</td>
<td>36.1*</td>
<td>44.7</td>
</tr>
<tr>
<td>Prior bypass surgery, %</td>
<td>2.3</td>
<td>7.4*</td>
<td>0</td>
</tr>
<tr>
<td>Diabetes mellitus, %</td>
<td>12.3</td>
<td>19.1*</td>
<td>15.6</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td>57±11%</td>
<td>58±12%</td>
<td>57±11%</td>
</tr>
<tr>
<td>No. of comorbid medical conditions</td>
<td>2.8±2.3</td>
<td>2.7±2.0</td>
<td>2.8±2.2</td>
</tr>
<tr>
<td>Married, %</td>
<td>72.1</td>
<td>79.1</td>
<td>80.9</td>
</tr>
<tr>
<td>College graduate, %</td>
<td>15.5</td>
<td>25.6*</td>
<td>15.6</td>
</tr>
<tr>
<td>CCS class III/IV, %</td>
<td>74.9</td>
<td>68.1</td>
<td>69.5</td>
</tr>
</tbody>
</table>

*\( P < 0.05 \) compared with persistent smokers.

### Table 2. Clinical Events According to Smoking Status

<table>
<thead>
<tr>
<th>Event</th>
<th>Persistent Smokers ( (n=301) )</th>
<th>Nonsmokers ( (n=990) )</th>
<th>Quitters ( (n=141) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial hospitalization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedural success, %†</td>
<td>95.6</td>
<td>95.9</td>
<td>98.4</td>
</tr>
<tr>
<td>Q-wave myocardial infarction, %</td>
<td>1.5</td>
<td>1.4</td>
<td>0</td>
</tr>
<tr>
<td>Bypass surgery, %</td>
<td>1.5</td>
<td>0.3*</td>
<td>0.9</td>
</tr>
<tr>
<td>Repeat PTCA, %</td>
<td>1.5</td>
<td>1.7</td>
<td>0</td>
</tr>
<tr>
<td>Vascular complications, %</td>
<td>3.4</td>
<td>2.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Between hospital discharge and 6 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q-wave myocardial infarction, %</td>
<td>0.3</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Bypass surgery, %</td>
<td>1.7</td>
<td>0.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Repeat PTCA, %</td>
<td>10.3</td>
<td>11.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Any event, %</td>
<td>12.6</td>
<td>11.1</td>
<td>7.8</td>
</tr>
<tr>
<td>Between hospital discharge and 1 year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q-wave myocardial infarction, %</td>
<td>0.3</td>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>Bypass surgery, %</td>
<td>3.0</td>
<td>1.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Repeat PTCA, %</td>
<td>13.9</td>
<td>12.8</td>
<td>7.8</td>
</tr>
<tr>
<td>Any event, %</td>
<td>16.0</td>
<td>13.9</td>
<td>9.2</td>
</tr>
</tbody>
</table>

*\( P < 0.05 \) compared with persistent smokers.

†Procedural success indicates achievement of <50% diameter stenosis in the absence of myocardial infarction or repeat revascularization during the index hospitalization.
Little is known about the determinants of improved quality of life in patients undergoing percutaneous coronary revascularization. In this study of >1400 patients, we found that regardless of smoking status, patients who underwent percutaneous coronary revascularization procedures derived significant improvement in most dimensions of health-related quality of life. However, the health status of patients who continued to smoke after their revascularization procedures (nearly 25%) improved substantially less than that of nonsmokers. In fact, 6 months and 1 year after PTCA, adjusted

P<0.001 than smokers. Quitters also demonstrated significantly greater benefits in both physical health (7.9 versus 4.2 points, P<0.001) and mental health (3.6 versus 0.1 points, P=0.001) than smokers at the 6-month time point. Similar findings were observed at 1-year follow-up.

Despite these differences in numerous dimensions of health, anginal status according to the Canadian Cardiovascular Society (CCS) classification did not differ according to smoking status. At 6-month follow-up, adjusted analyses (by logistic regression) demonstrated a 2-class or greater improvement in CCS class among 79% of nonsmokers, 76% of quitters, and 72% of persistent smokers (P=0.21).

Discussion

We found similar differences in the extent of quality-of-life improvement according to smoking status at 1-year follow-up (Table 3). Persistent smokers demonstrated significantly less improvement in health-related quality of life than nonsmokers for 6 SF-36 scales (physical functioning, role functioning, physical, general health perception, vitality, social functioning, and mental health) and significantly less improvement than quitters for 3 SF-36 scales (physical functioning, social functioning, and mental health). At both 6 months and 1 year, there were no dimensions of health for which persistent smokers had greater improvement after PTCA than either nonsmokers or quitters.

Improvement in the physical and mental health summary scales also differed significantly according to smoking status (Figures 1 and 2). Although both smokers and nonsmokers improved after PTCA, at 6-month follow-up, nonsmokers had greater adjusted gains in both physical health (6.8 versus 4.2 points, P<0.001) and mental health (3.4 versus 0.1 points,
changes in quality-of-life scores were 25% to 75% lower for smokers than for nonsmokers for each dimension of health. Moreover, we found that improvements in quality of life for those patients who quit smoking at the time of their revascularization procedure were substantially greater than for smokers and essentially indistinguishable from those of nonsmokers.

