Relationship of Unrecognised Myocardial Infarction, Diabetes Mellitus and Type of Surgery to Postoperative Cardiac Outcomes in Vascular Surgery

A. Roghi1, B. Palmieri2, W. Crivellaro3, F. Faletra1 and M. Puttini2

1Departments of Cardiology, 2Vascular Surgery, 3Institute of Clinical Physiology, National Research Council Section of Milan, Niguarda Ca’Granda Hospital, Milan, Italy

Objectives: to evaluate preoperative clinical, surgical and instrumental variables as predictors of postoperative cardiac events in patients undergoing different types of elective major vascular surgery.

Material and methods: on the basis of an algorithm including clinical and test echocardiographic data, we prospectively stratified 604 consecutive patients into low, intermediate and high-risk groups. The value of the variables in predicting postoperative cardiac events was assessed by means of multivariate analysis.

Results: there were 16 major postoperative cardiac events and six of 16 postoperative deaths were cardiac related (1%). Significant predictors of cardiac complications were unrecognised myocardial infarction (odds ratio – (OR) 5.6), coronary artery disease (OR 2.5), severe hypertension (OR 2.1) and peripheral vascular surgery (OR 1.9). In the intermediate-risk group, the best correlates with cardiac complications were unrecognised myocardial infarction (OR 3.3) and diabetes (OR 2.5).

Conclusions: our results suggest the importance of identifying patients with unrecognised ischaemic heart disease and of using aggressive perioperative protocols for managing diabetic patients undergoing peripheral vascular procedures.

Key Words: Coronary disease; Vascular diseases; Risk assessment; Surgery; Postoperative complications.

Introduction

Postoperative cardiac complications represent a major element of vascular surgical risk, and depend on patient and procedure-related risk factors. In the preoperative assessment of low and intermediate-risk surgical procedures, the cardiac-risk indexes used over the last 20 years are generally effective in suggesting risk-reduction strategies, including cancelling the procedure. However, in the case of high-risk procedures, the severity of the vascular disease itself often reduces the opportunities for risk reduction in patients in whom the presence of many coronary artery disease-related determinants would otherwise suggest the adoption of a conservative management policy.

On the basis of these considerations, and the observation that coronary artery disease is the leading cause of mortality and morbidity after vascular surgery,1–3 various tests such as diprydame thallium scintigraphy,4–6 exercise,7 Holter monitoring8 and dobutamine stress echocardiography11 have been proposed as offering incremental value when assessing preoperative cardiac risk.

However, recent studies have questioned the value of such provocative tests11–14 on the grounds of the efficacy of clinical cardiac-risk indexes in stratifying low and high-risk patients, and the inadequacy of stress testing for assessing cardiac risk in intermediate-risk patients.14

The present study was prospectively designed to reassess the role of clinical and surgical preoperative variables as predictors of postoperative cardiac events in a population of patients stratified into low, intermediate and high-risk groups on the basis of a previously validated algorithm including clinical and rest echocardiographic data14 (Table 1). Although our algorithm is very similar to that recently proposed by the AHA/ACC task-force,15 it differs insofar as it suggests the use of resting echocardiographic evaluation in all except low-risk patients as a means of exploring the possibility of myocardial revascularisation in those with coronary artery disease and impaired left vent-
Table 1. Cardiac risk assessment.

<table>
<thead>
<tr>
<th>Low risk</th>
<th>Intermediate risk</th>
<th>High risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age ≤70 yrs:</td>
<td>Age &gt;70 yrs and/or:</td>
<td>LVEF &lt;50% and/or:</td>
</tr>
<tr>
<td>Normal ECG</td>
<td>Angina CCS I/II</td>
<td>Angina CCS III–IV</td>
</tr>
<tr>
<td>No coronary artery disease</td>
<td>Diabetes mellitus</td>
<td>CHF</td>
</tr>
<tr>
<td>Mild hypertension</td>
<td>Previous M.I. (≥6 months)</td>
<td>Previous M.I. (&lt;6 months)</td>
</tr>
<tr>
<td></td>
<td>LVEF ≥50%</td>
<td></td>
</tr>
</tbody>
</table>

ECG: electrocardiogram.
CCS: Canadian Cardiovascular Society Classification.
M.I.: myocardial infarction.
LVEF: left ventricular ejection fraction.
CHF: congestive heart failure.

