Surgical Ineligibility and Mortality Among Patients With Unprotected Left Main or Multivessel Coronary Artery Disease Undergoing Percutaneous Coronary Intervention

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Background—Decisions to proceed with surgical versus percutaneous revascularization for multivessel coronary artery disease are often based on subtle clinical information that may not be captured in contemporary registries. The present study sought to evaluate the association between surgical ineligibility documented in the medical record and long-term mortality among patients with unprotected left main or multivessel coronary artery disease undergoing percutaneous coronary intervention.

Methods and Results—All subjects undergoing nonemergent percutaneous coronary intervention for unprotected left main or multivessel coronary artery disease were identified at 2 academic medical centers from 2009 to 2012. Documentation of surgical ineligibility was assessed through review of electronic medical records. Cox proportional hazard models adjusted for known mortality risk factors were created to assess long-term mortality in patients with and without documentation of surgical ineligibility. Among 1013 subjects with multivessel coronary artery disease, 218 (22%) were deemed ineligible for coronary artery bypass graft surgery. The most common explicitly cited reasons for surgical ineligibility in the medical record were poor surgical targets (24%), advanced age (16%), and renal insufficiency (16%). After adjustment for known risk factors, documentation of surgical ineligibility remained independently associated with an increased risk of in-hospital (odds ratio, 6.26; 95% confidence interval, 2.16–18.15; P<0.001) and long-term mortality (hazard ratio, 2.98; 95% confidence interval, 1.88–4.72, P<0.001) after percutaneous coronary intervention.

Conclusions—Documented surgical ineligibility is common and associated with significantly increased long-term mortality among patients undergoing percutaneous coronary intervention with unprotected left main or multivessel coronary disease, even after adjustment for known risk factors for adverse events during percutaneous revascularization. (Circulation. 2014;130:2295-2301.)

Key Words: eligibility determination ▪ percutaneous coronary intervention ▪ risk adjustment ▪ surgery

The optimal revascularization strategy for patients with left main or multivessel coronary artery disease has been an important focus for comparative effectiveness research. Several cohort studies and meta-analyses have suggested that coronary artery bypass graft surgery is associated with reduced adverse events compared with percutaneous coronary intervention (PCI) for revascularization of these patients. Additional randomized trials have confirmed that diabetic patients with this coronary anatomy may particularly benefit from surgical revascularization, although outcomes among nondiabetic patients are similar. With this in mind, clinical guidelines and appropriate use criteria have favored surgical revascularization among patients with left main or multivessel coronary artery disease when there are no other extenuating circumstances. In clinical practice, however, physicians commonly encounter patients who would have been excluded from clinical trials because of significant medical comorbidities and thus may not be subject to their findings.

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The most compelling reason clinicians may choose one revascularization strategy over another is that a patient is deemed eligible for only one of the potential options. The determination of eligibility for surgical revascularization is inherently subjective and may be attributable to factors such as the perceived frailty of the patient or the quality of the distal arteries to accept bypass grafts. Several of these characteristics are not measured or are too subtle to be captured in procedural registries and thus are not incorporated into commonly used risk models for percutaneous revascularization. Therefore, these risk models may inadequately characterize
procedural risk in several situations in which they are commonly used: comparative effectiveness research, assessment of hospital quality, and clinical decision making. Previous examination of the prevalence and impact of documented ineligibility for surgical revascularization has been limited to a single study of patients with unprotected left main disease. There are limited data examining surgical ineligibility among the broader population of patients with “surgical anatomy,” including patients with multivessel coronary artery disease.

With this in mind, the present study sought to examine the frequency of documented surgical ineligibility among patients with known unprotected left main or multivessel coronary artery disease undergoing PCI and to assess the association between surgical ineligibility and mortality after adjustment for risk factors routinely used to predict mortality in clinical registries for PCI.

