Risk prediction of 30-day readmission after infrainguinal bypass for critical limb ischemia

James T. McPhee, MD, Louis L. Nguyen, MD, MBA, MPH, Karen J. Ho, MD, C. Keith Ozaki, MD, Michael S. Conte, MD, and Michael Belkin, MD, Boston, Mass, and San Francisco, Calif

Objective: Hospital readmission after lower extremity bypass is a large cost burden and has become a focal point for policy change directed at disease-specific bundling strategies. The purpose of this study was to evaluate rates and predictors of 30-day readmission from a large, multicenter trial data set.

Methods: We analyzed the PRoject of Ex-Vivo vein graft ENgineering via Transfection III (PREVENT III) data set of 1404 critical limb ischemia (CLI) patients undergoing lower extremity vein graft bypass at 83 North American centers. The primary end point was readmission within 30 days. Secondary end points included graft patency and limb salvage evaluated in the context of readmission. The data set was split into a two-thirds derivation set and a one-third validation set for the purposes of creating a risk prediction model. A whole number integer risk score was assigned to independent predictors of readmission. Summary risk scores were collapsed into categories and defined as low (0-1 points), medium (2-5 points), and high (>5 points).

Results: We analyzed 1356 vein graft bypass patients, of which 23 (1.7%) died in-hospital and were excluded from the readmission analyses. In the derivation data set of 866 patients, 211 (24.4%) were readmitted within 30 days of discharge. The most common reasons for readmission were wound infection in index leg (39.8%), an additional procedure in the index leg (20.8%), and nonvascular reasons (19%). By multivariable analysis, factors associated with 30-day hospital readmission (odds ratio [95% confidence limits]) included female gender (1.5 [1.0, 2.1]), current smoking (1.6 [1.1, 2.4]), in-hospital loss of graft patency (1.8 [1.0, 3.2]), dialysis (2.0 [1.2, 3.2]), and tissue loss (1.7 [1.1, 2.5]). In the derivation set, rates of readmission correlated to risk category. The 30-day readmission rates were 15.6% for low-risk patients (0-1 points), 24.1% for moderate-risk (2-5 points) patients, and 38.0% for high-risk (>5 points) patients. Similarly, in the validation set, the rates were 16.5%, 25.4%, and 38.1% for low-, medium-, and high-risk groups, respectively. Thirty-day readmission was not associated with loss of long-term graft patency but was associated with long-term limb loss (hazard ratio, 2.1; 95% confidence interval, 1.4-3.1; P = .0002).

Conclusions: Readmission after lower extremity bypass for CLI is common (24%). Certain characteristics, such as female gender, current smoking, dialysis-dependence, tissue loss, and in-hospital graft-related events, are associated with increased risk. Readmission is associated with long-term limb loss. These data provide benchmark values for this complex patient population and may prove useful when hospital readmission is used as a quality metric for hospital performance. (J Vasc Surg 2013;57:1481-8.)
the former has been shown to allow for a more discrimi-
nating prediction model.6

The purpose of the current study was to create a simple
risk prediction model to determine the factors that predict
30-day readmission after lower extremity bypass surgery
using a cohort from a previously conducted randomized
controlled trial.

METHODS

Database. This study was a retrospective cohort anal-
ysis using data from a previously conducted multi-
institutional randomized controlled trial, the PROject of
Ex-Vivo vein graft ENgineering via Transfection III
(PREVENT III).7 The details of the PREVENT III data-
base have been previously described7,8 and included 1404
patients who underwent lower extremity bypass surgery
with a vein graft for critical limb ischemia (CLI) (rest pain,
ulceration, or gangrenous tissue loss). Follow-up informa-
tion was available for up to 1 year. For the current study, 48
patients who underwent bypass at Brigham and Women’s
Hospital were excluded because their data were previously
analyzed for a similar work.4

End points. The primary end point was hospital read-
mission ≤30 days of the date of discharge. The readmission
analysis excluded 23 patients who died during the index
hospitalization. Each patient was considered only once in
this analysis. Secondary end points included primary, assis-
ted primary, and secondary patency rates and limb salvage
to out 1 year of follow-up. Graft patency was defined using
standard criteria.9

