Variation in Use of Blood Transfusion in Coronary Artery Bypass Graft Surgery

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PATIENTS WHO UNDERGO CARDIAC SURGERY receive a significant proportion of the 14 million units of allogeneic red blood cells (RBCs) transfused annually in the United States.1 Numerous observational studies in patients who underwent cardiac surgery have shown an association between RBC transfusion and adverse outcome, including morbidity, mortality, resource utilization, and quality of life.2-9 To date, no large randomized trials of transfusion thresholds have been conducted in cardiac surgery to our knowledge to address this issue.

Almost 20 years ago, the study by Goodnough et al10 demonstrated that there was significant practice variability in transfusion practices at 18 US centers. However, this study and subsequent studies11-14 were limited in size and did not adjust for hospital or patient factors. Since these earlier studies, the Society of Thoracic Surgeons (STS) and Society of Cardiovascular Anesthesiologists published transfusion recommendations in 2007.15 However, the degree to which guidelines have resulted in consensus in community transfusion practice is unknown. Therefore, the primary goal of our study was to assess use of RBC, fresh-frozen plasma, and platelet transfusions in coronary artery bypass graft (CABG) surgery in contemporary practice. Our analyses specifically addressed the degree to which transfusion practices varied among US hospitals, after adjusting for patient characteristics.

Context Perioperative blood transfusions are costly and have safety concerns. As a result, there have been multiple initiatives to reduce transfusion use. However, the degree to which perioperative transfusion rates vary among hospitals is unknown.

Objective To assess hospital-level variation in use of allogeneic red blood cell (RBC), fresh-frozen plasma, and platelet transfusions in patients undergoing coronary artery bypass graft (CABG) surgery.

Design, Setting, and Patients An observational cohort of 102 470 patients undergoing primary isolated CABG surgery with cardiopulmonary bypass during calendar year 2008 at 798 sites in the United States, contributing data to the Society of Thoracic Surgeons Adult Cardiac Surgery Database.

Main Outcome Measures Perioperative (intraoperative and postoperative) transfusion of RBCs, fresh-frozen plasma, and platelets.

Results At hospitals performing at least 100 on-pump CABG operations (82 446 cases at 408 sites), the rates of blood transfusion ranged from 7.8% to 92.8% for RBCs, 0% to 97.5% for fresh-frozen plasma, and 0.4% to 90.4% for platelets. Multivariable analysis including data from all 798 sites (102 470 cases) revealed that after adjustment for patient-level risk factors, hospital transfusion rates varied by geographic location (P = .007), academic status (P = .03), and hospital volume (P < .001). However, these 3 hospital characteristics combined only explained 11.1% of the variation in hospital risk-adjusted RBC usage. Case mix explained 20.1% of the variation between hospitals in RBC usage.

Conclusion Wide variability occurred in the rates of transfusion of RBCs and other blood products, independent of case mix, among patients undergoing CABG surgery with cardiopulmonary bypass in US hospitals in an adult cardiac surgical database.

JAMA. 2010;304(14):1568-1575 www.jama.com

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tified software systems. This information is sent semiannually to the STS Data Warehouse and Analysis Center at the Duke Clinical Research Institute, Durham, North Carolina. A series of data quality checks are performed before a site’s data are aggregated into the national sample. Although participation in the STS database is voluntary, data completeness is high, with overall preoperative risk factors missing in fewer than 5% of submitted cases.22

Because the data used in analyses of the STS ACSD represent a limited data set (no direct patient identifiers) that was originally collected for nonresearch purposes, and the investigators do not know the identity of individual patients, the analysis of these data was declared by the Duke University Health System Institutional Review Board to be research not involving human subjects and is therefore considered exempt (Duke University Health System Protocol 00005876).

