C Reactive protein, moderate alcohol consumption, and long term prognosis after successful coronary stenting: four year results from the GENERATION study

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OBJECTIVES: To determine the impact of moderate alcohol consumption on long term prognosis after successful coronary stenting, and whether it could be related to preprocedural plasma C reactive protein (CRP).

Design: Part of the prospectively designed GENERATION study which investigated the impact of several biochemical factors, including plasma CRP, on long term prognosis after coronary stenting.

Setting: Tertiary referral centre.

Patients: 483 consecutive patients with stable or unstable coronary artery disease who underwent successful coronary stenting and were followed for up to four years. Information about alcohol consumption was collected prospectively.

Interventions: Successful coronary stenting.

Main outcome measures: The incidence of the composite end point of readmission to hospital for unstable angina, non-fatal myocardial infarction, or cardiac death, whichever occurred first.

Results: By the end of follow up the incidence of the composite end point was 22.8%. Patients with a baseline plasma CRP concentration of <0.68 mg/dl (defined by ROC analysis) did not show any difference in the composite end point (p = 0.9) or its components, regardless of the amount of alcohol consumed during follow up. However, among patients with plasma CRP concentration of ≥0.68 mg/dl, those who drank moderately had a lower incidence of the composite end point (p < 0.001) or its components.

Conclusions: Moderate alcohol consumption may have a beneficial impact on the long term prognosis following successful coronary stenting. The extent of this effect is positively related to preprocedural inflammatory status. An anti-inflammatory action of moderate alcohol consumption cannot be excluded.

METHODS

Study patients

This study was part of the prospectively designed GENERATION study, which investigated the impact of several biochemical factors, including preprocedural plasma concentrations of CRP, on long term morbidity and mortality for up to three years after successful coronary stenting.

Details of the study design, inclusion and exclusion criteria, and the long term results for the first three years of follow up have been published previously. In summary,
The primary endpoint was the composite of readmission to hospital for unstable angina, non-fatal myocardial infarction, or cardiac death, whichever occurred first. Cardiac death was defined as sudden unexplained death, death from fatal myocardial infarction, or death after readmission to hospital for heart failure or possible acute myocardial ischaemia. New non-fatal myocardial infarction was defined as prolonged angina accompanied by new ECG abnormalities and elevation of creatine kinase-MB (to more than twice normal). New unstable angina was defined as rest angina with new ECG abnormalities without elevation of creatine kinase-MB. The diagnosis of cardiac death, non-fatal myocardial infarction, or unstable angina was verified by death certificates, discharge medical reports, hospital records, new ECGs, or telephone contact with attending physicians.

Patients were followed up clinically at one, three, and six months and subsequently every six months for up to three years. After the end of the third year of follow up, the

### Table 1 Baseline clinical characteristics

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (n = 181)</th>
<th>Group 2 (n = 123)</th>
<th>Group 3 (n = 170)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>60 (10.2)</td>
<td>59.6 (9.8)</td>
<td>58.4 (10.2)</td>
<td>0.3</td>
</tr>
<tr>
<td>Male sex</td>
<td>142 (78.5%)</td>
<td>103 (83.7%)</td>
<td>143 (84.1%)</td>
<td>0.3</td>
</tr>
<tr>
<td>Hypertension</td>
<td>83 (45.9%)</td>
<td>53 (43.1%)</td>
<td>68 (40%)</td>
<td>0.5</td>
</tr>
<tr>
<td>Current smoking</td>
<td>117 (64.6%)</td>
<td>81 (65.9%)</td>
<td>116 (68.2%)</td>
<td>0.8</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>41 (22.7%)</td>
<td>22 (17.9%)</td>
<td>30 (17.6%)</td>
<td>0.4</td>
</tr>
<tr>
<td>Hypercholesterolaemia</td>
<td>99 (54.7%)</td>
<td>68 (55.3%)</td>
<td>91 (53.5%)</td>
<td>0.9</td>
</tr>
<tr>
<td>Past myocardial infarction*</td>
<td>14 (7.7%)</td>
<td>11 (8.9%)</td>
<td>16 (9.4%)</td>
<td>0.8</td>
</tr>
<tr>
<td>Past coronary angioplasty*</td>
<td>7 (3.9%)</td>
<td>5 (4.1%)</td>
<td>8 (4.7%)</td>
<td>0.9</td>
</tr>
<tr>
<td>Past bypass surgery*</td>
<td>5 (2.8%)</td>
<td>4 (3.3%)</td>
<td>3 (1.8%)</td>
<td>0.7</td>
</tr>
<tr>
<td>Admission qualifying event</td>
<td>Stable angina</td>
<td>33 (18.2%)</td>
<td>32 (26%)</td>
<td>42 (24.7%)</td>
</tr>
<tr>
<td></td>
<td>NST ACS</td>
<td>81 (44.8%)</td>
<td>48 (39%)</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>STE MI</td>
<td>67 (37%)</td>
<td>43 (35%)</td>
<td>66 (38.8%)</td>
</tr>
<tr>
<td></td>
<td>CRP (mg/dl)</td>
<td>0.7 (0.6)</td>
<td>0.7 (0.7)</td>
<td>0.7 (0.5)</td>
</tr>
</tbody>
</table>