**Methods**

**Population**

All patients presenting to 2 academic medical centers within an integrated health system (Brigham and Women’s Hospital and Massachusetts General Hospital) who undergo percutaneous or surgical coronary revascularization are included in an ongoing institutionally sponsored registry, the Partners Long-Term Outcomes Database. This registry includes data fields for the National Cardiovascular Data Registry CathPCI Registry and the Society of Thoracic Surgeons data set and relies on linkage to the National Death Index to assess long-term mortality using direct identifiers. The present project focused on patients with coronary anatomy suitable for surgical revascularization who subsequently underwent PCI. Surgical anatomy was defined as one of the following: unprotected left main coronary artery disease (>50%), 3-vessel coronary artery disease (>70%), or 2-vessel coronary artery disease with stenosis (>70%) in the proximal left anterior descending artery as defined in the appropriate use criteria for PCI.

To ensure that only nonemergent cases were included, subjects who underwent emergent revascularization for cardiac arrest, cardiogenic shock, or ST-segment–elevation myocardial infarction were excluded from the analysis. Patients with a history of prior coronary artery bypass graft surgery were also excluded because they represent a subgroup of patients for whom the underlying coronary anatomy and risks of repeat surgical revascularization are unique. The present project has been reviewed and approved with a waiver of informed consent from the institutional review board at Partners Healthcare.

**Measurements**

Clinical and procedural information was abstracted from the electronic medical record and included in the institutional registry. The entire electronic medical record, including admission notes, consult notes, nursing notes, outpatient notes, catheterization reports, and discharge summaries, was then queried to identify the presence of a cardiothoracic surgery consult note or explicit documentation of surgical ineligibility at any time before percutaneous revascularization. Surgical ineligibility was defined by the treating clinicians using terms such as “ineligible for surgery” or “too high risk for surgery” independently of the views of the physician chart abstractors. Therefore, subjects who did not have clear and explicit documentation of surgical ineligibility were considered eligible for bypass surgery. Similarly, subjects with a documented patient preference for percutaneous revascularization were also deemed eligible for surgery and noted to have explicit documentation of a discussion regarding treatment options. For those who were deemed ineligible, the explicitly documented reasons for surgical ineligibility in the medical record were recorded and further categorized according to a previously published taxonomy. To assess interobserver variability, 2 independent, blinded physicians reviewed the electronic medical record for a random 10% of the cohort, and the results were compared. Long-term mortality was assessed through a review of the National Death Index and subsequent linkage with the institutional registry, as described previously.

**Statistical Analysis**

Summary statistics were reported as means with standard deviations for continuous variables or medians and interquartile ranges for nonnormally distributed continuous data. We used \( r \) tests and Mann-Whitney \( U \) tests to compare normally and nonnormally distributed continuous variables, respectively, and \( \chi^2 \) tests were used to evaluate differences in proportions. Interobserver variability was assessed with the \( \kappa \) statistic. Kaplan-Meier survival curves were generated, stratified by the presence or absence of surgical ineligibility documentation, and log-rank tests were used to compare the curves. With the use of a previously validated model for procedural risk from the National Cardiovascular Data Registry CathPCI data set, logistical regression models were created with and without the addition of documented surgical ineligibility as a covariate to assess in-hospital mortality. Similar Cox proportional hazards models with and without documentation of surgical ineligibility were also created to assess long-term mortality. The variables incorporated into both of these models included demographic characteristics (age, body mass index), medical history (cerebrovascular disease, heart failure, peripheral vascular disease, diabetes mellitus, renal disease requiring hemodialysis, prior PCI), cardiac function (ejection fraction), presentation (cardiogenic shock, ST-elevation myocardial infarction), and angiographic characteristics (in-stent thrombosis, chronic total occlusion, disease in the left main coronary artery, disease in the proximal left anterior descending coronary artery, multivessel coronary artery disease). These models were then used to calculate predicted in-hospital and long-term mortality, respectively. To quantify the extent to which surgical ineligibility improved mortality prediction over the National Cardiovascular Data Registry risk score, we calculated the adjusted hazard ratio and integrated discrimination index for surgical ineligibility as described previously. \( C \) Statistics were also computed for the model with and without the addition of surgical ineligibility as a covariate. These \( C \) statistics were subsequently compared by use of the the method of Delong, the standard method to compare correlated or nested \( C \) statistics. All statistical analyses were performed with SAS 9.3 (SAS Institute Inc, Cary, NC). A value of \( \text{P}<0.05 \) was considered statistically significant.

