Variations in Coronary Procedure Utilization Depending on Body Mass Index

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Background: Increased body mass index (BMI) (calculated as weight in kilograms divided by the square of height in meters) is a risk factor for coronary heart disease and is associated with lower preventive services utilization. The relationship between BMI and utilization of diagnostic or therapeutic procedures for coronary heart disease has not been examined.

Methods: We evaluated 109,664 Medicare patients who were hospitalized for acute myocardial infarction in a non-governmental acute care hospital between 1994 and 1996, were 65 years or older, and weighed 159 kg or less. We used logistic regression to examine the relationship of BMI with utilization of cardiac catheterization, percutaneous coronary intervention, and coronary artery bypass grafting while adjusting for patient and hospital characteristics.

Results: Participants had a mean age of 75.8 years; 53% were men and 90% were white. Individuals with a BMI of 25.0 to 35.0 had the highest rates of coronary procedure utilization. Compared with patients with a BMI of 25.0 to 29.9, those with a BMI of 35.0 to 39.9 had a reduced adjusted odds ratio (OR) of receiving coronary artery bypass grafting (OR, 0.88; 95% confidence interval [CI], 0.79-0.98), whereas patients with a BMI of 40.0 or greater had the lowest odds of receiving cardiac catheterization (OR, 0.82; 95% CI, 0.73-0.92), percutaneous coronary intervention (OR, 0.89; 95% CI, 0.77-1.03), and coronary artery bypass grafting (OR, 0.68; 95% CI, 0.57-0.82). Patients who did not receive coronary revascularization had higher mortality rates than those who did.

Conclusions: For patients hospitalized with acute myocardial infarction, those with a very high BMI were less likely to receive invasive coronary procedures. Future research should investigate reasons for these variations in coronary procedure utilization.

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In the past 15 years, there has been extensive literature documenting that the use of coronary procedures can vary depending on patient characteristics, such as race and sex. Potential reasons for these variations include differences in index disease severity, in comorbid illness severity, in patient preferences, and in physician recommendations. Furthermore, disease prevalence, response to non-invasive therapies, and response to invasive therapies all may vary depending on patient characteristics. Physicians need to be aware of these variations to make proper therapeutic recommendations and to avoid the introduction of systematic bias that might compromise the care of individuals with certain characteristics. For these reasons, understanding disparities in health care remains a priority in health policy.

Little research has evaluated whether health care disparities exist in relation to a patient’s body weight. Recent literature examining outcomes after percutaneous coronary intervention (PCI) gives conflicting data regarding whether body weight is associated with either mortality or procedure complications, with the largest study showing increased risk for underweight and extremely obese patients. For cardiac surgery, obese patients are at higher risk for wound infections and at lower risk for needing a blood transfusion, but, similar to PCI, results are conflicting for mortality and other serious outcomes, with the largest study showing higher risk for severely obese patients. Few studies have examined variations in utilization of specific health care interventions as a function of body weight. Specifically, we did not identify any studies evaluating the relationship between body weight and the use of coronary procedures.

The association of obesity with utilization of coronary procedures is increas-
The prevalence of obesity is rising, with recent studies classifying more than 65% of Americans as overweight or obese (body mass index [BMI] calculated as weight in kilograms divided by the square of height in meters) ≥25.12 Because obesity is an independent risk factor for coronary heart disease (CHD) and contributes to the development of other risk factors for CHD, such as hypertension, diabetes mellitus, and hyperlipidemia, this increase in prevalence has profound implications regarding the diagnosis and treatment of CHD.13

The goal of this study is to determine whether increased body weight is associated with variations in coronary procedure utilization in patients hospitalized with acute myocardial infarction (AMI). Because these procedures may be perceived as being riskier as the patient’s body weight increases, we hypothesize that obese patients are less likely to receive coronary procedures compared with normal-weight patients.