Previous Studies
Several previous studies have examined improvements in health-related quality of life after percutaneous coronary revascularization. Two of these studies used the SF-36 health status instrument and reported improvements of 10 to 25 points for most health domains—similar to the findings in our overall patient population. None of these studies had a large enough sample size to examine the extent of benefit of PTCA among patient subgroups, however.

The impact of smoking on health-related quality of life has also been examined in cross-sectional samples of the general population. These studies have found that smokers tend to have worse quality of life than nonsmokers, both in terms of respiratory problems and self-rated general health perception. One retrospective study assessed the impact of smoking cessation on health-related quality of life and found that individuals who quit smoking >11 years previously had higher quality-of-life scores than both current smokers and never-smokers. To our knowledge, however, no studies have examined the impact of smoking on health status in a longitudinal fashion. Our study is thus the first to demonstrate that continued cigarette smoking has an adverse impact on the improvement in quality of life derived from a medical intervention.

Clinical Significance
At both 6- and 12-month follow-up, adjusted gains in quality of life for both nonsmokers and quitters were 4 to 7 points higher than for smokers across a broad range of health domains. On a population basis, such differences in health status are large. For example, a longitudinal study of patients with chronic stable angina found that the difference between those who reported worsening of their anginal symptoms and those who reported improvement ranged from 1 point for the role-physical scale to 9 points on the social functioning scale. Similarly, an examination of population-based means by age group revealed that decrements of 4 to 7 points in SF-36 scores were associated with 5 years of aging.

Finally, for the SF-36 summary scales, previous population-based studies have found that a change of >3.8 on the physical function scale was associated with substantial improvement in physical health. Similarly, a change of 7.2 points on the mental health scale was associated with substantial improvement in mental health. Thus, the adjusted differences in change scores for physical health between smokers and nonsmokers (2.6 points) or quitters (3.7 points) would appear to be clinically significant. Although the observed differences in mental health according to smoking status were slightly greater in absolute terms (3.3 to 3.5 points), the clinical significance of these differences may actually be somewhat less than for physical health.

We have previously used the SF-36 health status instrument to compare late-term quality of life in patients randomized to stenting or conventional PTCA as part of the multicenter Stent Restenosis Study (STRESS). Interestingly, despite substantial reductions in both angiographic restenosis and the need for further revascularization procedures after stent implantation in STRESS, late differences in health status between stenting and PTCA were much smaller than those between smokers and quitters in the current study. In fact, only for the pain scale did the late differences associated with stenting (versus balloon angioplasty) exceed those seen after smoking cessation in the present study (8.9 versus 7.4 points). In this light, it is interesting to note that in the United States, coronary stenting has been widely embraced by the interventional cardiology community and is currently performed in 70% to 80% of all percutaneous coronary interventions at an annual cost of >1 billion dollars, whereas programs to promote smoking cessation are relatively under-supported by both third-party payers and the medical community.

Study Limitations
Our study has several important limitations. First, because patients in this study were participants in 2 clinical trials, the generalizability of our results is uncertain. However, the major restrictions on study entry were lesion-specific characteristics (vessel size, lesion length) that relate to suitability for specific interventional devices but would be unlikely to affect the quality of life of patients after PTCA. Moreover, compared with the most recent National Heart, Lung, and Blood Institute PTCA registry, patients in our study were similar in age, extent of coronary disease, and smoking status.

Second, we did not have complete follow-up quality-of-life data for all of the eligible population. Nonetheless, considering the size of the study and the level of detail of the health survey, our 80% response rate at 6 months compares favorably with previous studies of quality-of-life outcomes in patients with heart disease.

Third, observed differences may be due to residual confounding. Since smoking is known to be associated with a variety of other conditions (eg, pulmonary disease, peripheral vascular disease, psychiatric conditions) that may adversely affect multiple dimensions of both physical and emotional health, we attempted to adjust for baseline differences in each of these conditions in our analysis. Nonetheless, it is possible that our adjustment methods were inadequate or that other unmeasured confounders accounted for the observed differences. For instance, patients who quit smoking may have been more likely to attempt to improve their health in other ways, such as through exercise and diet, which may have resulted in greater gains in health-related quality of life. Although we cannot entirely exclude such unmeasured confounding, the fact that adjusted quality-of-life scores at baseline were similar for smokers and nonsmokers (data not shown) suggests that our model adjusted adequately for important confounding factors. Moreover, the similar extent of health status improvement between nonsmokers and quitters also argues for a true biological effect.
Conclusions
Although previous studies have demonstrated that smoking cessation among patients with established coronary disease reduces the subsequent risk of myocardial infarction or cardiac death, this is the first study to demonstrate that the quality-of-life benefits of a therapeutic intervention (PTCA) may also be diminished by continued smoking. These findings should provide further motivation for physicians to recommend specific smoking cessation interventions including drug treatment or formal smoking cessation programs to patients at the time of percutaneous coronary revascularization.

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