AN ECONOMIC ANALYSIS & COMPARISON OF PERCUTANEOUS CORONARY INTERVENTION & CORONARY ARTERY BYPASS GRAFT SURGERY

JONATHAN ALEXANDER BOCK ‘11
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Franklin & Marshall College
PO Box 3003
Lancaster, PA 17604-3003
ABSTRACT

This study of cardiovascular disease in adults investigates the interdependence and relative impacts of two specific medical interventions for coronary artery disease (CAD) patients. The goal of this study is to determine the extent to which invasive CAD procedures have favorable economic cost and quality-of-life related outcomes with a specific focus on the economic cost and quality-of-life related impacts of percutaneous coronary intervention (PCI) and coronary artery bypass graft (CABG) surgery, taking into account both quantitative and qualitative measures and outcomes. According to the American Heart Association, the problem of cardiovascular disease affects over 30% of adults in the U.S. with an economic cost of $503.2 billion in 2010. However, despite the magnitude of the cardiovascular disease problem, there have been relatively few comparative effectiveness studies on CAD treatment, and even fewer investigating costs and benefits (both direct and indirect). Specifically, there is a need to better understand the future impact of these treatments on future healthcare spending and the economic outcomes of cardiovascular health promotion.

This study contributes to existing literature by using recent data to conduct statistical calculations on the differences in hard outcomes between PCI and CABG procedures. Furthermore, this study compares differences and significance levels in both long and short-term outcomes, suggesting policy recommendations based on the results of this study. Finally, this study recommends a direction for future research on coronary artery disease and appropriate considerations for future research to take into account. This study will use data collected in existing studies and databases and use statistical analyses and calculations to develop a cost-benefit analysis of cardiovascular disease. The principal questions addressed in this study are: 1) Based on current conditions, the health of U.S. adults, and the medical technology and resources at our disposal, what costs and benefits can be expected for coronary artery disease patients? 2) What are the comparative costs, benefits, and effectiveness of current treatment options?

This study found that it is reasonable to assume that, when controlling for age, mean life expectancies between CABG and PCI patients do not differ significantly. Although quality-of-life outcomes among CABG patients were generally superior to PCI patients one year after the procedures, this study discovered that both quantitative and qualitative long-term outcomes do not differ significantly between CABG and PCI patients. Therefore, this study highlights the importance of considering long-term outcomes when making medical decisions by showing that although hospital charges for CABG surgery far exceed charges for PCI initially, a greater need among PCI patients for repeat procedures contributes to similar long-terms costs between these two procedures.
INTRODUCTION

This study of cardiovascular disease in adults investigates the interdependence and relative impacts of two specific medical interventions for coronary artery disease (CAD) patients. The goal of this study is to determine the extent to which invasive CAD procedures have favorable economic cost and quality-of-life related outcomes with a specific focus on the economic cost and quality-of-life related impacts of percutaneous coronary intervention (PCI, which includes balloon angioplasty and stenting) and coronary artery bypass graft (CABG) surgery, taking into account both quantitative and qualitative measures and outcomes.

The fact is that cardiovascular disease is a formidable problem affecting over 30% of adults in the U.S. with an economic cost of $503.2 billion in 2010\(^1\). However, despite the magnitude of the cardiovascular disease problem, there have been relatively few comparative effectiveness studies on CAD treatment, and even fewer investigating costs and benefits (both direct and indirect). Specifically, there is a need to better understand the future impact of these treatments on future healthcare spending and the economic outcomes of cardiovascular health promotion. A recent study by the American Heart Association predicts that the cost of cardiovascular disease will triple between now and 2030, exceeding $800 billion per year\(^2\). In a country whose health care expenditures already exceed 17 percent of the GDP, a threefold increase of the cardiovascular disease cost burden is particularly ominous.

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Although this is a topic of upmost importance from both health and economic standpoints, the vast majority of the existing research that examined the economics of cardiovascular disease is out-of-date. This study contributes to existing literature by using recent data to conduct statistical calculations on the differences in hard outcomes between PCI and CABG procedures. Furthermore, this study compares differences and significance levels in both long and short-term outcomes, suggesting policy recommendations based on the results of this study. Finally, this study recommends a direction for future research on coronary artery disease and appropriate considerations for future research to take into account. This study will use data collected in existing studies and databases and use statistical analyses and calculations to develop a cost-benefit analysis of cardiovascular disease. The principal questions addressed in this study are:

1. Based on current conditions, the health of U.S. adults, and the medical technology and resources at our disposal, what costs and benefits can be expected for coronary artery disease patients?

2. What are the comparative costs, benefits, and effectiveness of current treatment options?

The first section of this paper will introduce coronary artery disease. This is followed by in-depth analyses of hard and soft outcomes between CABG and PCI procedures. Differences in outcomes between the two procedures are examined in both the long and short-term. This analysis is comprised of a series of progressive steps. First is the determination of the direct medical charges for PCI and CABG to coronary artery disease patients from current data in medical databases and existing studies. This step uses an empirical approach to gathering the
needed information. For example, the U.S. Department of Health and Human Services’ Agency for Healthcare Research and Quality’s database was used to find the average costs and charges of performing PCI and CABG surgeries. This resource provides information, on both state and national levels, about various procedures such as: patient gender and mean age, the number of discharges, mean charges (total amount the hospital billed for the encounter), mean lengths of stay, the percent of deaths from the procedure, and aggregate costs. An important part of this step is determining whether or not we can assume that patient hard outcomes significantly differ between these two procedures. The hard data acquired from the medical databases and studies are used to determine whether or not quantitative outcomes such as life expectancy significantly differ between CAD patients who underwent PCI procedures compared to those who had CABG surgeries. Statistical measures such as z-tests and hypothesis testing are used to determine the levels of significance. Next, long-term costs and outcomes from the two procedures are compared using cost-benefit, cost-effectiveness, and cost-utility analyses. This study also examines differences in qualitative outcomes (such as quality-of-life) between coronary artery disease patients who underwent CABG and those who obtained PCI. The next step provides the average quality-adjusted life years gained following PCI procedures and compares the result to the average quality-adjusted life years gained following CABG surgery. The quality-adjusted life years are then used in the subsequent step by transforming the quality-adjusted life years into monetary values using David Cutler’s method described in Your Money or Your Life. The final step in this section will involve conducting cost-benefit, cost-effective, and cost-utility analyses by comparing and contrasting the results from the previous steps. Finally, the study’s conclusion is stated, followed by policy recommendations for these procedures. This study also includes an appendix that suggests the direction future studies on CABG and PCI should take. This study will
guide the reader through these progressive steps by describing the involved formulas and processes in detail.
SECTION 1
CORONARY ARTERY DISEASE INTRODUCTION