Patient Population
Hospital variation in the frequency of blood product administration was analyzed in a contemporary sample of isolated primary CABG operations using cardiopulmonary bypass (CPB) performed at hospitals participating in the STS ACSD between January 1, 2008, and December 31, 2008. The time frame for this analysis was chosen to represent the most contemporary data available and to minimize the effect of potential changes over time. Hospitals (n = 798) contributing at least 1 adult cardiac case per month during 2008 were included. Unless stated otherwise, all analyses included all 798 sites (102,470 cases). To increase the homogeneity of the study population, we only included patients undergoing primary cardiac surgery and excluded patients who previously underwent median sternotomy. Additional exclusion criteria included (1) combination of CABG surgery with valve or other major surgical interventions; (2) off-pump CABG surgery; (3) age younger than 18 years; (4) emergent status, elective and urgent status were allowed; (5) preoperative cardiogenic shock or need for cardiopulmonary resuscitation within 1 hour before surgery; and (6) presence of infective endocarditis preoperatively. In addition, we excluded 122 patients with incomplete data for perioperative blood usage.

Variable Definitions
Blood and Blood Products. The STS database collects the number of units of packed RBCs, platelets, or fresh-frozen plasma administered to the patient intraoperatively and postoperatively during hospitalization. The measurement of packed RBCs does not include preoperatively donated or intraoperatively cell-saved autologous blood. All blood and blood product values reported herein reflect the sum of each of the products administered intraoperatively and postoperatively.

Academic vs Nonacademic Hospitals. Academic status was defined as hospitals that have residency programs, according to the STS participant information database.

Geographic Region. Hospitals were grouped into 9 regions using categories defined by the US Census Bureau as follows: New England (Maine, Massachusetts, Vermont, New Hampshire, Rhode Island, and Connecticut), Mid-Atlantic (New Jersey, New York, and Pennsylvania), South Atlantic (Delaware, District of Columbia, West Virginia, Virginia, Maryland, North Carolina, South Carolina, Georgia, and Florida), Great Lakes (Illinois, Indiana, Michigan, Ohio, and Wisconsin), Pacific (Alaska, Hawaii, Oregon, Washington, and California), Mountain (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming), Plains (North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, and Missouri), West South Central (Oklahoma, Louisiana, Arkansas, and Texas), and East South Central (Mississippi, Alabama, Tennessee, and Kentucky).

Hospital CABG Surgery Volumes in 2008. The annual hospital volume for primary isolated CABG surgery during 2008 was categorized into 4 groups (quartiles), with an approximately equal number of patients in each group. The categories were quartile 1 (<115 cases), quartile 2 (115-183 cases), quartile 3 (184-299 cases), and quartile 4 (≥300 cases).

Statistical Analyses. Baseline characteristics were summarized as percentage or median (interquartile range) as appropriate and compared for patients receiving vs not receiving any RBCs in the intraoperative or postoperative period. To quantify between-hospital variation in blood usage, we calculated the percentage of patients undergoing primary isolated CABG surgery at each hospital who received any RBCs, any fresh-frozen plasma, and any platelets in the intraoperative or postoperative period. To display the results graphically, we plotted hospital-specific percentages of patients receiving blood products against hospital-specific numbers of eligible cases. We superimposed lines representing 99.9% binomial prediction limits23 (FIGURE 1). The binomial prediction limits indicate the range of results that would normally occur as a result of random statistical variation for a hospital whose true frequency of using blood products is equal to the mean for all hospitals.

Additional analyses focused on determining the amount of hospital-level variation in blood product usage that is due to true signal variation, as opposed to random statistical variation (ie, noise), and exploring factors that might explain the signal variation. Separate analyses were performed for RBCs, fresh-frozen plasma, and platelets. A series of 2-level hierarchical logistic regression models with hospital-specific random intercepts were fit to the patient-level data. In each model, the end point was a patient-level binary variable coded as 1 if the patient received the blood product and as 0 otherwise. Model 1 contained only hospital-specific random intercepts and no covariates. This model was used for estimating the distribution of true hospital usage rates of blood products af-
ter subtracting out the effect of random sampling variation. Results were summarized in tabular form by presenting selected percentiles of the hospital distribution. These percentiles were calculated from the estimated mean and variance of the random effects parameters (assumed to be normally distributed on the log-odds scale) and were transformed from the scale of log-odds to the scale of probabilities to facilitate interpretation. The same estimates were used to construct a histogram depicting the estimated distribution of true hospital-specific usage rates (Figure 2).

