The Impact of Bleeding Avoidance Strategies on Hospital-Level Variation in Bleeding Rates Following Percutaneous Coronary Intervention

Insights From the National Cardiovascular Data Registry CathPCI Registry

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ABSTRACT

OBJECTIVES The aim of this study was to explore whether the use of bleeding avoidance strategies (BAS) explains variability in hospital-level bleeding following percutaneous coronary intervention.

BACKGROUND Prior studies have reported that bleeding rates following percutaneous coronary intervention vary markedly among hospitals, but the extent to which use of BAS explains this variation is unknown.

METHODS Using the American College of Cardiology National Cardiovascular Data Registry’s CathPCI Registry, estimated hospital-level bleeding rates from 2,459,686 procedures at 1,358 sites were determined. A series of models were fit to estimate random-effect variance, adjusting for patient risk (using the validated CathPCI bleeding risk model, C statistic = 0.77) and various combinations of BAS (transradial access, bivalirudin, vascular closure device use). The rate of any BAS use was also estimated for each hospital, and the association between percentage BAS use and predicted bleeding rates was determined.

RESULTS In total, 125,361 bleeding events (5.1%) were observed; patients experiencing bleeding events had lower rates of radial access (5.0% vs. 11.2%; p < 0.001), bivalirudin therapy (43.8% vs. 59.4%), and vascular closure device use (32.9% vs. 42.4%, p < 0.001) than those without bleeding. There was significant variation in bleeding rates across hospitals (median 5.0%; interquartile range [IQR]: 2.7% to 6.6%), which persisted after incorporating patient-level risk (median 5.1%; IQR: 4.0% to 4.4%). Patient factors accounted for 20% of the overall hospital-level variation, and radial access plus bivalirudin use accounted for an additional 7.8% of the overall hospital-level variation. The median hospital rate of any BAS use was 86.6% (IQR: 72.5% to 94.1%). A significant decrease in observed hospital-level bleeding was seen in hospitals above the median in BAS use (adjusted odds ratio: 0.90; 95% confidence interval: 0.88 to 0.93).

CONCLUSIONS A modest proportion of the variation in hospitals’ rates of bleeding following percutaneous coronary intervention is attributable to differential use of BAS. Further analyses are required to determine the remaining approximately 70% causes of variation in percutaneous coronary intervention bleeding seen among hospitals.

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Periprocedural bleeding is among the most common complications following percutaneous coronary intervention (PCI) and is associated with increased risk for short- and long-term mortality, stroke, increased length of hospital stay, and higher cost (1–9). Multiple bleeding avoidance strategies (BAS) have been developed to reduce the incidence of this common but preventable complication, including transradial access, targeted periprocedural anticoagulation (with bivalirudin), and the use of vascular closure devices. Although these strategies have been shown to reduce bleeding complications post-PCI, previous studies have shown significant variation in BAS use across patient populations (10,11), with lower use among patients at high risk for bleeding complications.

There are limited outcomes-based quality measures following PCI with which to evaluate hospitals. Post-PCI bleeding rates are shared with providers participating in the National Cardiovascular Data Registry’s CathPCI Registry, and comparison of post-PCI bleeding rates across facilities has been proposed as a performance measure in the Centers for Medicare and Medicaid Services Acute Care Episode Demonstration Program. Although recent studies have demonstrated wide variation in hospital-level bleeding following PCI (12), data on the use of BAS such as radial access, bivalirudin, and potentially vascular closure devices across hospitals is limited. The available data demonstrate that BAS are used in patients at low risk for bleeding rather than in patients most likely to benefit—a “risk-treatment” paradox (10,13)—however, there may be other unmeasured care processes that affect hospital-level bleeding rates, such as antithrombotic drug dosing, manual compression protocols, and the use of ultrasound-guided femoral access. To date, no large-scale study has compared the association between BAS use and hospital-level bleeding rates and the extent to which individual patient risk and the use of specific BAS may explain the hospital-level variation in observed post-procedural bleeding. Therefore, we used data from the CathPCI Registry to: 1) determine hospital-level variation in observed bleeding rates following PCI; 2) evaluate the extent to which the use of specific BAS may explain the variance in bleeding rates across hospitals; and 3) assess the relationship between hospital-level BAS use and bleeding rates. We hypothesized that there would be significant variation in hospital-level post-PCI bleeding rates, that some of this variation would be explained by patient risk and the use of BAS, and that high use of BAS would be associated with lower rates of bleeding.