The high incidence of coronary artery disease and diabetes mellitus in patients undergoing vascular surgery,\textsuperscript{16} of evaluating the presence of silent heart disease in those with abnormal ECG findings.

**Methods**

**Patients**

Six hundred and fourteen consecutive patients referred to the Department of Vascular Surgery of Niguarda Hospital for elective vascular surgery were prospectively studied over a 4-year period. Informed consent was obtained and the protocol was approved by the local Ethics Committee.

**Clinical data**

Previous myocardial infarction was diagnosed on the basis of clinical history and electrocardiographic (ECG) evidence of Q waves with a depth of at least 1 mm and lasting at least 0.04 s according to the Minnesota Code criteria.

In the absence of a history of acute myocardial infarction, angina or congestive heart failure, unrecognised myocardial infarction was defined as ECG evidence of Q waves with the above characteristics or negative T waves, with echocardiographic wall motion abnormalities occurring in the same coronary territory: (1) hypokinesis: reduced endocardial excursion and/or systolic wall thickening; (2) akinesis: no endocardial excursion and/or systolic wall thickening (3) dyskinesia: paradoxical systolic wall motion. Ventricular wall areas showing reduced diastolic thickness (≤6 mm) and increased echorefractivity were considered scar tissue. The patients in whom there was a disagreement between the echocardiographic and ECG findings were not considered as having an unrecognised myocardial infarction.

Angina was defined as chest pain having at least three of the following characteristics: a substernal location, precipitation by stress, a duration of less than 15 min and resolution after rest or nitroglycerine. It was graded using the Canadian Cardiovascular Society Classification (CCS).

Congestive heart failure was diagnosed on the basis of previous episodes of pulmonary oedema or clinical evidence of related signs and symptoms.

Diabetes mellitus was diagnosed on the basis of the revised criteria of United States National Diabetes Data Group of the National Institutes of Health, and classified as type 1 insulin-dependent and immune-mediated; type 2 non-insulin dependent and immune mediated; type 2 non-insulin dependent and non-immune mediated.

Severe hypertension was defined as a diastolic blood pressure of 110 mmHg or more treated with two or more drugs.

Chronic obstructive pulmonary disease (COPD) was diagnosed on the basis of clinical evidence including chest X-ray, spirometry and blood-gas exchange analysis. The patients were stratified into low, intermediate and high-risk groups on the basis of previously reported clinical criteria\textsuperscript{13,15,17,18} using a previously validated algorithm (Table 1).

**Echocardiography**

Rest echocardiography (Acuson 128 XP 10 C, Mountain View, California) was performed in all intermediate and high-risk patients 1–10 days before surgery using American Society of Echocardiography standard parameters.\textsuperscript{20}
Cardiac Risk Assessment in Vascular Surgery

Type of surgical procedure

Four procedures were considered: aortic (thoraco-abdominal and abdominal aneurysms, aorto-bifemoral bypass, aorto-visceral artery bypass), peripheral (femoro-popliteal and femoro-distal bypass and profundoplasty), carotid (carotid endarterectomy) and miscellaneous (iliaco-femoral endarterectomy or bypass and extra-anatomic bypass).

Perioperative management

General, thoracic epidural or local analgesia (carotid endarterectomy) was used. Haemodynamic monitoring was used for selected high-risk patients. Beta-blockers were not routinely used. Following cardiac risk stratification, individual tailoring of the cardiac and surgical management was allowed in high-risk patients.

Postoperative management

Twelve-lead ECG recordings and cardiac enzyme measurements (creatinine kinase and MB isoenzyme) were repeated in all patients during the immediate postoperative period and daily until discharge.