**Results**

**Population**

Among 6960 subjects undergoing nonemergent PCI from 2009 to 2012, 1013 (15%) had unprotected left main or multivessel coronary artery disease. Using all available documents in the electronic medical record, the treating clinicians deemed 218 subjects (22%) ineligible for surgical revascularization (Figure 1). The interobserver agreement of assessing documentation of surgical ineligibility within the electronic medical record was high (\( \kappa=0.923; \) 95% confidence interval [CI], 0.837–1.000).

**Demographics**

The demographic characteristics for those with documentation of surgical ineligibility and those without are reproduced in Table 1. Ineligible subjects were older (72 versus 67 years; \( \text{P}<0.001 \)) and more likely to be female (42% versus 66%; \( \text{P}=0.039 \)). A greater proportion of patients deemed ineligible for surgery had concomitant cerebrovascular disease (27% versus 13%; \( \text{P}<0.001 \)), chronic lung disease (30% versus 14%; \( \text{P}<0.001 \)), congestive heart failure (38% versus 12%; \( \text{P}<0.001 \)), diabetes mellitus (45% versus 38%; \( \text{P}=0.039 \)), hypertension (92% versus 86%; \( \text{P}=0.015 \)), peripheral artery disease (36% versus 15%; \( \text{P}<0.001 \)), and prior myocardial
The unadjusted in-hospital mortality among patients under- 
Mortality
insufficiency (16%) were the most commonly cited character-
poor surgical targets (24%), advanced age (16%), and renal 
(37%), the discharge summary (24%), or the cardiac catheter-
Figure 1. Study population. Flow diagram depicting inclusion and 
exclusion criteria for analysis.

infarction (52% versus 31%; P<0.001). The predicted in-hos-
pital mortality for those who were surgically ineligible was 
also increased (0.023 versus 0.009; P<0.01).

Angiography
The angiographic characteristics for those with and without 
documentation of surgical ineligibility are shown in Table 2. 
Subjects ineligible for surgical revascularization were more 
likely to undergo procedures through the femoral approach 
(81% versus 63%; P<0.001). A larger proportion of patients 
deemed ineligible for surgery had left main disease (33% ver-
sus 10%; P<0.001) and had high-complexity lesions (51% 
versus 34%; P<0.001). The number of lesions (P<0.001), 
stents placed (P<0.001) and the length of stents (P<0.001) 
were all significantly greater among surgically ineligible 
patients undergoing percutaneous revascularization. Subjects 
deemed eligible for surgical revascularization, however, had a 
greater number of vessels revascularized (P<0.001).

Ineligibility
The sources of documentation for surgical ineligibility are 
included in Table 3. As shown, a documented evaluation by 
the cardiothoracic surgery service was present in 95 of the 
1013 patients (9%) undergoing percutaneous revascularization 
with surgical anatomy. In the 218 patients deemed ineligible, 
formal surgical evaluation and documentation were identified 
in 63 of the 218 patients (29%). For those deemed ineligible 
for surgery, the majority of documentation addressing surgi-
cal candidacy was obtained from a cardiology consult note 
(37%), the discharge summary (24%), or the cardiac catheter-
ization report (21%) detailing the revascularization procedure. 
The majority of patients considered eligible for surgery did 
not have explicit documentation discussing surgical candidacy 
in the electronic medical record (81%). As shown in Table 4, 
poor surgical targets (24%), advanced age (16%), and renal 
insufficiency (16%) were the most commonly cited character-
istics deemed to significantly increase surgical risk.