Model 2 contained hospital-specific random intercepts plus patient-level covariates, which included age, female sex, race, left ventricular ejection fraction, body surface area, serum creatinine, date of surgery (dichotomized into first vs second 6-month period), procedure, need for dialysis, atrial fibrillation, hypertension, immunosuppressive treatment, percutaneous coronary intervention less than 6 hours before surgery, presence of intra-aortic balloon pump or administration of inotropes, peripheral vascular disease, unstable angina (no myocardial infarction <7 days), left main disease, aortic stenosis, aortic insufficiency, mitral insufficiency, tricuspid insufficiency, chronic lung disease, cerebrovascular disease or cerebrovascular accident, diabetes, number of diseased coronary vessels, myocardial infarction, acuity status, congestive heart failure, New York Heart Association class, preoperative hematocrit, and use of medications, including warfarin, aspirin, adenosine diphosphate inhibitor within 5 days, or glycoprotein IIb/IIIa inhibitor. Model 2 was used for quantifying between-hospital signal variation after subtracting out differences due to patient-level risk factors. A hospital's risk-adjusted RBC usage rate was calculated as 

$$\frac{1}{1/1 + \exp[-(\alpha + \beta_j)]},$$

where the constant $\alpha$ was chosen to reflect the baseline probability of receiving RBCs for an "average" patient and $\beta_j$ denotes the $j$-th hospital's random intercept parameter. Percentiles were based on the estimated mean and variance of the $\beta_j$'s. This method was also used for fresh-frozen plasma and platelets.

Model 3 contained the factors in model 2, plus 3 hospital-specific factors (academic status, region, and vol-

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**Figure 1.** Observed Variation in Hospital-Specific Transfusion Rates for Primary Isolated CABG Surgery With Cardiopulmonary Bypass During 2008 (N=798 Sites)
volume). This model was used to explore the effect of each hospital-level factor while adjusting for differences in patient case mix. The effect of each hospital-level covariate was summarized by reporting odds ratios (ORs) with 95% confidence intervals (CIs). The ability of hospital and patient factors to explain between-hospital variation in transfusion rates was examined. To quantify between-hospital variation, the predicted log odds from model 3 was averaged within each hospital and decomposed as the sum of 3 components (namely, the contributions of patient factors, hospital covariates, and hospital random effects). The percentage of between-hospital variation explained by hospital covariates was calculated as the squared Pearson correlation between the hospital factor component of the average log odds and the sum of all 3 components. An analogous calculation was used to quantify the percentage of variation explained by patient factors (ie, case mix).

Hierarchical logistic regression with random intercepts was used to assess the association between the percentage of patients receiving RBCs at a hospital and the patient-level end point of all-cause mortality. All-cause mortality was defined as death during the same hospitalization as surgery or after discharge but within 30 days of surgery. To minimize misclassification error in the hospital-specific transfusion rates, only hospitals with at least 100 on-pump isolated CABG operations were included in these analyses. Hospitals were assigned to 4 groups according to the percentage of patients receiving RBC transfusion intraoperatively or postoperatively (7.8%-43.2%, 43.3%-55.9%, 56.0%-65.6%, and 65.7%-92.8%). Rates of mortality were compared across categories of hospital transfusion rates with and without adjustment for patient factors (model 2 covariates).

Parameters of the various models were estimated using a penalized quasi-likelihood approximation as implemented in SAS version 9.2 PROC GLIMMIX (SAS Institute, Cary, North Carolina). R statistical package version 2.9.0 (R Foundation for Statistical Computing, Vienna, Austria) was also used. P < .05 was considered significant. All tests were 2-sided and were not adjusted for multiple comparisons.