Clinical outcomes

The primary outcomes were overall mortality and major cardiac complications: (1) death unrelated to other non-cardiac diseases occurring within 30 days of the surgical procedure; (2) myocardial infarction, defined as autopsy evidence, new ECG Q waves of at least 1 mm in depth and lasting at least 0.04 s, or persistent ST-segment depression associated with an increase in serum creatine kinase/MB isoenzyme to \( \geq 20 \text{ ng per millilitre} \); (3) congestive heart failure, defined as pulmonary rales and orthopnoea, classical chest-film changes, or a pulmonary-capillary wedge pressure persistently greater than 18 mmHg in patients undergoing haemodynamic monitoring; (4) major arrhythmias, defined as ventricular tachycardia or atrial fibrillation and/or bradyarrhythmias leading to low-output syndrome.

The secondary outcomes were minor cardiac complications: (1) myocardial ischaemia, defined as a new ST-T abnormality (ST depression \( \geq 1 \text{ mm} \) 60 ms after the J point or T wave inversion) on at least two successive daily 12-lead electrocardiograms; (2) minor arrhythmias, defined as unsustained and clinically uncomplicated tachyarrhythmias.

Regional left ventricular function impairment was echocardiographically assessed as standard clinical practice in order to clarify all postoperative ischaemic or haemodynamic disorders.

Statistical analysis

The continuous values are expressed as mean values \( \pm \text{SD} \). One-way ANOVA was used to compare the estimates of the continuous variables in the three risk groups, and contingency table analysis to compare categorical variables. Univariate analysis (Biomedical Computer Program, Statistical Software INC., Los Angeles, CA, U.S.A.) was performed to determine the significant predictors in the study population as a whole, and in the intermediate and high-risk groups. The variables that proved to be significant predictors in the study population as a whole and in the intermediate-risk patients were then entered into a stepwise logistic regression model in order to determine the multivariate predictors of adverse cardiac events. A probability value of \(<0.05\) was considered significant.

Results

A total of 614 patients were enrolled over a period of 4 years. The vascular procedure was subsequently cancelled in 10 high-risk patients, and so the study population comprised 604 patients of a mean age \( \pm \text{SD} \) of 64 \( \pm \) 11 years (Tables 2 and 3). Prior to surgery, 18 high-risk patients underwent non-invasive cardiac evaluation, 31 coronary angiography and ten myocardial revascularisation. There were three simultaneous coronary artery by-pass graft (CABG) and carotid endarterectomy (CEA), six CABG and one percutaneous transluminal coronary angioplasty (PTCA). Two hundred and thirty-four patients undergoing haemodynamic monitoring; (4) major arrhythmias, defined as ventricular tachycardia or atrial fibrillation and/or bradyarrhythmias leading to low-output syndrome.

The secondary outcomes were minor cardiac complications: (1) myocardial ischaemia, defined as a new ST-T abnormality (ST depression \( \geq 1 \text{ mm} \) 60 ms after the J point or T wave inversion) on at least two successive daily 12-lead electrocardiograms; (2) minor arrhythmias, defined as unsustained and clinically uncomplicated tachyarrhythmias.

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Clinical outcomes

Of the 16 major events (Table 4), four occurred during surgery (two cases of ventricular tachycardia, one myocardial infarction, one cardiogenic shock), eight
Table 2. Preoperative clinical and anamnestic data; all patients and risk groups.