Mortality
The unadjusted in-hospital mortality among patients under-
going percutaneous revascularization was greater for those 
deemed ineligible for cardiac surgery (15 of 218, 7%) com-
pared with those who were eligible for the procedure (5 of 
793, 1%; P<0.001). Unadjusted long-term mortality was also 
significantly greater in subjects deemed ineligible for 
surgery compared with those who were considered surgical 
candidates, as shown in Figure 2 (hazard ratio, 4.81; 95% 
CI, 3.12–7.40). After adjustment for predicted mortality risk, 
surgical ineligibility remained independently associated with 
increased odds of in-hospital death (odds ratio, 6.26; 95% CI, 
2.16–18.15; P<0.001) and long-term mortality (hazard ratio, 
2.98; 95% CI, 1.88–4.72; P<0.001). The addition of surgical 
ineligibility to the previously validated risk-adjustment model 
significantly improved the predictive capability of the model 
(c statistic, 0.753 of National Cardiovascular Data Registry 
risk score versus 0.792 including surgical ineligibility vari-
able; P<0.01). The integrated discrimination improvement 
after the addition of surgical ineligibility to the model was 
0.04 (95% CI, 0.02–0.05), and the relative integrated dis-
tristion improvement was 0.40 (95% CI, 0.21–0.60), sug-
gest ing marked improvement in risk discrimination with the 
addition of surgical ineligibility to the risk model.

Discussion
The present study evaluated >1000 consecutive patients with 
left main or multivessel coronary artery disease undergoing 
percutaneous revascularization in an integrated health system. 
Within this population, we found that documented surgical 
ineligibility was common and was associated with signific-
antly greater in-hospital and long-term mortality even after 
accounting for risk factors used in a contemporary and widely 
used risk-adjustment model for percutaneous revasculariza-
tion. In fact, the addition of surgical ineligibility as a covari-
te to this model significantly improved its ability to predict 
mortality. These findings have important implications for 
comparative effectiveness research, the evaluation of hospital 
quality and procedural appropriateness, and the application of 
risk-prediction estimates to guide clinical decision making.

Comparative Effectiveness Research
The optimal revascularization strategy for patients with mul-
tivessel coronary artery disease has long been a subject of 
interest in comparative effectiveness research. Over the last 
3 decades, numerous randomized trials have been performed 
to evaluate clinical outcomes among those treated with surgi-
cal or percutaneous revascularization.\textsuperscript{18} \textsuperscript{34} Observational data, 
however, have not always remained consistent with these 
findings.\textsuperscript{19,20} Previous research has demonstrated that surgical 
ineligibility, a characteristic often not measured in contempo-
ary observational data sets, was associated with a 5- to 6-fold 
increase in mortality among 101 patients undergoing unpro-
tected left main PCI.\textsuperscript{12} Our results expand on these findings 
by including all patients with coronary anatomy that would 
favor surgical revascularization according to current profes-
sional society guidelines and appropriate use criteria: those 
with 3-vessel coronary artery disease or 2-vessel disease with a 
severe stenosis in the proximal left anterior descending artery. 
The data demonstrate that documentation of surgical ineligibility 
confers additional risk in these populations as well, even 
after adjustment for contemporary risk factors. It is possible
that surgical ineligibility in itself may represent a variety of other clinical characteristics that are poorly captured in administrative or clinical data sets, including general frailty or poor psychosocial support. As a result of both their high prevalence and large effect size, these unmeasured characteristics have the potential to undermine the results of large observational studies, even those using rigorous statistical methods to limit confounding.21

### Hospital Quality Assessment and Appropriateness

Risk-adjusted mortality is a commonly used benchmark to assess hospital PCI quality. The accuracy of such reports hinges, in part, on the inclusion of prognostically important variables in risk-adjustment models and their distribution among hospitals.22 In Massachusetts, where these data are used to publicly profile hospital performance, documenting PCI cases done for compassionate use was found to significantly improve mortality risk prediction and to attenuate the decline in procedures performed in the setting of cardiogenic shock.23 Similarly, our findings support the idea that documented surgical ineligibility may be an important variable to consider in risk-adjustment models used for hospital quality assessment.

