Clinical Research

Indication for Surgery, the Revised Cardiac Risk Index, and 1-Year Mortality

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Background: Patients who undergo vascular surgery are at increased risk of perioperative cardiovascular morbidity and mortality. The Revised Cardiac Risk Index (RCRI) is a validated and widely used bedside tool for estimating the risk of a perioperative major adverse myocardial event. We hypothesized that inclusion of the indication for surgery would add independent and prognostic information to the RCRI in predicting all-cause 30-day and 1-year mortality in open infrainguinal vascular surgical procedures.

Methods: This was a retrospective study of 603 patients who underwent open infrainguinal bypass vascular surgery between January 2002 and January 2008 at a tertiary care medical center. RCRI and indication for surgery were determined. The primary outcomes of interest were all-cause 30-day mortality (which included all in-hospital mortality, regardless of time) and all-cause 1-year mortality.

Results: Overall 30-day mortality was 32 (5.3%). Independent risk factors for early death were RCRI score, being of age ≥80 years, American Society of Anesthesiologists Physical Status classification = 4, and emergency surgery. Overall 1-year mortality, including early deaths, was 114 (18.9%). Indication for surgery, RCRI score, age, American Society of Anesthesiologists Physical Status classification = 4, female sex, and emergency surgery were all independent predictors of 1-year mortality.

Conclusions: The RCRI score was associated with both 30-day and 1-year mortality in patients undergoing lower extremity bypass surgery. Indication for surgery was predictive of 1-year mortality but not of 30-day mortality.

INTRODUCTION

Patients who undergo vascular surgery are at increased risk for perioperative cardiovascular morbidity and mortality. The American College of Cardiology/American Heart Association (ACC/AHA) perioperative guidelines for noncardiac surgery classify peripheral vascular procedures as being high risk.1 These guidelines also advise careful evaluation of long-term outcomes in such cases.

Given the probable comorbidities of this patient population, understanding perioperative and long-term risk facilitates informed consent and the preoperative testing process.

The Revised Cardiac Risk Index (RCRI) is a validated and widely used bedside tool for estimating a patient’s risk of a major adverse myocardial event within 30 days of surgery.2 However, a recent meta-analysis of the RCRI found that this index does not perform well in predicting death in the...
perioperative period after vascular surgery as compared with other noncardiac procedures. Although indication for lower extremity bypass surgery is associated with poor outcomes, the current ACC/AHA guidelines do not consider indication for vascular surgery to be important in stratifying risk. Indications for this surgery include chronic limb ischemia (claudication, ischemic rest pain, or tissue loss) and acute indications such as aneurysm repair and graft thrombosis. We hypothesized that inclusion of the indication for surgery would add independent and prognostic information to the RCRI score in predicting all-cause 30-day and 1-year mortality in patients undergoing open infrainguinal bypass surgery.

MATERIALS AND METHODS

This was a retrospective study of vascular surgery patients performed at the Mount Sinai School of Medicine Hospital, New York, NY, an urban tertiary care teaching hospital. The Mount Sinai Hospital Institutional Review Board approved the study, and a waiver of informed consent was obtained. Between January 2002 and January 2008, a total of 603 adults who underwent open femoral–distal arterial bypass vascular surgery procedures and satisfied our inclusion criteria were included in the study. All patients aged >18 years who underwent emergent and nonemergent operations were included. Those undergoing suprainguinal vascular surgery were excluded. In cases involving multiple procedures performed during the study period, only the first one was included in the analysis. Six patients for whom indication for surgery could not be determined were excluded.

Data Collection

We obtained the following information from the electronic medical records: age, sex, body mass index, American Society of Anesthesiologists Physical Status (ASA-PS) classification, medications, and type of anesthesia.

For each subject, we reviewed the chart for documented and self-reported history, and we calculated an RCRI score. One point was assigned for each of the following variables: (a) baseline serum creatinine of \( \geq 2 \) mg/dL (to convert to micromoles per liter, multiply by 88.4), (b) history of congestive heart failure, (c) history of ischemic heart disease, (d) history of cerebral vascular disease, and (e) history of diabetes mellitus requiring insulin. In addition, the RCRI score routinely assigns one point for high-risk surgery. However, infrainguinal vascular procedures are not considered high risk for this purpose (in contrast to their classification as high risk by the ACC/AHA). Ischemic heart disease is defined as any of the following: (a) previous Q wave on electrocardiogram, (b) previous nitrate use, (c) previous coronary artery bypass or percutaneous intervention, (d) previous positive noninvasive test indicating ischemia, or (e) previous myocardial infarction. Cerebral vascular disease is defined as either previous cerebral vascular accident or transient ischemic attack.

