

# Implementing a Health System–wide Patient Blood Management Program with a Clinical Community Approach

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## ABSTRACT

**Background:** Patient blood management programs are gaining popularity as quality improvement and patient safety initiatives, but methods for implementing such programs across multihospital health systems are not well understood. Having recently incorporated a patient blood management program across our health system using a clinical community approach, we describe our methods and results.

**Methods:** We formed the Johns Hopkins Health System blood management clinical community to reduce transfusion overuse across five hospitals. This physician-led, multidisciplinary, collaborative, quality-improvement team (the clinical community) worked to implement best practices for patient blood management, which we describe in detail. Changes in blood utilization and blood acquisition costs were compared for the pre- and post-patient blood management time periods.

**Results:** Across the health system, multiunit erythrocyte transfusion orders decreased from 39.7 to 20.2% (by 49%;  $P < 0.0001$ ). The percentage of patients transfused decreased for erythrocytes from 11.3 to 10.4%, for plasma from 2.9 to 2.2%, and for platelets from 3.1 to 2.7%, ( $P < 0.0001$  for all three). The number of units transfused per 1,000 patients decreased for erythrocytes from 455 to 365 (by 19.8%;  $P < 0.0001$ ), for plasma from 175 to 107 (by 38.9%;  $P = 0.0002$ ), and for platelets from 167 to 141 (by 15.6%;  $P = 0.04$ ). Blood acquisition cost savings were \$2,120,273/yr, an approximate 400% return on investment for our patient blood management efforts.

**Conclusions:** Implementing a health system-wide patient blood management program by using a clinical community approach substantially reduced blood utilization and blood acquisition costs. (**ANESTHESIOLOGY 2017; XXX:00-00**)

**G**IVEN that blood transfusion is the most common procedure performed in U.S. hospitals,<sup>1</sup> and one of the top five overused procedures according to The Joint Commission,<sup>2</sup> it seems prudent that hospitals implement patient blood management (PBM) programs.<sup>3,4</sup> Curtailing the overuse of blood transfusions fits well with the Choosing Wisely Campaign, which has focused on opportunities to reduce unnecessary tests and procedures since its launch in 2013. Now five national societies, including the American Society of Anesthesiologists (ASA), have adopted Choosing Wisely aims to reduce unnecessary transfusions.<sup>5,6</sup>

PBM programs also share common goals with the Perioperative Surgical Home, introduced and defined by the ASA as a “patient-centered, physician-led interdisciplinary team-based system of coordinated patient care.”<sup>7</sup> The Perioperative Surgical Home aims to enhance value and achieve

### What We Already Know about This Topic

- Blood transfusion is the most common procedure performed in U.S. hospitals and is often overutilized
- Encouraging evidence-based transfusion practice can improve blood utilization

### What This Article Tells Us That Is New

- Methods are described for implementing a patient blood management program across a multiinstitutional healthcare system as a quality improvement and patient safety effort
- Promoting best practices for patient blood management across a health system can reduce unnecessary transfusions, overall blood utilization, and costs, with a 400% return on financial investment

a better patient experience, improve health care, and lower costs. Moreover, the cost-saving potential is substantial with

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PBM because, in the current U.S. healthcare environment, blood is poorly or not reimbursed.<sup>8</sup> In the five adult hospitals in our health system, we spend almost \$30 million/yr for blood acquisition; however, the true cost is three to four times that,<sup>9</sup> owing to the tremendous overhead involved in bringing blood from donor to recipient. Blood is a valuable and often scarce resource; therefore, avoiding unnecessary transfusions will increase blood availability for patients who truly need this lifesaving therapy.

In this article, we describe the implementation of our health system-wide PBM program, using a “clinical community” approach, first described by Professor Mary Dixon-Woods *et al.*<sup>10</sup> at Leicester University as a physician-led, self-governing network of stakeholders who work together to identify and achieve goals related to quality in health care.<sup>11</sup> This approach is particularly suited to encourage participation in quality improvement efforts by connecting frontline providers across a multiinstitutional healthcare system and creating a densely networked community with strong horizontal links that exert pressure to conform to initiatives and goals. Such an approach was successfully used in a national effort to reduce central line-associated bloodstream infections in intensive care units.<sup>12</sup> Clinical communities achieve success in a sustainable way by supporting clinicians to drive quality improvement. The clinical communities rely on accountable physician leaders to engage, enable, and excite their clinical teams. Anesthesiologists make natural team leaders in a PBM program because they are on the front line, administering blood to patients in the operating rooms and intensive care units, and collaborating with multiple other specialties providing care to patients. Thus, anesthesiologists can lead by education and promotion of best practices across the healthcare system.

Several authors have described the methods and results of PBM programs used in their own institutions.<sup>13–15</sup> One area in the PBM field that lacks adequate information relates to implementing a PBM program across a multihospital health system. Because hospitals are merging at a rapid pace, or being bought out by health system corporations, the need for system-wide PBM programs is increasing. Having established a PBM program over the past 5 yr, and expanded it throughout five hospitals in our health system during the past 3 yr, we are able to report on the methods used and lessons learned. With this information, other health systems may choose to adopt clinical communities into their quality improvement efforts to promote patient safety, reduce risk and cost, and thus increase the value of health care delivered.

