Determinants of Cardiac Catheterization Use in Older Medicare Patients With Acute Myocardial Infarction

Dennis T. Ko, MD, MSc; Joseph S. Ross, MD, MHS; Yongfei Wang, MS; Harlan M. Krumholz, MD, SM

Background—Cardiac catheterization is substantially underused among higher-risk patients with acute myocardial infarction (AMI) with appropriate indications but overused among patients with inappropriate indications. We sought to determine the importance of anticipated benefit and anticipated harm on the use of cardiac catheterization among older patients with AMI.

Methods and Results—We performed an analysis of Medicare fee-for-service beneficiaries hospitalized with an AMI between 1998 and 2001. Multivariate models were developed to determine relative importance of anticipated benefit (baseline cardiovascular risk), anticipated harm (bleeding risk, comorbidities), and demographic factors (age, sex, race, regional invasive intensity) in predicting cardiac catheterization use within 60 days of AMI admission. Analyses were stratified by American College of Cardiology/American Heart Association class I or II as appropriate, and class III as inappropriate. Determinants of reduced likelihood of cardiac catheterization among 42,241 AMI patients with appropriate indications included (in order of importance) older age (likelihood $\chi^2=1309.5$), higher bleeding risk score (likelihood $\chi^2=471.2$), more comorbidities (likelihood $\chi^2=276.6$), female sex (likelihood $\chi^2=162.9$), hospitalization in low (likelihood $\chi^2=67.9$) or intermediate intensity invasive regions (likelihood $\chi^2=22.4$) (all $P<0.001$), and baseline cardiovascular risk (likelihood $\chi^2=6.4$, $P=0.01$). Among 2,398 AMI patients with inappropriate indications, significant determinants of greater procedure likelihood included younger age, male sex, lower bleeding risk score, and fewer comorbidities.

Conclusions—Regardless of the procedure indication, the decision to perform cardiac catheterization in this population appears largely driven by demographic factors and potential harm rather than potential benefit of the procedure. (Circ Cardiovasc Qual Outcomes. 2010;3:00-00.)

Key Words: cardiac catheterization • acute myocardial infarction • determinants of use • Medicare beneficiaries

An early invasive strategy improves outcomes for patients with acute myocardial infarction (AMI), especially those at higher risk for future cardiovascular events. Nevertheless, data have consistently demonstrated that selection of patients for cardiac catheterization is suboptimal. In particular, cardiac catheterization is substantially underused among higher-risk patients with appropriate indications who would be expected to derive the largest benefit. In contrast, cardiac catheterization is overused among patients with inappropriate indications in which invasive procedures may be considered to be ineffective. Understanding utilization patterns can improve appropriate selection of patients, which in itself would be expected to lead to better outcomes for those with AMI.

Previous studies have focused on evaluating the association of specific individual factors on cardiac catheterization, including sociodemographic predictors such as age, sex, or race, as well as market supply/availability. The use of cardiac catheterization after AMI is highly influenced by regional practice patterns as demonstrated by the tremendous regional variation in its use within the United States. However, little insight is available on the importance of anticipated benefit and anticipated harm in the use of cardiac catheterization among patients with AMI. Anticipated benefit...
of a therapy in the population is predominantly dependent on a patient’s baseline risk of future adverse cardiovascular events; however, greater risk has been shown to paradoxically reduce the likelihood of some treatments.\textsuperscript{14–17} Anticipated harm of a therapy such as older age, a patient’s bleeding risk, or number of comorbidities reduces the propensity of receiving many therapies.\textsuperscript{15,18,19} No population-based study has examined the relative importance and the interplay of these complex factors in the selection of patients for cardiac catheterization after AMI. For example, it may be possible that the risk of bleeding is more important in clinical decision-making even though baseline risk is most important in estimating anticipated benefit of a therapy.

Accordingly, the main objective of this study was to examine the impact of anticipated benefit as determined by baseline cardiovascular risk, and anticipated harm as determined by the risk of bleeding and comorbidities, on utilization of cardiac catheterization after AMI. In addition, the importance of these factors will be assessed in the context of important demographic factors such as age, sex, race, and regional invasive intensity.

### WHAT IS KNOWN

- Cardiac catheterization is underused among higher-risk appropriate patients but overused among lower-risk inappropriate patients.
- Specific individual factors such as age, sex, and race have been shown to predict appropriate and inappropriate use of cardiac catheterization.
- However, little is known about the importance of the anticipated benefit and anticipated harm of a procedure on utilization patterns.