PATIENT SAMPLE

The patient sample was obtained from the Cooperative Cardiovascular Project, a large cohort study initiated by the Health Care Financing Association with the aim of measuring the quality of health care for Medicare patients with AMI. The Cooperative Cardiovascular Project cohort included all Medicare patients discharged with a principal diagnosis of AMI (code 410 of the International Classification of Diseases, Ninth Revision, Clinical Modification), excluding a fifth digit of 2, which would indicate AMI in the 8 weeks preceding the index admission) from all nonfederal acute care hospitals during a specified 8-month period in each of 46 states between January 1, 1994, and February 21, 1996. Hospital bills (UB-92 claims) in the Medicare National Claims History File were used to identify patients. Alabama, Connecticut, Iowa, and Wisconsin were excluded because the sampling was modified in these states.

An AMI was defined as a creatine phosphokinase MB fraction greater than 0.05; a lactate dehydrogenase level exceeding 1.5 times the upper limit of normal, with a higher isoenzyme 2 level than isoenzyme 1 level; or the presence of 2 of the following conditions: chest pain, a doubling of the creatine phosphokinase level, or evidence of new MI on an electrocardiogram.

Data concerning patient characteristics, presentation of illness, severity of illness, coexisting conditions, laboratory test results, treatment, and complications were abstracted from medical records at 2 abstraction centers. The average agreement between abstractors was 95%.16 Starting with a sample of 206,986 patients, the following deletions were made sequentially: cases that did not meet the clinical criteria for AMI (n=27,509), hospital admissions other than the index admission (n=13,433), invalid ZIP codes of residences (n=2), persons treated outside the 50 United States (n=1,316), and persons with a terminal illness (n=598). This yielded a net sample of 164,128.

STATISTICAL ANALYSIS

Patients were classified into groups depending on BMI and according to the classification system of the National Institutes of Health.17 Patients who weighed more than 159 kg (n=34) were excluded because many catheterization tables that were in use during the study period were restricted at that weight cutoff value. Patients who were classified as underweight (BMI <18.5; n=3649) were excluded because our hypothesis involved patients who were above normal weight and because underweight patients have reduced survival due to known and unknown comorbid illness. Finally, we excluded patients who were hospitalized in a facility that did not offer the cardiac procedure in question, either cardiac catheterization (n=48,781) or open heart surgery (n=82,593). Therefore, the final sample size was 109,664 patients for the cardiac catheterization and PCI models and 75,850 patients for the coronary artery bypass grafting (CABG) model.

The primary outcome variable was utilization of a cardiac procedure during the initial AMI hospitalization. Patients in this sample were seen at 1972 unique hospitals. Using generalized estimating equations,18 adjusting for clustering of patients within hospitals did not significantly alter model results; therefore, separate logistic regressions were performed using each of the 3 coronary procedures—cardiac catheterization, PCI, or CABG—as the outcome variable. Each BMI classification was represented by an indicator variable in the models. The BMI classifications of overweight (25.0-29.9) and obesity class 1 (30.0-34.9) had the highest rates of procedure use. Overweight was chosen as the referent category because of its higher prevalence.

For multivariable analyses, independent variables that might clinically affect the decision to use coronary procedures were included in the models. Patient characteristics included age (continuous), sex, race (white or nonwhite), and cigarette smoking history (current or not current). Patient socioeconomic status was represented by the median household income for the patient’s ZIP code area (continuous). Medical history was represented by indicator variables for history of severe chronic illness (human immunodeficiency virus positive or AIDS, immunosuppression, liver failure or cirrhosis, metastatic cancer, lymphoma, or leukemia), multiple other clinical conditions (Table 1), and serum creatinine level at presentation (continuous). Previous cardiac intervention was represented by indicator variables for previous PCI or CABG. Severity of AMI variables included the presence of anterior MI, the presence of ST-segment elevation on electrocardiography, the duration of chest pain at presentation (continuous), and peak creatine phosphokinase level (continuous). Hospital variables included the prehospitalization setting of the patient (transfer from another acute care hospital/emergency department or other), the discharge disposition of the patient (transfer to another acute care hospital or other), hospital ownership (for-profit, not-for-profit, or government), and hospital teaching status (non-teaching, resident physician-bed ratio ≤0.1, or resident physician-bed ratio >0.1).