Values are mean (SD) or n (%).
*History of occurrence six months or more before study.

Group 1, less than one alcoholic drink a week or none; group 2, one to six alcoholic drinks a week; group 3, one to two alcoholic drinks a day; NST ACS, non-ST elevation acute coronary syndrome; STE MI, ST elevation myocardial infarction.

### Table 2 Baseline angiographic and coronary stenting related data

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (n = 181)</th>
<th>Group 2 (n = 123)</th>
<th>Group 3 (n = 170)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEF (%)</td>
<td>49.6 (7.1)</td>
<td>50 (7.6)</td>
<td>50 (6.5)</td>
<td>0.8</td>
</tr>
<tr>
<td>Multivessel CAD</td>
<td>73 (40.3%)</td>
<td>50 (40.7%)</td>
<td>56 (32.9%)</td>
<td>0.3</td>
</tr>
<tr>
<td>Characteristics of the 539 treated vessels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of vessels</td>
<td>205</td>
<td>142</td>
<td>192</td>
<td></td>
</tr>
<tr>
<td>Left anterior descending</td>
<td>104 (57.5%)</td>
<td>77 (62.6%)</td>
<td>104 (61.2%)</td>
<td>0.6</td>
</tr>
<tr>
<td>Left circumflex</td>
<td>41 (22.7%)</td>
<td>21 (17.1%)</td>
<td>30 (17.6%)</td>
<td>0.5</td>
</tr>
<tr>
<td>Right coronary</td>
<td>58 (32%)</td>
<td>42 (34.1%)</td>
<td>56 (32.9%)</td>
<td>0.9</td>
</tr>
<tr>
<td>Graft</td>
<td>2 (1.1%)</td>
<td>2 (1.6%)</td>
<td>2 (1.2%)</td>
<td>0.9</td>
</tr>
<tr>
<td>Characteristics of the 554 treated lesions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of lesions</td>
<td>212</td>
<td>145</td>
<td>197</td>
<td></td>
</tr>
<tr>
<td>Preprocedurally</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B2 or C</td>
<td>120 (56.9%)</td>
<td>78 (53.7%)</td>
<td>109 (55.3%)</td>
<td>0.9</td>
</tr>
<tr>
<td>Lesion stenosis (%)</td>
<td>83.4 (7.9)</td>
<td>83.2 (7.7)</td>
<td>83.2 (8.6)</td>
<td>0.9</td>
</tr>
<tr>
<td>RLD (mm)</td>
<td>3.3 (0.4)</td>
<td>3.4 (0.3)</td>
<td>3.3 (0.4)</td>
<td>0.9</td>
</tr>
<tr>
<td>MLD (mm)</td>
<td>0.55 (0.27)</td>
<td>0.56 (0.27)</td>
<td>0.56 (0.31)</td>
<td>0.9</td>
</tr>
<tr>
<td>Postprocedurally</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lesion stenosis (%)</td>
<td>8.8 (8.7)</td>
<td>9.2 (9.1)</td>
<td>7.9 (7.8)</td>
<td>0.4</td>
</tr>
<tr>
<td>MLD (mm)</td>
<td>3.16 (0.47)</td>
<td>3.12 (0.41)</td>
<td>3.17 (0.42)</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Values are mean (SD) or n (%).