### Table 1. Demographic Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Ineligible (n=218)</th>
<th>Eligible (n=793)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>72±12</td>
<td>67±12</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>187 (58)</td>
<td>522 (66)</td>
<td>0.039</td>
</tr>
<tr>
<td>Race, n (%)</td>
<td>9 (4)</td>
<td>22 (3)</td>
<td>0.117</td>
</tr>
<tr>
<td>Asian</td>
<td>10 (5)</td>
<td>35 (4)</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>13 (6)</td>
<td>39 (5)</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>1 (1)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Native American</td>
<td>1 (1)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>184 (84)</td>
<td>676 (85)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1 (1)</td>
<td>21 (3)</td>
<td></td>
</tr>
<tr>
<td>Insurance payer, n (%)</td>
<td>61 (28)</td>
<td>338 (43)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Commercial</td>
<td>154 (71)</td>
<td>445 (56)</td>
<td></td>
</tr>
<tr>
<td>International</td>
<td>0 (0)</td>
<td>3 (1)</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>3 (1)</td>
<td>7 (1)</td>
<td></td>
</tr>
<tr>
<td>Presenting symptoms, n (%)</td>
<td>76 (35)</td>
<td>146 (18)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No angina</td>
<td>23 (11)</td>
<td>190 (24)</td>
<td></td>
</tr>
<tr>
<td>Stable angina</td>
<td>65 (30)</td>
<td>215 (27)</td>
<td></td>
</tr>
<tr>
<td>Unstable angina</td>
<td>49 (22)</td>
<td>223 (28)</td>
<td></td>
</tr>
<tr>
<td>Non-ST-segment-elevation myocardial infarction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical comorbidities, n (%)</td>
<td>58 (27)</td>
<td>106 (13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>65 (30)</td>
<td>110 (14)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chronic lung disease</td>
<td>82 (38)</td>
<td>92 (12)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>99 (45)</td>
<td>299 (38)</td>
<td>0.039</td>
</tr>
<tr>
<td>Diabes mellitus</td>
<td>205 (94)</td>
<td>741 (93)</td>
<td>0.751</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>201 (92)</td>
<td>682 (86)</td>
<td>0.015</td>
</tr>
<tr>
<td>Hypertension</td>
<td>78 (36)</td>
<td>120 (15)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Peripheral arterial disease</td>
<td>114 (52)</td>
<td>244 (31)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prior myocardial infarction</td>
<td>64 (29)</td>
<td>272 (34)</td>
<td>0.170</td>
</tr>
<tr>
<td>Prior percutaneous intervention</td>
<td>5 (3)</td>
<td>11 (1)</td>
<td>0.342</td>
</tr>
<tr>
<td>Vavular heart disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory values</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glomerular filtration rate, mL/min</td>
<td>62±35</td>
<td>74±28</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>In-hospital mortality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predicted mortality (NCDR CathPCI)</td>
<td>0.023±0.034</td>
<td>0.009±0.032</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

All data are presented as mean±SD for continuous variables and number (percentage) for categorical variables. NCDR indicates National Cardiovascular Data Registry.