Several patients in the sample were missing measurements for height (n=14,339; 13% of the total sample), weight (n=7828; 7%), or both (n=16,614; 15%), and fewer patients were missing data for other predictor variables. Rather than exclude these patients, we used Markov chain Monte Carlo methods to multiply impute values for missing variables under a multivariate normal model.19 Each of 10 imputed data sets was analyzed using the logistic regression models; we then combined parameter estimates and standard errors according to the rules developed by Rubin.20 All models provided good discriminative ability (c indexes, 0.72-0.78).21

Next we sought to evaluate whether variations in coronary procedure use translated into variations in 1-year mortality rates, depending on patient BMI. In this observational data set, the relationship between procedure use and survival is confounded by several other variables, for example, patients who received a procedure were systematically different than those who did not, and several of these variables were also related to mortality. A direct comparison of mortality rates for procedure use vs no procedure use may be biased owing to these sys-
The patient sample had a mean±SD age of 75.8±7.2 years; 53.2% were men and 90.4% were white (Table 1). The 2 highest BMI classifications were predominantly composed of women (Table 1). In addition, persons in the lower BMI classifications were more likely to be older or to smoke cigarettes. The proportion of patients with specific comorbid illnesses also varied by BMI classification.

Patients with a normal BMI (18.5-24.9) and obesity class 3 (BMI ≥ 40.0) had the lowest raw utilization rates with specific comorbid illnesses also varied by BMI classification. The estimated coefficients from the 2 models were then applied to the entire sample, yielding 2 predicted probabilities of mortality for each patient. Each set of predicted mortality rates was averaged within each BMI category. The difference between each of the 2 rates represents the average causal treatment difference within the BMI category. We then applied these steps to the 10 imputed data sets and combined estimates. Bootstrap resampling was used to estimate standard errors of the difference in mortality rates. These procedures were then repeated for CABG. For the CABG analyses, obesity class 2 and obesity class 3 were combined owing to a small number of events. For all analyses, P=.05 was used as the level of significance. Analyses were performed using statistical software (SAS version 8.02; SAS Institute Inc, Cary, NC).

### RESULTS

The patient sample had a mean±SD age of 75.8±7.2 years; 53.2% were men and 90.4% were white (Table 1). The 2 highest BMI classifications were predominantly composed of women (Table 1). In addition, persons in the lower BMI classifications were more likely to be older or to smoke cigarettes. The proportion of patients with specific comorbid illnesses also varied by BMI classification.
indexes were 0.77, 0.78, and 0.72 for CATH, PCI, and CABG, respectively.

Mortality rates after AMI also seemed to vary by BMI classification (Table 4). Compared with patients who did not receive a procedure, mortality rates were lower for patients who received PCI or CABG regardless of BMI class. The average causal treatment difference, however, was greater for the lower BMI classes than for the higher BMI classes. For example, normal-weight patients who did not receive PCI had an adjusted mortality rate of 0.37 compared with 0.29 for those who received PCI.