CAD, coronary artery disease; group 1, less than one alcoholic drink a week or none; group 2, one to six alcoholic drinks a week; group 3, one to two alcoholic drinks a day; LVEF, left ventricular ejection fraction; MLD, minimum lumen diameter; RLD, reference lumen diameter.
Alcohol consumption and prognosis in coronary stenting

The GENERATION protocol was amended. Extension of the follow up period to up to five years was included in the protocol amendment. The scientific committee for the study decided to extend the follow up in order to evaluate the consistency of the three year results.

In the original protocol and in the amendment, information on the daily consumption of alcohol during follow up was obtained prospectively. Patients were initially preclassified into four groups according to their self reported alcohol consumption during the follow up period: group 1, less than one alcoholic drink a week or none; group 2, one to six alcoholic drinks a week; group 3, one to two alcoholic drinks a day (moderate alcohol consumption); and group 4, more than two alcoholic drinks a day. Drinking habits were updated during the predefined follow up intervals, and the average daily or weekly alcohol consumption was estimated. However, during follow up, no patient drank more than two alcoholic drinks a day, so the cohort was subsequently reclassified into three groups: group 1, less than one alcoholic drink a week or none; group 2, one to six alcoholic drinks a week; group 3, one to two alcoholic drinks a day (moderate alcohol consumption).

In the present report, the results for the original primary end point during the first four years of the extended follow up are presented. The original and the amended protocols were approved by the local ethics committee, and informed consent was obtained from all participants at the time of recruitment.

CRP assays
Venous blood samples for biochemical analysis were obtained during screening. All blood samples for CRP were initially analysed using a quantitative turbidimetric method (Dade Behring, Marburg, Germany) with a lower limit of detection at 0.5 mg/dl. Subsequently when a highly sensitive nephelometric analytical method was available (Dade Behring; lower limit of detection, 0.1 mg/dl), all deep frozen (–80°C) stored plasma samples with CRP values of < 0.5 mg/dl were reanalysed.

Statistical analysis
Values are expressed as mean (SD). Comparisons of continuous variables among the groups were made using analysis of variance (ANOVA) or the Kruskal–Wallis test, as appropriate. Bonferroni adjusted ANOVA, t tests, or Mann–Whitney U tests were used, as appropriate, for pairwise comparisons between the groups. Associations between two categorical variables were tested using χ² tests or Fisher’s exact tests. Receiver operating characteristic (ROC) curves were constructed for CRP values to determine their accuracy in predicting the primary end point (measured by the area under the ROC curve, range 0.5–1). To avoid arbitrary cut off points of CRP for the prediction of the primary end point, the “optimal” cut off point with the highest predictive accuracy which separated the cohort into two populations was estimated by ROC analysis. Cox’s proportional hazards model was used to assess the significance of any difference noted in the incidence of the primary end point or its components among the groups. Event-free survival was analysed using the Kaplan–Meier method, and log rank testing was used for comparisons among the curves.

All tests were two tailed and a probability value of p < 0.05 was considered significant. Statistical analysis was done with SPSS statistical software (release 10.0, SPSS Inc, Illinois, USA).

RESULTS
Baseline characteristics
There were no significant differences in baseline clinical or interventional characteristics or types of alcoholic drink consumed among the three groups (tables 1–3). The majority of the patients with ST elevation myocardial infarction had received intravenous thrombolysis after admission (147 of 177; 82.5%) and five underwent either primary or rescue angioplasty. Twenty five patients with ST elevation myocardial infarction (with a preprocedural left ventricular ejection fraction of > 35%) had not received acute reperfusion therapy because there were contraindications. Glycoprotein IIb/IIIa inhibitors were given in 15.8% of the patients with non-ST elevation acute coronary syndromes.

Long term follow up
Clinical follow up was obtained in 474 patients (474 of 483; 98.1%) at (mean (SD)) 36 (10) months (range 1–50 months); surviving patients were followed up for 38 (10) months.
(range 21–50 months). By the end of follow up, 42 patients (8.2%) had been readmitted to hospital for unstable angina, 41 (8.6%) suffered a non-fatal myocardial infarct, and 25 (5.2%) had died for cardiac reasons. During this period, the patients received several drugs including aspirin, ticlopidine, statins, β blockers, calcium channel blockers, and angiotensin converting enzyme inhibitors, with no significant differences among the study groups (data not presented).

