

Variability in Blood and Blood Component Utilization as Assessed by an Anesthesia Information Management System

Steven M. Frank, M.D.,* Will J. Savage, M.D.,† Jim A. Rothschild, M.D.,‡ Richard J. Rivers, M.D.,* Paul M. Ness, M.D.,§ Sharon L. Paul, B.S., M.S.,|| John A. Ulatowski, M.D., Ph.D., M.B.A.#

ABSTRACT

Background: Data can be collected for various purposes with anesthesia information management systems. The authors describe methods for using data acquired from an anesthesia information management system to assess intraoperative utilization of blood and blood components.

Methods: Over an 18-month period, data were collected on 48,086 surgical patients at a tertiary care academic medical center. All data were acquired with an automated anesthesia recordkeeping system. Detailed reports were generated for blood and blood component utilization according to surgical service and surgical procedure, and for individual surgeons and anesthesiologists. Transfusion hemoglobin trigger and target concentrations were compared among surgical services and procedures, and between individual medical providers.

Results: For all patients given erythrocytes, the mean transfusion hemoglobin trigger was 8.4 ± 1.5 , and the target was 10.2 ± 1.5 g/dl. Variation was significant among surgical services (trigger range: 7.5 ± 1.2 – 9.5 ± 1.1 , $P = 0.0001$; target range: 9.1 ± 1.2 – 11.3 ± 1.4 g/dl, $P = 0.002$), surgeons (trigger range: 7.2 ± 0.7 – 9.8 ± 1.0 , $P = 0.001$; target range: 8.8 ± 0.9 – 11.8 ± 1.3 g/dl, $P = 0.001$), and anesthesiologists (trigger range: 7.2 ± 0.8 – 9.6 ± 1.2 , $P = 0.001$; target range: 9.0 ± 0.9 – 11.7 ± 1.3 g/dl, $P = 0.0004$). The use of erythrocyte salvage, fresh frozen plasma, and platelets varied threefold to fourfold among individual surgeons compared with their peers performing the same surgical procedure.

What We Already Know about This Topic

- Blood use varies considerably among clinicians, even for similar procedures, and varies across various operations.

What This Article Tells Us That Is New

- Electronic information systems can be used to generate detailed information about blood use by individuals and services. Mean differences in the hemoglobin transfusion trigger range varied by about 2 g/dl among various surgical services, surgeons, and anesthesiologists.

Conclusions: The use of data acquired from an anesthesia information management system allowed a detailed analysis of blood component utilization, which revealed significant variation among surgical services and surgical procedures, and among individual anesthesiologists and surgeons compared with their peers. Incorporating these methods of data acquisition and analysis into a blood management program could reduce unnecessary transfusions, an outcome that may increase patient safety and reduce costs.

* Associate Professor, Department of Anesthesiology/Critical Care Medicine, The Johns Hopkins Medical Institutions, Baltimore, Maryland. † Assistant Professor, Department of Pathology (Transfusion Medicine), The Johns Hopkins Medical Institutions. ‡ Chief Resident, Department of Anesthesiology/Critical Care Medicine, The Johns Hopkins Medical Institutions. § Professor, Department of Pathology (Director, Transfusion Medicine), The Johns Hopkins Medical Institutions. || Director of Medical Informatics, Department of Anesthesiology/Critical Care Medicine, The Johns Hopkins Medical Institutions. # The Mark C. Rogers Professor and Chairman, Department of Anesthesiology/Critical Care Medicine, The Johns Hopkins Medical Institutions.

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Address correspondence to Dr. Frank: Department of Anesthesiology, Zayed Tower, Suite 6208L-C4, 1800 Orleans Street, Baltimore, Maryland 21287. sfrank3@jhmi.edu. Information on purchasing reprints may be found at www.anesthesiology.org or on the masthead page at the beginning of this issue. ANESTHESIOLOGY's articles are made freely accessible to all readers, for personal use only, 6 months from the cover date of the issue.

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OPTIMIZING the use of blood products in the perioperative period is a difficult but important task that has direct implications for patient safety, cost containment, and conservation of a valuable resource that is often in short supply. Assessing overall hospital use of blood products is not difficult, but in a large institution that offers a wide variety of surgical specialties and procedures, tracking the use of blood products by specific procedure and medical provider presents a challenge. Transfusion practice has been shown to vary significantly between institutions^{1,2} and among providers within the same institution.³ Furthermore, this variability in transfusion practice has not changed substantially over the past two decades.^{2,4} Even the Secretary of Health and Human Services has recently stated publicly that there is “a need for more uniform standards for transfusion practice in an effort to improve patient safety and to reduce

morbidity,” and that “improvements in rational blood use have lagged.”**

Lately, great emphasis has been placed on optimizing the utilization of blood in surgical patients. Recent guidelines, all released within the past 5 yr, describe hemoglobin transfusion triggers of 6–7 g/dl for most patients,^{5,6} or a higher trigger of 7–10 g/dl for selected high-risk patients.⁷ Although these guidelines attempt to define the lowest acceptable hemoglobin, the decision to transfuse intraoperatively should take into account multiple physiologic parameters, rather than an isolated laboratory measurement, thus making it difficult to standardize transfusion practice.