One of the most deadly and costly forms of cardiovascular disease is a condition known as coronary atherosclerosis, or its more commonly recognized name, coronary artery disease. In the year 2006, an estimated 17,600,000 U.S. residents were suffering from coronary artery disease, and the estimated economic cost of CAD exceeded $156 billion in 2008\(^3\). Coronary artery disease is characterized by progressive narrowing and inflammation of the arteries supplying the heart muscle, resulting in damage to the heart. This is a serious condition because coronary arteries are the major blood vessels that supply the heart with blood, nutrients, and oxygen. Therefore, the narrowing of these major blood vessels often lead to heart attack and/or heart failure. There are multiple contributing factors to the risk of developing coronary artery disease. Some concern lifestyle choices, while others are based on genetic factors and characteristics. The main contributors that increase one’s risk of CAD are smoking (nicotine constricts blood vessels while carbon monoxide damages their inner lining), high blood pressure, high cholesterol, diabetes, and radiation therapy to the chest used for treating certain types of cancer. Risk is also known to increase with age. Furthermore, men are generally at a greater risk of developing CAD than women. Obesity, physical inactivity, and high levels of stress also increase one’s risk for this

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\(^3\) American Heart Association. “Cardiovascular Disease Statistics”. Webpage Last Updated: May 4\(^{th}\), 2011.
disease. Genetics can also be another risk factor. (Specifically, the site reveals that one’s risk is “highest if [one’s] father or a brother was diagnosed with heart disease before age 55, or [one’s] mother or a sister developed it before age 65”).

There are a number of ways to treat coronary artery disease, including lifestyle changes, medications, and procedures. Lifestyle changes often include quitting smoking, eating healthy foods, exercising regularly, losing excess weight, and reducing stress. Medications often used to treat coronary artery disease include cholesterol-modifying drugs, aspirin, nitroglycerin, angiotensin-converting enzyme inhibitors and angiotensin receptor blockers, and calcium channel blockers.

Changing lifestyle choices affects the risk of developing or worsening coronary artery disease and cardiovascular disease in general. In fact, a recent study of the reduction of US deaths due to CAD from 1980 to 2000 attributes approximately 44% to changes in risk factors in the population. According to David Cutler, behavioral changes account for between 10 and 33 percent of lower cardiovascular disease mortality.

However, there is one important consideration to take into account when evaluating the effectiveness of changes in lifestyle choices on one’s risk of coronary artery disease—the processes that lead to CAD often occur long before physical symptoms arise. Coronary atherosclerosis is characterized by a gradual buildup of collections of cholesterol within walls of the coronary arteries. This process causes hardening of the arterial walls and the narrowing of

the artery, thus limiting the proper blood flow needed to sustain the health of the heart muscle. Although the actual process of atherosclerosis can begin as early as one’s teenage years, the symptoms or health problems usually do not occur until later in adulthood when the arterial narrowing becomes severe. In other words, although coronary artery disease generally does not affect individuals until mid to late adulthood, the process that leads to coronary artery disease often begins at young ages. This underscores the importance of emphasizing healthy lifestyle behaviors beginning early in life, especially in those at higher risk, recognizing that the positive effects arising from these changes often take considerable time to appear. Therefore, it is common among sufferers of coronary artery disease that more aggressive treatments are needed to restore and improve blood flow. Examples of such procedures include PCI and coronary artery bypass graft surgery—two common procedures that will be the central topic of this project. In general, both PCI and CABG procedures effective treat CAD patients with multi-vessel disease.
The only exceptions are in instances where the left main artery is blocked\(^8\) or the patient has diabetes, and in these cases, CABG surgeries tend to have better results.

Percutaneous coronary intervention (PCI) encompasses a variety of procedures used to treat patients with diseased arteries of the heart, for example, chest pain caused by decreased blood flow due to a slow build-up of fats, cholesterol, and other substances (referred to as plaque). Sudden decreased of blood flow due to a blood clot can cause a heart attack. Typically, PCI is performed by threading a slender catheter and a tiny balloon from an artery in the groin to a trouble spot in an artery of the heart. The balloon is then inflated, compressing the plaque and dilating (widening) the narrowed coronary artery so that blood can flow more easily (balloon angioplasty). The artery can be held open after angioplasty by inserting an expandable metal stent. Stents are wire mesh tubes used to support open arteries after PCI balloon angioplasty\(^9\). Some stents slowly release medication to help keep the artery open.

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\(^8\) In the BARI study, patients with left main stenosis greater than 50% were excluded from the sample.

\(^9\) American Heart Association. “Percutaneous Coronary Interventions (previously called Angioplasty, Percutaneous Transluminal Coronary [PTCA], or Balloon Angioplasty)”. Last Updated: 2011.
In coronary artery bypass surgery, a surgeon creates a graft to bypass blocked coronary arteries using a vessel from another part of the patient’s body\(^\text{10}\). This allows blood to flow around the blocked or narrowed coronary artery. Because this requires open-heart surgery, it is often reserved for cases of multiple narrowed coronary arteries\(^\text{11}\). Depending on the number of coronary arteries that are blocked, patients may undergo more than bypass graft procedures. The surgical procedure itself is quite complicated, therefore an array of medical personnel other than the surgeon are usually present. For example, cardiac anesthesiologists, surgical nurses, and blood flow specialists are often involved in these procedures as well. Additional measures are often sought to further improve patient outcomes. After surgery, the patient is moved to a hospital bed in the cardiac surgical intensive care unit where the patient’s heart rate and blood pressure are continuously monitored for up to 24 hours. During this time, medications that regulate circulation and blood pressure and breathing tubes are often needed to ensure the patient’s safety. Total costs continue to accumulate after discharge, since CABG patients are often enrolled in physician-supervised cardiac rehabilitation programs and continue to take a number of medications\(^\text{12}\). Since the validity of the calculations in this study rely on accurate medical data, several technical economic and statistical considerations that may affect the analyses and conclusions should be considered.

Technical economic and statistical considerations include assuring comparative dates of data collection (given rapid advancement in technology and rapid changes in data and statistics). Also, there is the need for caution when cost and outcome data come from different countries or even specific hospitals where experience and technical resources may differ considerably.

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\(^{10}\) The Mayo Clinic. “Coronary Artery Disease: Treatments and Drugs”. Last Updated: November 5, 2010.

\(^{11}\) The Mayo Clinic. “Coronary Artery Disease: Treatments and Drugs”. Last Updated: November 5, 2010.