CRP and long term prognosis

ROC analysis indicated that CRP values predicted the composite primary end point reasonably accurately (fig 1A), with an “optimal” cut off point at 0.68 mg/dl (fig 1B). The 164 patients with values of ≥0.68 mg/dl were at higher risk for the composite end point (hazard ratio (HR) 5.5, 95% confidence interval (CI) 3.6 to 8.2; p < 0.001) or its components than patients with values of <0.68 mg/dl (fig 2A). In particular, the former were at higher risk than the latter for either readmission to hospital for unstable angina (HR 6.1, 95% CI 3.1 to 11.8; p < 0.001), non-fatal myocardial infarction (HR 6.0, 95% CI 3.1 to 12; p < 0.001), or cardiac death (HR 4.0, 95% CI 1.8 to 9.9; p = 0.001) (fig 2A).

Alcohol consumption and long term prognosis

The effect of alcohol on long term prognosis was identical in male and female subjects, and did not vary with the type of drink consumed (data not presented). The distribution of the events according to alcohol consumption during the follow up is presented in fig 2B. There was no significant difference in the incidence of either the composite end point or its components between groups 1 and 2. However, patients in group 3 were at lower risk for the composite end point than those in group 2 (HR 0.5, 95% CI 0.3 to 0.8; p = 0.004) or group 1 (HR 0.7, 95% CI 0.5 to 0.9; p = 0.001). In particular, group 3 patients were at lower risk for readmission to hospital for unstable angina (HR 0.5, 95% CI 0.2 to 0.9; p = 0.03; and 0.7 (0.5 to 0.9), p = 0.04, respectively) than groups II and I; and for non-fatal myocardial infarction (HR 0.4, 95% CI 0.2 to 0.9; p = 0.04; and HR 0.6, 95% CI 0.4 to 0.9; p = 0.01). However, the risk for cardiac death (HR 0.5, 95% CI 0.2 to 1.5; p = 0.3; and HR 0.7, 95% CI 0.4 to 1.2; p = 0.2) was not significantly lower in group 3 patients.

CRP, alcohol consumption, and long term prognosis

The distribution of the events according to the baseline plasma CRP values and alcohol consumption during follow up is presented in fig 3. Kaplan-Meier curves for the primary composite end point according to the baseline plasma CRP values and alcohol consumption during follow up are presented in fig 4. Among the patients with baseline CRP values of <0.68 mg/dl there was no difference in the long term prognosis, regardless to the amount of alcohol consumed (figs 3A and 4A). However, among those with baseline CRP values of ≥0.68 mg/dl, group 3 patients had a significantly lower incidence of the composite end point than group 2 (HR 0.3, 95% CI 0.1 to 0.5; p < 0.001) and group 1 (HR 0.5, 95% CI 0.3 to 0.6; p < 0.001) (figs 3B and 4B). This was true for all components of the composite end point. In particular, group 3 patients were at lower risk for readmission to hospital for unstable angina than groups 2 and 1 patients (HR 0.3, 95% CI 0.1 to 0.8); p = 0.02; and HR 0.5, 95% CI 0.3 to 0.8; p = 0.008, respectively), for non-fatal myocardial infarction (HR 0.3, 95% CI 0.1 to 0.9; p = 0.02; and HR 0.5, 95% CI 0.3 to 0.8), or for cardiac death (HR 0.2, 95% CI 0.1 to 0.7; p = 0.002; and HR 0.4, 95% CI 0.2 to 0.8, p = 0.02) (fig 3B).

Figure 2 Distribution of the four year composite primary end point or its components among the subgroups defined by CRP (A) or alcohol consumption (B), CD, cardiac death; CE, composite primary end point; MI, non-fatal myocardial infarction; p* = p for trend.

