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 2398 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;3:54-62.)

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.\(^1\)\(^2\) 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.\(^3\)\(^-\)\(^6\) In contrast, cardiac catheterization is overused among patients with inappropriate indications in which invasive procedures may be considered to be ineffective.\(^6\)\(^7\) 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.\(^6\)\(^8\)\(^-\)\(^11\) 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.\(^5\)\(^12\)\(^13\) 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

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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.

Methods

The National Heart Care Project

The National Heart Care project obtained data through chart abstraction of a random sample of Medicare fee-for-service beneficiaries hospitalized between March 1998 and April 1999, and March 2000 to April 2001 with a principal discharge diagnosis of AMI (International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code 410) from each state and the District of Columbia.\textsuperscript{6,20} The study sample included patients 65 years of age and older who had a confirmed AMI (including ST-segment elevation and non-ST-segment–elevation AMI) using chart abstracted information.\textsuperscript{6} Patients who were initially hospitalized at a facility without cardiac invasive capability and received a cardiac procedure within 60 days of an AMI were included in the study cohort. Admissions in which the patients were transferred in from another hospital were excluded because we lacked information that described the first hospitalization. Patients who had been hospitalized with a recurrent AMI during the study period were also excluded, so that each patient was represented in the database with only 1 index hospitalization.

Main Outcome Measure

The primary outcome of the study was the use of cardiac catheterization within 60 days of an AMI admission. Cardiac catheterization use was determined by linking the hospital medical records and Medicare Part A billing records for ICD-9-CM codes associated with the procedure (37.22, 37.33, 88.53 to 88.57), which captures cardiac procedures performed for hospitalized patients.\textsuperscript{6}

Appropriateness of Cardiac Catheterization

Appropriateness of cardiac catheterization was based on the American College of Cardiology/American Heart Association (ACC/AHA) guidelines and criteria previously reported (Appendix 1).\textsuperscript{9,7,20–22} The strong indication group consisted of patients in whom cardiac catheterization was generally recognized as “beneficial, useful and effective” (ACC/AHA class I). We did not include “reinfarction during hospitalization” as a class I indicator because this data field was not captured in our dataset. The equivocal group (ACC/AHA class II) included patients who had conditions for which the effectiveness of cardiac catheterization was unclear. The weak indication group (ACC/AHA class III) consisted of patients for whom cardiac catheterization was considered unlikely to be effective (Appendix 1).

Determinants of Cardiac Catheterization Use

Baseline Cardiovascular Risk

We determined baseline cardiovascular risk of hospitalized AMI patients using the Global Registry of Acute Coronary Events (GRACE) prediction risk score.\textsuperscript{23} The GRACE risk score variables include age, admission characteristics (heart rate, Killip class, systolic blood pressure, cardiac arrest at admission, ST-segment deviation), and laboratory values (serum creatinine, positive cardiac markers). Although the GRACE risk score was originally developed using an acute coronary syndrome population, it has been validated previously in other AMI cohorts.\textsuperscript{24} The plausible range of GRACE risk score is from 1 to 372, with higher score indicating higher predicted risk.

Bleeding Risk

We calculated the predicted risk of in-hospital major bleeding among our AMI cohort using the Cardiovascular Disease Quality Improvement Initiative Registry (CRUSADE) bleeding risk score.\textsuperscript{25} The bleeding risk prediction score variables, in order of significance, are baseline hematocrit, creatinine clearance, heart rate, sex, heart failure at presentation, prior vascular disease, diabetes mellitus, and systolic blood pressure. Plausible bleeding score ranges from 1 to 96, with higher score indicating higher risk of bleeding.

We replaced missing values with median values for continuous variables to calculate risk scores for each patient. Missing data were infrequent in our cohort. Of the 16 data variables in the prediction models, most had less than 1% missing frequencies, except for serum creatinine, hematocrit, and body weight, in which frequencies of missing were 2.4%, 3.0%, and 4.9%, respectively.

