Multifactorial risk index for prediction of intraoperative blood transfusion in endovascular aneurysm repair

Eitezaz Mahmood, BA,[a,b] Robina Matyal, MD,[b] Ariel Mueller, MA,[b] Feroze Mahmood, MD, FASE,[b] Avery Tung, MD,[c] Mario Montealegre-Gallegos, MD,[b] Marc Schermerhorn, MD,[d] and Sajid Shahul, MD,[b,c] Chicago, Ill; and Boston, Mass

ABSTRACT

Background: In some institutions, the current blood ordering practice does not discriminate minimally invasive endovascular aneurysm repair (EVAR) from open procedures, with consequent increasing costs and likelihood of blood product wastage for EVARs. This limitation in practice can possibly be addressed with the development of a reliable prediction model for transfusion risk in EVAR patients. We used the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database to create a model for prediction of intraoperative blood transfusion occurrence in patients undergoing EVAR. Afterward, we tested our predictive model on the Vascular Study Group of New England (VSGNE) database.

Methods: We used the ACS NSQIP database for patients who underwent EVAR from 2011 to 2013 (N = 4709) as our derivation set for identifying a risk index for predicting intraoperative blood transfusion. We then developed a clinical risk score and validated this model using patients who underwent EVAR from 2003 to 2014 in the VSGNE database (N = 4478).

Results: The transfusion rates were 8.4% and 6.1% for the ACS NSQIP (derivation set) and VSGNE (validation) databases, respectively. Hemoglobin concentration, American Society of Anesthesiologists class, age, and aneurysm diameter predicted blood transfusion in the derivation set. When it was applied on the validation set, our risk index demonstrated good discrimination in both the derivation and validation set (C statistic = 0.73 and 0.70, respectively) and calibration using the Hosmer-Lemeshow test (P = .27 and 0.31) for both data sets.

Conclusions: We developed and validated a risk index for predicting the likelihood of intraoperative blood transfusion in EVAR patients. Implementation of this index may facilitate the blood management strategies specific for EVAR. (J Vasc Surg 2018;67:778-84.)

Because of the lower incidence of severe perioperative complications, endovascular aneurysm repair (EVAR) has become a preferred approach for abdominal aortic aneurysm (AAA) repair.[1-3] Consequently, perioperative management protocols for EVAR that were initially modeled on experience of open AAA repair have been revised. In particular, transfusion testing and blood ordering practices for EVAR remain hospital specific and are modeled on the bleeding risk of an open AAA repair. However, the incidence of major bleeding is lower for EVAR, and significant resources are invested in preoperative blood typing, red cell antibody screening, and crossmatching for EVAR patients. Overordering of these

blood products may limit the availability of blood for emergency cases, result in wasted units if they are unable to be stored for future use, and increase blood bank workload and costs.[4,5]

Although several guidelines for perioperative blood management exist, most are not procedure specific.[6-11] Knowledge of procedure-specific risk factors for intraoperative blood transfusion may improve resource allocation, contain costs, and facilitate the development of blood conservation protocols.[12] The aim of this study was to create a clinically useful and reliable model for predicting intraoperative blood transfusions in patients undergoing EVAR. To develop our algorithm, we used databases from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) and the Vascular Study Group of New England (VSGNE).

METHODS

Data source. This retrospective case-control cohort study included data from the ACS NSQIP and the VSGNE databases. The NSQIP data set was used for derivation, and the VSGNE data set was used for validation. The Institutional Review Board at Beth Israel Deaconess Medical Center declared this study exempt from review because neither the ACS NSQIP nor the VSGNE database has any patient identifiers.

We queried the ACS NSQIP database for patients ≥18 years old who underwent EVAR from 2011 to 2013. The ACS NSQIP database includes information on >300 variables describing preoperative risk factors, intraoperative variables, and 30-day postoperative morbidity and mortality. ACS NSQIP data are generated from manual chart abstraction and are regularly audited.