Furthermore, since health outcomes may take years to manifest, cost and benefit projections must be uniformly adjusted (such as into present values). There also is the need for vigilance when pricing non-market goods such as time or quality of life. This study will be attentive of these technical economic and statistical considerations in the calculations in the subsequent sections.
SECTION 2
CORONARY ARTERY DISEASE ANALYSIS

PART A:

In the year 2008, 918,877 patients with coronary artery disease were discharged from hospitals across the country. This number represents roughly 2.3% of total medical discharges during that year. The medical charges for these patients averaged $51,906 per procedure\(^{13,14}\). However, the average cost of coronary artery disease per patient—defined as a hospital’s actual costs of providing the care—was $15,854 in 2008, with the aggregate cost of CAD in 2008 totaling $14,529,014,336 and a national bill of $47,562,992,953. The average age for these patients was 65 years, and 63.3% were male. Two of the most common invasive medical procedures used to treat patients suffering from coronary artery disease are PCI and CABG\(^{15}\).

Out of these discharged patients with coronary artery disease, 384,403 underwent percutaneous coronary angioplasty. The average charge for performing PCI procedures was

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\(^{13}\) U.S. Department of Health & Human Services’ Agency for Healthcare Research.

\(^{14}\) Note that charges represent what the hospital billed, while costs tend to reflect the actual costs of production. Charges are the total amount billed by the hospital for the encounter, but not the actual cost of providing care or the payment received by the hospital (e.g., hospital reimbursement). With an insurance plan, a patient would probably not bear the full hospital bill. This number represents the mean hospital charge for all procedures undergone by CAD patients.

\(^{15}\) U.S. Department of Health & Human Services’ Agency for Healthcare Research.
Furthermore, CAD patients undergoing PCI procedures stayed on average 1.9 days in the hospital. The average age for these patients was 65 years, and 65.0% were male. Of the discharged patients with coronary artery disease, 149,734 underwent coronary artery bypass graft surgery. This number represents roughly 0.4% of total medical discharges during that year. The average charge (total amount billed for each procedure) for the CABG surgeries, however, was $105,754. Furthermore, CAD patients undergoing CABG procedures stayed on average 8.2 days in the hospital. The average age for these discharged patients was also 65 years, and 73.1% were male.

For coronary artery disease sufferers, hospital bills for CABG surgery totaled to more than twice that of PCI procedures. To what extent are the differences in charges related to differences in quantitative outcomes such as life expectancy or mortality rates, or qualitative outcomes such as health related quality-of-life outcomes?

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16 This charge represents the average hospital charge for a PCI procedure for coronary artery disease in 2008. Note that this charge does not represent all PCI procedures conducted in 2008. In 2008, the average hospital charge for PCI for heart attack victims was $64,279, $70,502 for patients with cardiac dysrhythmias, and $89,577 for patients with congestive heart failure.
18 This charge represents the average hospital charge for a CABG procedure for coronary artery disease in 2008. Note that this charge does not represent all CABG procedures conducted in 2008. In 2008, the average hospital charge for CABG for heart attack victims was $142,336 and $206,124 for patients with congestive heart failure.
PART B: QUANTITATIVE OUTCOMES

The differences in hospital charges between the PCI groups and the CABG groups are astounding. It would be worth investigating whether or not this cost difference is reflected in differences in outcomes. In other words, if CABG patient outcomes are significantly superior to PCI outcomes, then perhaps this cost discrepancy is reasonable. Therefore, hard outcomes such as life expectancy and mortality rates between these two procedures have been examined. Since mean ages do not significantly differ between CAD patients seeking PCI procedures and those seeking CABG surgery, it is now time to determine whether hard outcomes significantly differ between these two procedures. A number of researchers have conducted studies on outcomes associated with PCI and CABG procedures. The Bypass Angioplasty Revascularization Investigation (BARI) study investigated the long-term outcomes of CAD patients undergoing PCI and CABG procedures.

"The BARI randomized trial was designed to test whether percutaneous transluminal coronary balloon angioplasty (PCI) compromised 5-year survival compared with coronary artery bypass grafting (CABG) in patients with multivessel coronary artery disease (CAD). The long-term follow-up of this large cohort of selected patients with multivessel CAD randomized to receive either balloon angioplasty or coronary bypass surgery shows similar rates of survival and freedom from MI [i.e. heart attack] over 10 years."²⁰

The BARI study determined, among a sample of patients with the same mean age, the mean life expectancies between PCI and CABG groups. Furthermore, the BARI study also determined the life expectancies between PCI and CABG patients based on whether or not the

²⁰ The BARI Investigators. “The Final 10-Year Follow-Up Results From the BARI Randomized Trial”. Journal of the American College of Cardiology. 2007.
patient had diabetes. The mean life expectancies are represented in the table below.

Table 1

<table>
<thead>
<tr>
<th>PROCEDURE</th>
<th>SUBGROUP</th>
<th>MEAN LIFE EXPECTANCY (Years)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI</td>
<td>All PCI</td>
<td>8.63</td>
<td>465</td>
</tr>
<tr>
<td>CABG</td>
<td>All CABG</td>
<td>8.86</td>
<td>469</td>
</tr>
<tr>
<td>PCI</td>
<td>No Diabetes</td>
<td>9.02</td>
<td>373</td>
</tr>
<tr>
<td>CABG</td>
<td>No Diabetes</td>
<td>9.05</td>
<td>355</td>
</tr>
<tr>
<td>PCI</td>
<td>Diabetes</td>
<td>6.93</td>
<td>92</td>
</tr>
<tr>
<td>CABG</td>
<td>Diabetes</td>
<td>8.07</td>
<td>114</td>
</tr>
</tbody>
</table>

It is also relevant to note that a meta-analysis (consisting of 13 studies) compared 7,964 eligible patients with CAD that were randomized to CABG or PCI and found that overall, neither procedure provided a statistically superior survival advantage after one, three, or eight years after the procedure\(^{21}\). Therefore, it is reasonable to assume that, among coronary artery disease patients, and controlling for other variables, mean life expectancies between CABG and PCI procedures as a whole do not differ significantly (the diabetic subgroup is an exception). Similarly, z-tests comparing the mean 5-year and 10-year survival rates in the BARI study yield similar results. Table 2 reveals mortality results from the BARI study, followed by z-tests comparing these mortality rates.