Since the development of anesthesia information management systems (AIMS) more than 20 yr ago, multiple uses of the data acquired from these systems have been described. Examples include improving the processes of billing for anesthesia services,⁸ collecting data for risk management,⁹ increasing the accuracy of charted physiologic parameters,^{10,11} and even assisting in the tracking of controlled substances to detect drug diversion.¹² Assuming that the relevant information is collected, it seems logical that automated records can be used to systematically evaluate the intraoperative utilization of blood products.

In this study, we describe methods for assessing blood product utilization using AIMS-acquired data to provide an accurate and targeted assessment of intraoperative blood product use. To our knowledge, using AIMS for this purpose has not been described previously. For erythrocyte transfusions, we used the concept of transfusion “triggers” and “targets” to assess the initiation and endpoint of transfusion, respectively, based on measured hemoglobin concentration. We tested the hypothesis that AIMS-acquired data can be used to assess blood product utilization and that wide variation in utilization exists between surgical services and surgical procedures, and among individual surgeons and anesthesiologists within the same institution.

Materials and Methods

Setting and Data Collection

The Johns Hopkins Hospital is a 926-bed tertiary care university-affiliated medical center in Baltimore, Maryland, where approximately 37,000 surgical procedures are performed each year. The total institutional cost of acquisition for blood products is approximately \$25 million, and approximately one-half of all blood product costs are for erythrocyte units.

Intraoperative blood and blood component transfusion data were collected with an automated anesthesia information management system (Metavision®, iMdSoft, Needham, MA). Approximately 90% of all cases were charted electronically, with the remainder charted on paper records in remote locations where blood products are very rarely administered. The data used were collected over an 18-month period from

February 2010, to August 2011. After receiving Institutional Review Board approval (Johns Hopkins Medical Institutions, Baltimore, Maryland) we retrospectively reviewed and analyzed the data as part of an Interdisciplinary Blood Management Program. Data from all pediatric patients (age younger than 18 yr) were analyzed and reported separately from those of adult patients.

Surgical procedures were identified by the procedure name used for posting the case in the Operating Room Medical Information System. If the procedure was changed intraoperatively, the new procedure name was updated in the system. For every surgical procedure, all blood products given and hemoglobin values measured were manually entered into the anesthetic record at the time of administration to the patient. Utilization of erythrocytes and fresh frozen plasma (FFP) was analyzed to determine the percentage of patients who received these components and the number of units administered. Platelets were analyzed as a dichotomous variable, as the percentage of patients receiving them. Cell salvage utilization was analyzed by evaluating the percentage of patients given returned cell-salvaged erythrocytes and the volume of cell salvage product returned to the patient.

Hemoglobin Transfusion Triggers and Targets

For erythrocyte transfusions, we used the concept of transfusion “triggers” and “targets” to assess the initiation and endpoint of transfusion, respectively, based on measured hemoglobin concentrations. The lowest and last intraoperative hemoglobin values were extracted from the database for each patient who was given erythrocytes and had hemoglobin measurements. We evaluated hemoglobin transfusion triggers and targets by using the time stamp from the AIMS-acquired data. The lowest hemoglobin value defined the trigger only if it occurred before the beginning of the first erythrocyte transfusion and was determined by comparing the two time stamps. The transfusion target was defined as the last intraoperative hemoglobin value only if it occurred after the last erythrocyte transfusion was completed. A hemoglobin trigger or target was considered to be missing if these criteria were not met.

Individual surgeons and anesthesiologists were assessed to compare the mean transfusion hemoglobin triggers and targets among providers. All anesthesiologists or surgeons who had more than 10 transfused patients with complete hemoglobin data were included in the analysis. The average transfusion targets were displayed graphically in rank order to illustrate the range of values among surgeons and among anesthesiologists. Pediatric cardiac surgery patients (younger than 18 years) were not included in the analysis of hemoglobin triggers and targets because most have a chronically high hemoglobin concentration secondary to cyanotic heart disease.

Data Extraction and Statistical Analysis

Metavision® uses the client-server software architecture model. All data variables automatically receive date and time

** Boston Globe, June 28, 2011, Associated Press, http://articles.boston.com/2011-06-28/news/29713729_1_blood-transfusions-blood-banks-blood-loss. Accessed January 12, 2012.