The VSGNE is a regional collaboration between academic and community hospitals in the New England area. The data for vascular operations are prospectively collected in a registry containing >100 clinical and demographic variables by trained nurses or clinical abstractors at each participating institution. The VSGNE allows benchmarking among centers for quality assurance and improvement activities. We queried the VSGNE database for all patients who underwent an EVAR procedure from 2003 to 2014. Patients with a ruptured aneurysm in either cohort were excluded from all analyses.

Outcomes. Our primary analysis in the derivation data set focused on the incidence of intraoperative blood transfusion in the ACS NSQIP database. To capture intraoperative blood transfusions, we used a previously described method by Stangenberg et al.[13]

In the validation analysis, we compared intraoperative transfusion rates in VSGNE with model predictions. An intraoperative blood transfusion was defined as transfusion of at least one unit of packed red blood cells in the operating room.

Statistical methods. Descriptive statistics for categorical variables are presented as frequencies or proportions, and means ± standard deviations were calculated for continuous variables. The χ^2 or Fisher exact test was used to compare proportions, and t-tests were used to compare means.

The ACS NSQIP database was used as the training data set or derivation data set for our prediction model, and the VSGNE database was used as the validation data set. Univariate and multivariable logistic regression was performed on the ACS NSQIP database with preoperative patient comorbidities, demographic factors, and other characteristics to determine independent predictors of intraoperative blood transfusion. A multivariable model was created using stepwise model selection with entry and stay criteria of .15 and .05, respectively. Using the variables identified by our multivariable model as independent predictors of a blood transfusion, we then created an individual clinical risk score. To do this, we assigned point-based scores and summed them to create a total risk score. Individual points were based on quartiles for continuous predictors and severity for categorical predictors. The performance of our clinical risk score was then assessed using the C statistic and Hosmer-Lemeshow goodness-of-fit test in both the training (ACS NSQIP) and validation (VSGNE) data sets. The C statistic is calculated from the area under the

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective review of prospectively collected data in the National Surgical Quality Improvement Program (NSQIP) database, with validation of a prediction model using the prospectively collected data of the Vascular Study Group of New England (VSGNE) database
- **Take Home Message:** Of 4709 endovascular aneurysm repair patients from the NSQIP database, 8.4% required blood transfusion. Hemoglobin concentration, American Society of Anesthesiologists class, age, and aneurysm diameter predicted need for blood transfusion. A risk index to predict transfusion was validated using data from the VSGNE database.
- **Recommendation:** The authors suggest a validated model to predict blood use during endovascular aneurysm repair.

curve of the receiver operating characteristic curve and is a measure of discriminatory power.

All analyses were conducted using SAS JMP Pro 13.0 or SAS 9.3 (SAS Institute, Cary, NC), and P values < .05 were considered statistically significant.

RESULTS

Overall, 4709 patients in the ACS NSQIP database underwent EVAR, of which 8.4% received an intraoperative blood transfusion. In the VSGNE database, 4478 patients underwent EVAR and 6.1% were transfused. In the derivation data set (NSQIP), several differences were observed between patients who were transfused and those who were not (Table I). Factors associated with transfusion in the ACS NSQIP data set included advanced age (77.3 vs 74.0 years; $P <$ .0001), female gender (27.2% vs 18.1%; $P <$ .0001), low preoperative hemoglobin concentration (11.6 vs 13.5 g/dL; $P <$ .0001), and increased anterior-posterior aneurysm diameter (64.3 vs 56.7 mm; $P =$ .0003).

Comparison of the cohorts. NSQIP and VSGNE data sets are compared in Table II. Age was similar between the two cohorts, as were the proportion of female patients and smokers and the size of the aneurysm. A much larger proportion of patients in the VSGNE data set had congestive heart failure at baseline ($P <$ .0001). Contrarily, a higher proportion of patients in the ACS NSQIP cohort (15.4% vs 7.0%; $P <$ .0001) presented with a nonelective status.

Derivation of the multivariable model. Using multivariable logistic regression in the derivation cohort, we identified preoperative hemoglobin concentration (odds ratio [OR], 0.59 per 1 g/dL increase; 95% confidence interval [CI], 0.55-0.63), American Society of