Table 2

<table>
<thead>
<tr>
<th>PROCEDURE</th>
<th>SUBGROUP</th>
<th>5-Yr SURVIVAL (%)</th>
<th>10-Yr SURVIVAL (%)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI</td>
<td>All PCI</td>
<td>86.3</td>
<td>71.0</td>
<td>915</td>
</tr>
<tr>
<td>CABG</td>
<td>All CABG</td>
<td>89.2</td>
<td>73.5</td>
<td>914</td>
</tr>
<tr>
<td>PCI</td>
<td>No Diabetes</td>
<td>91.0</td>
<td>77.0</td>
<td>742</td>
</tr>
<tr>
<td>CABG</td>
<td>No Diabetes</td>
<td>91.45</td>
<td>77.3</td>
<td>734</td>
</tr>
<tr>
<td>PCI</td>
<td>Diabetes</td>
<td>66.5</td>
<td>45.5</td>
<td>173</td>
</tr>
<tr>
<td>CABG</td>
<td>Diabetes</td>
<td>79.9</td>
<td>57.9</td>
<td>180</td>
</tr>
</tbody>
</table>

Let $n_p$ = the number of PCI procedures, $n_c$ = the number of CABG surgeries, $\theta_p$ = PCI group survival rate, and $\theta_c$ = CABG group survival rate. We now want to test whether $H_0 : \theta_p = \theta_c$ (in other words, whether or not survival rates between PCI and CABG significantly differ among the patients in the BARI study. An unbiased point estimator of $\theta_c - \theta_p$ is $\hat{\Theta}_c - \hat{\Theta}_p$, where $\hat{\Theta}_c = \frac{X_c}{n_c}$ and $\hat{\Theta}_p = \frac{X_p}{n_p}$ are the sample proportions. This estimator has a normal distribution with mean

$$\theta_c - \theta_p$$

and standard deviation

$$\sqrt{\frac{\theta_c(1-\theta_c)}{n_c} - \frac{\theta_p(1-\theta_p)}{n_p}}.$$  

Under the null hypothesis, this can be rewritten as

$$\sqrt{\theta_\lambda(1-\theta_\lambda)\left(\frac{1}{n_c} + \frac{1}{n_p}\right)},$$

where $\theta_\lambda$ is the common value of $\theta_c$ and $\theta_p$. To estimate $\theta_\lambda$, we can pool the PCI and CABG subgroups together since they are presumed to have the same probability of mortality. Therefore, $\theta_\lambda$ can be estimated by taking the total number of successes divided by the total number of patients in each patient subgroup. We get:

$$\hat{\theta}_\lambda = \frac{X_c + X_p}{n_c + n_p}.$$  

So,
after standardizing, our test statistic becomes \( Z = \frac{\hat{\Theta}_c - \hat{\Theta}_p}{\sqrt{\frac{1}{n_c} + \frac{1}{n_p}}} \sim N(0,1). \)

For all PCI and CABG patients’ 5-year mortality rates,
\[
\hat{\Theta}_\lambda = \frac{815.29 + 789.65}{915 + 914} = 0.8775 \text{ and } Z = \frac{0.892 - 0.863}{\sqrt{0.8775(1 - 0.8775)}} = 0.029 = 1.90
\]

For non-diabetic PCI and CABG patients’ 5-year mortality rates,
\[
\hat{\Theta}_\lambda = \frac{671.24 + 675.22}{734 + 742} = 0.9122 \text{ and } Z = \frac{0.9145 - 0.91}{\sqrt{0.9122(1 - 0.9122)}} = 0.0045 = 0.306
\]

For the diabetic PCI and CABG patients’ 5-year mortality rates,
\[
\hat{\Theta}_\lambda = \frac{143.82 + 115.05}{180 + 173} = 0.7333 \text{ and } Z = \frac{0.799 - 0.665}{\sqrt{0.7333(1 - 0.7333)}} = 0.134 = 2.85
\]

Similarly, for the 10-year mortality rates in the BARI study,

For all PCI and CABG patients,
\[
\hat{\Theta}_\lambda = \frac{671.8 + 649.65}{914 + 915} = 0.7225 \text{ and } Z = \frac{0.735 - 0.71}{\sqrt{0.7225(1 - 0.7225)}} = 0.025 = 1.196
\]

For non-diabetic PCI and CABG patients,
\[
\hat{\Theta}_\lambda = \frac{567.4 + 571.34}{734 + 742} = 0.7715 \text{ and } Z = \frac{0.773 - 0.77}{\sqrt{0.7715(1 - 0.7715)}} = 0.003 = 0.137
\]

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\(^{22}\) Levine, Alan. Department of Mathematics, Franklin & Marshall College. Adapted by Jonathan A. Bock
Finally, for diabetic PCI and CABG patients,

\[ \hat{\Theta}_x = \frac{104.22 + 78.72}{180 + 173} = 0.5182 \text{ and } Z = \frac{0.579 - 0.455}{\sqrt{0.5182(1 - 0.5182)} \sqrt{\frac{1}{180} + \frac{1}{173}}} = \frac{0.124}{0.0532} = 2.33 \]

Table 3: Significance of differences in mortality rates between CABG and PCI based on subgroups and follow-up periods

<table>
<thead>
<tr>
<th>SUBGROUP</th>
<th>5-YR. Z-VALUE</th>
<th>SIGNIFICANT?</th>
<th>10-YR. Z-VALUE</th>
<th>SIGNIFICANT?</th>
</tr>
</thead>
<tbody>
<tr>
<td>All CABG &amp; PCI</td>
<td>1.90</td>
<td>No</td>
<td>1.196</td>
<td>No</td>
</tr>
<tr>
<td>No Diabetes</td>
<td>0.306</td>
<td>No</td>
<td>0.137</td>
<td>No</td>
</tr>
<tr>
<td>Diabetes</td>
<td>2.85</td>
<td>Yes</td>
<td>2.33</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The results suggest that the differences in charges between the two procedures do not reflect long-term differences in hard outcomes (both life expectancy and 5 and 10-year mortality rates) between the two procedures as a whole. On the other hand, differences in soft outcomes, such as health-related quality of lives, may justify the price difference between PCI and CABG procedures.
PART C: QUALITATIVE OUTCOMES

A number of studies have consistently discovered that the quality of life for patients who undergo CABG surgery is significantly superior to the quality of life for similar patients undergoing PCI procedures. In order to more meaningfully compare outcomes between PCI procedures and CABG procedures for coronary artery disease victims, this study will next utilize the concept of quality-adjusted life years. Consider the following decisions and how one should answer them:

1. Should $10,000 be allocated towards a medical procedure that would extend Patient A’s life by 8 years or should the same $10,000 be allocated toward helping Patient B cope with chronic depression?
2. Should a $3,000 treatment be provided to help Patient C’s drug and alcohol addiction or should the money be used instead to treat Patient D’s eating disorder?