**Methods**

**Data Source and Study Population.** Among the National Cardiovascular Data Registries, the CathPCI Registry is the largest quality improvement program for PCI in the world. Cosponsored by the American College of Cardiology and the Society for CardiovascularAngiography and Interventions, it captures detailed clinical data on baseline patient and hospital characteristics, clinical presentation, procedural complications, and in-hospital outcomes among patients undergoing PCI at >1,500 sites across the United States. Details of the design and conduct of this registry have been previously described. Data are systematically collected using third-party software platforms certified by the American College of Cardiology or through a secure, Web-based platform and are regularly audited for data completeness and accuracy (14). The Duke University Medical Center Institutional Review Board granted a waiver of informed consent and authorization for this study, as data are collected without individual patient identifiers.

Between July 2009 and June 2013, we identified 2,516,937 patients undergoing PCI at 1,453 hospitals. We excluded patients with missing variables necessary to define bleeding (n = 10,210) and those who underwent coronary artery bypass grafting (n = 30,238). We further excluded patients undergoing PCI at sites that reported no bleeding events (n = 13,752); patients who had contraindications to, were blinded to, or had missing information for bivalirudin administration (n = 2,573); and patients who presented at hospitals performing <50 PCIs annually (n = 478).

**Data Definitions and Outcomes.** Patients were treated using any BAS if: 1) they underwent PCI via radial artery access; 2) bivalirudin was used for...
periprocedural anticoagulation regardless of arterial site of access, or, in case of femoral access; 3) they received vascular closure device to assist with hemostasis at the conclusion of the procedure.

The outcome of interest was the rate of CathPCI bleeding, defined as site-reported arterial access-site bleeding (either external or a hematoma >10 cm for femoral access, >5 cm for brachial access, or >2 cm for radial access); retroperitoneal, gastrointestinal, or genitourinary bleeding; intracranial hemorrhage; cardiac tamponade; post-procedural hemoglobin decrease of ≥3 g/dl in patients with pre-procedural hemoglobin levels ≥16 g/dl; or post-procedural non-bypass surgery-related blood transfusion for patients with pre-procedural hemoglobin levels ≥8 g/dl.

**STATISTICAL ANALYSIS.** We compared baseline demographic, clinical, presentation, and hospital characteristics for patients by tertile of hospital-level use of BAS following PCI. Continuous variables are expressed as median values with interquartile ranges (IQRs), and categorical values are presented as percentages. We used Pearson chi-square tests for categorical variables and Wilcoxon rank sum tests for continuous variables.

The observed rate of bleeding for each hospital was calculated as the observed number of bleeding events divided by the total number of admissions. To estimate adjusted hospital bleeding rates by patient risk, we used logistic regression with random intercepts for hospital. The log odds for random hospital were assumed to be normally distributed, with mean equal to the intercept and variance equal to the random-effect variance or variation in log odds attributable to between-hospital differences. We estimated these parameters and transformed from the log-odds scale to the probability scale. The hospital-specific intercepts were used to estimate hospital-specific bleeding rates.

To assess whether the use of BAS attenuates the variation in adjusted hospital-level bleeding rates, we fit a series of 8 models and estimated random-effect variance. We used the percentage of proportional change in variance (PCV) to assess the incremental effect of adding variables to the model. The PCV is calculated as follows: $PCV = (\frac{V_1 - V_2}{V_1}) \times 100$, where $V_1$ is the variance of the initial model and $V_2$ is the variance of the model with more terms. The 8 models were: 1) unadjusted; 2) patient risk adjusted; 3) patient risk adjusted plus radial; 4) patient risk adjusted plus bivalirudin; 5) patient risk adjusted plus vascular closure device; 6) patient risk adjusted plus radial and bivalirudin; 7) patient risk adjusted plus bivalirudin and vascular closure device; and 8) patient risk adjusted plus radial, bivalirudin, and vascular closure device. We calculated the PCV for model 2 versus 1 and for all other models versus model 2. The patient risk-adjusted models included variables from the previously validated CathPCI bleeding model (15). Specifically, included covariates were sex, age, body mass index,

![FIGURE 1 Study Population Characteristics](image-url)
TABLE 1  Patient Characteristics by Tertile of Hospital Use of Bleeding Avoidance Strategies