In the adjusted analyses, there was also an inverted $U$ relationship between coronary procedure use and BMI (Table 3 and the Figure). As in the unadjusted analyses, normal-weight patients had lower odds than the referent BMI classification of receiving each of the coronary procedures. However, the relationship was not as strong after adjusting for known predictors of coronary procedure use. On the upper end of the BMI classification system, individuals with obesity class 2 (BMI of 35.0-39.9) were less likely to receive CABG (odds ratio, 0.88; 95% confidence interval, 0.79-0.98) than the referent patients. Meanwhile, individuals with obesity class 3 were less likely to receive PCI than nondiabetic patients to receive cardiac catheterization or open heart surgery at the admitting hospital; prehospitalization setting and discharge disposition of patients. In contrast to the relationship seen in patients with a normal BMI, adjusting for possible confounding characteristics strengthened the relationship between severe obesity and lower coronary procedure use. Odds ratios for individuals with obesity class 3 were of comparable magnitude to the lower odds of procedure use for patients of nonwhite race and female sex (Table 3). In addition, patients with diabetes mellitus were less likely than nondiabetic patients to receive cardiac catheterization or PCI but as likely to receive CABG.

In addition, patients with diabetes mellitus were less likely to receive PCI or CABG regardless of BMI class. The average causal treatment difference, however, was greater for the lower BMI classes than for the higher BMI classes. For example, normal-weight patients who did not receive PCI had an adjusted mortality rate of 0.37 compared with 0.29 for those who received PCI.

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); CABG, coronary artery bypass grafting; CATH, cardiac catheterization; PCI, percutaneous coronary intervention.

Table 2. Frequency of Coronary Procedures by BMI Classification

<table>
<thead>
<tr>
<th>BMI Classification</th>
<th>Normal Weight (18.5-24.9)</th>
<th>Overweight (25.0-29.9)</th>
<th>Obesity Class 1 (30.0-34.9)</th>
<th>Obesity Class 2 (35.0-39.9)</th>
<th>Obesity Class 3 (≥ 40.0)</th>
<th>Height or Weight Data Missing</th>
<th>Total Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilities with a cardiac catheterization laboratory Sample size, No.</td>
<td>37,414</td>
<td>36,884</td>
<td>13,585</td>
<td>3706</td>
<td>1461</td>
<td>16,614</td>
<td>109,664</td>
</tr>
<tr>
<td>CATH, %</td>
<td>45.4</td>
<td>56.4</td>
<td>58.2</td>
<td>56.7</td>
<td>51.6</td>
<td>18.0</td>
<td>47.0</td>
</tr>
<tr>
<td>PCI, %</td>
<td>17.6</td>
<td>21.5</td>
<td>22.1</td>
<td>21.8</td>
<td>19.2</td>
<td>7.9</td>
<td>18.2</td>
</tr>
<tr>
<td>Facilities with a capacity for open heart surgery Sample size, No.</td>
<td>26,028</td>
<td>25,980</td>
<td>9,534</td>
<td>2,532</td>
<td>980</td>
<td>10,796</td>
<td>75,850</td>
</tr>
<tr>
<td>CABG, %</td>
<td>14.1</td>
<td>18.8</td>
<td>18.9</td>
<td>18.2</td>
<td>14.3</td>
<td>2.9</td>
<td>14.8</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); CABG, coronary artery bypass grafting; CATH, cardiac catheterization; NA, not applicable; PCI, percutaneous coronary intervention.

Table 3. Unadjusted and Adjusted Odds Ratios for Utilization of Coronary Procedures*