Obviously these questions have strong ethical implications—how could one possibly place a value on a person’s health? And how should it be done? Two concepts—quality-adjusted life years (QALYs) and the social value of health—arose in response to such medical and ethical dilemmas. Sarah J. Whitehead and Shehzad Ali explain that “the quality-adjusted life year (QALY) is routinely used as a summary measure of health outcomes [in] economic evaluations, which
incorporates the impact on both the quantity and quality of life” and are primarily used to correct someone’s life expectancy based on the levels of health-related quality of life he is predicted to experience throughout the course of his life, or part of it. QALY calculations involve two measures in particular—they are calculated by multiplying the patient’s life expectancy by his or her health-related quality of life (HRQoL). The health-related quality of life weight is a measure of a patient’s utility in a particular health state. It is measured on a cardinal scale of [0,1], where 0 represents death and 1 represents perfect health. For example, a patient with a life expectancy of 10 years will have a quality-adjusted life expectancy of 6 years, if his or her health-related quality of life weight is 0.6. “Several measures have been used to assess HRQOL and related concepts of functional status. Among them are the Medical Outcomes Study Short Forms (SF-12 and SF-36), the Sickness Impact Profile, and the Quality of Well-Being Scale.” QALYs that occur in the future are discounted to present values to account for the time lag until they are experienced. According to Franco Sassi of the LSE, the present value of quality-adjusted life expectancy (QALE) for an individual can be calculated using the equation:

\[
QALE = \int_{x=a}^{a+L} Q e^{-r(x-a)} dx = Q \frac{1-e^{-rL}}{r}
\] (1)

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25 Utility states are uniformly distributed from [0,1]. In other words, a patient’s change in utility from 0.3 to 0.4 is equivalent to a change from 0.8 to 0.9.


The integrand in the equation above represents the quality-adjusted life year as a function of time (i.e. years lived). Therefore, taking the integral yields the summation of the area under the curve—in other words, the quality-adjusted life expectancy. This study will use a discount rate of \( r=0.03 \) for its calculations, which is a typical value for discounting future costs into the present value, according to David Cutler. He makes note of the fact that many of the costs and benefits of medical interventions come in the future. Therefore, the costs and the benefits of medical innovation must be discounted to the present, and Cutler believes that a 3 percent discount rate is most appropriate in these situations\(^28\). In order to value particular health states, QALYs must be transformed into monetary values by implementing the concept of the social value of health.

David Cutler has much to offer with his method of “valuing/pricing” health. Cutler notes that “the traditional economic analysis values health as the amount that a person will earn over their lifetime” and that “many courts use a similar calculation”. However, Cutler argues against this methodology, because it “violates our basic sense of fairness”. He notes that this type of reasoning implies that there is “no value in keeping older people alive” if they are retired and not working. Furthermore, he argues that this methodology leads to valuing the rich more than the poor, since the rich earn more. Cutler argues for a different methodology on the valuation of life. He makes it clear that in addition to the person affected and his or her family, we must also consider the impact of health changes for one person on the financial status of everyone else. Cutler says that economists can estimate the value of a year of life by observing the choices people make. He uses air bags as an example to prove his point.

“Consider peoples’ willingness to pay for an airbag in their car. Air bags are now standard on new cars, but they did not use to be. When air bags were optional, people had the choice of buying one at a cost of about $300, or not. Many people wanted an air bag at that price...It turns out that air bags save the life of one driver in 10,000. Paying $300 to save one person in 10,000 is equivalent to paying $3 million for each life saved. Thus, the air bag suggests that most people value a life at least $3 million”

Cutler reveals that the willingness to pay (WTP) concept can be illustrated using various examples such as whether or not to buy a fire alarm, the choice of working in a riskier or safer job, and so on. He concludes that:

“Across a range of studies, a common conclusion is that the implied [monetary] value of remaining life ranges from $3 million on the low side to $7 million on the high side, with an average of perhaps $5 million. Most health economists use a number like this...For our purposes, we care about years of life more than life as a whole, because medical interventions are frequently evaluated that way...Most studies value a year of life at $75,000 to $150,000. [Cutler uses] $100,000 as the value of a year in good health (emphasis mine), which is approximately in the middle.

One may point out that the value of $100,000 for a year of good health is greater than the average annual income in the United States. However, people are usually more willing to give up more than their annual income to be alive. This reasoning is not contradictory unless the monetary value of one’s life exceeds his lifetime earnings. To illustrate this reasoning, consider people taking vacations. “Most people spend more on a week’s vacation than they could afford to spend if they were on vacation permanently—even if they still earned their regular salary. People are willing to cut back on their consumption at home to enjoy vacation more.”

Therefore, the value of a specific health state is calculated by multiplying the quality-adjusted life expectancy by the social value of health. One can also compare and contrast the

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values of specific procedures by multiplying the change in QALYs following the treatment by the social value of health. In other words, the QALY and social value of health concepts allow one to “quantify” and thus compare the values of the expected health outcomes that would result from Patient A, B, C, and D's medical procedures.

Cutler mentions that “medical advance has a cost and a benefit”. Money spent on medical procedures have an opportunity cost—they cannot be spent on public works, infrastructure, or other alternative uses. The benefits are the value of increased longevity and a higher quality of life, plus the positive effects of those health changes on others. Indeed, a number of studies have compared costs with patient quality-of-life following different medical procedures by utilizing the concepts of the QALY and the social value of health. What is interesting to note is that the vast majority of studies comparing quality-of-life differences between CABG and PCI patients have relatively short follow-up times. For example, a 2005 study published in the Journal of the American Heart Association conducted an in-depth examination and analysis of the quality-of-life for patients with multivessel coronary artery disease who were treated using PCI procedures (n=676) or with CABG surgery (n=410). The patients' quality-of-life was assessed using the self-administered Seattle Angina Questionnaire, which is designed to measure the functional status of coronary artery disease patients by addressing physical limitation, angina stability, angina frequency, treatment satisfaction, and disease perception. This questionnaire scores patients between 0 and 100 (i.e. SAQ quality-of-life score), where a higher score represents a higher quality-of-life. It should be noted that the baseline SAQ quality-of-life

scores (medicated patients without any past procedures) were roughly equivalent between both groups: $56.0 \pm 23.9$ for PCI patients and $56.1 \pm 23.2$ for CABG patients. Therefore, the differences in quality of life after the procedures should not reflect differences in the patients’ quality-of-life at baseline. Also, the average ages between the two groups were virtually identical: $66.1 \pm 11.1$ years old for PCI patients and $66.0 \pm 10.6$ years old for CABG patients. Average body mass indexes were similar between the two groups—on average $29.2$ for PCI patients and $28.5$ for CABG patients. Researchers found that in both procedures, the patients’ quality-of-lives were affected by their risk level for re-stenosis, which is the re-narrowing of a blood vessel or artery. The table below depicts the 2005 study’s findings.