<table>
<thead>
<tr>
<th>Low (n = 452 Sites)</th>
<th>Middle (n = 453 Sites)</th>
<th>High (n = 453 Sites)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
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</tr>
<tr>
<td>Age, yrs</td>
<td>65 (56-73)</td>
<td>65 (56-74)</td>
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<tr>
<td>Women</td>
<td>32.8</td>
<td>32.5</td>
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<tr>
<td>BMI, kg/m²</td>
<td>29.2 (25.8-33.5)</td>
<td>29.0 (25.7-33.3)</td>
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<tr>
<td>Race</td>
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<tr>
<td>White</td>
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<td>87.9</td>
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<tr>
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<td>8.0</td>
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<tr>
<td>Asian</td>
<td>1.9</td>
<td>2.3</td>
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<tr>
<td>Other</td>
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<td>0.8</td>
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<tr>
<td>Hispanic ethnicity</td>
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<td><strong>Clinical characteristics</strong></td>
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<tr>
<td>Prior myocardial infarction</td>
<td>30.7</td>
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<tr>
<td>Prior heart failure</td>
<td>12.7</td>
<td>12.0</td>
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<td>Prior PCI</td>
<td>40.9</td>
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<tr>
<td>Prior CABG</td>
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<tr>
<td>Prior CVA</td>
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<td>12.6</td>
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<td>Peripheral vascular disease</td>
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<td>Diabetes</td>
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<tr>
<td>Hypertension</td>
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<td>82.4</td>
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<td>Dyslipidemia</td>
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<tr>
<td>Current/recent smoker</td>
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<td>27.0</td>
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<td>Renal failure</td>
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<td>2.5</td>
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<tr>
<td><strong>Presentation features</strong></td>
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<tr>
<td>Clinical presentation</td>
<td></td>
<td></td>
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<tr>
<td>Stable angina/atypical chest pain</td>
<td>17.2</td>
<td>19.1</td>
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<tr>
<td>Unstable angina</td>
<td>39.1</td>
<td>38.2</td>
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<td>NSTEMI</td>
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<td>19.3</td>
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<tr>
<td>STEMI</td>
<td>16.6</td>
<td>15.5</td>
</tr>
<tr>
<td>Cardiogenic shock within 24 h</td>
<td>2.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Cardiac arrest within 24 h</td>
<td>2.0</td>
<td>1.8</td>
</tr>
<tr>
<td><strong>Procedural characteristics</strong></td>
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<td>Access site</td>
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<td></td>
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<tr>
<td>Femoral</td>
<td>90.9</td>
<td>89.1</td>
</tr>
<tr>
<td>Radial</td>
<td>8.7</td>
<td>10.5</td>
</tr>
<tr>
<td>IABP</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Multivessel disease</td>
<td>52.8</td>
<td>53.5</td>
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<tr>
<td>Multivessel PCI</td>
<td>12.4</td>
<td>14.0</td>
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<td>Drug-eluting stent</td>
<td>70.8</td>
<td>72.8</td>
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<td>Bare-metal stent</td>
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<td>19.2</td>
</tr>
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<td>Vascular closure device</td>
<td>25.9</td>
<td>44.0</td>
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<td><strong>Procedural medications</strong></td>
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<td>Aspirin</td>
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<td>Clopidogrel</td>
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<td>Prasugrel</td>
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<td>13.9</td>
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<td>Unfractionated heparin</td>
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<td>Low-molecular weight heparin</td>
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<td>Bivalirudin</td>
<td>40.0</td>
<td>61.1</td>
</tr>
<tr>
<td>Glycoprotein IIb/IIIa inhibitor</td>
<td>33.4</td>
<td>25.8</td>
</tr>
<tr>
<td>CathPCI mortality risk score,%</td>
<td>0.2 (0.1-0.7)</td>
<td>0.2 (0.1-0.7)</td>
</tr>
<tr>
<td>CathPCI bleeding risk score,%</td>
<td>3.4 (2.0-7.0)</td>
<td>3.4 (2.0-6.8)</td>
</tr>
</tbody>
</table>

Values are median (interquartile range) or %. All p < 0.001.

BMI = body mass index; CABG = coronary artery bypass graft surgery; CVA = cerebrovascular accident; IABP = intra-aortic balloon pump; NSTEMI = non-ST-segment elevation myocardial infarction; PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction.
presentation (Table 1). Patients experiencing bleeding events had lower rates of radial access (5.0% vs. 11.2%, p < 0.001), bivalirudin therapy (43.8% vs. 59.4%, p < 0.001), and vascular closure device use (32.9% vs. 42.4%, p < 0.001) than those without bleeding.