### Table 2. Procedural Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Ineligible (n=218)</th>
<th>Eligible (n=793)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedural access, n (%)</td>
<td></td>
<td>177 (81)</td>
<td>496 (63)</td>
</tr>
<tr>
<td>Femoral</td>
<td>34 (16)</td>
<td>263 (33)</td>
<td></td>
</tr>
<tr>
<td>Coronary anatomy, n (%)</td>
<td></td>
<td>71 (33)</td>
<td>78 (10)</td>
</tr>
<tr>
<td>Left main disease</td>
<td>89 (41)</td>
<td>315 (40)</td>
<td></td>
</tr>
<tr>
<td>3-Vessel disease</td>
<td>58 (27)</td>
<td>400 (50)</td>
<td></td>
</tr>
<tr>
<td>Coronary anatomy complexity, n (%)</td>
<td>8 (4)</td>
<td>48 (6)</td>
<td>0.173</td>
</tr>
<tr>
<td>Bifurcation lesions</td>
<td>3 (1)</td>
<td>15 (2)</td>
<td>0.610</td>
</tr>
<tr>
<td>High lesion complexity (type C)*</td>
<td>110 (51)</td>
<td>272 (34)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Coronary intervention</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vessels treated, n</td>
<td>1.42±0.57</td>
<td>1.57±0.61</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lesions treated, n</td>
<td>2.00±1.00</td>
<td>1.71±0.87</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Stents placed, n</td>
<td>2.31±1.62</td>
<td>1.87±1.17</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total stent length, mm</td>
<td>38 (18–64)</td>
<td>30 (18–46)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Coronary intervention vessels, n (%)</td>
<td>47 (22)</td>
<td>39 (5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Left main</td>
<td>135 (62)</td>
<td>523 (66)</td>
<td>0.289</td>
</tr>
<tr>
<td>Left anterior descending</td>
<td>94 (43)</td>
<td>275 (34)</td>
<td>0.022</td>
</tr>
<tr>
<td>Left circumflex coronary artery</td>
<td>62 (28)</td>
<td>278 (35)</td>
<td>0.067</td>
</tr>
<tr>
<td>Right coronary artery</td>
<td>30 (14)</td>
<td>9 (1)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

All data presented as mean±SD or median (interquartile range) for continuous variables and number (percentage) for categorical variables. *High lesion complexity is defined as a lesion with at least 1 of the following characteristics: diffuse (length > 2 cm), excessive tortuosity of the proximal segment, extremely angulated segments (>90°), total occlusions (>3 months), or inability to protect major side branches.

### Table 3. Documentation Source of Surgical Ineligibility

<table>
<thead>
<tr>
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<th>Ineligible (n=218)</th>
<th>Eligible (n=793)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical consult documentation, n (%)</td>
<td>63 (29)</td>
<td>32 (5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Eligibility documentation source, n (%)</td>
<td>43 (21)</td>
<td>40 (5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cardiology catheterization report</td>
<td>77 (37)</td>
<td>50 (6)</td>
<td></td>
</tr>
<tr>
<td>Cardiology consult note</td>
<td>50 (24)</td>
<td>35 (4)</td>
<td></td>
</tr>
<tr>
<td>Surgical consult note</td>
<td>36 (17)</td>
<td>24 (3)</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>0 (0)</td>
<td>644 (81)</td>
<td></td>
</tr>
</tbody>
</table>
were surgically eligible (Elig; log-rank \( P < 0.001 \)).

with a significant increase in mortality compared with those who surgical ineligibility. Surgical ineligibility (Inelig) was associated
term mortality among those with surgical anatomy undergoing

Figure 2.

Mortality. Kaplan–Meier estimates comparing long-
term mortality among those with left main or multivessel coronary artery disease when there is no compelling indication for one treatment modality over the other.9–11 When a compelling indication may exist, however, the guidelines advocate for a heart team approach with input from cardiac surgeons and interventional cardiologists. Interestingly, the present study suggests that formal consultation and electronic documentation from a cardiac surgeon were uncommon in patients with left main or multivessel coronary artery disease undergoing PCI. Perhaps cardiologists treating these patients used risk prediction instruments such as the Society of Thoracic Surgeons score or EuroSCORE to determine the potential morbidity of undergoing surgical revascularization.24,25 As previously described, these scores aid clinicians in identifying patients who may be at high risk for surgical revascularization and thus benefit from a less invasive approach. The data from the present study suggest that increased surgical risk that leads to operative ineligibility does not automatically imply that percutaneous revascularization is a safer option. In fact, the addition of surgical ineligibility to similar risk scores developed for percutaneous revascularization suggests increased procedural risk. Furthermore, our data suggest that percutaneous revascularization in these patients results in fewer vessels treated and perhaps greater residual ischemia.