RESULTS

Among the 102,592 cases of primary isolated CABG surgery with CPB submitted from 798 hospitals in 2008, 102,470 cases (99.9%) had complete information about perioperative RBC, platelet, and fresh-frozen plasma transfusions. The rates of perioperative transfusion were 56.1% (95% CI, 55.8%-56.4%) for packed RBCs, 19.3% (95% CI, 19.1%-19.6%) for fresh-frozen plasma, and 24.7% (95% CI, 24.5%-25.0%) for platelets. Patients receiving RBC transfusion (n = 57,445) were more likely to be women, were older, had received adenosine diphosphate inhibitors, had lower preoperative hematocrit, and exhibited other traditional risk factors for morbidity and mortality compared with those patients who did not receive RBC transfusions (Table 1).

Between-Hospital Variation in Blood Usage

There was dramatic variability in the observed hospital-specific transfusion rates for all 3 blood products in 102,470 patients undergoing isolated primary CABG surgery at 798 hospitals (Figure 1). To ensure that between-center differences would not be dominated by random statistical variation, we also analyzed the subset of hospitals performing at least 100 eligible on-pump CABG operations during the year. At these 408 sites (n = 82,446 cases), the frequency of blood transfusion rates ranged from 7.8% to 92.8% for RBCs, 0% to 97.5% for fresh-frozen plasma, and 0.4% to 90.4% for platelets.

The estimated distribution of transfusion rates based on hierarchical modeling is shown in Table 2. According to this model, hospitals at the 99th percentile of the distribution were 4.6 times more likely to use RBCs (90.6%/19.7% = 4.6), 31.2 times more likely to use fresh-frozen plasma (71.7%/3.2% = 31.2), and 22.5 times more likely to use platelets (76.4%/3.4% = 22.5) compared with hospitals at the 1st percentile of the distribution. This wide variation was not explained by patient risk factors. Comparing the 1st and 99th percentiles, hospitals at the 99th percentile of the distribution were 7.7 times more likely to use RBCs (94.5%/12.2%), 34.8 times more likely to use fresh-frozen plasma (73.1%/2.1%), and

![Figure 2. Estimated Distribution of Hospital-Specific Transfusion Rates for Primary Isolated CABG Surgery With CPB During 2008 (N = 102,470)](image-url)
24.3 times more likely to use platelets (77.6%/3.2%), even after adjusting for patient risk factors (Table 2).

### Hospital Characteristics and Blood Usage

Table 3 shows unadjusted and adjusted associations between hospital characteristics and blood usage. The frequency of perioperative RBC usage decreased across categories of increasing CABG surgery volume from 61.4% (95% CI, 59.4%-63.4%) in quartile 1 to 51.6% (95% CI, 48.0%-55.2%) in quartile 4 (P < .001). The adjusted ORs for RBC usage were inversely related to volume and were statistically significant for quartile 2 (OR, 0.71; 95% CI, 0.59-0.86), quartile 3 (OR, 0.61; 95% CI, 0.49-0.76), and quartile 4 (OR, 0.51; 95% CI, 0.38-0.66) compared with quartile 1.

There was also substantial geographic variation in RBC usage. In the unadjusted analysis, blood usage was significantly lower in all 8 regions compared with the West South Central region. After adjusting for patient risk factors, blood usage was found to be significantly lower in 7 of the 8 geographic regions (OR of these 7 regions ranged between 0.45 and 0.67). Blood usage was more than 2-fold lower in the Mountain (OR, 0.45; 95% CI, 0.31-0.64) and New England (OR, 0.46; 95% CI, 0.29-0.72) regions compared with the West South Central region.

A significant association (OR, 1.32; 95% CI, 1.04-1.69; P = .03) was observed between academic hospital status and perioperative RBC usage, after adjusting for patient-level risk factors. However, these 3 hospital characteristics combined only explained 11.1% of the variation in hospital risk-adjusted RBC usage. Case mix explained 20.1% of the variation between hospitals in RBC usage.