<table>
<thead>
<tr>
<th>BMI Classification</th>
<th>Normal Weight (18.5-24.9)</th>
<th>Overweight (25.0-29.9)</th>
<th>Obesity Class 1 (30.0-34.9)</th>
<th>Obesity Class 2 (35.0-39.9)</th>
<th>Obesity Class 3 (≥ 40.0)</th>
<th>Nonwhite Race</th>
<th>Female Sex</th>
<th>Diabetes Mellitus</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATH Unadjusted</td>
<td>0.65 (0.63-0.67)</td>
<td>1.00</td>
<td>1.06 (1.02-1.10)</td>
<td>1.06 (0.99-1.13)</td>
<td>0.93 (0.84-1.03)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Adjusted†</td>
<td>0.85 (0.83-0.88)‡</td>
<td>1.00</td>
<td>0.97 (0.93-1.02)</td>
<td>0.94 (0.87-1.01)</td>
<td>0.82 (0.73-0.92)‡</td>
<td>0.88 (0.84-0.92)‡</td>
<td>0.76 (0.74-0.78)‡</td>
<td>0.83 (0.80-0.85)‡</td>
</tr>
<tr>
<td>PCI Unadjusted</td>
<td>0.77 (0.74-0.79)</td>
<td>1.00</td>
<td>1.03 (0.99-1.08)</td>
<td>1.05 (0.96-1.14)</td>
<td>0.93 (0.82-1.06)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Adjusted†</td>
<td>0.91 (0.88-0.95)†</td>
<td>1.00</td>
<td>1.02 (0.97-1.07)</td>
<td>1.04 (0.96-1.14)</td>
<td>0.89 (0.77-1.03)</td>
<td>0.83 (0.78-0.88)‡</td>
<td>0.92 (0.89-0.96)‡</td>
<td>0.76 (0.73-0.79)‡</td>
</tr>
<tr>
<td>CABG Unadjusted</td>
<td>0.70 (0.67-0.73)</td>
<td>1.00</td>
<td>0.99 (0.94-1.06)</td>
<td>0.98 (0.88-1.09)</td>
<td>0.78 (0.65-0.93)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Adjusted†</td>
<td>0.88 (0.84-0.93)‡</td>
<td>1.00</td>
<td>0.94 (0.88-1.00)</td>
<td>0.88 (0.79-0.98)‡</td>
<td>0.68 (0.57-0.82)‡</td>
<td>0.76 (0.71-0.82)‡</td>
<td>0.66 (0.63-0.69)‡</td>
<td>1.03 (0.98-1.08)‡</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); CABG, coronary artery bypass grafting; CATH, cardiac catheterization; NA, not applicable; PCI, percutaneous coronary intervention.

*Data are given as odds ratio (95% confidence interval).
†Adjusted analyses included variables for patient demographics; comorbid illnesses, including previous coronary interventions, recent surgery, or trauma; severity of acute myocardial infarction; availability of cardiac catheterization or open heart surgery at the admitting hospital; prehospitalization setting and discharge disposition of the patient; hospital ownership; and hospital teaching status. For the adjusted models, $c$ indexes were 0.77, 0.78, and 0.72 for CATH, PCI, and CABG, respectively.
‡Denotes statistical significance.
ceived PCI, resulting in an average causal treatment difference of 0.08. In contrast, the average causal treatment difference for patients with obesity class 3 was 0.03. The trend was similar for the CABG analyses.

As a result of the higher prevalence of CHD, obese persons are more likely than normal-weight persons to require diagnostic and therapeutic coronary procedures.13 These procedures, however, may be limited at high body weights because manufacturers’ recommendations restrict patient body weight to less than 159 kg on many cardiac catheterization tables. Regardless of equipment weight capacity, physicians might be hesitant to perform diagnostic catheterization for patients who are severely obese owing to perceptions about increased morbidity, technical difficulty, and issues of constrained therapeutic options. Because of their high CHD risk status, however, obese persons may derive sufficient benefit from these procedures to outweigh perceived risks. Furthermore, if diagnostic tests are not performed to document CAD, it is possible that obese persons might not receive maximally appropriate therapy. Finally, visual documentation of CAD by cardiac catheterization might also supply motivation for patients to change unhealthy behaviors.24

In a large national sample of Medicare patients hospitalized for AMI, we found that the utilization of 3 coronary procedures varied substantially with BMI. Normal-weight patients were less likely than heavier patients to receive each of the 3 procedures. Overweight and class 1 obese individuals had the highest rates of procedure utilization rather than normal-weight individuals, who

Figure. Adjusted odds ratios for the utilization of cardiac catheterization (A), percutaneous coronary intervention (B), and coronary artery bypass grafting (C) according to body mass index (BMI) (calculated as weight in kilograms divided by the square of height in meters). Error bars represent 95% confidence intervals.