We recorded the indication for surgery by using the Rutherford grade classification, which categorizes symptoms of chronic limb ischemia. This classification includes claudication, rest pain, and tissue loss, that is, gangrene. Patients who presented with acute limb ischemia were categorized as acute.

Outcomes and Measurement

The primary outcomes of interest were all-cause 30-day mortality (which included all in-hospital mortality, regardless of time) and all-cause 1-year mortality. We obtained this information from hospital discharge summaries and the Social Security Death Index, a public database that lists dates of death for anyone registered with the Social Security Administration.

Statistical Methods

Data were entered in an Excel file and transferred to SAS version 9.1 (SAS/STAT 9.1 User’s Guide, SAS Institute Inc., Cary, NC) for statistical analysis. Contingency tables were constructed to describe associations between factors. The primary objective of this analysis was to evaluate the RCRI score and indication for surgery as predictors of all-cause 30-day and 1-year mortality in patients undergoing lower extremity bypass surgery. Whether indication for surgery provided independent information in these cases was of particular interest. Factors were first reviewed individually for a significant or near-significant \( (p < 0.10) \) association with an outcome. Independent factors were identified in separate multiple logistic regression analyses.

The joint effect of RCRI and indication for surgery (Rutherford classification) was tested first. Then, when appropriate, RCRI and/or indication for surgery were forced into a stepwise multiple logistic regression analysis to identify other factors that added independent information concerning outcome. Models that included the other independent factors were considered with and without the addition of RCRI and indication. Age, body mass index, and sex were included because of their association with poor outcomes.
outcome after vascular surgery. A diagnosis of diabetes mellitus was considered because the RCRI score includes only those with diabetes who are on insulin, and diabetes has been proposed as an explanation for poor long-term outcome after infrainguinal bypass surgery.

Dyslipidemia was evaluated because of its association with atherosclerosis and coronary artery disease. Anesthesia type was studied because neuraxial analgesia has been suggested to decrease catecholamine levels and hypercoagulability and to improve outcomes after vascular surgery. The use of beta-blockers, clonidine, aspirin, and 3-hydroxy-3-methylglutaryl-coenzyme A (HMG-CoA) reductase inhibitors was analyzed because of their association with improvements in perioperative outcome. ASA-PS classification and emergency surgery were considered because of their association with postoperative outcome.

A Kaplan–Meier life table was used to describe the cumulative incidence of death over the course of the first year.

RESULTS

Patient demographics and clinical characteristics are shown in Table I. Patients with claudication were younger (median age, 66.0 years) than those who presented with other indications (median age, 74.0 years). The median RCRI score for patients who had claudication, rest pain, and acute surgery was 1, whereas those who presented with gangrene had a median RCRI score of 2. At the time of surgery, 61% of patients were taking a beta-blocker and 35% were taking an HMG-CoA reductase inhibitor. Among those with tissue loss, 61% were found to be taking a beta-blocker, but only 32% were taking an HMG-CoA reductase inhibitor (data not shown).

Thirty-Day Mortality

In our patient population, the overall 30-day mortality was 32 (5.3%). There were no early deaths reported in patients with an RCRI score of 0, regardless of surgical indication. In univariate analysis, early death was associated with RCRI score (p < 0.001), age (p = 0.02), ASA-PS class (p = 0.0004), and emergency procedure (p = 0.004). Indication for surgery was not associated with early death. When the RCRI score and indication for surgery were considered jointly, the RCRI score, but not indication for surgery, was associated with death at 30 days. Therefore, only the RCRI score was forced into the stepwise model to identify other significant factors. Independent risk factors for early death were as follows: (a) RCRI score, (b) being of age ≥80 years, (c) ASA-PS classification = 4, and (d) emergency surgery (Table II).

One-Year Mortality

Overall 1-year mortality, including early deaths, was 114 (18.9%). In univariate analysis, 1-year mortality was significantly associated with (a) indication for...
Although the overall long-term mortality rate (18.9%) in this study was similar to the one that was previously reported (16.3%), mortality rates varied considerably by surgical indication. In our study, the overall 1-year mortality was only 3% in patients who had claudication. Those who presented with limb tissue loss, in contrast, had an overall 1-year mortality of 22%. Open infrainguinal bypass surgery is considered high risk by the ACC (in contrast to the RCRI classification), and careful consideration of the indication for surgery is a prudent first step for risk assessment.