### Hospital-Specific RBC Transfusion Rates and All-Cause Mortality

In both unadjusted and adjusted analyses, there was no significant association between hospital-specific RBC transfusion rates and all-cause mortality (eTable, available at http://www.jama.com).

### Comment

Our large observational study shows that there is enormous variability in the rates of transfusion of RBCs, fresh-frozen plasma, and platelets in patients undergoing isolated primary CABG surgery across a large number of US hospitals, even after adjusting for patient- and hospital-level risk factors. Our analysis of blood transfusion practices represents patients who have undergone surgery at 798 US hospitals. Because the STS database includes the majority of US patients who underwent cardiac surgery, our findings present a comprehensive picture of transfusion practices in patients undergoing CABG surgery.

Almost 20 years ago, the study by Goodnough et al showed significant variability in transfusion practice in 540 patients who underwent cardiac surgery across 18 institutions and drew at-
Several subsequent studies provided additional data on this topic, but these are no longer contemporary, had no or limited risk-adjustment, and were limited in size.\textsuperscript{11,13,14} Despite nearly 2 decades of awareness of inconsistent transfusion practices and the publication of clinical practice guidelines, there has been no improvement in disparate transfusion practices. For example, Goodnough et al\textsuperscript{10} found that the transfusion rates for RBCs, fresh-frozen plasma, and platelets ranged from 17\% to 100\%, 0\% to 90\%, and 0\% to 80\%, respectively. In our analysis, transfusion rates were similar. This variability cannot be attributed to inclusion of hospitals with small denominators. Indeed, in hospitals reporting at least 100 eligible on-pump CABG operations (82,446 cases at 408 sites), transfusion rates among patients undergoing primary isolated on-pump CABG surgery still ranged from 7.8\% to 92.8\% for RBCs, 0\% to 97.5\% for fresh-frozen plasma, and 0.4\% to 90.4\% for platelets. Moreover, the variation persisted after adjustment for a large number of patient and hospital factors.

We found that patients at academic hospitals and those in the lowest quartile of volume were more likely to receive RBC transfusion compared with other hospitals. We also observed variation in RBC usage based on geographic region. These differences are unexplained and warrant further study.

### Table 2. Estimated Percentiles of the Distribution of Hospital-Specific True Transfusion Rates in Patients Who Underwent Primary Isolated CABG Surgery During 2008\textsuperscript{a}

<table>
<thead>
<tr>
<th>Model</th>
<th>Probability of Transfusion in Percentile, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st</td>
</tr>
<tr>
<td>Red blood cells</td>
<td></td>
</tr>
<tr>
<td>Unadjusted</td>
<td>19.7</td>
</tr>
<tr>
<td>Adjusted</td>
<td>12.2</td>
</tr>
<tr>
<td>Fresh-frozen plasma</td>
<td></td>
</tr>
<tr>
<td>Unadjusted</td>
<td>2.3</td>
</tr>
<tr>
<td>Adjusted</td>
<td>2.1</td>
</tr>
<tr>
<td>Platelets</td>
<td></td>
</tr>
<tr>
<td>Unadjusted</td>
<td>3.4</td>
</tr>
<tr>
<td>Adjusted</td>
<td>3.2</td>
</tr>
</tbody>
</table>

### Table 3. Association Between Perioperative RBC Transfusion and Hospital Characteristics in Patients Who Underwent Primary Isolated CABG Surgery During 2008