Clinical Decision Making

Clinical guidelines and appropriate use criteria have favored surgical revascularization for patients with left main or multivessel coronary artery disease when there is no compelling indication for one treatment modality over the other.9–11 When a compelling indication may exist, however, the guidelines advocate for a heart team approach with input from cardiac surgeons and interventional cardiologists. Interestingly, the present study suggests that formal consultation and electronic documentation from a cardiac surgeon were uncommon in patients with left main or multivessel coronary artery disease undergoing PCI. Perhaps cardiologists treating these patients used risk prediction instruments such as the Society of Thoracic Surgeons score or EuroSCORE to determine the potential morbidity of undergoing surgical revascularization.24,25 As previously described, these scores aid clinicians in identifying patients who may be at high risk for surgical revascularization and thus benefit from a less invasive approach. The data from the present study suggest that increased surgical risk that leads to operative ineligibility does not automatically imply that percutaneous revascularization is a safer option. In fact, the addition of surgical ineligibility to similar risk scores developed for percutaneous revascularization suggests increased procedural risk. Furthermore, our data suggest that percutaneous revascularization in these patients results in fewer vessels treated and perhaps greater residual ischemia.

Limitations

The present study should be interpreted in the context of several limitations. Ascertainment of surgical ineligibility was based on documentation in the electronic medical record. Thus, discussions about surgical ineligibility that took place during the course of patient care but were not explicitly documented could lead to the misclassification of patients as eligible for surgical revascularization. It is important to note that the inclusion of these patients as surgically ineligible would only serve to increase the measured mortality difference between the 2 populations, rather than demonstrating improved mortality in the ineligible group. Residual confounding between surgical ineligibility and mortality may also exist outside the collected data. Furthermore, the present analysis does not evaluate differences in outcomes among surgically ineligible patients who are treated medically and those who receive percutaneous revascularization in the setting of disease salvage or compassionate use. The mortality rates for similar patients treated conservatively may be even higher than those observed with PCI. Finally, the population

<table>
<thead>
<tr>
<th>Criteria Associated With Surgical Ineligibility</th>
<th>Prevalence, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor targets/conduits</td>
<td>52 (24)</td>
</tr>
<tr>
<td>Advanced age</td>
<td>35 (16)</td>
</tr>
<tr>
<td>Renal insufficiency</td>
<td>35 (16)</td>
</tr>
<tr>
<td>Severe lung disease</td>
<td>32 (15)</td>
</tr>
<tr>
<td>Severe systolic dysfunction</td>
<td>31 (14)</td>
</tr>
<tr>
<td>Malignancy</td>
<td>24 (11)</td>
</tr>
<tr>
<td>Severe peripheral arterial disease</td>
<td>17 (8)</td>
</tr>
<tr>
<td>Extensive nonviable myocardium</td>
<td>14 (6)</td>
</tr>
<tr>
<td>Severe aortic calcification</td>
<td>13 (6)</td>
</tr>
<tr>
<td>Cachexia</td>
<td>9 (4)</td>
</tr>
<tr>
<td>Hematologic abnormality</td>
<td>9 (4)</td>
</tr>
<tr>
<td>End-stage liver disease</td>
<td>8 (4)</td>
</tr>
<tr>
<td>Morbid obesity</td>
<td>7 (3)</td>
</tr>
<tr>
<td>Severe cerebrovascular disease</td>
<td>7 (3)</td>
</tr>
<tr>
<td>Cognitive dysfunction</td>
<td>6 (3)</td>
</tr>
<tr>
<td>Gastrointestinal bleeding</td>
<td>6 (3)</td>
</tr>
<tr>
<td>Systemic infection</td>
<td>5 (2)</td>
</tr>
<tr>
<td>Chest wall abnormality</td>
<td>2 (1)</td>
</tr>
<tr>
<td>Immunosuppressed</td>
<td>2 (1)</td>
</tr>
<tr>
<td>Pulmonary hypertension</td>
<td>1 (1)</td>
</tr>
</tbody>
</table>