Statistical analysis. Categoric variables were compared
using $\chi^2$ or the Fisher exact test, where appropriate. Conti-
uous variables were compared using the two-tailed Student
$ t$-test. Univariate predictors of 30-day readmission were
analyzed using unadjusted odds ratios (ORs). For multi-
variable analysis, continuous variables, such as age, weight
(kilograms), length of stay (days), operative time (minutes),
and quality of life characteristics, were dichotomized using
the 75th percentile as the cut point. In-hospital graft events
were defined as loss of primary, assisted, or secondary
patency before the date of discharge from the index
admission. Ordinal variables were collapsed into dichoto-
mous variables for the purpose of risk score development.
Patency and limb salvage rates were compared using the log-
rank test. A Cox proportional hazard model was created to
evaluate predictors of the secondary end point of limb
salvage. This was performed by backward elimination
technique using $P < .05$ for inclusion in the fitted model.
Factors included in the model were readmission status, age,
sex, race, smoking status, dialysis-dependence, diabetes,
hypertension, coronary artery disease/myocardial infarction
(MI), tissue loss indication, prior bypass, inflow vessel,
outflow vessel, postoperative MI, stroke, graft failure,
wound infection, and length of stay.

Risk prediction model. To create and subsequently
test our risk prediction model for hospital readmission after
lower extremity bypass, the initial cohort was randomly
divided into separate derivation and validation data sets.
The derivation set (n = 866) contained two-thirds of the
patients and the validation set (n = 467) contained the
remaining one-third of the initial total cohort. A multi-
variable logistic regression model with hospital readmission
as the dependent variable was created using a backward
elimination technique. A value of $P < .25$ was used as the
cut point for elimination. Factors included in the elimi-
nation model were age, sex, race, diabetes, baseline weight,
hypertension, previous MI, dialysis-dependence, surgical
indication (tissue loss vs rest pain), hyperlipidemia, hyper-
cholesterolemia, liver disease, current smoking, baseline
activity score, baseline pain score and baseline emotional
score derived from the Vascular Quality of Life Question-
naire,10 inflow artery, outflow artery, vein quality (<3 vs
>3 mm) length of surgery, hospital length of stay, hospital
type (private vs academic), concomitant debridement
procedure, in-hospital wound infection, in-hospital MI,
and in-hospital stroke.

Significant multivariable predictors of readmission were
used to create whole-number risk scores. The $\beta$-coefficient
for each significant factor in the final model was divided by
the smallest predictive $\beta$-coefficient (female gender) and
the result was rounded to the nearest whole number,
a technique that has been previously described.11,12 Each
patient in the derivation and validation set was issued an
overall risk score by summing their risk factors. These
summary scores were used to divide the patients into three
clinically relevant groups to create low-, medium-, and
high-risk groups for 30-day readmission. Model discrimi-
nation was assessed with the area under the receiver oper-
ating characteristic curve represented as the C statistic. The
fit of the model was assessed using the Hosmer-Lemeshow
goodness-of-fit test.

Internal validation. The calculated risk score for 30-
day readmission based on the derivation set was applied
to the validation set to allow for comparison between the
two groups. Discrimination of the model in the validation
set was assessed by the C statistic. Model calibration was
assessed with observed-to-expected rates of readmission as
a function of the designated risk categories in the deriva-
tion and validation data sets. The three points on the
observed vs expected figures represent low-, medium-, and
high-risk groups.