<table>
<thead>
<tr>
<th>Outcome</th>
<th>No. of Patients</th>
<th>Transfused, % (95% CI)</th>
<th>Unadjusted OR (95% CI)</th>
<th>P Value</th>
<th>Adjusted OR (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West South Central</td>
<td>8275</td>
<td>61.0 (55.6-66.5)</td>
<td></td>
<td>.04</td>
<td>1 [Reference]</td>
<td>.007</td>
</tr>
<tr>
<td>East South Central</td>
<td>9693</td>
<td>55.9 (51.1-60.7)</td>
<td>0.65 (0.48-0.87)</td>
<td>.003</td>
<td>0.79 (0.54-1.15)</td>
<td>.21</td>
</tr>
<tr>
<td>Great Lakes</td>
<td>21353</td>
<td>57.9 (55.4-60.3)</td>
<td>0.69 (0.55-0.87)</td>
<td>.001</td>
<td>0.67 (0.51-0.89)</td>
<td>.007</td>
</tr>
<tr>
<td>Mid-Atlantic</td>
<td>11365</td>
<td>57.7 (53.7-61.8)</td>
<td>0.66 (0.51-0.85)</td>
<td>.001</td>
<td>0.53 (0.38-0.74)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Mountain</td>
<td>4563</td>
<td>49.5 (44.8-54.1)</td>
<td>0.48 (0.36-0.64)</td>
<td>&lt;.001</td>
<td>0.45 (0.31-0.64)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>New England</td>
<td>3902</td>
<td>58.1 (50.4-65.8)</td>
<td>0.62 (0.43-0.89)</td>
<td>.01</td>
<td>0.46 (0.29-0.72)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Pacific</td>
<td>11562</td>
<td>54.2 (49.5-58.8)</td>
<td>0.74 (0.58-0.94)</td>
<td>.02</td>
<td>0.55 (0.40-0.75)</td>
<td>&lt;.001</td>
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<td>Plains</td>
<td>8083</td>
<td>54.0 (49.3-58.7)</td>
<td>0.56 (0.43-0.73)</td>
<td>&lt;.001</td>
<td>0.54 (0.39-0.76)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>23772</td>
<td>54.5 (51.3-57.8)</td>
<td>0.63 (0.50-0.80)</td>
<td>&lt;.001</td>
<td>0.60 (0.45-0.81)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Hospital volume, quartile\textsuperscript{b}</td>
<td>102,470</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (n = 441)</td>
<td>25530</td>
<td>61.4 (59.4-63.4)</td>
<td>1 [Reference]</td>
<td>.04</td>
<td>1 [Reference]</td>
<td>.007</td>
</tr>
<tr>
<td>2 (n = 177)</td>
<td>25509</td>
<td>56.9 (54.4-59.3)</td>
<td>0.74 (0.64-0.85)</td>
<td>&lt;.001</td>
<td>0.71 (0.59-0.86)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>3 (n = 116)</td>
<td>25783</td>
<td>54.4 (51.7-57.1)</td>
<td>0.65 (0.56-0.77)</td>
<td>&lt;.001</td>
<td>0.61 (0.49-0.76)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>4 (n = 64)</td>
<td>25648</td>
<td>51.6 (48.0-55.2)</td>
<td>0.58 (0.47-0.71)</td>
<td>&lt;.001</td>
<td>0.51 (0.38-0.66)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Academic status</td>
<td>102,470</td>
<td></td>
<td></td>
<td>.008</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>Nonacademic</td>
<td>92,213</td>
<td>55.3 (53.8-56.8)</td>
<td>1 [Reference]</td>
<td>.008</td>
<td>1 [Reference]</td>
<td>.03</td>
</tr>
<tr>
<td>Academic hospital</td>
<td>10,257</td>
<td>62.7 (59.0-66.4)</td>
<td>1.29 (1.07-1.56)</td>
<td>.008</td>
<td>1.32 (1.04-1.69)</td>
<td>.03</td>
</tr>
</tbody>
</table>

Abbreviations: CABG, coronary artery bypass graft; CI, confidence interval; OR, odds ratio; RBC, red blood cell.

The annual hospital volume for primary isolated CABG surgery during 2008 was categorized into 4 groups (quartiles) with an approximately equal number of patients in each group as described in the “Methods” section (quartile 1=lowest volume, quartile 4=highest volume).
Our study has several limitations. First, data on RBC, platelet, and fresh-frozen plasma transfusions have not undergone audit; therefore, we cannot be absolutely sure of the accuracy of data reported by sites. Some of the variability in observed transfusion rates might be due to differences in the accuracy with which programs document usage. For example, sites may rely on only one or a combination of paper or electronic medical record, blood bank records, or both. However, our analysis only included patients who had data available on blood product usage at both time points (intraoperative and postoperative).

