Understanding Variability in Hospital-Specific Costs of CABG Represents an Opportunity for Standardizing Care and Improving Resource Utilization

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None of the authors have any relevant financial relationships to disclose.
Background

Healthcare spending in the United States is of interest to every citizen in this country.

Cardiac surgery continues to have a heavy cost burden on overall healthcare spending in the United States, with approximately 1% of all healthcare dollars, or $15 billion, spent on inpatient cardiac surgical care.

Despite higher costs, the quality of CABG care in the United States has not been demonstrated to be measurably superior to that in other countries.
Study Aim

To examine the cost of CABG in the United States, and to specifically determine what variables drive its cost, including that which is due to the independent effect of the hospital itself

This variable, the independent effect of the hospital, may represent opportunities for cost savings
Study Design

Data Source
Nationwide Inpatient Sample

Study Population
Adult patients (>17 years of age)
Isolated CABG
Redo and non-elective CABG included
Study period: January 1, 2005 to December 31, 2008
Data and Statistical Analysis

**Primary Outcome**

Inpatient costs of CABG

**Variation in Hospital-Specific Costs**

Mixed effect linear regression model incorporating variables associated with cost of CABG in univariate linear regression analysis (exploratory p-value < 0.20)
Mixed Effect Linear Regression Model

**Patient**

Age, sex, primary payer status, Charlson comorbidity index

**Operative**

Elective versus non-elective, number of vessels bypassed, CPB, use of IMA, same admission cardiac catheterization, IABP, pacemaker or AICD, VAD, ECMO, same admission angioplasty or coronary stent, redo CABG

**Complications**

Respiratory failure, pneumonia, acute renal failure, sepsis, stroke, pulmonary embolism, gastrointestinal bleed, wound complication, hemorrhage, cardiac shock or arrest

**Hospital**

Hospital region, teaching status, urban versus rural, annual CABG volume

**Other**

Length of hospitalization, in-hospital mortality, year of operation
<table>
<thead>
<tr>
<th>Variable</th>
<th>Study Population (n=183,973)</th>
<th>Missing Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>65.2 ± 10.8</td>
<td>14 (0.008%)</td>
</tr>
<tr>
<td>Male Sex</td>
<td>133,573 (73%)</td>
<td>14 (0.008%)</td>
</tr>
<tr>
<td>Payment Status</td>
<td></td>
<td>260 (0.1%)</td>
</tr>
<tr>
<td>Medicare</td>
<td>95,287 (52%)</td>
<td></td>
</tr>
<tr>
<td>Private Insurance</td>
<td>73,367 (40%)</td>
<td></td>
</tr>
<tr>
<td>Medicaid</td>
<td>8,912 (5%)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>6,147 (3%)</td>
<td></td>
</tr>
<tr>
<td>Charlson Comorbidity Score</td>
<td></td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Zero</td>
<td>38,420 (21%)</td>
<td></td>
</tr>
<tr>
<td>One</td>
<td>59,675 (32%)</td>
<td></td>
</tr>
<tr>
<td>Two or Greater</td>
<td>85,878 (47%)</td>
<td></td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Atrial Fibrillation</td>
<td>45,959 (25%)</td>
<td></td>
</tr>
<tr>
<td>Myocardial Infarction</td>
<td>71,663 (39%)</td>
<td></td>
</tr>
<tr>
<td>Congestive Heart Failure</td>
<td>39,412 (21%)</td>
<td></td>
</tr>
<tr>
<td>Peripheral Vascular Disease</td>
<td>21,096 (11%)</td>
<td></td>
</tr>
<tr>
<td>Cerebrovascular Disease</td>
<td>16,072 (9%)</td>
<td></td>
</tr>
<tr>
<td>COPD</td>
<td>38,493 (21%)</td>
<td></td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>56,365 (31%)</td>
<td></td>
</tr>
<tr>
<td>Chronic Renal Insufficiency</td>
<td>15,790 (9%)</td>
<td></td>
</tr>
<tr>
<td>Liver Disease</td>
<td>762 (0.4%)</td>
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</tbody>
</table>
## Operative Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Study Population (n=183,973)</th>
<th>Missing Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urgent or Emergent Case</td>
<td>100,178 (55%)</td>
<td>306 (0.2%)</td>
</tr>
<tr>
<td>Number of Coronary Vessels Bypassed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One</td>
<td>26,255 (15%)</td>
<td>7,750 (4%)</td>
</tr>
<tr>
<td>Two</td>
<td>64,201 (36%)</td>
<td></td>
</tr>
<tr>
<td>Three</td>
<td>57,728 (33%)</td>
<td></td>
</tr>
<tr>
<td>Four or More</td>
<td>28,039 (16%)</td>
<td></td>
</tr>
<tr>
<td>Use of Cardiopulmonary Bypass</td>
<td>133,748 (73%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Use of Internal Mammary Artery</td>
<td>163,136 (89%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Cardiac Catheterization During Admission</td>
<td>101,052 (55%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Intra-aortic Balloon Pump</td>
<td>17,366 (9%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Permanent Pacemaker or AICD</td>
<td>3,133 (2%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>VAD as Postcardiotomy Support</td>
<td>203 (0.1%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Extracorporeal Membrane Oxygenation</td>
<td>37 (0.02%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Coronary Angioplasty During Admission</td>
<td>5,601 (3%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Non-Drug-Eluting Stent During Admission</td>
<td>1,355 (0.7%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Drug-Eluting Stent During Admission</td>
<td>1,587 (0.9%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Variable</td>
<td>Study Population (n=183,973)</td>
<td>Missing Data</td>
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<tr>
<td>------------------------------</td>
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</tr>
<tr>
<td>Teaching Hospital</td>
<td>104,259 (57%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northeast</td>
<td>27,108 (15%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Midwest</td>
<td>45,625 (25%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>South</td>
<td>81,249 (44%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>West</td>
<td>29,991 (16%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Rural Location</td>
<td>6,351 (3%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Annual Hospital CABG Volume*</td>
<td>441 ± 340</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