RESULTS

After the 48 Brigham and Women’s Hospital patients
were excluded from the 1404 in the PREVENT III cohort,
the remaining 1356 patients comprised the cohort of
interest for this study. Table I reports the baseline char-
acteristics of patients randomly assigned to the derivation
(two-thirds) and validation (one-third) data sets. The
baseline characteristics for the derivation and validation
sets were similar. Both groups were predominantly male
(>60%; $P = .63$), with similar rates of diabetes (>60%;
$P = .68$), current smoking (>25%; $P = .1$), dialysis depen-
dence (~12%; $P = .93$), and tissue loss indications (>70%;
$P = .74$). The 23 patients (1.7%) who died in-hospital after
Table I. Baseline characteristics of lower extremity bypass patients in the derivation and validation data sets

<table>
<thead>
<tr>
<th>Variablea</th>
<th>Derivation set (n = 881)</th>
<th>Validation set (n = 475)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>68.5 (11.6)</td>
<td>68.1 (11.6)</td>
<td>.60</td>
</tr>
<tr>
<td>Median (range)</td>
<td>69 (26-99)</td>
<td>69 (30-95)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td>.63</td>
</tr>
<tr>
<td>Male</td>
<td>569 (64.6)</td>
<td>300 (63.2)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>312 (35.4)</td>
<td>175 (36.8)</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td>.04</td>
</tr>
<tr>
<td>White</td>
<td>618 (70.1)</td>
<td>359 (75.6)</td>
<td></td>
</tr>
<tr>
<td>Non-white</td>
<td>263 (29.9)</td>
<td>116 (24.4)</td>
<td></td>
</tr>
<tr>
<td>Comorbid conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>565 (64.1)</td>
<td>299 (63.0)</td>
<td>.68</td>
</tr>
<tr>
<td>Current smoker</td>
<td>223 (25.4)</td>
<td>142 (29.9)</td>
<td>.1</td>
</tr>
<tr>
<td>Hypertension</td>
<td>732 (83.1)</td>
<td>370 (77.9)</td>
<td>.02</td>
</tr>
<tr>
<td>Prior MI</td>
<td>268 (30.4)</td>
<td>142 (29.9)</td>
<td>.85</td>
</tr>
<tr>
<td>Current dialysis-dependence</td>
<td>108 (12.3)</td>
<td>59 (12.4)</td>
<td>.93</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>889 (44.4)</td>
<td>209 (44.1)</td>
<td>.95</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>396 (45.1)</td>
<td>198 (41.9)</td>
<td>.39</td>
</tr>
<tr>
<td>Indication for procedure</td>
<td></td>
<td></td>
<td>.40</td>
</tr>
<tr>
<td>Rest pain</td>
<td>218 (24.8)</td>
<td>125 (26.5)</td>
<td></td>
</tr>
<tr>
<td>Nonhealing ulcer</td>
<td>338 (38.4)</td>
<td>186 (39.4)</td>
<td></td>
</tr>
<tr>
<td>Gangrene</td>
<td>323 (36.8)</td>
<td>161 (34.1)</td>
<td></td>
</tr>
<tr>
<td>Prior infrainguinal reconstruction</td>
<td>242 (27.5)</td>
<td>123 (25.9)</td>
<td>.56</td>
</tr>
<tr>
<td>Technical details</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflow vessel</td>
<td></td>
<td>252 (53.0)</td>
<td>.25</td>
</tr>
<tr>
<td>Common femoral artery</td>
<td>414 (47.0)</td>
<td>252 (53.0)</td>
<td></td>
</tr>
<tr>
<td>Superficial femoral artery</td>
<td>226 (26.6)</td>
<td>104 (21.9)</td>
<td></td>
</tr>
<tr>
<td>Profunda femoral artery</td>
<td>35 (4.0)</td>
<td>20 (4.2)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>206 (23.4)</td>
<td>99 (20.8)</td>
<td></td>
</tr>
<tr>
<td>Recipient artery</td>
<td></td>
<td></td>
<td>.57</td>
</tr>
<tr>
<td>Popliteal artery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above knee</td>
<td>89 (10.1)</td>
<td>54 (11.4)</td>
<td></td>
</tr>
<tr>
<td>Below knee</td>
<td>197 (22.4)</td>
<td>104 (21.9)</td>
<td></td>
</tr>
<tr>
<td>Tibial</td>
<td>461 (52.3)</td>
<td>258 (54.2)</td>
<td></td>
</tr>
<tr>
<td>Pedal</td>
<td>108 (12.2)</td>
<td>52 (11.0)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>26 (3.0)</td>
<td>7 (1.5)</td>
<td></td>
</tr>
</tbody>
</table>

MI, Myocardial infarction; SD, standard deviation. 
*Data are shown as number (%) and continuous data as indicated.

their index procedure were excluded from readmission risk analyses. 