Figure 3 Distribution of the four year composite primary end point or its components among the subgroups defined by alcohol consumption in patients with CRP concentrations of <0.68 mg/dl (A) or ≥0.68 mg/dl (B), CD, cardiac death; CE, composite primary end point; MI, non-fatal myocardial infarction; p* = p for trend.
DISCUSSION

During the last several years, CRP—a sensitive and non-specific inflammatory marker—has been extensively studied and shown to have incremental prognostic value as an indicator of short or long term coronary artery disease related ischaemic complications.28–31 Our present substudy has shown that the value of raised plasma CRP for predicting long term ischaemic complications is consistent for up to four years after successful coronary stenting. In addition, the study showed that moderate alcohol consumption has a beneficial effect on long term prognosis following successful coronary stenting, and this effect is strongly dependent on baseline plasma CRP values. In particular, moderate alcohol consumption was associated with a reduced incidence of the composite end point or its components in patients with a baseline plasma CRP of ≥ 0.68 mg/dl but not in those with a value < 0.68 mg/dl. These results suggest that the beneficial effect of moderate alcohol consumption on coronary artery disease related ischaemic complications may be mediated, at least in part, through an anti-inflammatory mechanism.

Previous non-randomised clinical observational studies22–24 have shown a protective effect of moderate alcohol consumption in reducing ischaemic complications in patients with coronary artery disease. It is well known that moderate alcohol consumption induces a rise in concentrations of high density lipoproteins (HDL),13 15 16 but a multivariate analysis showed that only 50% of the beneficial effect of alcohol on coronary artery disease related mortality could be attributed to this effect.25 26 Other mechanisms have been proposed, such as a favourable action of moderate alcohol consumption on the haemostatic profile27 28 or possible antioxidant properties of the compounds of some drinks, but these mechanisms are not well supported.27–29 This is the first long term prospective study in patients with established coronary artery disease that suggests a possible anti-inflammatory effect30 of moderate alcohol consumption. It is also conceivable that some of the other effects of moderate alcohol consumption—including increases in HDL or antithrombotic effects—may lessen the impact of inflammation in patients with atherosclerosis. The precise mechanisms of this interaction are unknown.

Study limitations

Our study has limitations that must be taken into account. First, the cut off point that we used for CRP is not a generally applied value. This cut off point “optimally” dichotomised the GENERATION population for predicting the end points in our study. Second, the recently recommended high sensitivity CRP assay was not available at the beginning of the study, and was applied only in patients with values of < 0.5 mg/dl at the first estimation. Third, only patients with successful coronary stenting were included and consequently the study findings may apply only in such patients, and should not be extrapolated to the entire coronary artery disease population. Fourth, the assessment of alcohol consumption was based on self report and this might have led to some misclassification. Fifth, the study patients did not drink the same types of beverage, even though there were no significant differences among the groups. Sixth, only average daily or weekly drinking was estimated, and issues of how and when the drinks were consumed were ignored. Seventh, drinking habits before recruitment were not assessed. Finally, this was not a randomised study, and healthier subjects were more likely to have moderate alcohol consumption. This may have introduced bias. However, there were no significant differences in baseline characteristics among the study groups, and as CRP values were not decoded before three years of follow up, no one was aware of their baseline plasma CRP levels.

Conclusions

The beneficial effect of moderate alcohol consumption on long term prognosis following successful coronary stenting may depend on the preprocedural plasma CRP concentration. An anti-inflammatory action of moderate alcohol consumption may be partly responsible for this effect, but further study is needed.

Authors’ affiliations

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J A Ambrose, M C DeVoe, Department of Medicine, The Comprehensive Cardiovascular Center, Saint Vincent Catholic Medical Centers, New York, USA

REFERENCES


A 60 year old man was referred for diagnostic evaluation of severe right arm hypertension and suspected aortic coarctation. Hypertension and a systolic murmur were diagnosed when he was 20 years old. The patient suffered from a stroke a few months before admission. Physical examination revealed a grade 3/6 systolic murmur at precordium radiating to the mid back, and weak and delayed femoral pulses. Blood pressure was 185/90 mm Hg in the right arm and 130/75 mm Hg in the left arm. The chest x-ray revealed rib notching caused by congestive collateral circulation. Thoracic magnetic resonance (MR) angiography demonstrated an extreme coarctation at the isthmus of the aorta, and a tight ostial stenosis at the origin of the left subclavian artery originating from the stenotic segment. The left internal mammary artery appeared hypertrophic and tortuous (left panel). Catheterisation showed a mean pressure gradient of 60 mm Hg across the coarctation. Angiography confirmed the MR diagnosis (right panel).
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