Hospital characteristics by tertile of BAS use are described in Table 2. The lowest tertile hospitals were larger with a higher average annual PCI volume than the highest tertile hospitals. Hospital location setting and affiliation were modestly but statistically different across groups.

**HOSPITAL-LEVEL VARIATION IN BLEEDING RATES AND THE INFLUENCE OF BAS USE.** There was significant variation in unadjusted bleeding rates across hospitals (Figure 2). The median hospital rate of bleeding was 5.0% (IQR: 3.65% to 6.56%), but wide variation, with a hospital bleeding rate of 2.12% in the 5th percentile but 9.84% in the 95th percentile. After risk adjustment that incorporated individual bleeding risk using the CathPCI bleeding risk model (15) and accounting for in-hospital clustering, the median hospital bleeding rate was similar (5.14%; IQR: 4.00% to 6.60%), with a similar range (5th percentile 2.65%, 95th percentile 9.36%).

We created a series of mixed-effects models to estimate the hospital-level variance in bleeding across the spectrum of the different BAS and calculated the PCV compared with the unadjusted model (model 1) (Table 3). After adjusting for patient risk factors using the CathPCI bleeding risk model (model 2), the PCV in bleeding rates across hospitals decreased by 20%. However, the addition of any individual BAS use or a combination of the various BAS options (models 3 to 8) only modestly explained the variation of bleeding rates, and more than 70% of the variation in bleeding remained unexplained, even after adjustment for patient risk factors and BAS use. For example, this analysis suggests that the model incorporating radial use and bivalirudin (model 6) explained an additional 7.8% of the overall variation in hospital-level bleeding rates after adjusting for patient factors. Conversely, the use of vascular closure devices only (model 5) explained only an additional 0.88% of the overall variation after accounting for patient-level factors.

**PATIENT-LEVEL BAS USE AND PREDICTED BLEEDING.** We compared the predicted risk for bleeding among patients receiving BAS with that among those who did not receive BAS. Patients receiving any BAS had lower overall predicted risk for bleeding than patients not receiving any BAS (3.2% vs. 4.5%, p < 0.0001). Patients undergoing either radial access or bivalirudin use during PCI had a lower predicted bleeding risk than those not (3.1% vs. 4.1%, p < 0.0001).

**ASSOCIATION BETWEEN HOSPITAL BAS USE AND PATIENT-LEVEL BLEEDING RATES.** The median hospital rate of any BAS use was 86.6% (IQR: 72.5% to 94.1%). Increased hospital rate of BAS use was associated with decreased probability of a bleeding event at the patient level (Figure 3). After performing mixed-effects logistic regression modeling adjusting for patient bleeding risk factors and percentage of hospital BAS use, we identified a nonlinear relationship between hospital percentage BAS use and patient-level bleeding. On the basis of the spline plot (Figure 4), we modeled hospital percentage BAS using a continuous linear spline with 1 knot at 85%, the median value of hospital percentage BAS. There was minimal reduction in patient-level bleeding per 5% increase in BAS use for hospitals below the median in BAS use (adjusted odds ratio: 0.99; 95% confidence interval: 0.98 to 1.00) but a significant 10% reduction in the odds of patient-level bleeding among hospitals above the median in BAS use (adjusted odds ratio: 0.90; 95% confidence interval: 0.88 to 0.93).

**DISCUSSION**

In a large, nationally representative analysis of almost 2.5 million PCI procedures across 1,358 sites, we report the following findings: 1) substantial variation in bleeding rates and use of BAS was observed across hospitals, but patient mix explained just one-fifth of the overall hospital level variation in bleeding; 2) the median hospital rate of any BAS use was 86.6%, and higher use of BAS was associated with reduced levels of bleeding at the hospital level; 3) although BAS use...
was associated with lower risk for bleeding, the use of BAS to reduce PCI bleeding modestly accounted for <10% of the hospital-level variation in bleeding; and 4) hospitals with high levels of BAS show lower rates of post-PCI bleeding, likely by implementing these strategies across the spectrum of bleeding risk. These data have several implications for both clinical care and quality improvement. First, the implementation of BAS routinely may reduce the risk-treatment paradox by reducing bleeding events in the patients at highest risk for this complication. Second, there are likely unmeasured hospital strategies related to BAS that account for the remaining variation in hospital level bleeding rates.