Table 1. Blood Product Use for Adult Surgical Services with the Greatest Intraoperative Transfusion Requirements

| Surgical Service | % of Patients Transfused Erythrocytes | % of Patients Transfused by Number of Erythrocyte Units | | | | | % of Patients Given Cell Salvage Erythrocytes (Volume in ml) | % of Patients Given FFP | % of Patients Given Platelets |
|---|---------------------------------------|---|-------|-------|-------|------|--|-------------------------|-------------------------------|
| | | 1 U | 2-3 U | 4-5 U | 6-8 U | ≥9 U | | | |
| Adult cardiac (n = 1,561) | 45.3 | 12 | 18.3 | 7.9 | 3.3 | 3.5 | 68.4 (740 ± 290) | 27.5 | 29.7 |
| Orthopedic-spine (n = 607) | 33.3 | 7 | 14.5 | 6 | 2.8 | 2.8 | 20.8 (560 ± 250) | 18.8 | 3.8 |
| Transplant (n = 693) | 18.5 | 5.2 | 7.8 | 2.2 | 1.4 | 1.9 | 0.1 (1,000) | 10.4 | 7.2 |
| Pancreatic-biliary (n = 1,365) | 17.5 | 5.8 | 7.8 | 2.2 | 1.2 | 0.6 | 0 | 5.8 | 1.8 |
| Vascular (n = 1,039) | 14.9 | 3.9 | 7.9 | 1.1 | 1.3 | 0.8 | 6 (1900 ± 550) | 5.2 | 3.4 |
| Neurosurgery (n = 3,531) | 9.2 | 3.1 | 4.2 | 1.1 | 0.5 | 0.4 | 0.4 (420 ± 310) | 3.0 | 2.9 |
| Thoracic (n = 1,117) | 6.2 | 2.7 | 2.6 | 0.6 | 0.2 | 0.1 | 0.1 (350) | 2.0 | 1.6 |
| Gynecologic (n = 1,269) | 3.7 | 1.4 | 1.7 | 0.2 | 0.2 | 0.1 | 0 | 0.5 | 0.5 |
| All patients (all surgical services) (n = 48,086) | 6.2 | 2.0 | 2.6 | 0.76 | 0.38 | 0.34 | 2.9 (770 ± 340) | 2.5 | 1.8 |

FFP = fresh frozen plasma.

stamps. All data are stored in a Microsoft 2005 SQL Server (Microsoft Inc., Redmond, WA) backend platform and are available for reporting in a replicated database. Using Structured Query Language on an InterSystems Caché® server (InterSystems Inc., Cambridge, MA), we extracted all data parameters related to blood utilization from a subset of more than 200 Metavision® data tables. A series of software programs was developed to package the data variables into a flat.txt format data export file suitable for importing into Excel® (Microsoft Inc., Redmond, WA). Once created, these software programs can be executed easily on an *ad hoc* basis to produce an updated export file.

One hundred patients were randomly selected for validation of the transfusion and hemoglobin data. Data from these patients were compared with the original anesthetic and blood bank records to verify accuracy, which was 100%. To further verify accuracy of the data, we sorted the blood component and hemoglobin values for all patients sequentially to identify outliers. Four patients had errant hemoglobin values above 100 g/dl, which were corrected by reconciliation with the electronic medical record. For these patients, a misplaced decimal point was identified that was most likely a manual entry error. There were no extreme outliers representing errors for the blood component administration. Data for all surgical patients were imported into a data analysis software program (JMP version 9.0, SAS Institute Inc., Cary, NC). Continuous data are given as mean ± SD and were analyzed by Student *t* tests or one-way analysis of variance where appropriate. Dichotomous variables were analyzed by the chi-square test. Hemoglobin trigger and target value distributions are reported as the 10th, 25th, 50th, 75th, and 90th percentiles and compared by Kruskal-Wallis tests. All statistical tests were two-tailed, and *P* values less than 0.05 were used to define significance.

Results

Over the 18-month time period, 48,086 surgical patients were entered into the automated anesthesia recordkeeping system. Overall, 2,981 patients (6.2%) were transfused with erythrocyte units intraoperatively. A total of 9,440 erythrocyte units and

4,769 FFP units were given. Of the patients who were transfused, 993 (33.3%) were given one unit of erythrocytes, 1,273 (42.7%) were given two to three units, 367 (12.3%) were given four to five units, 185 (6.2%) were given six to eight units, and 164 (5.5%) were given nine or more units. Hemoglobin concentration was measured and recorded for 2,861 (96.0%) of the transfused patients. The timing of the hemoglobin measurements allowed evaluation of the transfusion hemoglobin trigger in 69% of transfused patients and evaluation of the hemoglobin target in 73% of transfused patients.

The surgical services with the greatest intraoperative blood product requirements are shown in table 1. Adult cardiac surgery patients were transfused more frequently than patients on any other service and also received a greater number of erythrocyte units than did those on other services when they were transfused. The adult cardiac surgery service also had the greatest number of patients who received cell salvage, FFP, and platelets. The orthopedic-spine, transplant, pancreatic-biliary, and vascular surgical services followed in descending order for the percentage of patients transfused with erythrocytes and for the percentage of patients given FFP. Orthopedic-spine and vascular surgery had the second and third greatest use of cell salvage blood, respectively.