<table>
<thead>
<tr>
<th>PROCEDURE</th>
<th>RESTENOSIS RISK</th>
<th>SAMPLE SIZE</th>
<th>SAQ SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI</td>
<td>Low</td>
<td>393</td>
<td>87.5±4.8</td>
</tr>
<tr>
<td>CABG</td>
<td>Low</td>
<td>153</td>
<td>86.6±4.5</td>
</tr>
<tr>
<td>PCI</td>
<td>Intermediate</td>
<td>453</td>
<td>87.3±8.7</td>
</tr>
<tr>
<td>CABG</td>
<td>Intermediate</td>
<td>225</td>
<td>92.1±8.6</td>
</tr>
<tr>
<td>PCI</td>
<td>High</td>
<td>181</td>
<td>76.3±9.8</td>
</tr>
<tr>
<td>CABG</td>
<td>High</td>
<td>54</td>
<td>86.4±9.5</td>
</tr>
</tbody>
</table>

The differences in the SAQ quality-of-life scores between CABG and PCI patients appear to be significant, especially for intermediate and high-risk patients. The z-tests calculated below reveal some interesting results.
Z = \frac{\overline{Q}_p - \overline{Q}_c - d}{\sqrt{\frac{\sigma_p^2}{n_p} + \frac{\sigma_c^2}{n_c}}} = \frac{87.5 - 86.6 - 0}{\sqrt{\frac{4.8^2}{393} + \frac{4.5^2}{153}}} = \frac{0.9}{0.437} = 2.059 \text{ for a low risk of re-stenosis.}

Z = \frac{\overline{Q}_p - \overline{Q}_c - d}{\sqrt{\frac{\sigma_p^2}{n_p} + \frac{\sigma_c^2}{n_c}}} = \frac{87.3 - 92.1 - 0}{\sqrt{\frac{8.7^2}{453} + \frac{8.6^2}{225}}} = \frac{-4.8}{0.7041} = -6.817 \text{ for an intermediate risk of re-stenosis.}

Z = \frac{\overline{Q}_p - \overline{Q}_c - d}{\sqrt{\frac{\sigma_p^2}{n_p} + \frac{\sigma_c^2}{n_c}}} = \frac{76.3 - 86.4 - 0}{\sqrt{\frac{9.8^2}{181} + \frac{9.5^2}{54}}} = \frac{-10.1}{1.484} = -6.806 \text{ for a high risk of re-stenosis.}

When the CAD patient was at a low risk for re-stenosis, there was no significant difference between the SAQ quality of life scores between CABG and PCI. However, for patients that were at an intermediate and high risk for re-stenosis, the difference between SAQ quality of life scores between CABG and PCI patients was statistically significant. There are limitations to this study's conclusions, however. For example, it would be unwise to give great weight to the results from the 2005 SAQ quality of life study since the follow-up period was only 12 months. On the other hand, an analysis of the BARI study revealed that the “early differences between CABG and PCI charges and quality of life were no longer significant after 10 to 12 years of follow-up and that CABG was cost-effective as compared with PCI for multivessel disease”\textsuperscript{37}. Therefore, when considering lifetime benefits and costs, it would be wiser to analyze the results of the BARI study. Specifically, during the 10 years of observation during the BARI study, PCI patients gained an

average of 6.45 QALYs and CABG patients gained an average of 6.58 QALYs. The next step is to perform cost-benefit, cost-effectiveness, and cost-utility analyses by transforming these QALYs into monetary values and comparing them to the lifetime costs accrued by the PCI and CABG patients in the BARI study.

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PART D: ECONOMIC ANALYSIS

In this part, quality-adjusted life years are transformed into monetary values by using David Cutler’s estimation of the economic value of one healthy year of life. This study has already shown that invasive surgery significantly increases quality-adjusted life expectancy for patients with coronary artery disease. However, these procedures are very expensive. How do the costs compare against the benefits?

Using Cutler’s value for one healthy year of healthy life at $100,000, Table 5 shows the mean QALYs gained per patient for the procedure groups in the BARI study, with the addition of a “QALYs Value” column, which transforms the gain in quality-adjusted life years into monetary values (using a social value of health of $100,000 per quality-adjusted life year). In other words, the QALYs Value column expresses the monetary benefit from obtaining the treatment. Also added is a column revealing the mean lifetime costs of the patients in the BARI study.

Table 5

<table>
<thead>
<tr>
<th>PROCEDURE</th>
<th>MEAN L.E.</th>
<th>MEAN QALYs</th>
<th>MEAN QALYs VALUE</th>
<th>MEAN LIFETIME COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL PCI</td>
<td>8.63</td>
<td>6.45</td>
<td>$645,000</td>
<td>$120,725&lt;sup&gt;39&lt;/sup&gt;</td>
</tr>
<tr>
<td>ALL CABG</td>
<td>8.86</td>
<td>6.58</td>
<td>$658,000</td>
<td>$122,997&lt;sup&gt;40&lt;/sup&gt;</td>
</tr>
</tbody>
</table>


Note that lifetime costs differ from hospital charges in Part A because the latter charges represent short-term costs (mostly for the procedure itself and associated fees). Since the QALYs Value column represents the expected lifetime benefit, it should be compared to the expected lifetime cost for these patients in present value terms. The long-term cost convergence is attributable to the frequency with which repeat PCI procedures may be necessary in about 96 percent of PCI patients during 10-12 years of follow up (See Figure 3). These repeat PCI procedures contribute to overall cost and thereby cost-benefit calculations.

Several calculations such as the cost-benefit ratio, the cost-effectiveness ratio, and the cost-utility ratio will be used in examining how PCI and CABG costs and benefits compare.

In a cost-benefit analysis, all costs and benefits are expressed in monetary terms. The net benefit is calculated by subtracting total costs from total benefits, while the cost-benefit ratio

<table>
<thead>
<tr>
<th>Medical resource use</th>
<th>CABG (n=469)</th>
<th>PTCA (n=465)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital days</td>
<td>52.1</td>
<td>48.3</td>
<td>0.10</td>
</tr>
<tr>
<td>Outpatient visits</td>
<td>118.5</td>
<td>123.9</td>
<td>0.75</td>
</tr>
<tr>
<td>Nursing facility days</td>
<td>46.3</td>
<td>23.6</td>
<td>0.20</td>
</tr>
<tr>
<td>Outpatient tests</td>
<td>6.7</td>
<td>7.0</td>
<td>0.42</td>
</tr>
<tr>
<td>CABG procedures</td>
<td>1.05</td>
<td>0.48</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PTCA procedures</td>
<td>0.39</td>
<td>1.96</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Cost (in 2002 US $, discounted)