### WHAT THE STUDY ADDS

- We observed that patients’ bleeding risk and number of comorbidities were substantially more predictive of the use of cardiac catheterization than their risk of dying.
- This article provides new insights into the decision-making process of physicians who are much more concerned about potential harm or side effects compared with potential gain when selecting patients for cardiac invasive procedures.
Regional Intensity of Cardiac Invasive Procedures

To account for the geographic variations in invasive practice across the United States, we classified hospital referral regions into 3 groups to represent low, intermediate, and high invasive intensity based on the number of cardiac catheterizations performed per 1000 Medicare enrollees in each region (for example, low invasive intensive regions had the lowest tertile of cardiac catheterization use). These data were obtained from the 1999 Aggregated Surgical Discharge Data File using residential or hospital Zip codes.

Statistical Analysis

We explored the association between demographic factors (age, sex, race, and regional invasive intensity), anticipated benefit (baseline cardiovascular risk), and anticipated harm (bleeding risk and number of comorbid conditions) with cardiac catheterization utilization after AMI. Our analyses were stratified by procedure indication in which we first examined predictors of underutilization among AMI patients with ACC/AHA class I or II indications and repeated all the analyses among patients with ACC/AHA class III indications to determine factors associated with overutilization.

In each stratum, baseline characteristics of patients who received cardiac catheterization were compared with those who did not. We then examined the relationship between the use of cardiac catheterization with selected factors with survey logistic regression analyses. All analyses incorporated probability weights based on the inverse sampling fraction for the population size of each state, and all models were adjusted for clustering of patients at the hospital level. The contribution of each variable to the overall model was determined using likelihood ratio. The discriminative ability of the model was determined by the area under the receiver operating characteristic curve.

Probability plots were constructed to illustrate how the utilization of invasive therapy was correlated with 2 significant determinants simultaneously (eg, baseline cardiovascular risk and the number of comorbid factors) after adjusting for remaining covariates in the multivariable logistic regression models. Due to the concerns of significant correlation between predicting factors, for example, increasing age may increase baseline risk and bleeding risk, we calculated Pearson correlation coefficients among all candidate variables and performed formal diagnostic testing. The correlations between most of the variables were negligible to small, and all the variables had Variance Inflation Factors of <5, indicating no evidence of multicollinearity.

Additional analyses were undertaken to examine the robustness of our results. First, we stratified AMI based on the presence or absence of ST-segment elevation on ECGs. Second, we also altered the timeframe of capturing cardiac catheterizations to 30 days (from 60 days). None of these analyses altered the determinants of cardiac catheterization.

We conducted the statistical analyses using SAS software, version 9.1 (SAS Institute, Inc, Cary, NC). All statistical tests were 2-tailed, and probability values of <0.05 were considered statistically significant. Use of the National Heart Care Project database was approved by the Yale University School of Medicine Human Investigation Committee.

Results

Baseline Characteristics Among ACC/AHA Class I and II Patients

After applying inclusion and exclusion criteria, our study cohort consisted of 42 241 Medicare beneficiaries who had ACC/AHA class I or II indications for cardiac catheterization. The mean age among those with class I or II indications was 78.4 years; 51.2% were female; and 86.3% were white. Cardiac catheterization within 60 days of hospitalization was performed for 40.6% of patients who had class I or II indications.

Determinants of Cardiac Catheterization Among Class I and II Patients

Demographic and clinical characteristics of AMI patients who underwent cardiac catheterization differed substantially from those who did not. Patients who received cardiac catheterization were younger, more likely to be male, had a lower GRACE score, lower bleeding risk, fewer comorbid conditions, and were more likely to be hospitalized in higher intensive regions (all P<0.001) (Table 1). Cardiac catheterization within 60 days of hospitalization was performed for 40.6% of patients who had class I or II indications. The cardiac catheterization rate was 46.0% for patients with ST-segment elevation myocardial infarction and 38.4% for patients with non–ST-segment elevation myocardial infarction.

Table 2 illustrates the independent determinants of cardiac catheterization among AMI patients who had ACC/AHA class I or II indications. Significant determinants of reduced likelihood of cardiac catheterization use in order of their respective contribution to the overall model included older age (likelihood χ²=1309.5, P<0.001); higher bleeding risk score (likelihood χ²=471.2, P<0.001); greater number of comorbid conditions (likelihood χ²=276.6, P<0.001); female sex (likelihood χ²=162.9, P<0.001); and hospitalization at lower intensity (likelihood χ²=67.9, P<0.001) or intermediate intensity invasive regions (likelihood χ²=22.4, P<0.001). GRACE risk score (likelihood χ²=6.4, P=0.01) was weakly associated with cardiac catheterization use, and race (likelihood χ²=3.4, P=0.07) was not a significant independent predictor of use in multivariate models. The area under the receiver operating characteristic curve was 0.75, indicating good discriminative ability of the aggregated determinants to predict cardiac catheterization use.