<table>
<thead>
<tr>
<th></th>
<th>All patients ((n=604))</th>
<th>Low risk ((n=161))</th>
<th>Intermediate risk ((n=354))</th>
<th>High risk ((n=89))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td>67 ± 9</td>
<td>63 ± 5</td>
<td>69 ± 10</td>
<td>67 ± 9</td>
</tr>
<tr>
<td><strong>Sex (M/F)</strong></td>
<td>485/119</td>
<td>130/31</td>
<td>278/76</td>
<td>77/12</td>
</tr>
<tr>
<td><strong>Hypertension ≥2 drugs</strong></td>
<td>221 (36%)</td>
<td>30 (20%)</td>
<td>140 (39%)</td>
<td>51 (57%)</td>
</tr>
<tr>
<td><strong>Diabetes mellitus</strong></td>
<td>122 (20%)</td>
<td>—</td>
<td>105 (30%)</td>
<td>17 (19%)</td>
</tr>
<tr>
<td><strong>Previous M.I.</strong></td>
<td>168 (29%)</td>
<td>—</td>
<td>105 (30%)</td>
<td>63 (70%)</td>
</tr>
<tr>
<td><strong>Unrecognised M.I.</strong></td>
<td>22 (4%)</td>
<td>—</td>
<td>14 (4%)</td>
<td>8 (9%)</td>
</tr>
<tr>
<td><strong>Angina</strong></td>
<td>65 (11%)</td>
<td>—</td>
<td>34 (10%)</td>
<td>21 (23%)</td>
</tr>
<tr>
<td><strong>CHF</strong></td>
<td>10 (2%)</td>
<td>—</td>
<td>10 (3%)</td>
<td>11 (12%)</td>
</tr>
<tr>
<td><strong>Arrhythmia</strong></td>
<td>43 (7%)</td>
<td>—</td>
<td>36 (10%)</td>
<td>7 (8%)</td>
</tr>
<tr>
<td><strong>LVEF &lt;50%</strong></td>
<td>46 (8%)</td>
<td>—</td>
<td>46 (8%)</td>
<td>19 (3%)</td>
</tr>
<tr>
<td><strong>LVEF &gt;50%&lt;35%</strong></td>
<td>19 (3%)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Serum creatinine (mg/dl)</strong></td>
<td>1.34 ± 0.94</td>
<td>1.15 ± 0.79</td>
<td>1.33 ± 0.77</td>
<td>1.70 ± 1.61</td>
</tr>
</tbody>
</table>

M.I.: myocardial infarction.
CHF: congestive heart failure.
LVEF: left ventricular ejection fraction.

Table 3. Preoperative clinical and anamnestic data: surgical subgroups.

<table>
<thead>
<tr>
<th></th>
<th>Aortic ((n=234))</th>
<th>Peripheral ((n=150))</th>
<th>CEA ((n=166))</th>
<th>Miscellaneous ((n=54))</th>
<th>(p) value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td>68.2 ± 7.2</td>
<td>66 ± 10</td>
<td>67.4 ± 9.5</td>
<td>64.7 ± 9.1</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Low-risk</strong></td>
<td>68 (29%)</td>
<td>39 (26%)</td>
<td>37 (23%)</td>
<td>17 (31%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Intermediate-risk</strong></td>
<td>134 (57%)</td>
<td>88 (59%)</td>
<td>107 (64%)</td>
<td>25 (46%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>High-risk</strong></td>
<td>32 (14%)</td>
<td>23 (15%)</td>
<td>22 (13%)</td>
<td>12 (22%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Sex (M/F)</strong></td>
<td>213/21</td>
<td>113/37</td>
<td>117/49</td>
<td>42/12</td>
<td>0.0001†</td>
</tr>
<tr>
<td><strong>Hypertension ≥2 drugs</strong></td>
<td>93 (40%)</td>
<td>52 (35%)</td>
<td>57 (34%)</td>
<td>19 (35%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Diabetes mellitus</strong></td>
<td>23 (10%)</td>
<td>61 (41%)</td>
<td>32 (19%)</td>
<td>6 (11%)</td>
<td>0.0001†</td>
</tr>
<tr>
<td><strong>Angina</strong></td>
<td>96 (41%)</td>
<td>55 (36%)</td>
<td>67 (40%)</td>
<td>20 (37%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>M.I.</strong></td>
<td>66 (28%)</td>
<td>42 (28%)</td>
<td>45 (27%)</td>
<td>15 (28%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Unrecognised M.I.</strong></td>
<td>7 (3%)</td>
<td>9 (6%)</td>
<td>5 (3%)</td>
<td>1 (2%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>CHF</strong></td>
<td>3 (1%)</td>
<td>2 (1%)</td>
<td>3 (2%)</td>
<td>2 (4%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Arrhythmia</strong></td>
<td>21 (9%)</td>
<td>12 (8%)</td>
<td>9 (5%)</td>
<td>1 (2%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>COPD</strong></td>
<td>35 (15%)</td>
<td>6 (4%)</td>
<td>11 (7%)</td>
<td>8 (15%)</td>
<td>0.001†</td>
</tr>
<tr>
<td><strong>LVEF</strong></td>
<td>60 ± 9</td>
<td>57 ± 9</td>
<td>58 ± 9</td>
<td>55 ± 10</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Serum creatinine (mg/dl)</strong></td>
<td>1.46 ± 1.09</td>
<td>1.37 ± 1.07</td>
<td>1.21 ± 1.42</td>
<td>1.38 ± 1.25</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