In the two-thirds derivation data set (n = 866), the overall rate of 30-day readmission was 24.4% (n = 211). The reasons for readmission were wound infection in the index leg (39.8%), an additional procedure in the index leg (20.8%), nonvascular reasons (19%), index graft failure (6.2%), procedural (6.2%), new peripheral arterial disease (2.8%), stroke (2.4%), MI (0.96%), and unknown (1.9%). Univariate analysis of the derivation data set showed the factors that were significantly associated with 30-day readmission were (OR [95% confidence limits]): female gender (1.5 [1.1, 2.0]; P = .019), dialysis-dependence (1.7 [1.1, 2.6]; P = .016), and in-hospital loss of graft patency (1.9 [1.2, 3.1]; P = .39; Table II).

By multivariable backward elimination, after adjustment for other factors, five variables were significantly predictive of 30-day readmission in the derivation data set (OR [95% confidence limits]): female gender (1.5 [1.0, 2.1]; P = .036), current smoking (1.6 [1.1, 2.4]; P = .022), dialysis-dependence (2.0 [1.2, 3.2]; P = .006), in-hospital graft event (1.8 [1.0, 3.2]; P = .037), and tissue loss as the surgical indication (1.7 [1.1, 2.5]; P = .02). Table III reports the β-coefficients and calculated risk scores associated with these factors. Ultimately, female gender and current smoking status were each assigned a risk score of 1, dialysis-dependence and in-hospital graft events were each assigned a risk score of 2, and tissue loss as the surgical indication was assigned a score of 3.

The potential 30-day readmission risk scores ranged from 0 to 9. No patients had a score of 9, and only one patient had a score of 8 (Table IV). The risk scores were collapsed into three risk groups and defined as low

Table II. Unadjusted odds ratios of 30-day readmission in the derivation data set

<table>
<thead>
<tr>
<th>Variables</th>
<th>OR (95% CL)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age ≥ 75 (vs &lt;75) years</td>
<td>1.0 (0.72, 1.4)</td>
<td>.99</td>
</tr>
<tr>
<td>Female gender (vs male)</td>
<td>1.5 (1.1, 2.0)</td>
<td>.019</td>
</tr>
<tr>
<td>Non-white race (vs white)</td>
<td>1.2 (0.83, 1.6)</td>
<td>.39</td>
</tr>
<tr>
<td>Comorbid conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus (vs none)</td>
<td>1.3 (0.94, 1.8)</td>
<td>.11</td>
</tr>
<tr>
<td>Current smoker (vs none)</td>
<td>1.1 (0.79, 1.6)</td>
<td>.53</td>
</tr>
<tr>
<td>Hypertension (vs none)</td>
<td>1.2 (0.77, 1.8)</td>
<td>.44</td>
</tr>
<tr>
<td>Previous MI (vs none)</td>
<td>.99 (0.71, 1.4)</td>
<td>.97</td>
</tr>
<tr>
<td>Current dialysis (vs none)</td>
<td>1.7 (1.1, 2.6)</td>
<td>.016</td>
</tr>
<tr>
<td>Indication for procedure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tissue loss (vs rest pain)</td>
<td>1.3 (0.93, 2.0)</td>
<td>.11</td>
</tr>
<tr>
<td>Operative characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior infrainguinal reconstruction</td>
<td>.75 (0.52, 1.1)</td>
<td>.11</td>
</tr>
<tr>
<td>CFA inflow (vs other)</td>
<td>.84 (0.61, 1.1)</td>
<td>.26</td>
</tr>
<tr>
<td>Popliteal outflow (vs other)</td>
<td>.80 (0.57, 1.1)</td>
<td>.21</td>
</tr>
<tr>
<td>Surgery length &gt;5.25 hours</td>
<td>1.1 (0.76, 1.5)</td>
<td>.69</td>
</tr>
<tr>
<td>(vs ≤5.25 hours)</td>
<td>1.0 (0.76, 1.4)</td>
<td>.80</td>
</tr>
<tr>
<td>Postoperative factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharged on oral anticoagulant</td>
<td>1.1 (0.80, 1.6)</td>
<td>.50</td>
</tr>
<tr>
<td>In-hospital wound infection</td>
<td>.98 (0.56, 1.7)</td>
<td>.94</td>
</tr>
<tr>
<td>In-hospital MI</td>
<td>.76 (0.36, 1.6)</td>
<td>.47</td>
</tr>
<tr>
<td>In-hospital graft event</td>
<td>1.9 (1.2, 3.1)</td>
<td>.01</td>
</tr>
</tbody>
</table>