Our study’s primary goal was to assess the variability between hospitals with respect to transfusion; therefore, as such it was not prospectively designed to focus on the association between hospital transfusion rate and adverse outcome. Nevertheless, our limited analysis (eTable) appears to suggest that there is no strong association between hospital transfusion rate and mortality. This does not necessarily contradict the large body of literature showing an association between transfusion and adverse outcome because those studies focused on patient-level risk.²⁻⁹ Our analysis of mortality focused on comparing groups of hospitals according to their hospital-level transfusion rates. We specifically did not compare mortality of individual patients who did vs did not receive transfusion. We can state, however, that even if higher transfusion rates at some hospitals are not deleterious they may still represent potentially unnecessary care that is costly. The acquisition costs of a unit of RBCs, fresh-frozen plasma, and platelets (apheresis) were $214, $60, and $539, respectively, in 2006.¹ These costs underestimate the true direct and indirect costs of transfusion.²⁵ For example, a recent analysis estimated the total cost of each RBC transfusion to range from $522 to $1183 (mean cost, $761 per RBC unit).²⁶ Therefore, even if unnecessary transfusion is not deleterious, a reduction in the observed variability might result in significant cost savings.

As is the case in other areas of medicine, the degree of variability in clinical practice we observed represents a potential quality improvement opportunity. This is particularly complex in relation to transfusion practice in CABG surgery. The decision to transfuse has multiple triggers, resulting from a wide array of clinical scenarios and the consequent inability to apply standardized algorithms. The multiplicity of health care practitioners in CABG surgery care generates differences of opinion about safety and efficacy. Transfusion thresholds will change during the course of care; the threshold for a rapidly bleeding patient is different than for a stable patient postoperatively. Improvement in quality related to transfusion practice in CABG surgery is a multifactorial, complex but critically important, challenge. Studies have demonstrated that use of a blood conservation program significantly improves transfusion rates over time.²⁷⁻³¹ This may be a more effective way of improving transfusion rates, as opposed to publishing guidelines, which may not be that helpful as our study suggests. In addition, the role of lack of data from randomized trials cannot be overstated. To our knowledge, there has never been a large randomized trial of the safety and efficacy of blood transfusion in cardiac surgery;²³ therefore, some of the variability we observed may be due to honest differences between clinicians in the perceived benefits and risks of transfusion.

Author Contributions: Dr Bennett-Guerrero had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Bennett-Guerrero, O’Brien, Ferguson, Gammie, Song. Acquisition of data: Peterson, Gammie, Song. Analysis and interpretation of data: Bennett-Guerrero, Zhao, O’Brien, Gammie, Song. Drafting of the manuscript: Bennett-Guerrero, O’Brien, Gammie, Song. Critical revision of the manuscript for important intellectual content: Zhao, O’Brien, Ferguson, Peterson, Gammie, Song. Statistical analysis: Zhao, O’Brien, Song. Obtained funding: Peterson, Song.

Financial Disclosures: Dr Bennett-Guerrero is principal investigator (grant R01 HL101382-01 from the National Institutes of Health) for a multicenter study assessing the impact of blood transfusion on peripheral and cerebral oxygenation and the microcirculation. He is also a named inventor on a patent application related to methods of washing red blood cells. No other authors have any disclosures.

Role of the Sponsors: This study was supported by the Society of Thoracic Surgeons (STS) through the National Adult Cardiac Surgery Database and the Duke Clinical Research Institute (DCRI).

REFERENCES
USE OF BLOOD TRANSFUSION IN CABG SURGERY

Reality, no matter how widened and heightened our perceptions, never ceases to be anything but the effect on us of an infinite mystery.

—Laurens van der Post (1906-1996)