Table 2 shows a comparison of surgical services for hemoglobin transfusion triggers and targets. For all patients given erythrocytes, the mean transfusion hemoglobin trigger was 8.4 ± 1.5, and the mean target was 10.2 ± 1.5 g/dl. There was significant variation between surgical services for both hemoglobin trigger (*P* = 0.0001) and hemoglobin target (*P* = 0.002). The service with the lowest hemoglobin trigger was adult cardiac surgery (7.5 ± 1.2 g/dl), and the service with the highest hemoglobin trigger was orthopedic-spine (9.5 ± 1.1 g/dl). The service with the lowest hemoglobin target was adult cardiac (9.1 ± 1.2 g/dl), and the service with the highest hemoglobin target was pancreatic-biliary (11.3 ± 1.4 g/dl).

Four surgical procedures with substantial blood requirements are shown in table 3, illustrating significant differences in transfusion rates among different surgeons performing the same procedure. The total number of procedures performed

Table 2. Erythrocyte Transfusion Hemoglobin Triggers and Targets for Transfused Patients

| Surgical Service (No. of Transfused Patients) | Transfusion Hb Trigger (g/dl)* | Transfusion Hb Target (g/dl)* | Distribution of Transfusion Hb Trigger and Target (g/dl) | | | | |
|---|--------------------------------------|-------------------------------------|--|---|---|---|---|
| | | | 10 th Percentile Trigger†/Target† | 25 th Percentile Trigger†/Target† | 50 th Percentile Trigger†/Target† | 75 th Percentile Trigger†/Target† | 90 th Percentile Trigger†/Target† |
| Adult cardiac (n = 707) | 7.5 ± 1.2 | 9.1 ± 1.2 | 6.3/7.8 | 6.8/8.2 | 7.4/8.9 | 8.0/9.8 | 8.8/10.7 |
| Orthopedic-spine (n = 202) | 9.5 ± 1.1 | 11.1 ± 1.1 | 8.1/9.6 | 8.7/10.4 | 9.6/11.1 | 10.3/11.8 | 11.3/12.4 |
| Transplant (n = 128) | 8.2 ± 1.1 | 10.1 ± 1.2 | 6.9/8.5 | 7.3/9.3 | 8.3/10.3 | 9.1/11.0 | 9.9/11.8 |
| Pancreatic-biliary (n = 239) | 9.1 ± 1.4 | 11.3 ± 1.4 | 7.4/9.7 | 8.0/10.3 | 9.0/11.3 | 10.0/12.0 | 11.4/13.1 |
| Vascular (n = 155) | 8.4 ± 1.1 | 10.9 ± 1.7 | 7.1/8.9 | 7.7/9.7 | 8.1/10.8 | 9.0/11.7 | 9.8/13.3 |
| Neurosurgery (n = 325) | 9.3 ± 1.3 | 10.9 ± 1.2 | 7.6/9.2 | 8.3/10.1 | 9.2/11.0 | 9.9/11.7 | 11.0/12.4 |
| Thoracic (n = 69) | 8.8 ± 1.4 | 10.3 ± 1.4 | 7.2/8.5 | 7.7/9.2 | 8.2/10.0 | 9.8/11.0 | 10.9/12.3 |
| Gynecologic (n = 47) | 7.9 ± 1.0 | 9.7 ± 1.5 | 6.5/7.7 | 6.5/8.6 | 7.8/9.3 | 8.6/10.4 | 9.3/12.3 |
| All patients (all surgical services) (n = 2,846) | 8.4 ± 1.5 | 10.2 ± 1.5 | 6.7/8.3 | 7.4/9.2 | 8.3/10.3 | 9.3/11.3 | 10.3/12.1 |

* $P < 0.0001$ for variation among surgical services (one-way analysis of variance). † $P < 0.01$ for variation among surgical services (Kruskal-Wallis).

Hb = hemoglobin.

by an individual surgeon did not consistently correlate with blood requirements. For the primary coronary artery bypass graft procedure, the transfusion hemoglobin triggers and targets were very similar among surgeons. For the Whipple procedure, the difference among surgeons was significant, with a 1.8 g/dl difference between the lowest and highest hemoglobin triggers ($P < 0.05$) and a 1.9 g/dl difference between the lowest and highest hemoglobin targets ($P < 0.05$). For patients undergoing posterior lumbar fusion, the difference between the lowest and highest hemoglobin triggers was 1.6 g/dl ($P < 0.05$), but the hemoglobin targets were similar among surgeons (0.4 g/dl difference among surgeons). FFP and platelet use among surgeons varied threefold to fourfold for the primary coronary artery bypass graft,

Whipple, and lumbar fusion procedures ($P < 0.05$ for all comparisons). The use of cell salvage was significantly different between surgeons for lumbar fusion surgery ($P < 0.05$).

For pediatric surgery, the two surgical services with the greatest blood product requirements were cardiac and orthopedics. Of pediatric patients who underwent cardiac surgery, 59.1% received erythrocytes, 18.6% received cell salvage erythrocytes, 30.8% received FFP, and 22.4% received platelets. Of pediatric patients who underwent orthopedic surgery, 9.3% received erythrocytes, 1.8% received cell salvage erythrocytes, 11.3% received FFP, and only 0.77% received platelets. Pediatric patients on the cardiac surgery service by far exceeded those on other pediatric surgical services for blood component requirements.