*inclusive of all CABGs, including those performed concomitant with another major procedure
Outcomes of CABG in the Study Population

Length of Hospitalization (days)

Mean: 9.4 ± 7.2
Median: 7 (6-11)
Costs of CABG at the Hospital Level

Aggregated at the Hospital Level
Mean Cost Per CABG: $40,424
Standard Deviation of Average Cost Between Hospitals: $12,130
Mixed Effect Linear Regression Model for Cost of CABG: Patient-Level Variables

Covariate
- Hospital Effect
- Age (increasing, per year)
- Male Sex
- Medicare
- Medicaid
- Other Payment

Reference
- Private Insurance
- Charlson Comorbidity Score of 0
- 1
- 2 or Greater

Coefficient for Cost of CABG
Mixed Effect Linear Regression Model for Cost of CABG:
Operative Variables

- Hospital Effect
- Urgent or Emergent Case
- Reference
  - 1-vessel CABG
  - 2-vessel CABG
  - 3-vessel CABG
  - 4-vessel CABG
- Cardiopulmonary Bypass
- Internal Mammary Artery Not Used
- Cardiac Catheterization
- Intra-aortic Balloon Pump
- Permanent Pacemaker or AICD
- VAD as Postcardiotomy Support
- ECMO
- Coronary Angioplasty
- Non-Drug-Eluting Stent
- Drug-Eluting Stent
- Redo CABG

Coefficient for Cost of CABG

0  20000  40000  60000
Mixed Effect Linear Regression Model for Cost of CABG: Hospital-Level and “Other” Variables

Covariate
- Hospital Effect
- Teaching Hospital
- Midwest
- West
- Northeast
- Hospital in Rural Location
- Hospital Volume (decreasing, per 100 cases)
- Length of Hospital Stay (increasing, per day)
- In-Hospital Mortality
- Year of Operation (more recent, per year)

Coefficient for Cost of CABG

Reference South Region
Mixed Effect Linear Regression Model for Cost of CABG: Postoperative Complications

Covariate
- Hospital Effect
- Respiratory Failure
- Pneumonia
- Acute Renal Failure
- Sepsis
- Stroke
- Pulmonary Embolism
- Gastrointestinal Bleed
- Wound Complication
- Hemorrhage
- Cardiac Shock or Arrest

Coefficient for Cost of CABG
Summary

For CABG, there are only 5 variables that are greater drivers of cost than the Hospital Effect:

- VAD (coefficient 52,094)
- ECMO (coefficient 28,999)
- Mortality (coefficient 16,758)
- Permanent Pacemaker/ICD (15,831)
- Sepsis (coefficient 11,303)
- Hospital Effect (coefficient 9,560)

As point of comparison, urgent/emergent coefficient is 693
Conclusions

Controlling for what we determined to be the 34 significant variables that drove cost, the individual hospital remained an extremely important variable.

Understanding the reasons for this hospital center variability may provide us with opportunities to substantially decrease costs of CABG in the United States.
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