CAD: coronary artery disease.
M.I.: myocardial infarction.
CHF: congestive heart failure.
COPD: chronic obstructive pulmonary disease.
LVEF: left ventricular ejection fraction.
CEA: carotid endoarterectomy.
†Significant \(p\) value between all groups.
To convert creatinine values to micromoles per litre, multiply by 88.4.

The day after the surgical procedure (six myocardial infarctions, two pulmonary oedemas), two after 3 days (two myocardial infarctions), one after 10 days (pulmonary oedema) and one after 14 days (sudden death at home). The great majority of the minor cardiac complications (ECG negative T waves) occurred during the first two postoperative days.

Ten of the 16 deaths were non-cardiac (1.6%): three patients died of multiple organ failure, one of massive pulmonary embolism, one of stroke, one of septic shock, two of intestinal infarction, one of respiratory failure and one of haemorrhagic hypovolaemia. The cardiac mortality rate was 1%; five patients died of myocardial infarction and one of congestive heart failure.

There was a significant difference in major events between the low, intermediate and high-risk patients, as well as between the aortic, peripheral and carotid procedures (Table 5). Of the 23 patients with presurgical unrecognised myocardial infarction, 14 were stratified to the intermediate and nine to the high-risk group. In one high-risk patient the surgical procedure was completed. Of the 14 intermediate-risk patients, two suffered myocardial infarctions (one cardiac death); of the eight high-risk patients, one suffered myocardial infarction (complicated by pulmonary oed-
Cardiac Risk Assessment in Vascular Surgery

Table 4. Overall and cardiac mortality by risk group and vascular procedure.

<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Overall Mortality</th>
<th>Cardiac Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-risk</td>
<td>2 (1.2%)</td>
<td>—</td>
</tr>
<tr>
<td>(161 pts)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate-risk</td>
<td>6 (1.7%)</td>
<td>2 (0.6%)</td>
</tr>
<tr>
<td>(354 pts)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-risk</td>
<td>8 (9%)</td>
<td>4 (4.5%)</td>
</tr>
<tr>
<td>(89 pts)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>16 (2.6%)</td>
<td>6 (1%)</td>
</tr>
</tbody>
</table>

*p value = 0.0009

Aortic (234 pts) 10 (4.2%) 2 (0.85%)
Peripheral (150 pts) 4 (2.6%) 2 (1.3%)
CEA (166 pts) 2 (1.2%) 2 (1.2%)
Miscellaneous (54 pts) — —
Total 16 (2.6%) 6 (1%)

*p value = n.s.

CEA: carotid endarterectomy.

Table 5. Minor and major postoperative cardiac events by risk group and vascular procedure.

<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Minor Events</th>
<th>Major Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-risk (161 pts)</td>
<td>9 (5.5%)</td>
<td>—</td>
</tr>
<tr>
<td>Intermediate-risk (354 pts)</td>
<td>43 (12.1%)</td>
<td>7 (2%)</td>
</tr>
<tr>
<td>High-risk (89 pts)</td>
<td>8 (9%)</td>
<td>8 (9%)</td>
</tr>
<tr>
<td>All patients (604 pts)</td>
<td>60 (9.9%)</td>
<td>15 (2.5%)</td>
</tr>
</tbody>
</table>

*p value = 0.0001*

Aortic (234 pts) 37 (16%) 5 (2.1%)
Peripheral (150 pts) 11 (7%) 8 (5.3%)
CEA (166 pts) 5 (3%) 2 (1.2%)
Miscellaneous (54 pts) 7 (18.5%) —
Total 60 (9.9%) 15 (2.5%)

*p value = 0.0001*

CEA: carotid endarterectomy.* Distribution of events between risk groups and type of surgical procedure: significant *p value between all groups (chi square analysis). Minor events: myocardial ischaemia, minor arrhythmias. Major events: death, myocardial infarction, congestive heart failure, major arrhythmias.