The 1-year mortality rate of patients with rest pain or claudication was lower than that of patients with lower extremity tissue loss among those with an RCRI of >2 (15 vs. 35%, \( p = 0.22 \)), as well as among patients with an RCRI of \( \leq 2 \) (5 vs. 17%, \( p = 0.002 \)). These data can be used in the informed consent process when patients are considering further surgery.

Because vascular surgery is considered a high-risk procedure, preoperative stress testing is often performed to guide further management before surgery. Given the pain associated with claudication, this patient population may not be able to provide a history of achieving four metabolic equivalents (the equivalent of walking up two flights of stairs). Our data suggest that patients who present with claudication have a low risk of perioperative death or long-term mortality. Further studies should evaluate whether stress testing is prudent or cost-effective in this subgroup of vascular surgery patients, provided medical management has been optimal.

Guidelines from the ACC/AHA suggest that clinicians should focus on the long-term management of patients undergoing vascular surgery. Consideration of indication for surgery may prompt the clinician to identify high-risk vascular surgery patients and ensure adequate medical follow-up outside the immediate perioperative period. These guidelines discuss magnitude of surgery and surgery type as important variables for immediate perioperative outcome. Our work demonstrates that indication for surgery should also be considered in the analysis of long-term outcome.

Differences in 30-day and 1-year predictors of death in patients undergoing noncardiac surgery have been reported. Our data show that the RCRI is associated with both 30-day mortality and 1-year mortality in patients undergoing lower extremity bypass surgery. In contrast, indication for surgery is associated with 1-year mortality, but not with 30-day mortality. Our data are consistent with previously reported studies showing that patients who present for urgent and emergent surgery are at

### Table II. Multivariate analysis for in-hospital mortality or death within 30 days

<table>
<thead>
<tr>
<th>Patient characteristic</th>
<th>OR</th>
<th>95% CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCRI score</td>
<td>1.7</td>
<td>1.2-2.4</td>
<td>0.002</td>
</tr>
<tr>
<td>Age ≥80 years</td>
<td>2.2</td>
<td>1.1-4.7</td>
<td>0.04</td>
</tr>
<tr>
<td>ASA-PS = 4</td>
<td>2.2</td>
<td>1.0-5.0</td>
<td>0.05</td>
</tr>
<tr>
<td>Emergency</td>
<td>7.3</td>
<td>2.3-24.3</td>
<td>0.0008</td>
</tr>
</tbody>
</table>

CI, confidence interval; OR, odds ratio.

*There were 32 deaths among 568 patients with rest pain, tissue loss, and acute indications for surgery. There were no in-hospital deaths among 35 patients who presented with claudication.

DISCUSSION

Previous studies have shown that the RCRI score is an independent indicator of longer term outcome in patients undergoing a variety of procedures, including open and endovascular repair. These analyses, however, included a variety of vascular procedures with different mortality rates and did not consider indication for surgery. In our analysis, the RCRI score was significantly associated with risk of death at 1 year after open infrainguinal bypass surgery. However, indication for surgery, as well as factors such as age, ASA-PS status, sex, and emergency surgery, provided additional significant and prognostic information.
increased risk for perioperative morbidity at 30 days. At 1 year, emergent surgery continues to be a risk factor for poor outcome.

Indication for surgery may be a more accurate reflection of a patient’s overall health status compared with the RCRI. The reliability of the RCRI depends on the diagnosis of comorbid conditions. In patients with limited access to health care, an accurate score may not be possible. Furthermore, patients who present with gangrene may be less compliant with medication or may have limited access to preventive healthcare resources, compared with those who present with claudication. About 65% of patients with tissue loss have been found to be taking a beta-blocker, but only 32% were taking an HMG-CoA reductase inhibitor. For this reason, indication for lower extremity surgery, that is, gangrene, may reflect a patient’s undiagnosed comorbidities, serving as a useful objective adjunct to quantify long-term risk. An atherosclerotic burden may manifest itself as an indication for vascular surgery.

The influence of sex on outcomes in these patients has been reported.9,10,22 Our results show that female sex is not associated with in-hospital mortality, but is definitely associated with death after 1 year. This finding may be explained by anatomical differences and difficulty with vascular intervention, extent of disease, and access to health care for preventing complications.8,23,24 Chronic cardiac medication did not show an independent association with outcome in this study.