Table 3. Intraoperative Blood Product Requirements and Transfusion Hemoglobin Triggers and Targets

| Surgical Procedure | % of Patients Transfused Erythrocytes | % of Patients Transfused Erythrocytes | | | | | % of Patients Given Cell Salvage Erythrocytes (Volume in ml) | % of Patients Given FFP | % of Patients Given Platelets | Hb Trigger in Patients Transfused (g/dl) | Hb Target in Patients Transfused (g/dl) |
|-----------------------------------|---|--|-------|-------|-------|------|---|-------------------------------|-------------------------------------|--|---|
| | | 1 U | 2-3 U | 4-5 U | 6-8 U | ≥9 U | | | | | |
| Primary CABG (n = 455)* | 42.4† | 12.5 | 20.9 | 7.4 | 0.9 | 0.7 | 86.7 (720 ± 240) | 19.2† | 25.7† | 7.2 ± 0.8 | 8.9 ± 1.1 |
| Surgeon A (n = 31) | 54.8 | 25.8 | 12.9 | 16.1 | 0 | 0 | 83.3 (650 ± 220) | 22.2 | 36.1 | 7.2 ± 0.8 | 9.2 ± 1.3 |
| Surgeon B (n = 112) | 55.4 | 12.5 | 24.1 | 13.4 | 2.7 | 2.7 | 84.3 (655 ± 210) | 29.9 | 41.3 | 7.6 ± 0.6 | 8.7 ± 0.9 |
| Surgeon C (n = 193) | 40.4 | 13.0 | 22.8 | 4.2 | 0.5 | 0 | 86.9 (750 ± 260) | 19.2 | 13.1 | 6.9 ± 0.8 | 8.9 ± 1.1 |
| Surgeon D (n = 113) | 28.3 | 8.0 | 16.8 | 3.5 | 0 | 0 | 90.4 (750 ± 230) | 7.1 | 27.8 | 7.3 ± 0.6 | 8.6 ± 0.9 |
| Whipple (n = 371)* | 27.2† | 11.3 | 11.3 | 2.4 | 1.4 | 0.8 | 0 | 7.5† | 0.8† | 9.2 ± 1.5† | 11.4 ± 1.4† |
| Surgeon A (n = 153) | 35.9 | 17.7 | 13.1 | 3.3 | 1.3 | 0.7 | 0 | 9.8 | 0.7 | 9.6 ± 1.5 | 11.6 ± 1.4 |
| Surgeon B (n = 31) | 12.9 | 0 | 9.7 | 3.2 | 0 | 0 | 0 | 3.2 | 3.2 | 7.8 ± 1.8 | 9.7 ± 1.8 |
| Surgeon C (n = 65) | 10.8 | 4.6 | 6.2 | 0 | 0 | 0 | 0 | 3.1 | 0 | 8.9 ± 0.7 | 11.2 ± 0.9 |
| Surgeon D (n = 54) | 27.8 | 11.1 | 11.1 | 1.9 | 3.7 | 0 | 0 | 5.6 | 0 | 8.4 ± 1.2 | 10.2 ± 0.9 |
| Post. lumbar fusion (n = 346)* | 41.6† | 11.3 | 18.5 | 7.2 | 2.6 | 2.0 | 20.5 (490 ± 290)† | 19.9† | 3.5† | 9.4 ± 1.1† | 11.2 ± 1.0 |
| Surgeon A (n = 51) | 58.8 | 17.7 | 35.3 | 3.9 | 0 | 2.0 | 31.4 (450 ± 260) | 27.4 | 2.0 | 9.6 ± 1.0 | 11.1 ± 1.2 |
| Surgeon B (n = 49) | 57.1 | 10.2 | 28.6 | 16.3 | 2.0 | 0 | 49 (520 ± 330) | 20.4 | 0 | 9.2 ± 0.9 | 10.9 ± 0.8 |
| Surgeon C (n = 18) | 55.6 | 27.8 | 16.7 | 11.1 | 0 | 0 | 0 | 11.1 | 0 | 10.3 ± 0.3 | 11.3 ± 0.5 |
| Surgeon D (n = 38) | 52.6 | 7.9 | 21.0 | 7.9 | 10.5 | 5.3 | 36.8 (530 ± 250) | 39.5 | 2.6 | 10.1 ± 0.8 | 11.3 ± 1.1 |
| Surgeon E (n = 41) | 36.6 | 7.3 | 14.6 | 9.8 | 2.4 | 2.4 | 12.2 (500 ± 350) | 17.3 | 2.4 | 8.7 ± 1.1 | 11.0 ± 1.2 |
| Surgeon F (n = 46) | 30.6 | 8.7 | 13.0 | 4.4 | 4.4 | 0 | 2.2 (500) | 19.4 | 4.4 | 9.7 ± 1.0 | 11.3 ± 0.8 |

* Total number of cases for each procedure is greater than the sum of cases for listed surgeons because other surgeons with fewer cases are not listed but were included in the totals. † $P \leq 0.05$ for variation among surgeons (one-way analysis of variance).