Given the large number of PCIs performed annually and the attendant costs, risk-adjusted, outcomes-based performance measures following PCI are critical in fairly comparing care quality across institutions. Currently used performance measures endorsed by the National Quality Forum include in-hospital mortality following PCI and risk-adjusted 30-day readmission following PCI (16); however, rates of PCI-related in-hospital mortality are low, and 30-day readmission rates following PCI are largely affected by factors not directly related to the index procedure (17); furthermore, it is unclear if either of these metrics can be significantly improved by modifications in care practices (18). As such, PCI-related bleeding appears to be an attractive performance measure. It is the most common noncardiac complication following PCI and is associated with increases in short- and long-term morbidity and mortality, length of stay, and cost. There is significant hospital-level variation in rates of bleeding and strategies exist to reduce bleeding, thus providing a clear opportunity for quality improvement and dissemination of best practices. This is particularly important given that prior studies have shown a risk-treatment paradox for BAS with significantly less application in higher risk patients. However, our analysis highlights a number of limitations with respect to using bleeding rates as a performance measure using current data collection.

In this context, it is important to determine if variation in post-PCI bleeding rates is due simply to differences in patient mix across hospitals, variation in the application of BAS (i.e., the risk-treatment paradox), both, or some unmeasured factor(s). We found that patient-level factors and BAS use explained only 26% of the overall variation in bleeding rates across hospitals. However, patients receiving BAS were at lower predicted risk for bleeding than patients not receiving BAS. This suggests that a significant proportion of hospitals may be using BAS in patients at relatively low risk, despite the likelihood of increased benefit in high-risk patients as described by Marso et al. (10). Among hospitals that used BAS in more than 85% of patients, however, we observed lower rates of overall bleeding, demonstrating that a strategy to broadly use BAS in all patients (i.e., overcoming the risk-treatment paradox) is a reasonable strategy to reduce overall variation in hospital bleeding rates.

As PCI-related bleeding becomes more prominent as a potential hospital quality indicator, it will be important to ensure that hospital bleeding rates are standardized according to patient risk. However, our analysis demonstrates that even after taking patient
risk and BAS use into account, more than two-thirds of the overall variation in bleeding rates continues to remain unexplained, highlighting a significant limitation in the use of bleeding rates as a performance measure under the current data collection structure. As such, the stringent use of bleeding rate measures to determine reimbursement rates or to penalize institutions by payers and regulators may be premature at this time, given the significant variability in bleeding that is not well understood at this time offers providers no clear path to improve patient outcomes. Similar to using post-PCI mortality or readmission within 30 days following PCI, there are important limitations with the use of post-PCI as a key performance metric. Therefore, it may be more relevant to use other measures of quality (e.g., appropriate use criteria) instead of these incomplete performance standards measures as a key metric in quality improvement. Indeed, a recent analysis demonstrated a temporal increase in PCI meeting appropriateness criteria, highlighting the utility of such an approach (19). However, none of these metrics should be used for determining reimbursement until they have been appropriately vetted as performance measures. Analyses such as ours may facilitate this determination for candidate performance measures such as appropriate use criteria.

Accordingly, our study additionally highlights the need to collect more granular data on procedural factors and bleeding events to develop more accurate risk adjustment models to account for the variability in bleeding rates across hospitals. Currently, data are not systematically collected with respect to appropriate dosing of anticoagulant and antiplatelet medications, especially in women and older patients, sheath management, interoperator variability in femoral access technique, and other factors that may explain the significant variation in bleeding across sites. It also underscores the need for consistent application of appropriate BAS in all patients, especially those at particularly high risk for bleeding complications following PCI. As hospitals develop quality improvement strategies to reduce