Figures 1 and 2 illustrate the independent impact of strong determinants (age, sex, bleeding risk, comorbidities, and invasive regions) on utilization of cardiac catheterization. We plotted 2 significant factors in each graph simultaneously after imputing average values for other factors to illustrate the independent and additive relationship of each variable with cardiac catheterization. No statistical interaction was detected between factors shown in Figure 1 and Figure 2 (ie, none of the curves crossed over). For example, in Figure 1A, the estimated probability of cardiac catheterization utilization ranged from 40.5% (no comorbidity) to 21.2% (more than 4 comorbidities) among women. Among men, estimated utilization of cardiac catheterization was significantly higher at 58.8% (no comorbidity) to 30.2% (>4 comorbidities). In Figure 2, we plotted the estimated probability of cardiac catheterization between sex, bleeding risk, and invasive regions with age. We found a linear relationship where the likelihood of cardiac catheterization was 8.3% lower (adjusted odds ratio [OR], 0.917; 95% confidence interval [CI], 0.913 to 0.921) for each increased year in age.

Determinants of Cardiac Catheterization Among Class III AMI Patients

There were 2398 AMI Medicare beneficiaries who had ACC/AHA class III indications for cardiac catheterization. The mean age was 79.0 years; 51.9% were female, and 85.5% were white, with a mean GRACE score of 198 and mean...
bleeding score of 57. Cardiac catheterization was performed in 20.3% of patients who had ACC/AHA class III indications.

Significant determinants of cardiac catheterization use among AMI patients with ACC/AHA class III procedure indications were similar to the determinants in the appropriate cohort (classes I and II), with age (likelihood $\chi^2=71.6, P<0.001$), sex (likelihood $\chi^2=11.9, P=0.001$), bleeding risk score (likelihood $\chi^2=43.4, P<0.001$), and fewer number of comorbid conditions (likelihood $\chi^2=13.9, P<0.001$) being significant independent predictors of cardiac catheterization use (Table 3). Intensity of invasive region, GRACE risk score, and race were not significant independent predictors of use among AMI patients with class III indications. The area under the receiver operating characteristic curve of the model was 0.73.

**Discussion**

The present study provides important insights into clinical decision-making of physicians for older AMI patients. We
observed that patients’ bleeding risk and number of comorbidities were substantially more predictive of the use of cardiac catheterization after AMI than their risk of dying. These results suggest that physicians are significantly more concerned about potential harm compared with potential gain when selecting patients for cardiac invasive procedures.

Our findings may also provide an explanation of why discordant patterns of cardiac catheterization continue to exist in which procedures are underused among appropriate higher-risk patients and overused among inappropriate lower-risk patients. Practice guidelines and/or appropriateness criteria have been developed to guide physicians on the basis

Table 2. Relative Importance of Explanatory Factors in the Use of Cardiac Catheterization Among ACC/AHA Class I and II AMI Patients

<table>
<thead>
<tr>
<th>Description</th>
<th>Level</th>
<th>OR</th>
<th>95% CI</th>
<th>Likelihood χ²</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Each additional year</td>
<td>0.917</td>
<td>0.913–0.921</td>
<td>1309.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CRUSADE bleeding risk score</td>
<td>Each 5-point increase</td>
<td>0.824</td>
<td>0.810–0.838</td>
<td>471.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No. of comorbid conditions</td>
<td>Each additional comorbid factor</td>
<td>0.816</td>
<td>0.796–0.836</td>
<td>276.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex</td>
<td>Female</td>
<td>0.679</td>
<td>0.640–0.721</td>
<td>162.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Low regional invasive intensity</td>
<td>Reference (high invasive regions)</td>
<td>0.582</td>
<td>0.512–0.661</td>
<td>67.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Intermediate regional invasive intensity</td>
<td>Reference (high invasive regions)</td>
<td>0.755</td>
<td>0.672–0.848</td>
<td>22.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>GRACE risk score</td>
<td>Each 10-point increase</td>
<td>0.986</td>
<td>0.975–0.997</td>
<td>6.4</td>
<td>0.011</td>
</tr>
<tr>
<td>Race</td>
<td>White vs nonwhite</td>
<td>1.092</td>
<td>0.994–1.200</td>
<td>3.4</td>
<td>0.066</td>
</tr>
</tbody>
</table>

AMI indicates acute myocardial infarction.