CABG = Coronary artery bypass grafting; FFP = fresh frozen plasma; Hb = hemoglobin.

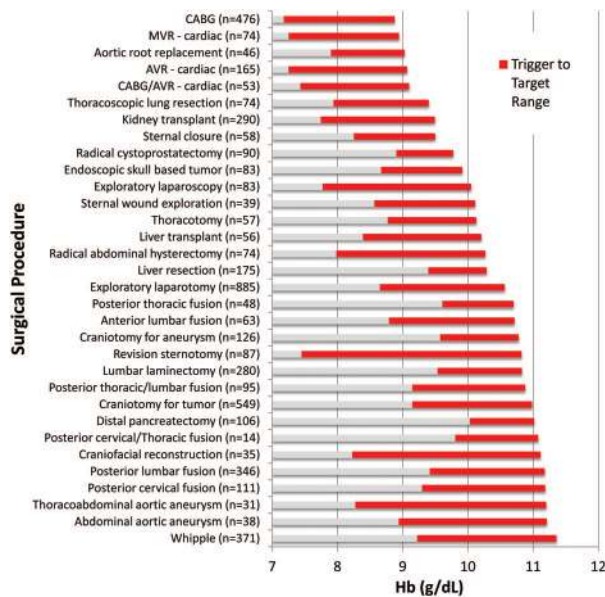


Fig. 1. Selected procedures with substantial blood requirements are compared showing transfusion hemoglobin triggers and targets. The mean hemoglobin trigger for each procedure is designated by the left edge of the red bars and the mean hemoglobin target by the right edge of the red bars. The span between the lowest and highest mean hemoglobin triggers was 2.8 g/dl and the span between the lowest and highest mean hemoglobin targets was 2.4 g/dl. AVR = aortic valve replacement; CABG = coronary artery bypass grafting; MVR = mitral valve replacement.

Selected surgical procedures with substantial blood requirements were compared to illustrate differences in transfusion hemoglobin triggers and targets (fig. 1). The procedure with the lowest hemoglobin trigger was coronary artery bypass graft (7.2 ± 0.8 g/dl), and that with the highest hemoglobin trigger was distal pancreatectomy (10.0 ± 1.4 g/dl). The procedure with the lowest hemoglobin target was coronary artery bypass graft (8.9 ± 1.1 g/dl), and that with the highest hemoglobin target was the Whipple (11.4 ± 1.4 g/dl). There was significant variation in hemoglobin trigger ($P = 0.001$) and hemoglobin target ($P = 0.003$) between surgical procedures.

We also compared erythrocyte transfusion practices among individual surgeons and anesthesiologists (fig. 2). Mean transfusion hemoglobin triggers and targets varied significantly among surgeons (trigger range: 7.2–9.8, $P = 0.001$; target range: 8.8–11.8 g/dl, $P = 0.001$) and among anesthesiologists (trigger range: 7.2–9.6, $P = 0.001$; target range: 9.0–11.7 g/dl, $P = 0.0004$). Four of the five surgeons with the lowest triggers and targets were adult cardiac surgeons. Eight of the nine anesthesiologists with the lowest hemoglobin targets were adult cardiac anesthesiologists. The surgeons with the highest mean hemoglobin targets were a pancreatic-biliary surgeon followed by a neurosurgeon. The anesthesiologists with the highest mean hemoglobin targets primarily provided anesthesia for neurosurgical and pancreatic-biliary patients.

Discussion

We describe methods for using AIMS-acquired data to analyze blood utilization according to specific surgical services and surgical procedures, and by individual surgeons and anesthesiologists. As part of a blood management program, these methods of assessing blood and blood component transfusion provide accurate and targeted information that has the potential for improving the utilization of blood products. Our analysis of hemoglobin transfusion triggers and targets demonstrates a wide variation in erythrocyte transfusion practice between surgical services and among individual medical providers. This information could potentially be used to provide feedback to individual providers to encourage more uniform standards for the administration of blood products, which has recently become an issue of high priority.^{13,14}

It has been estimated that AIMS has been adopted in anywhere from 15%–50% of large institutions.^{15,16} The proposed advantages of an AIMS include improved clinical documentation,^{10,11} improved data collection for clinical research,¹⁷ improved operating room utilization and resource management,¹⁸ cost containment,¹⁹ enhancement of quality improvement programs,^{9,20} and compliance with requirements of the regulatory authorities.²¹ Besides providing an accurate record of intraoperative physiologic parameters, AIMS-acquired data systematically provides a number of other useful parameters that can be used to assess practice patterns. Given the recent emphasis on optimizing blood management, we sought to determine whether a novel use of AIMS-acquired data was possible, that is, the assessment of blood and blood product utilization.