<table>
<thead>
<tr>
<th>Cost (in 2002 US $, discounted)</th>
<th>CABG (n=469)</th>
<th>PTCA (n=465)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospitals</td>
<td>70 284</td>
<td>69 221</td>
<td>0.24</td>
</tr>
<tr>
<td>Professional fees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient</td>
<td>21 697</td>
<td>20 961</td>
<td>0.06</td>
</tr>
<tr>
<td>Outpatient</td>
<td>5117</td>
<td>5294</td>
<td>0.70</td>
</tr>
<tr>
<td>Drugs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac</td>
<td>13 847</td>
<td>15 083</td>
<td>0.009</td>
</tr>
<tr>
<td>Noncardiac</td>
<td>5677</td>
<td>5450</td>
<td>0.93</td>
</tr>
<tr>
<td>Nursing facilities</td>
<td>4169</td>
<td>2310</td>
<td>0.20</td>
</tr>
<tr>
<td>Outpatient tests</td>
<td>2206</td>
<td>2405</td>
<td>0.35</td>
</tr>
<tr>
<td>Total cost</td>
<td>122 997</td>
<td>120 725</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Figure 3: Cumulative lifetime use and cost of medical resources in the Bypass Angioplasty Revascularization Investigation (BARI).

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41 Martin Brown explains that in cost-benefit, cost-effectiveness, and cost-utility analyses, “benefits are expressed in ‘natural units,’ e.g., life years” or quality-adjusted life years, which can then be compared to medical costs.

(also known as the social rate of return) is determined by dividing total benefits by total costs in present value terms. In the cost-effectiveness analysis, all costs are expressed in monetary terms while the benefits are expressed in life years. The cost-effectiveness ratio is calculated by dividing total costs (in present value terms) by the gain in life years. For the cost-utility analysis, costs are expressed in monetary terms, while the benefits are expressed in QALYs. To determine the cost-utility ratio, total costs (in present value terms) are divided by the number of QALYs gained\textsuperscript{43}. These results are summarized in Table 6.

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|c|}
\hline
\textbf{PROCEDURE} & \textbf{NET BENEFIT} & \textbf{COST-BENEFIT RATIO} & \textbf{COST-EFFECTIV. RATIO} & \textbf{COST-UTILITY RATIO} \\
\hline
PCI & $524,275 & 5.343 & $13,988.99 & $18,717.05 \\
CABG & $535,003 & 5.350 & $13,882.28 & $18,692.55 \\
\hline
\end{tabular}
\caption{Table 6}
\end{table}

Although the initial hospital charges for CABG surgery were more than twice that of PCI, the importance of considering long-term outcomes in this setting is demonstrated by this analysis.

Based upon the findings of this study, typical patients with coronary artery disease seeking a PCI procedure should realistically expect that the lifetime benefit from the procedure (measured in quality and length of life) would outweigh the lifetime cost of the procedure by an average of $524,275. By comparison, the typical coronary artery disease patient seeking CABG surgery should realistically expect that the lifetime benefit of undergoing this procedure would outweigh the lifetime cost by an average of $535,003. The total benefit from seeking PCI is, on

\textsuperscript{43} Brown, Martin L., PhD. Economic Analysis in Clinical Research. Division of Cancer Control and Population Sciences, National Cancer Institute.
average, 5.343 times greater than the total cost, while for CABG surgery, the total benefit is on average 5.35 times greater. Furthermore, for PCI patients, on average, society would be paying $13,988.99 per year of life lived, while CABG patients could expect society to pay, on average, $13,882.28 per year of life. Finally, PCI patients could expect society to pay, on average, $18,717.05 per quality-adjusted life year lived, while for CABG patients, society would pay, on average, $18,692.55 per quality-adjusted life year lived. The results from the cost-benefit, cost-effectiveness, and cost-utility analyses reveal that when considering both direct and indirect economic costs and benefits, the benefits of both treatments far outweigh the costs. Based on both quantitative and qualitative outcomes in the long-term (in excess of 10 years), the outcomes between PCI and CABG procedures converge. However, in the long-term, the total costs of these procedures also tend to converge.

Assuming that the rapid technological advancements in PCI will continue, one can speculate about the degree to which improved techniques and materials might change the cost-benefit equation. In the BARI study, a reasonable estimated short-term cost for one PCI is $90,182 ÷ 1.96 = $46,011.45. A 50% reduction of the need for repeat PCI would reduce mean lifetime PCI costs to $46,011 × 1.48 = $68,096 (a $90,182-$68,096=$22,086 decrease in lifetime costs). The resultant cost-benefit ratio, assuming other variables remained unchanged, would

\[ \text{Here, “society” is used instead “patient” because, due to insurance plans, the amount the hospitals bills for the encounters do not usually equal the amount the patient pays.} \]
\[ \text{Here, the short-term cost of performing a PCI is calculated by hospital costs plus inpatient professional fees ($90,182) divided by the average number of PCI procedures undergone per patient (1.96). Note that $90,182 is the average lifetime cost of hospital and professional fees for PCI—not the cost for a single procedure. Also note that these costs are different from those cited earlier in the paper. This is because the costs cited earlier are from a national database, while the $46,011 reflects the mean costs per PCI for patients in the BARI study.} \]
\[ \text{Although this is a hypothetical number, a 50% reduction (some time in the future) of the need for repeat PCI seems reasonable, given rapid advancements in medical technology and treatments.} \]
\[ \text{Note that this is a 50% reduction in the need for a repeat PCI—thus represented by a drop in the average number of PCI procedures per patient from 1.96 to 1.48.} \]
now be \( \frac{645,000}{120,725 - 22,086} = 6.539 \), compared to 5.343 described in the earlier analysis.

Furthermore, the resultant cost-effectiveness ratio decreases from $13,988.99 to $11,429.78 per life year and the cost-utility ratio decreases from $18,717.05 to $15,292.87 per quality-adjusted life year. Overall anticipated cost reduction also provides insight about the potential return on money invested in the research that might be needed to achieve this goal.
This study compared and contrasted the economic costs and benefits of percutaneous coronary intervention and coronary artery bypass graft surgery, taking into account both quantitative and qualitative measures and outcomes. This study found that it is reasonable to assume that, when controlling for age, mean life expectancies between CABG and PCI patients do not differ significantly. Although quality-of-life outcomes among CABG patients were generally superior to PCI patients one year after the procedures, this study discovered that both quantitative and qualitative long-term outcomes do not differ significantly between CABG and PCI patients. Therefore, this study highlights the importance of considering long-term outcomes when making medical decisions by showing that although hospital charges for CABG surgery far exceed charges for PCI initially, a greater need among PCI patients for repeat procedures contributes to similar long-term costs between these two procedures.