### TABLE 3 Impact of Risk Adjustment and Various Bleeding Avoidance Strategies on Variation on Bleeding Rates

<table>
<thead>
<tr>
<th>Model</th>
<th>Variance of Hospital Effect (95% CI)</th>
<th>PCV vs. Model 1</th>
<th>PCV vs. Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Unadjusted</td>
<td>0.22 (0.20-0.24)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Patient risk adjusted</td>
<td>0.17 (0.16-0.19)</td>
<td>19.94</td>
<td></td>
</tr>
<tr>
<td>3. Adjusted + radial</td>
<td>0.17 (0.16-0.19)</td>
<td>20.95</td>
<td>1.26</td>
</tr>
<tr>
<td>4. Adjusted + bivalirudin</td>
<td>0.16 (0.15-0.18)</td>
<td>24.62</td>
<td>5.85</td>
</tr>
<tr>
<td>5. Adjusted + VCD</td>
<td>0.17 (0.16-0.19)</td>
<td>20.64</td>
<td>0.88</td>
</tr>
<tr>
<td>6. Adjusted + radial + bivalirudin</td>
<td>0.16 (0.15-0.17)</td>
<td>26.14</td>
<td>7.75</td>
</tr>
<tr>
<td>7. Adjusted + bivalirudin + VCD</td>
<td>0.16 (0.15-0.18)</td>
<td>24.58</td>
<td>5.80</td>
</tr>
<tr>
<td>8. Adjusted + radial + bivalirudin + VCD</td>
<td>0.16 (0.15-0.18)</td>
<td>25.63</td>
<td>7.11</td>
</tr>
</tbody>
</table>

CI = confidence interval; PCV = percentage of the proportional change in variance; VCD = vascular closure device.

### FIGURE 3 Observed Use of Bleeding Avoidance Strategies

Percentage of patients (pts) receiving any bleeding avoidance strategy (BAS) by hospital and the risk-adjusted bleeding rate.

### FIGURE 4 Adjusted Spline Plot for Percentage of Bleeding Avoidance Strategy Use on Bleeding Rates

Adjusted spline plot predicting rates of bleeding by percentage of bleeding avoidance strategies (BAS) used. The vertical lines represent the spline knots at the 5th, 35th, 65th, and 95th percentiles of % any BAS.
rates of post-PCI bleeding, dissemination of best practices from high-performing centers may be critical in reducing the variation in hospital-level bleeding rates and lowering overall bleeding rates. This may include a detailed exploration of antithrombotic dosing protocols, sheath removal strategies, and transfusion practices between sites with high versus low observed bleeding.

**STUDY LIMITATIONS.** First, there may be significant institutional variation in the accuracy of reported bleeding events, including the underreporting of minor and clinically insignificant bleeding episodes. We tried to reduce the effect of underreporting by excluding sites that reported no bleeding events. Additionally, the CathPCI bleeding definition that was used incorporates clinically significant bleeding and is broadly concurrent with previous estimates of significant bleeding following PCI. Next, there may be differential reporting of bleeding events between sites that participate in the CathPCI Registry compared with sites that do not, which may signal a greater commitment to accurate reporting and quality improvement, thus limiting the overall generalizability of our results. Third, the CathPCI Registry captures only in-hospital outcomes and would not capture bleeding events that occurred following discharge. However, the vast majority of bleeding events following PCI occur in the first 24 h after the procedure, and even after excluding patients who were discharged on the day of their procedure, we report no meaningfully significant difference in our primary results. Finally, as with any observational analysis, we are unable to exclude the potential for unmeasured confounding.

**CONCLUSIONS**

In a large, national registry, we found wide variation in rates of hospital-level bleeding following PCI. Patient risk and the use of BAS explain at most 26% of the overall variation in observed hospital-level bleeding rates, and the use of various BAS at most explain an additional 7.8% of the overall variation after accounting for patient-level factors. This analysis highlights the need for more investigation of the causes of site-to-site variability in PCI-related bleeding following PCI.

**REFERENCES**


**PERSPECTIVES**

**WHAT IS KNOWN?** Previous studies have shown significant variation in bleeding rates following PCI across hospitals, but the extent to which using BAS explains this variation is unknown.

**WHAT IS NEW?** We demonstrate that about 1 in 20 patients undergoing PCI had bleeding events. Although there was wide hospital-level variation in bleeding, patient factors explained only 20% of this variation, and the use of radial access and bivalirudin only explained another 7.8% of the variation. More than 70% of the variation in bleeding remains unexplained.

**WHAT IS NEXT?** This study urges caution in the use of post-PCI bleeding as a performance measure, as a significant proportion of the hospital-level variation in bleeding remains unexplained. More granular data collection and further analyses are necessary to explain this variation in bleeding rates to develop best practices to mitigate bleeding following PCI.


**KEY WORDS** bleeding avoidance, PCI, performance measure, quality measure