Table 4. Adjusted* 1-Year Mortality Rates by BMI

<table>
<thead>
<tr>
<th>BMI Classification</th>
<th>Normal Weight (18.5-24.9)</th>
<th>Overweight (25.0-29.9)</th>
<th>Obesity Class 1 (30.0-34.9)</th>
<th>Obesity Class 2 (35.0-39.9)</th>
<th>Obesity Class 3 (≥ 40.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed overall</td>
<td>0.32</td>
<td>0.23</td>
<td>0.22</td>
<td>0.23</td>
<td>0.25</td>
</tr>
<tr>
<td>PCI modeled estimates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>0.35</td>
<td>0.26</td>
<td>0.25</td>
<td>0.26</td>
<td>0.26</td>
</tr>
<tr>
<td>No PCI</td>
<td>0.37</td>
<td>0.29</td>
<td>0.27</td>
<td>0.27</td>
<td>0.28</td>
</tr>
<tr>
<td>PCI</td>
<td>0.29</td>
<td>0.21</td>
<td>0.21</td>
<td>0.23</td>
<td>0.24</td>
</tr>
<tr>
<td>Difference (95% CI)</td>
<td>0.08 (0.06 to 0.1)</td>
<td>0.08 (0.06 to 0.08)</td>
<td>0.06 (0.05 to 0.08)</td>
<td>0.05 (0.02 to 0.07)</td>
<td>0.03 (-0.03 to 0.08)</td>
</tr>
<tr>
<td>CABG modeled estimates†</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>0.34</td>
<td>0.26</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>No CABG</td>
<td>0.35</td>
<td>0.27</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>CABG</td>
<td>0.28</td>
<td>0.21</td>
<td>0.22</td>
<td>0.24</td>
<td>0.24</td>
</tr>
<tr>
<td>Difference (95% CI)</td>
<td>0.07 (0.05 to 0.09)</td>
<td>0.06 (0.04 to 0.07)</td>
<td>0.04 (0.02 to 0.06)</td>
<td>0.02 (-0.02 to 0.05)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); CABG, coronary artery bypass grafting; CI, confidence interval; PCI, percutaneous coronary intervention.

*Adjusted analyses included variables for patient demographics; comorbid illnesses, including previous coronary interventions, recent surgery, or trauma; severity of acute myocardial infarction; availability of cardiac catheterization or open heart surgery at the admitting hospital; prehospitalization setting and discharge disposition of the patient; hospital ownership; hospital teaching status; cardiac arrest, shock, or bleeding before arrival; chest pain lasting longer than 60 minutes after arrival; serum creatinine level at arrival; and use of β-blockers or aspirin during hospitalization.

†For the CABG analysis, the 2 highest BMI classes were collapsed owing to the small number of events. Modeled estimates are derived from the 10 imputed data sets. For mean treatment difference, values may not sum perfectly with mortality rates because of rounding.
we expected would have the highest utilization rates. Rates of utilization decreased again in individuals with more severe obesity, with the lowest adjusted odds for all 3 procedures occurring in patients with obesity class 3. The disparity in procedure utilization seen in class 3 obese patients was similar to that seen in persons of nonwhite race and in women, 2 groups with well-described and extensively studied disparities in the utilization of coronary procedures.1,2 We examined the clinical consequences of these disparities by calculating the average treatment difference between patients who received PCI (or CABG) and those who did not. Patients who received these interventions had improved mortality rates across all BMI classes, but this difference was less prominent in the higher BMI classes.

Lower rates of utilization in normal-weight patients might be explained by their higher rates of comorbid illness. Procedures may not be considered in patients with significant comorbid illness because of the potential for complications or because of a poor baseline prognosis. The adjusted analyses demonstrated that much of the discrepancy in coronary procedure utilization seen in normal-weight persons could be explained by these patient characteristics.