The results from this study give rise to a number of policy implications. For example, a CAD patient with diabetes would, on average, benefit more both in the short and long-term by obtaining CABG surgery instead of a PCI procedure. It may be better for a CAD patient with a shorter life expectancy to undergo CABG surgery instead of PCI, since the improvements in quality of life in the former procedure are superior in the short-term. The results from the study on quality of life and risk of re-stenosis suggest that managing levels of re-stenosis in coronary artery disease patients could significantly improve quality-of-life. The calculations in this study’s analysis could be used to determine which specific types of interventions could yield a given
economic benefit at the minimum cost. Cost-benefit, cost-effectiveness, and cost-utility analyses illustrate the potential benefits of improving repeat procedure rates for PCI, however, there are several important considerations that would arise when considering this analysis. For example, would the increase in costs of undergoing more effective PCI procedures outweigh the benefits from fewer repeat procedures? Would investment aimed at decreasing repeat PCI procedures be the “best” allocation of medical resources? And what constitutes the “best” procedure? Although answering these questions will require further research and calculations, for a country whose cardiovascular disease costs will exceed $800 billion within just two decades, it would seem definitely worth further research.
APPENDIX

What types of coronary artery disease studies should take place in the future and how should they be conducted? A problem that is inherent in most of the studies that this study investigated is that the sample in the study is not representative of the target population. For example, consider the John Spertus study on re-stenosis and quality of life between CABG and PCI patients that was examined earlier. The study mentions “Data were prospectively collected from a consecutive series of patients undergoing coronary revascularization at the Mid America Heart Institute in Kansas City, Mo.” It seems fairly unlikely that Kansas City, Missouri would reflect the underlying characteristics of all CAD patients seeking PCI and CABG procedures. For example, Missouri’s mortality rates for PCI and CABG operations are both 0.30% higher than the national average. Furthermore, Missouri’s hospitals on average, charge less per PCI and CABG procedure than the national average. Instead, future studies on CAD outcomes should at the minimum, have a randomly selected sample of patients that reflect the true underlying population of CAD patients undergoing PCI and CABG. The data in the table on the next page are from the U.S. Department of Health & Human Services’ Agency for Healthcare Research and Quality’s 2008 State Procedural Database.
<table>
<thead>
<tr>
<th>State</th>
<th>PCI Mean Charge</th>
<th>PCI % Died</th>
<th>PCI Mean Age</th>
<th>CABG Mean Charge</th>
<th>CABG % Died</th>
<th>CABG Mean Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATIONAL</td>
<td>$56,258</td>
<td>0.90%</td>
<td>64</td>
<td>$117,094</td>
<td>2.00%</td>
<td>65</td>
</tr>
<tr>
<td>Arizona</td>
<td>$65,805</td>
<td>1.00%</td>
<td>66</td>
<td>$137,912</td>
<td>1.40%</td>
<td>66</td>
</tr>
<tr>
<td>Arkansas</td>
<td>$41,459</td>
<td>0.80%</td>
<td>64</td>
<td>$84,967</td>
<td>1.90%</td>
<td>64</td>
</tr>
<tr>
<td>California</td>
<td>$91,968</td>
<td>1.00%</td>
<td>65</td>
<td>$232,236</td>
<td>1.90%</td>
<td>66</td>
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<tr>
<td>Colorado</td>
<td>$68,664</td>
<td>1.00%</td>
<td>64</td>
<td>$128,946</td>
<td>1.60%</td>
<td>65</td>
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<tr>
<td>Florida</td>
<td>$70,088</td>
<td>0.90%</td>
<td>66</td>
<td>$148,411</td>
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<tr>
<td>Hawaii</td>
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<tr>
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<td>0.70%</td>
<td>66</td>
<td>$87,262</td>
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</tr>
<tr>
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<td>$50,048</td>
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<td>64</td>
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<td>Kentucky</td>
<td>$41,211</td>
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<td>1.50%</td>
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<td>Maine</td>
<td>$37,024</td>
<td>0.50%</td>
<td>63</td>
<td>$71,764</td>
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<td>65</td>
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<tr>
<td>Maryland</td>
<td>$16,983</td>
<td>1.00%</td>
<td>64</td>
<td>$42,064</td>
<td>1.60%</td>
<td>65</td>
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<tr>
<td>Massachusetts</td>
<td>$46,176</td>
<td>0.70%</td>
<td>64</td>
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<td>66</td>
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<tr>
<td>Michigan</td>
<td>$44,120</td>
<td>0.70%</td>
<td>64</td>
<td>$91,854</td>
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<td>Minnesota</td>
<td>$47,590</td>
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<td>64</td>
<td>$93,806</td>
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<tr>
<td>Missouri</td>
<td>$50,154</td>
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<td>64</td>
<td>$99,406</td>
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<td>Nebraska</td>
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<td>Nevada</td>
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<td>$50,605</td>
<td>1.10%</td>
<td>63</td>
<td>$119,502</td>
<td>1.80%</td>
<td>66</td>
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<td>65</td>
<td>$184,209</td>
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<td>1.40%</td>
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<td>North Carolina</td>
<td>$50,648</td>
<td>1.00%</td>
<td>63</td>
<td>$89,349</td>
<td>1.40%</td>
<td>64</td>
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<tr>
<td>Oklahoma</td>
<td>$56,036</td>
<td>1.10%</td>
<td>65</td>
<td>$98,685</td>
<td>2.10%</td>
<td>65</td>
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<td>Oregon</td>
<td>$39,703</td>
<td>1.30%</td>
<td>65</td>
<td>$84,840</td>
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<tr>
<td>South Carolina</td>
<td>$59,363</td>
<td>0.70%</td>
<td>63</td>
<td>$128,188</td>
<td>1.70%</td>
<td>63</td>
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<tr>
<td>Tennessee</td>
<td>$48,759</td>
<td>1.10%</td>
<td>63</td>
<td>$97,123</td>
<td>1.70%</td>
<td>63</td>
</tr>
<tr>
<td>Texas</td>
<td>$65,220</td>
<td>1.10%</td>
<td>64</td>
<td>$130,475</td>
<td>2.20%</td>
<td>64</td>
</tr>
<tr>
<td>Utah</td>
<td>$40,250</td>
<td>0.90%</td>
<td>64</td>
<td>$72,308</td>
<td>1.40%</td>
<td>66</td>
</tr>
<tr>
<td>Washington</td>
<td>$55,772</td>
<td>1.30%</td>
<td>64</td>
<td>$117,066</td>
<td>2.30%</td>
<td>65</td>
</tr>
<tr>
<td>West Virginia</td>
<td>$33,153</td>
<td>1.00%</td>
<td>63</td>
<td>$70,443</td>
<td>2.10%</td>
<td>63</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>$42,054</td>
<td>0.80%</td>
<td>65</td>
<td>$90,081</td>
<td>1.80%</td>
<td>66</td>
</tr>
</tbody>
</table>