Discussion

The main finding of this study is that unrecognised myocardial infarction, a history of coronary artery disease, severe hypertension and peripheral vascular surgery are predictors of postoperative adverse cardiac outcomes in patients undergoing major vascular surgery. Furthermore, the algorithm including clinical and rest echocardiographic variables is adequate for the stratification of patients into risk groups with significant differences in postoperative events.

Low risk group

Although the algorithm considered age as one of the discriminant variables for stratifying low-risk patients, one congestive heart failure (one cardiac death) and one multiorgan failure (one non-cardiac death). In this subgroup of patients, the cardiac mortality rate was 9% (2/22) and the major cardiac event rate 18% (4/22).

Univariate analysis

Among the patients as a whole, the preoperative variables significantly associated with a major adverse cardiac outcome in the univariate analysis were unrecognised myocardial infarction, diabetes mellitus, previous myocardial infarction, hypertension, angina, a left ventricular ejection fraction of less than 50% and peripheral vascular surgery. In the intermediate-risk patients they were unrecognised myocardial infarction, previous myocardial infarction and diabetes mellitus. In the high-risk group no preoperative variable was associated with postoperative cardiac outcomes.

Multivariate analysis

The results of the logistic regression analysis of the patients as a whole and in the intermediate-risk group are shown in Table 6. The preoperative predictors of cardiac complications in the patients as a whole were unrecognised myocardial infarction, coronary artery disease, severe hypertension and peripheral vascular surgery; in the intermediate-risk patients they were unrecognised myocardial infarction and diabetes.

The cardiac complication rate was 5% in the intermediate-risk patients with unrecognised myocardial infarction and diabetes mellitus undergoing peripheral vascular surgery (71 patients, 12%).

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Table 6. Multivariate analysis: independent predictors of major cardiac events.

<table>
<thead>
<tr>
<th></th>
<th>All patients</th>
<th>Intermediate-risk group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odds ratio (95% CI)</td>
<td>p value</td>
</tr>
<tr>
<td>Unrecognised M.I.</td>
<td>5.6 (2.2–13.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CAD</td>
<td>2.5 (1.1–5.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>2.1 (1.1–3.8)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Peripheral surgery</td>
<td>1.9 (1.0–1.3)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

M.I.: myocardial infarction.
CAD: coronary artery disease (including angina, known previous MI).
CI: confidence interval.

its irrelevance as a predictor of postoperative events suggests its re-evaluation in patients undergoing vascular surgery who have a normal electrocardiogram and no other predictors of events.

Intermediate-risk group

In the patients with preserved left ventricular function, previously unrecognised myocardial infarction and diabetes mellitus were the only two predictors of postoperative events. We assessed unrecognised myocardial infarction by means of echocardiographic regional wall motion analysis and ECG criteria using a prospective design and a continuous cohort of patients. The epidemiological Reykjavik study\textsuperscript{21} of a population sample of 9141 men reported a 31\% incidence of unrecognised myocardial infarction, closely correlated with age (5\% in the group aged 75–79 years). In agreement with these data, Lumley observed an incidence of 33\% in a selected cohort of patients undergoing exercise testing with myocardial perfusion imaging, with a significant correlation with diabetes; however, the retrospective design of the study and the small sample of patients precluded a more exhaustive evaluation of the clinic and anamnestic variables.