Patient blood management has recently become a focus of several national organizations and committees. In general, the overuse of blood transfusion has been recognized,^{22–24} and the adherence to evidence-based guidelines has been lacking. The American Society of Anesthesiologists Committee of Blood Management²⁵ and the Joint Commission¹³ have emphasized the importance of standardizing transfusion practice. It is important to recognize that expert consensus cautions against using a hemoglobin concentration as an absolute trigger for transfusion, recommending that the decision to transfuse be based on physiologic parameters such as evidence of shock, intravascular volume, duration and extent of anemia, and evidence of end-organ ischemia.⁶ Although optimal intraoperative transfusion triggers have not been clearly defined, well-designed, prospective, randomized clinical trials in critically ill intensive care unit patients, cardiac surgery patients, and postoperative orthopedic patients support a hemoglobin transfusion trigger of 7 or 8 g/dl.^{26–28} These studies have shown that a restrictive transfusion strategy results in 30- or 60-day mortality rates that are equivalent to those associated with a liberal transfusion strategy (hemoglobin trigger of 10 g/dl). Recently published evidence-based guidelines recommend transfusion for hemoglobin concentrations of 6 or 7 g/dl for most patients.^{5,6} For patients with carotid stenosis, acute coronary syndromes, or other high-

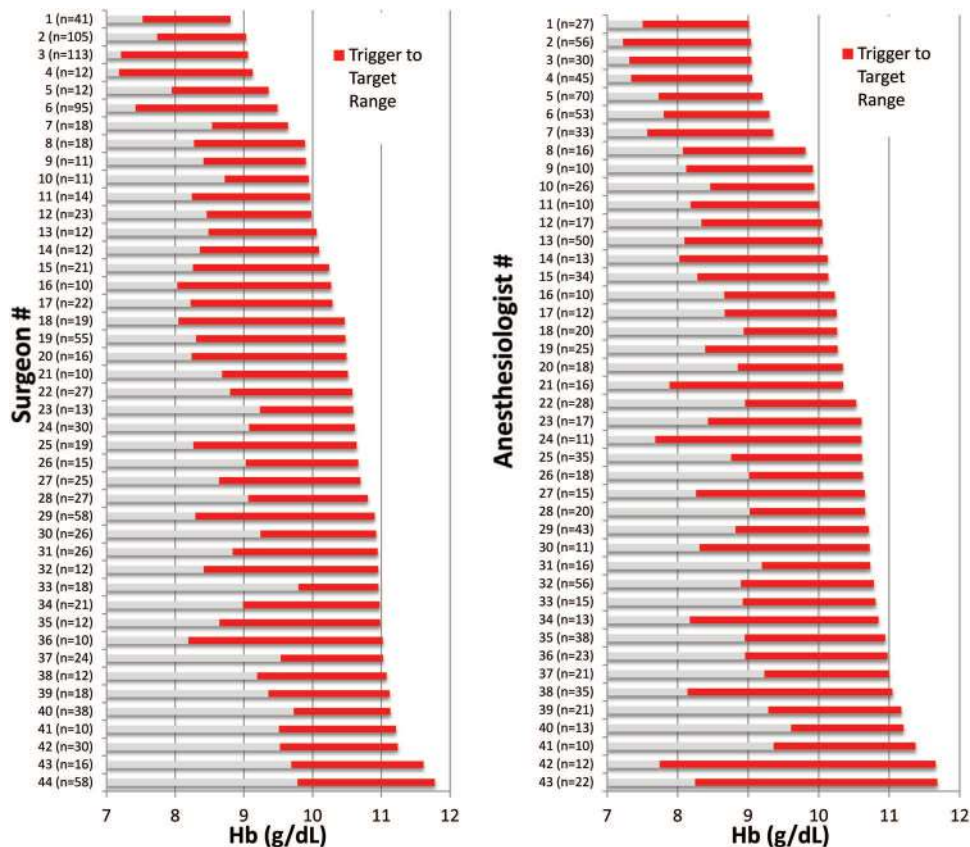


Fig. 2. Comparison of mean transfusion hemoglobin triggers and targets for all surgeons and anesthesiologists who had more than 10 patients in the database. The mean hemoglobin triggers are designated by the left edge of the *red bars* and the mean hemoglobin targets by the right edge of the *red bars*. The span between the lowest and highest hemoglobin triggers was 2.6 g/dl for surgeons and 2.4 g/dl for anesthesiologists. The span between lowest and highest hemoglobin targets was 3.0 g/dl for surgeons and 2.7 g/dl for anesthesiologists.

risk conditions, a higher transfusion trigger of 7–10 g/dl has been recommended.⁷ The data we report from our institution reveal that many clinicians use a more liberal transfusion strategy. One explanation for the liberal use of blood may be that because viral transmission risks for hepatitis B and C and human immunodeficiency virus are now lower than ever,²⁹ some clinicians assume that blood transfusion is associated with few or no consequences. Given the recognized risks, however, of other adverse effects related to transfusion, such as immunomodulation,³⁰ increased nosocomial infection,^{31,32} transfusion-related acute lung injury,³³ and perhaps even cancer recurrence,³⁴ clinicians should be cautious in giving blood to patients when risks might outweigh benefits. Reducing such risks should be the goal of any well-managed blood utilization program.