Table III. One-year mortality rates cross-tabulated by RCRI score and indication for surgery

<table>
<thead>
<tr>
<th>RCRI</th>
<th>Claudication</th>
<th>Rest pain</th>
<th>Tissue</th>
<th>Acute</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0/14 (0)</td>
<td>0/14 (0)</td>
<td>3/50 (6)</td>
<td>1/20 (5)</td>
<td>4/98 (4)</td>
</tr>
<tr>
<td>1</td>
<td>1/14 (7)</td>
<td>2/32 (6)</td>
<td>21/118 (18)</td>
<td>5/20 (25)</td>
<td>29/184 (16)</td>
</tr>
<tr>
<td>2</td>
<td>0/6 (0)</td>
<td>2/25 (8)</td>
<td>29/138 (21)</td>
<td>3/10 (30)</td>
<td>34/179 (19)</td>
</tr>
<tr>
<td>3</td>
<td>0/1 (0)</td>
<td>2/10 (20)</td>
<td>25/80 (31)</td>
<td>2/7 (29)</td>
<td>29/98 (30)</td>
</tr>
<tr>
<td>4</td>
<td>0/0 (0)</td>
<td>0/2 (0)</td>
<td>13/34 (38)</td>
<td>1/2 (50)</td>
<td>14/38 (37)</td>
</tr>
<tr>
<td>5</td>
<td>0/0 (0)</td>
<td>0/0 (0)</td>
<td>4/6 (67)</td>
<td>0/0 (0)</td>
<td>4/6 (67)</td>
</tr>
<tr>
<td>Total</td>
<td>1/35 (3)</td>
<td>6/83 (7)</td>
<td>95/426 (22)</td>
<td>12/59 (20)</td>
<td>114/603 (18.9)</td>
</tr>
</tbody>
</table>

(%) = mortality rate per group.

Fig. 1. Survival from service date to earlier of death or 1 year.
Table IV. Multivariate analysis for 1-year mortality

<table>
<thead>
<tr>
<th>Patient characteristic</th>
<th>OR</th>
<th>CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tissue loss or acute indication(^a)</td>
<td>3.7</td>
<td>1.6-8.5</td>
<td>0.0058</td>
</tr>
<tr>
<td>RCR score</td>
<td>1.5</td>
<td>1.2-1.8</td>
<td>0.0002</td>
</tr>
<tr>
<td>Age</td>
<td>1.04</td>
<td>1.02-1.06</td>
<td>0.0004</td>
</tr>
<tr>
<td>ASA-PS = 4</td>
<td>2.7</td>
<td>1.7-4.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Female</td>
<td>2.1</td>
<td>1.3-3.3</td>
<td>0.002</td>
</tr>
<tr>
<td>Emergency</td>
<td>3.0</td>
<td>1.1-8.1</td>
<td>0.03</td>
</tr>
</tbody>
</table>

There were 113 deaths among 568 patients with rest pain, tissue loss, and acute indications for surgery. There was one 1-year death among 35 patients with claudication. \(^a\)Factors offered in stepwise regression but not selected included dyslipidemia, beta-blockers, and statins, each of which had a p value between 0.07 and 0.10 in univariate analysis.

Our investigation has several limitations. First, it was a retrospective study that relied on medical records based on patient reporting and physician documentation. Second, it is possible that patients with limited access to the healthcare system are unaware of their own comorbidities. Third, although cardiac complications may be associated with noncardiac mortality, cause of death could not be determined in our study population.

**CONCLUSIONS**

Our study confirms that the RCRI is a useful tool for predicting short- and long-term outcomes. We believe that to improve on the RCRI, the indication for surgery should also be considered in the risk assessment of patients undergoing open lower extremity bypass surgery. Mortality rates are significantly different among patients presenting with claudication, rest pain, tissue loss, and acute indications. Furthermore, indication for surgery may guide an informed consent process and further preoperative testing. The lack of prognostic value of indication for surgery for 30-day mortality is of small significance compared with its utility for longer term outcomes. This outcome may be of interest to the perioperative physician and patient alike.

This investigation should prompt further studies in perioperative medicine to consider indication for surgery as an independent risk factor for perioperative and long-term mortality.

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V.K.M. had full access to all the data in the study and takes responsibility for the integrity of these data and the accuracy of their analysis. Study concept and design: V.K.M., B.C.F.; acquisition of data: M.M., B.C.F.; analysis and interpretation of data: V.K.M., C.B., J.E.E.; drafting of the manuscript: V.K.M., B.C.F., C.B., M.M., J.E.E.; critical revision of the manuscript for important intellectual content: V.K.M., B.C.F., C.B., M.M., D.B., J.E.E.; statistical analysis: C.B.; administrative, technical, or material support: M.M.; and study supervision: V.K.M., C.B.*

**REFERENCES**