Number of Chronic Comorbidities

Previous studies have shown that physicians become less attentive when managing an increasing number of preexisting conditions (irrespective of type of condition).\textsuperscript{19} Therefore, we examined the number of preexisting comorbid conditions (cardiovascular and noncardiovascular) that were not included in the baseline risk of bleeding risk models to determine their effect on cardiac catheterization utilization such as history of AMI, stroke, chronic obstructive pulmonary disease, smoking, prior cardiac procedures, dementia, mobility, and urinary continence.
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 ratio χ²=1309.5, P<0.001); higher bleeding risk score (likelihood ratio χ²=471.2, P<0.001); greater number of comorbid conditions (likelihood ratio χ²=276.6, P<0.001); female sex (likelihood ratio χ²=162.9, P<0.001); and hospitalization at lower intensity (likelihood ratio χ²=67.9, P<0.001) or intermediate intensity invasive regions (likelihood ratio χ²=22.4, P<0.001). GRACE risk score (likelihood ratio χ²=6.4, P=0.01) was weakly associated with cardiac catheterization use, and race (likelihood ratio 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>
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<tr>
<th>Description</th>
<th>Level</th>
<th>OR</th>
<th>95% CI</th>
<th>Likelihood $\chi^2$</th>
<th>$P$ Value</th>
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<tr>
<td>Age</td>
<td>Each additional year</td>
<td>0.917</td>
<td>0.913–0.921</td>
<td>1309.5</td>
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</tr>
<tr>
<td>CRUSADE bleeding risk score</td>
<td>Each 5-point increase</td>
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<td>0.810–0.838</td>
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<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>
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<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>
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<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.

Figure 1. 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 number of comorbidities. A, Sex and number of comorbidities. B, Bleeding risk and number of comorbidities. C, Invasive regional intensity and number of comorbidities.
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

Figure 2. 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.
are used substantially less frequently among higher-risk patients, an observation that has been previously termed a "treatment-risk paradox." Although we found no correlation between number of comorbidities and cardiovascular risk, we found that bleeding risk and cardiovascular risk are moderately correlated (−0.51 among class I/II patients, −0.36 among class III patients). As a result, the association between baseline cardiovascular risk and cardiac catheterization in adjusted analysis (OR, 0.86) was largely attenuated after adjustment (OR, 0.99). Because none of the previous studies adjusted specifically for side effects, adjustment of harm in previous observations might have reduced the importance of the treatment-risk paradox. Similarly, a recent study found that the treatment-risk paradox was largely attenuated after accounting for patients’ functional capacity and depressive symptoms, another example suggesting that many other factors can interfere with treatment decisions despite a therapy’s anticipated prognostic benefits.

Consistent with results of other investigations, we found that female patients compared with their male counterparts, and patients hospitalized in lower or intermediate invasive regions compared with those hospitalized in higher invasive regions, have lower likelihoods of receiving cardiac catheterization. Previously cited explanations include differences in demographics, clinical characteristics, and baseline risk, but we excluded these possibilities by accounting for all these factors in our predictive models. Other reasons to explain a sex discrepancy may include differences in symptom presentation, patient acceptance of the procedure, and physician preference due to inequalities of potential benefits. Despite numerous debates, the exact reasons that account for lower cardiac catheterization rates for women and lower invasive regions are unclear.

Previous studies have found marked racial disparities in the use of cardiac catheterization. In contrast, we did not find significant racial differences in cardiac catheterization use for AMI patients after adjusting for other demographic factors, estimated risk, and harm of the procedure. Because racial minorities traditionally have higher risk characteristics and probably also have higher potential risk of procedural complications, it is possible that anticipated harm may be in part responsible for the persistent racial differences in cardiac invasive procedure use as demonstrated in previous studies. In our study, we cannot exclude potential racial differences among patients who were transferred for cardiac catheterization because those patients were excluded.

Several potential limitations of our study merit consideration. First, we examined an older cohort of fee-for-service Medicare beneficiaries hospitalized from 1998 to 2001. This dataset was used because it contained detailed clinically abstracted information, which allowed us to calculate predicted risk scores and to categorize appropriateness of cardiac catheterizations. To our knowledge, no other cohort that has been assembled since the National Heart Care Project is truly nationally representative of the clinical practice in the United States with complete follow-up data. Although utilization of cardiac catheterization has increased in the interim across the United States, there is little evidence to suggest that utilization patterns have dramatically changed in this cohort. In fact, recent studies continue to demonstrate discrepancies in the use of cardiac invasive procedures. Second, we did not use other factors to predict anticipated harm such as potential for stroke or renal failure that may also be major concerns when referring patients for cardiac catheterization. However, bleeding is one of the most common complications of invasive procedures and is associated with substantial morbidity and mortality. Furthermore, considering other anticipated adverse effects would tend to strengthen the association of harm and utilization. Finally, the extent to which determinants of utilization reflect actual physician and patient decision-making processes is unknown because data regarding physician and patient perspectives were not available. However, perspectives may not always accurately reflect or correspond to actual utilization patterns.

In conclusion, underutilization of cardiac catheterization among an older cohort hospitalized with AMI is largely explained by the act of omission due to concern about an adverse event rather than a focus on the potential benefit of an invasive procedure in improving outcomes. Our study challenges national societies to develop practice guidelines to estimate net benefits of cardiac invasive procedures that incorporate anticipated risk of harm.

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Disclosures

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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