The decision to give blood in the operating room is often a controversial one. The surgeon and the anesthesiologist may advocate different hemoglobin trigger thresholds or different target ranges, often based on opinion and anecdotal experiences. Even with agreement on the hemoglobin triggers and targets, the intravascular volume in a given patient, which is sometimes difficult to assess, is often what determines the need for transfusion.⁵ In some institutions, the decision to

transfuse is made without any hemoglobin measurement because of the long turnaround time for laboratory testing. Adding to the controversy is the question of who makes the decision to transfuse, one that is often made jointly between the surgeon and the anesthesia provider. With the goal of following evidence-based guidelines for transfusion, the time to discuss the need for transfusion is certainly not during acute blood loss when the surgeons are preoccupied with achieving hemostasis. In general, many providers still practice the “10/30 rule” (hemoglobin of 10 g/dl, hematocrit of 30%) despite guidelines and clinical trials suggesting that lower transfusion triggers are associated with equivalent outcomes.^{5–7,26–28,35}

In addition to analyzing erythrocyte utilization data, we also were able to assess the use of cell salvage, FFP, and platelets according to services, procedures, and providers. The fact that cell salvage is considered by many to be contraindicated for cancer surgery explains why this method is not used by the pancreatic-biliary surgical service, where most patients had pancreatic cancer. Our analysis, however, did identify other services and surgeons for whom cell salvage may have been underutilized. For FFP and platelets, the disparity in utilization among surgeons was significant, even when assessed for the same surgical procedure. This informa-

tion is useful both for preoperative ordering of blood products and for sharing with individual surgeons and anesthesiologists to allow them to compare themselves with their peers as part of a quality improvement program. Perhaps further analysis of the AIMS database could reveal whether the relevant laboratory tests were performed to support the need for FFP and platelets.

Another major benefit of collecting and analyzing transfusion data by the methods we describe is the ability to predict intraoperative requirements to optimize preoperative ordering of blood products. Such information would be especially beneficial for preventing anesthesia providers who are unfamiliar with a given surgical procedure from ordering blood “just to be safe” when some of these procedures rarely or never require transfusion. For example, our data revealed that no patient of more than 500 ventriculoperitoneal shunt procedures was transfused, yet more than half of these patients had a type and screen or type and crossmatch ordered before surgery. Using this information, we aim to reduce costs and prevent delays in surgical start times by eliminating the need for preoperative blood ordering for this procedure and others that rarely or never require blood transfusion. These decisions are best made with institution-specific, surgeon-specific data on blood requirements, such as those that can be derived from AIMS-acquired data.

There are limitations in the current study. First, the accuracy of data collected by the methods we describe must be confirmed before attempting the data analysis. Our data for both the transfused blood products and the hemoglobin laboratory results were manually entered into the record during the case, a method that is a potential source of errors. To detect such errors and to verify the data, we checked any outlier data points against the original medical records, and erroneous data points were corrected. Second, the identification of hemoglobin triggers and targets depends on having hemoglobin data before the first erythrocyte transfusion begins and after the last transfusion ends. This necessity led to some degree of missing information because some patients received transfusions without having laboratory testing. For most patients who required transfusion, however, appropriate hemoglobin measurements were available to determine these values. It is unclear whether any missing trigger and target data could have led to a biased sampling of these measurements. Third, some providers had small numbers of transfused patients, making hemoglobin trigger and target summary data and comparison to peers less meaningful. For this reason we set a threshold for the minimum number of transfused patients to be included in the comparative analysis between providers. Last, surgical patients with ongoing bleeding that is likely to continue into the postoperative period represent a special circumstance. Although we did not specifically identify such patients, a higher hemoglobin trigger and target may be necessary to reduce the incidence of severe postoperative anemia.

The significant variability in transfusion practice that we have demonstrated represents a potential opportunity for quality improvement. The decision to transfuse is based on a variety of clinical variables that preclude the use of simple algorithms. Active bleeding, comorbid conditions, and intravascular volume are all important considerations. Given the previously cited evidence for the efficacy and safety of a restrictive transfusion strategy, significant cost reduction could be achieved by adopting this practice. Even a 10% reduction in erythrocyte use in our institution would result in more than \$1,000,000 in blood acquisition cost savings. Although the acquisition cost of an erythrocyte unit is approximately \$250, the true cost, including processing, storage, viral testing, and other overhead costs, amounts to three to four times the acquisition cost.³⁶ A successful blood management program based on reliable utilization data, therefore, has the potential to reduce costs substantially by reducing unnecessary transfusion.

In summary, we have described methods for using AIMS-acquired data that allow a detailed assessment of blood and blood component utilization. Our findings reveal significant variability in utilization among surgical services, surgical procedures, and individual medical providers. By evaluating transfusion practices in this fashion, appropriate feedback can be given to providers to potentially improve the utilization of blood components, with a primary goal of reducing unwarranted transfusion. If the methods we describe can be successfully incorporated into a blood management program, the potential exists to enhance patient safety, reduce costs, and conserve blood, a valuable and scarce resource.

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