All analyses incorporated probability weights based on the inverse sampling fraction for the population size of each state, and all models were adjusted for clustering at the hospital level. Definition of ACC/AHA classification is shown in the Data Supplement Appendix.
that a therapy is beneficial. However, most of these data are drawn from randomized studies that enrolled lower-risk patients compared with those seen in clinical practice.\textsuperscript{27,28} Physicians may feel reluctant to generalize clinical trial results to patients who are at higher risk of bleeding and have multiple comorbidities, and thus may not be certain whether older patients in clinical practice would expect a net benefit from invasive procedures. In addition, a fear of malpractice liability and a selection bias in view of public reporting might have further dissuaded physicians to perform procedures among patients with higher predicted risk of harm.\textsuperscript{29,30} Future prediction tools and practice guidelines should take into account the potential risk of treatment for patients at higher risk of complications to improve the ability of patients and physicians to make informed treatment decisions. Data from clinical registries may provide insights on these higher-risk patients in clinical practice.

Anticipated benefit of a therapy in the population is predominantly dependent on a patient’s baseline risk of future adverse cardiovascular events; however, another important finding is that baseline cardiovascular risk was a relatively weak predictor for cardiac catheterization use after accounting for other factors. This is surprising, as many studies have consistently demonstrated that cardiac invasive procedures

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2}
\caption{Estimated probability of cardiac catheterization utilization within 60 days of AMI among patients with ACC/AHA class I and II indications according to predicting factors and age. A, Sex and age. B, Bleeding risk and age. C, Invasive regional intensity and age. $Y$ axis describes the estimated probability of cardiac catheterization utilization by multivariable logistic regression models.}
\end{figure}
Table 3. Relative Importance of Explanatory Factors in the Use of Cardiac Catheterization Among ACC/AHA Class III AMI Patients

<table>
<thead>
<tr>
<th>Description</th>
<th>Level</th>
<th>OR</th>
<th>95% CI</th>
<th>Likelihood χ²</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Each additional year</td>
<td>0.922</td>
<td>0.904–0.939</td>
<td>71.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CRUSADE bleeding risk score</td>
<td>Each 5-point increase</td>
<td>0.772</td>
<td>0.715–0.834</td>
<td>43.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No. of comorbid conditions</td>
<td>Each additional comorbid factor</td>
<td>0.808</td>
<td>0.722–0.904</td>
<td>13.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex</td>
<td>Female</td>
<td>0.597</td>
<td>0.445–0.800</td>
<td>11.9</td>
<td>0.001</td>
</tr>
<tr>
<td>Low regional invasive intensity</td>
<td>Reference (high invasive regions)</td>
<td>0.774</td>
<td>0.548–1.093</td>
<td>2.1</td>
<td>0.146</td>
</tr>
<tr>
<td>Intermediate regional invasive intensity</td>
<td>Reference (high invasive regions)</td>
<td>0.740</td>
<td>0.523–1.047</td>
<td>2.9</td>
<td>0.089</td>
</tr>
<tr>
<td>GRACE risk score</td>
<td>Each 10-point increase</td>
<td>0.981</td>
<td>0.945–1.019</td>
<td>1.0</td>
<td>0.320</td>
</tr>
<tr>
<td>Race</td>
<td>White vs nonwhite</td>
<td>1.435</td>
<td>0.913–2.254</td>
<td>2.5</td>
<td>0.117</td>
</tr>
</tbody>
</table>

All analyses incorporated probability weights based on the inverse sampling fraction for the population size of each state, and all models were adjusted for clustering at the hospital level. Definition of ACC/AHA classification is shown in the Data Supplement Appendix.
the Heart and Stroke Foundation of Ontario. Dr Ross is currently supported by Department of Veterans Affairs Health Services Research and Development Service project TRP-02-149.

**Disclosures**

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**References**


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Appendix 1. The ACC/AHA appropriateness criteria for cardiac catheterization.

**Strong indication - ACC/AHA criteria for class**

Angina >24 hours after admission

Ischemia observed on an exercise stress test

Hypotension during hospitalization

Shock on admission or during hospitalization

**Equivocal indication – ACC/AHA criteria for class II**

Left ventricular ejection fraction <0.40

Previous bypass surgery or angioplasty

Congestive heart failure or pulmonary edema on admission or during hospitalization

Non-Q-wave myocardial infarction

**Weak indication – ACC/AHA criteria for class III**

Hepatic failure

Metastatic cancer

Terminal illness (life expectancy <6 months)

Flexion withdrawal, decorticate, decerebrate, or no motor response to cues

ACC/AHA, American College of Cardiology/American Heart Association