Patients with obesity class 3 also had evidence of increased comorbid illness. However, the relationship between obesity class 3 and decreased procedure utilization was actually strengthened by adjusting for possible confounding patient- and hospital-related factors. Furthermore, because patients weighing more than 159 kg were excluded, body weight restrictions placed by catheterization equipment manufacturers do not explain this effect.

Type 2 diabetes mellitus is highly correlated with obesity. Therefore, we performed analyses to examine how the prevalence of diabetes mellitus affected the utilization of coronary procedures in each BMI classification. Because the benefit from CABG over PCI is considered to be greater in diabetic patients than in nondiabetic patients,25 one would expect diabetic patients to be less likely to receive PCI and at least as likely to receive CABG compared with nondiabetic patients, regardless of BMI. We found this to be true, but we also found that patients with diabetes mellitus were less likely than nondiabetic patients to receive cardiac catheterization. The lower rate of cardiac catheterization in diabetic patients is concerning because catheterization is required before beneficial revascularization with CABG.

Epidemiologic studies26 have shown that mean BMI increases with age until approximately 65 years, after which mean BMI begins to decline. Furthermore, the optimal BMI in terms of survival may increase slightly with age, and the relative risk of mortality by BMI may decrease with age.26,27 These relationships are important to consider when interpreting data from the Cooperative Cardiovascular Project. In our analyses, no individual was younger than 65 years, and the mean age of the overall sample was 76 years. Therefore, as expected, the proportion of the sample that is classified as obese is less than would be seen in a younger sample.

This leads to an important limitation of our study. In a younger sample than the Cooperative Cardiovascular Project cohort, the highest rate of procedure utilization would likely occur at a lower BMI because younger individuals who are underweight or normal weight are likely to be healthier than elderly patients in these BMI classifications. This fact, combined with the likelihood that a younger sample would have a higher prevalence of overweight and obesity, might result in disparities in procedure utilization of greater magnitude or at even earlier stages of obesity. Therefore, in a younger patient sample, one would expect that a higher proportion of individuals would be deprived of potentially beneficial procedures. Examination of these questions in a more recent cohort is also warranted given the increasing prevalence of obesity and the improvements in procedural techniques and equipment technology.

Another limitation is that our study is an analysis of retrospective cohort data. One can only speculate as to why patients of differing BMI receive coronary procedures at different rates, and data collection is limited to that which is recorded in the medical record. In addition, height, weight, or both measurements were missing in 15% of the sample. In our analyses, we used multiple imputation, which should minimize the effect of this nonrandom pattern of missing data. Finally, the superior 1-year survival rate in patients who received PCI or CABG compared with those who did not was less pronounced in patients with a greater BMI. Future research should investigate whether the risks of coronary procedures outweigh the benefits in very obese patients.

In conclusion, we demonstrated that differing rates of coronary procedure utilization exist in patients of different BMI classes. In this patient sample, overweight and class 1 obese patients had the highest rates of utilization, whereas normal-weight and class 3 obese patients had significantly lower rates of utilization in comparison. Whereas increased morbidity may partially explain the lower utilization rates in patients with a normal BMI, it is unclear why severely obese patients have lower utilization rates. Moreover, unless it can be shown that the risks of these procedures outweigh the benefits in patients with severe obesity, initiatives may be necessary to prevent these variations in health care utilization. Finally, given the relationships between sex and BMI and between race and BMI, future research looking at health care disparities in women and racial minorities should consider BMI a confounder.
essarily reflect the views of the US Department of Health and Human Services, and neither does mention of trade names, commercial products, or organizations imply endorsement by the US government. The authors assume full responsibility for the accuracy and completeness of the ideas presented herein.

Additional Information: This article is a direct result of the Health Care Quality Improvement Program initiated by the Centers for Medicare and Medicaid Services, which has encouraged the identification of quality improvement projects derived from analysis of patterns of care.

REFERENCES