Our patients with echocardiographic evidence of Q waves or an ischaemic pattern such as negative T waves were carefully investigated in terms of symptoms and a history of heart disease, and underwent regional wall motion analysis. In the intermediate-risk group, we found that unrecognised myocardial infarction is a predictor of postoperative adverse cardiac outcomes (O.R 3.31) regardless of the type of surgery, or clinical variables such as diabetes or hypertension. The incremental risk of postoperative cardiac events related to unrecognised myocardial infarction may be due to the severity of the extent of coronary artery disease or (given the unpredictability of the time interval between the acute event and the surgical procedure) to the presence of unstable necrotic tissue and residual ischaemic myocardium. As unrecognised myocardial infarction is a relevant predictor of postoperative cardiac events, we suggest undertaking a careful resting ECG and rest echocardiographic evaluation of intermediate and high-risk patients. Where scar tissue is present (reduced regional wall thickness and echocardiographic hyper-reflectivity), myocardial revascularisation is ineffective and so we suggest aggressive perioperative management in an intensive care unit. In the case of two adjacent hypokinetic segments indicating hybernating myocardium, we suggest coronary angiography to explore the possibility of myocardial revascularisation with the aim of reducing the ischaemic burden and improving left ventricular function before vascular surgery.

High-risk group

In these patients, the observation that no clinical or surgical variable per se is a predictor of cardiac events suggests a synergistic interpolation between the severity of cardiac disease and advanced multi-organ disease as a possible explanation of the higher incidences of adverse outcomes. Of the 31 patients undergoing coronary angiography to explore the possibility of myocardial revascularisation before vascular surgery, only 10 had an adequate anatomical condition allowing them to undergo cardiac surgery or PTA.

Type of vascular surgery

The known association between diabetes and peripheral vascular surgery,\textsuperscript{16} was confirmed in our study, and probably explains the role of peripheral surgery as a predictor of an adverse cardiac outcome. Diabetes was an independent predictor only in the intermediate-risk patients, probably because of the presence of other
associated diseases in the high-risk group. The results of other studies are in partial agreement with our findings. Krupski et al. reported a perioperative morbidity rate of 25% and 8% in patients undergoing infrainguinal or aortic surgery, a difference that was mainly attributed to concomitant cardiac or diabetic factors. L’Italien et al. reported that patients undergoing infrainguinal procedures had a more than doubled risk of perioperative myocardial infarction than those undergoing aortic surgery, but this difference was reduced to insignificant levels after adjustment for comorbid factors. In our study, the incremental value of diabetes and peripheral surgery as predictors of postoperative events persisted even after adjustment for comorbid factors.

In agreement with previous studies, we observed a prevalence of males among the patients undergoing abdominal aortic surgery, which probably explains the differences in the incidence of chronic obstructive pulmonary disease associated with the different types of surgical procedures. The higher non-cardiac mortality rate among the patients undergoing aortic surgery may be explained by their more severe comorbidity and/or surgical variables such as intraoperative times and blood losses. Because we did not consider intraoperative variables as postoperative event predictors, further studies are needed to evaluate their relevance and relationship to presurgical predictors of cardiac and overall mortality.

The role of hypertension as a predictor of adverse cardiac events is still under discussion, but we found that severe hypertension was a strong independent predictor of postoperative events. Although hypertension was uniformly distributed among the patients undergoing different types of surgical procedures, 57% of the high-risk patients had severe hypertension. Given the significant impairment of left ventricular function in such patients, we suggest that hypertension may be a relevant trigger of postoperative events such as congestive heart failure, particularly in those undergoing abdominal aortic procedures. Because of the high incidence of non-cardiac comorbidities such as chronic renal disease and chronic obstructive pulmonary disease in these patients, careful periprosthetic management of hypertension is crucial for preventing severe adverse cardiac events.

Conclusions

Our data confirm that careful clinical and rest echocardiographic evaluations correctly assess the cardiac risk of patients undergoing major vascular surgery. Patients with electrocardiographic and rest echocardiographic evidence of unrecognised myocardial infarction are at the highest risk of postoperative cardiac events. Definite clinical evidence of coronary artery disease, severe hypertension and peripheral vascular surgery are important preoperative predictors of adverse cardiac outcomes; in the intermediate-risk group, diabetes mellitus and unrecognised myocardial infarction are predictors of postoperative events.

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