All data are presented as number (percentage) with the total number of patients deemed surgically ineligible (218) used as the denominator.

given its significant association with PCI outcomes and the likelihood that these patients would be concentrated at institutions that performed cardiac surgery. Many of the surgically ineligible patients who received percutaneous revascularization may have been treated as salvage cases or in the setting of compassionate use, 2 situations in which the inclusion of surgical ineligibility data could have significant impact on published mortality data and thus clinical practice in states with public reporting of outcomes. The increased anatomic complexity of the surgical ineligible patients supports this notion. In contrast, the surgically eligible patients were found to have lower anatomic complexity, suggesting greater clinical equipoise between surgical and percutaneous revascularization, thus leading to a large number of eligible patients pursuing PCI. Perhaps this should be considered in evaluations of hospital quality and procedural appropriateness.

Clinical Decision Making

Clinical guidelines and appropriate use criteria have favored surgical revascularization for patients with left main or multivessel coronary artery disease when there is no compelling indication for one treatment modality over the other.9–11 When a compelling indication may exist, however, the guidelines advocate for a heart team approach with input from cardiac surgeons and interventional cardiologists. Interestingly, the present study suggests that formal consultation and electronic documentation from a cardiac surgeon were uncommon in patients with left main or multivessel coronary artery disease undergoing PCI. Perhaps cardiologists treating these patients used risk prediction instruments such as the Society of Thoracic Surgeons score or EuroSCORE to determine the potential morbidity of undergoing surgical revascularization.24,25 As previously described, these scores aid clinicians in identifying patients who may be at high risk for surgical revascularization and thus benefit from a less invasive approach. The data from the present study suggest that increased surgical risk that leads to operative ineligibility does not automatically imply that percutaneous revascularization is a safer option. In fact, the addition of surgical ineligibility to similar risk scores developed for percutaneous revascularization suggests increased procedural risk. Furthermore, our data suggest that percutaneous revascularization in these patients results in fewer vessels treated and perhaps greater residual ischemia.

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in this study was gathered from subjects undergoing treatment at 2 academic tertiary care medical centers and may not be
generalizable to other settings. Additional prospective stud-
ies including diverse patient populations could be designed to
address these limitations.

Conclusions
Documented surgical ineligibility is common and is strongly
associated with increased mortality after percutaneous inter-
vention for patients with unprotected left main and multivess-
el coronary disease, even above and beyond commonly used
risk-adjustment models for percutaneous revascularization.

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Disclosures
None.

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**CLINICAL PERSPECTIVE**

Clinical guidelines and appropriate use criteria have favored surgical revascularization for patients with left main or multivessel coronary artery disease in the absence of a compelling indication for an alternative revascularization strategy. Several patients, however, are deemed at increased risk for coronary artery bypass grafting and thus are ineligible for this approach. In the present study, we evaluated the relationship between documented surgical ineligibility and mortality among patients undergoing percutaneous coronary intervention. The data demonstrate that documentation of surgical ineligibility is associated with an increased risk of in-hospital and long-term mortality among patients undergoing percutaneous revascularization, even after adjustment for known risk factors for adverse events. In fact, the addition of surgical ineligibility to commonly used risk models for percutaneous revascularization significantly improved their ability to predict mortality. These findings have important implications for comparative effectiveness research focused on identifying appropriate revascularization strategies for patients with multivessel coronary artery disease. Reporting of hospital quality and risk-adjusted mortality may also be affected because documentation of surgical ineligibility could be incorporated into risk-adjustment models, which ultimately could alter the assessment of adjusted outcomes and procedural appropriateness. Finally, these data could lead to changes in models used to provide risk-prediction estimates commonly used to guide clinical decision making for individual patients.
Surgical Ineligibility and Mortality Among Patients With Unprotected Left Main or Multivessel Coronary Artery Disease Undergoing Percutaneous Coronary Intervention

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