CFA, Common femoral artery; CI, confidence limits; MI, myocardial infarction; OR, odds ratio.

Table III. Multivariable predictors of 30-day readmission and risk score calculation in the derivation data set

<table>
<thead>
<tr>
<th>Predictor</th>
<th>β-coefficient</th>
<th>Integer score</th>
<th>OR (95% CL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female (vs male)</td>
<td>.190</td>
<td>1</td>
<td>1.5 (1.0, 2.1)</td>
</tr>
<tr>
<td>Current smoker (vs not)</td>
<td>.241</td>
<td>1</td>
<td>1.6 (1.1, 2.4)</td>
</tr>
<tr>
<td>Dialysis-dependent (vs not)</td>
<td>.341</td>
<td>2</td>
<td>2.0 (1.2, 3.2)</td>
</tr>
<tr>
<td>In-hospital graft event (vs none)</td>
<td>.500</td>
<td>2</td>
<td>1.8 (1.0, 3.2)</td>
</tr>
<tr>
<td>Tissue loss (vs rest pain)</td>
<td>.506</td>
<td>3</td>
<td>1.7 (1.1, 2.5)</td>
</tr>
</tbody>
</table>

CI, Confidence limits; OR, odds ratio.
(0-1 points), medium (2-5 points), and high (>5 points).
As shown in Fig 1 in the derivation set, the readmission rates were 15.6% for lowest-risk group, 25.1% for the medium-risk group, and 38.0% for the high-risk group. In the validation set, the readmission rates were 16.5% for the lowest risk group, 25.4% for the medium-risk group, and 38.1% for the high-risk group. Table V reports these rates along with the associated odds of readmission by risk category for the derivation and validation set.

The fitted model for risk of readmission displayed only a modest ability to discriminate between those who are and are not readmitted, with a C statistic of 0.60. This was associated with a Hosmer-Lemeshow $P = .36$, indicating the rate of observed-to-expected readmissions in the derivation set adequately fit the data. The validation set also displayed only a modest ability to discriminate, with a C statistic of 0.58. Fig 2 displays the observed vs expected readmission rates for the derivation and validation set by risk category, which overall displayed excellent calibration.

**Secondary outcomes.** By univariate analysis, patients who were readmitted ≤30 days of discharge had similar rates of 1-year primary patency as those who were not readmitted (52.4% ± 3.8% vs 56.5% ± 2.1%; $P = .10$). The two groups also had similar 1-year rates of assisted primary patency (72.9% ± 3.3% vs 74.8% ± 1.8%; $P = .36$) and secondary patency (77.9% ± 3.1% vs 78.6% ± 1.6%; $P = .34$). Patients who were readmitted ≤30 days had significantly lower rates of limb salvage at 1 year than those who were not readmitted (78.3% ± 3.0% vs 89.6% ± 1.2%; $P < .0001$; Fig 3).

By multivariable Cox regression analysis, 30-day readmission remained predictive of long-term limb loss (hazard ratio [HR], 2.1; 95% confidence interval, 1.4-3.0; $P = .0003$) after adjustment for other factors. Other predictors of limb-loss included diabetes, tibial or pedal outflow (vs popliteal), early graft-related events, and index hospital length of stay >10 days (Table VI).

**DISCUSSION**

This retrospective cohort study using data from a multi-center prospective randomized controlled trial has demonstrated an overall 24% rate of 30-day readmission after lower extremity bypass for CLI indications. This rate varies by risk category, with the lowest-risk group demonstrating a rate of 15.6%, whereas the medium-risk and high-risk groups had respective rates of 25.1% and 38.0%. Significant predictors of readmission included female gender, dialysis-dependence, current smoking, tissue loss indications, and in-hospital graft-related events. After adjustment for other factors, 30-day readmission was associated with long-term limb loss.

Readmission to the hospital after medical stays and surgical procedures has been identified as a potential area for quality improvement. Describing readmissions as “expensive, adverse events for patients,” the Centers for Medicare & Medicaid Services (CMS) has begun public reporting of risk-adjusted readmission rates after certain medical conditions, including MI, heart failure, and pneumonia. A recent publication by Brooke et al5 appropriately identified vascular surgery procedures as a likely target of this quality metric in the near future. They cited the recent results of a Medicare claims-based study by Jencks et al,3 which found vascular surgery procedures had the second highest readmission rate, at 23.9%, of all medical conditions and procedures evaluated as one possible reason for this specialized interest. Of note in the Medicare study, rates were not stratified by procedure type but rather reflect a global readmission rate.

After a comprehensive review of readmissions after vascular surgery procedures, a recent single-institution report from the University of Pennsylvania by Jackson et al15 identified open lower extremity bypass in conjunction with CLI as having the highest rate of unplanned readmission (>14% for both). Our group also recently conducted a retrospective cohort study from our own institution in which we found an overall unplanned readmission rate of 24%.
23% after lower extremity bypass surgery for all indications. Dialysis-dependence and congestive heart failure were the preoperative factors most strongly associated with readmission in that analysis.

The goal in this current study was to more formally risk-stratify patients using factors that would be known up until the date of hospital discharge, including preoperative characteristics, intraoperative factors, and in-hospital postoperative factors, to assess an individual patient’s risk of readmission on the date of discharge. We found similar results from the multicenter data set as we did in our own institutional series, including an overall readmission rate of 24% in the derivation data set. Tissue loss remained a strong predictor of readmission in both studies, as did dialysis-dependence and early graft-related events. Unique findings in the current multicenter-based work were the association with readmission of female gender and current smoking.

Although the etiology is unclear, female gender has been previously shown to be associated with wound complications in lower extremity bypass surgery, which was the most common reason for readmission in this study (~40%). That current smoking predicted readmission is not surprising. The untoward effects of current smoking compared with former or never smokers on wound-healing are well-described. Current smoking is also associated with early graft failure in lower extremity bypass. Graft-related and wound-related events were both common reasons for readmission in this study.

It is noteworthy that even the lowest-risk group in the derivation and validation data sets had readmission rates >15%. This indicates that even in the most optimal circumstances in lower extremity bypass for CLI, we can expect a relatively high basal rate of hospital readmission.

It is important to note that the only truly modifiable risk factor of the identified predictors in this study is tobacco use. The presence of other factors, such as tissue loss, hemodialysis, in-hospital graft events, and gender may be useful to identify and predict at-risk patients at the time of discharge. Identification of these risk factors would allow for extra measures to be taken, such as close clinical follow-up, increased level of nursing care, or delay of discharge until ongoing wound/graft or dialysis treatment-related issues can be addressed. That these characteristics are not modifiable is of particular importance from a policy standpoint, which will ultimately have the goal of decreasing readmission rates with financial penalties. The findings in this study could contribute to decision modeling or cost-effectiveness studies to determine how best to work within the confines of these high-risk characteristics. Studies looking specifically at the cost-effectiveness of prolonging a hospital stay to further address a complication or unrelated medical problem vs earlier discharge and a shorter interval return to care as an

<table>
<thead>
<tr>
<th>Risk</th>
<th>Derivation set</th>
<th>Validation set</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Readmission rate</td>
<td>OR (95% CI)</td>
</tr>
<tr>
<td>Low (0-1)</td>
<td>15.6 Ref</td>
<td></td>
</tr>
<tr>
<td>Moderate (2-5)</td>
<td>25.1 1.8 (1.1-2.9)</td>
<td></td>
</tr>
<tr>
<td>High (&gt;5)</td>
<td>38.0 3.3 (1.7-6.3)</td>
<td></td>
</tr>
</tbody>
</table>

CI, Confidence interval; OR, odds ratio.

Fig 2. A, The observed vs expected rate of readmission for the derivation data set. The data points represent low-, medium-, and high-risk groups. B, The observed vs expected rate of readmission for the validation data set. The data points represent low-, medium-, and high-risk groups.
inpatient or outpatient could better address the concern over how best to manage the higher-risk patient groups without unnecessarily penalizing individuals and institutions that are dedicated to caring for them.

An additional remarkable finding is the association between 30-day readmission and long-term limb loss in this study (HR, 2.1). This was a confirmatory finding from the results of our institutional-based study in which 30-day readmission was also predictive of loss of limb (HR, 1.7). In both analyses, this factor stood out even after adjustment for graft patency. Although no direct causality is implied, this indicates that readmission to the hospital is a surrogate reminder of the complexity of this disease process and may affect long-term outcomes.

It bears mentioning that the degree of discrimination provided by the fitted model in the derivation set was only modest, with a C statistic of 0.60. Likewise, the area under the receiver operating characteristic curve in the validation set was even less predictive, at 0.58. This inability to

Table VI. Cox proportional regression for predictors of limb loss in the derivation set

<table>
<thead>
<tr>
<th>Predictor</th>
<th>HR (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-day readmission</td>
<td>2.1 (1.4-3.1)</td>
<td>.0002</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.8 (1.1-2.9)</td>
<td>.015</td>
</tr>
<tr>
<td>Dialysis-dependence</td>
<td>1.6 (1.0-2.7)</td>
<td>.05</td>
</tr>
<tr>
<td>Long length of stay (&gt;10 days)</td>
<td>1.5 (1.0-2.2)</td>
<td>.05</td>
</tr>
<tr>
<td>Tibial or pedal outflow target</td>
<td>1.9 (1.1-3.2)</td>
<td>.01</td>
</tr>
<tr>
<td>In-hospital graft event</td>
<td>2.3 (1.3-3.8)</td>
<td>.002</td>
</tr>
</tbody>
</table>

CI, Confidence interval; HR, hazard ratio.
reliably discriminate patients that are truly high-risk vs low-risk for readmission has been extensively studied in the medical literature. A recent large systematic review by Kanasagara et al, which evaluated 26 readmission risk prediction models for medical patients, found that most models that rely on purely clinical information, such as comorbidities, generally tended to have poor discriminative ability. They did note that studies that incorporated more social factors, such as functional status, social support network, and living status in their models generally performed better for predicting readmission. Although the systematic review excluded surgical studies and is therefore not directly comparable to our work, the potential for poor model performance in surgical studies was appreciated by Brooke et al in their conceptual framework for ideal risk prediction in vascular surgery. In their recent report, they commented that “risk standardized readmission rates in vascular surgery will need to include existing variables currently collected in most health care systems as well as contextual variables aimed at measuring social, economic, and community-based support.”

In the current study, we did include quality of life variables in the regression model in an attempt to address this issue. We included the Vascular Quality of Life Questionnaire baseline activity score, pain score, and emotional scores that were collected as part of the initial PREVENT III study. Although the inclusion of these quality of life variables did improve the C statistic of the fitted model, none of the measured sociodemographic factors remained significant in the final model and, therefore, did not contribute to the prediction score calculation. It might be that more granular information, such as income level, living situation, and more well-defined functional status parameters, could improve the performance of prediction models such as ours.

Other limitations in this study include that the initial PREVENT III study did not capture whether readmissions were planned or unplanned, which may have contributed to the limited performance of the risk prediction model to some degree. That said, we found from our previous institutional review that just 2.7% of readmissions to some degree. That said, we found from our previous models such as ours, parameters, could improve the performance of prediction models.

In summary, lower extremity bypass procedures for CLI have a relatively high rate of 30-day hospital readmission. Patients can be stratified by readily available risk factors before discharge to determine how best to address their disposition and follow-up. The limited performance of the risk prediction model in discrimination is partially due to the inclusion of available sociodemographic factors, which highlights how complex a medical condition CLI truly is.

CONCLUSIONS

On the basis of the multi-institutional data, the expected overall readmission rate after lower extremity bypass for CLI is >20%. Until reliable models are developed with a high degree of discrimination for identifying vascular surgical patients at risk of hospital readmission, policy makers should be wary of widely instituting financial penalties for this difficult-to-predict quality metric.

AUTHOR CONTRIBUTIONS

Conception and design: JM, MB
Analysis and interpretation: JM, LN, MB
Data collection: JM, KH
Writing the article: JM
Critical revision of the article: CO, MC, LN, MB
Final approval of the article: JM, MB
Statistical analysis: JM, LN
Obtained funding: Not applicable
Overall responsibility: MB

REFERENCES


Submitted Sep 20, 2012; accepted Nov 14, 2012.

INVITED COMMENTARY

Ahmed M. Abou-Zam zam Jr, MD, Loma Linda, Calif

McPhee et al have reviewed the Project of Ex-Vivo graft Engineering via Transsection III (PREVENT III) database of patients undergoing lower extremity vein bypass for critical limb ischemia (CLI) and evaluated the rates and predictors of 30-day readmissions. In the nearly 1400 patients, there was an overall 30-day readmission rate of 24%. The factors predictive of readmission included female gender, current smoking, dialysis-dependence, in-hospital graft-related events, and tissue loss as an indication for surgery. A simple scoring system using these values had a moderate correlation with the readmission rates. The PREVENT III data have given interesting benchmarks for outcomes after vein bypass for CLI such as patency rates and wound complications. In the current report, the most common reason for readmission was wound infection (40%). However, nearly 21% of readmissions were for an “additional procedure in the index limb.” This clouds the issue of whether these readmissions were planned or unplanned. In many instances, patients with CLI require multiple interventions for limb salvage. Thus, patients who require minor foot amputations as a routine part of their treatment were identified as readmissions. However, the PREVENT III database did not discriminate between planned and unplanned readmissions. To overcome this, the authors point to a report of their own experience with >1500 bypasses with a 2.5% readmission rate in which only 3% of readmissions were planned. Although this may be true at their institution, extrapolation to the PREVENT III trial may not be reliable. Only a prospective study with unplanned readmission as a primary end point would solve this issue, and more data, such as in the current report, are necessary to lay the groundwork for meaningful outcomes benchmarks in CLI. The current report demonstrates that although the predictors of readmission cannot be modified, they can be identified at the time of discharge. This may help target patients who need special postdischarge care or delayed discharge to prevent readmission. In fast-track colon surgery, a simple measure, such as extending the length of stay by 1 day, reduced readmission rates in half. Perhaps further studies in CLI will identify similar measures to avoid readmissions.

The relevance of this current report rests on the very real impact that value-based purchasing is having on hospitals and providers. Identifying readmissions ≤30 days as a measure of quality of care is currently being done for acute myocardial infarction, heart failure, and pneumonia. Centers for Medicare and Medicaid Services has proposed “hospital-wide all-cause unplanned readmission” as a measure to be followed beginning in fiscal year 2015. To have relevant core measures, the anticipated outcomes must be known to identify provider outliers. Perhaps patients with CLI and other conditions requiring multiple planned interventions should be excluded from certain metrics. In view of value-based purchasing, having good data on a wide scale will help protect our best-intentioned treatments from unnecessary punitive measures when providing care to patients with CLI.

REFERENCES