## Materials and Methods

The Johns Hopkins Health System includes six hospitals, five of which are included in the current report; the sixth is a pediatric specialty hospital. Two are academic centers with residency training programs in multiple specialties, and the other three are community hospitals that cover a wide variety of medical and surgical specialties. Approval from the Johns

Hopkins Institutional Review Board (Baltimore, Maryland) was obtained to assess all blood utilization data.

### PBM Program Startup

The largest of the five hospitals is the Johns Hopkins Hospital (JHH), where a PBM program was started in January 2012. An educational campaign was begun with Grand Rounds lectures to each department, covering all methods used to improve blood utilization in a PBM program (listed in table 1). The focus was initially on surgical services and erythrocyte (RBC) hemoglobin (Hb) transfusion triggers (the Hb before the transfusion) and targets (the Hb after the transfusion) as we have previously described.<sup>16,17</sup> Emphasis was given to randomized trials, and now eight landmark studies support a restrictive over a liberal RBC transfusion strategy.<sup>18–25</sup> The educational campaign also involved spreading awareness of the hospital transfusion policy guidelines for plasma and platelets. Exceptions to laboratory value-based transfusion thresholds were made for patients who are actively bleeding or hemodynamically unstable. For data acquisition early on, we chose a commercially available system, IMPACT Online (Haemonetics Corp., USA), as a blood management intelligence portal, given its unique focus on all variables related to PBM. We have previously described using this system for data acquisition.<sup>16,26</sup> Although we have now obtained institutional support to develop our own data systems, we believe that early adoption of a commercial system enabled us to demonstrate sufficient success to justify continuing program efforts.

### Business Plan

A formal business plan was drafted for expanding the program across the health system. This included salary support for three physicians: an anesthesiologist as the medical director of the program at 50% effort, and two transfusion medicine specialists at 25 and 10% effort. These physicians coordinated and carried out the programmatic methods outlined in table 1. The business plan also included support for a nurse coordinator and a data manager, both at 50% effort. We continued using the IMPACT Online data portal for JHH (\$36,000/yr); however, the Epic electronic record (Epic, USA) became the primary source of PBM data across the entire health system. Including miscellaneous expenses, the total cost to support the PBM program was approximately \$400,000, not including existing infrastructure resources from the Division of Clinical Analytics to set up the data dashboards. The return on investment (ROI) with a 5, 10, and 15% reduction in blood acquisition cost was calculated to be 120, 340, and 560%, respectively.

### Expansion to All Five Hospitals

The steps taken to expand our PBM program across the health system are summarized in table 1. In July 2014, the Clinical Community was formed, which consisted of a multidisciplinary team of individuals organized around a central goal of quality improvement. To improve the

**Table 1.** Steps for Implementation of the Blood Management Clinical Community

1. Obtain support from health system leadership (business plan)
2. Assemble multidisciplinary team of stakeholders
3. Education (with emphasis on the eight randomized controlled trials supporting restrictive transfusion)<sup>18–25</sup>
4. Harmonize transfusion guidelines
5. Decision support for computerized provider order entry (with best practice advisories)
6. Data acquisition/analytics
7. Create dashboards
8. Transfusion guideline compliance audits with feedback (reports) to providers
9. Methods to improve blood utilization
  - Evidence-based transfusion triggers
  - “Why Give Two When One Will Do?” Choosing Wisely campaign for erythrocytes<sup>6,34</sup>
  - Preoperative anemia management
  - Antifibrinolytics (e.g., aminocaproic acid, tranexamic acid)
  - Intraoperative autologous cell salvage
  - Anesthetic management (autologous normovolemic hemodilution, controlled hypotension, normothermia)
  - Surgical methods (newer cautery methods, topical hemostatics, and sealants)
  - Reduce phlebotomy blood loss (smaller tubes, eliminate unnecessary testing)
  - Point-of-care testing (e.g., thromboelastography)

structure and impact of the program, we obtained support from the Johns Hopkins Armstrong Institute for Patient Safety and Quality Clinical Communities Project Management Office (Baltimore, Maryland), which formally helped transition the blood management program into a Clinical Community. This provided clinicians access to resources, such as technical experts and safety and quality researchers, who were otherwise not easily accessible or available. Support also was obtained from the health system leadership. Then a multidisciplinary group of providers was recruited from several departments (e.g., Surgery, Obstetrics/Gynecology, Anesthesiology, Perfusion, Pathology [Transfusion Medicine], Internal Medicine, Hematology, Bloodless Medicine, and Surgery) and from all five hospitals. We began having two meetings each month—one for the JHH PBM program and one for the Johns Hopkins Health System PBM program. At these monthly meetings, the collaborative spirit of the clinical community embraced the interdisciplinary membership and facilitated discussion of shared experiences and best practices used to promote quality improvement goals.

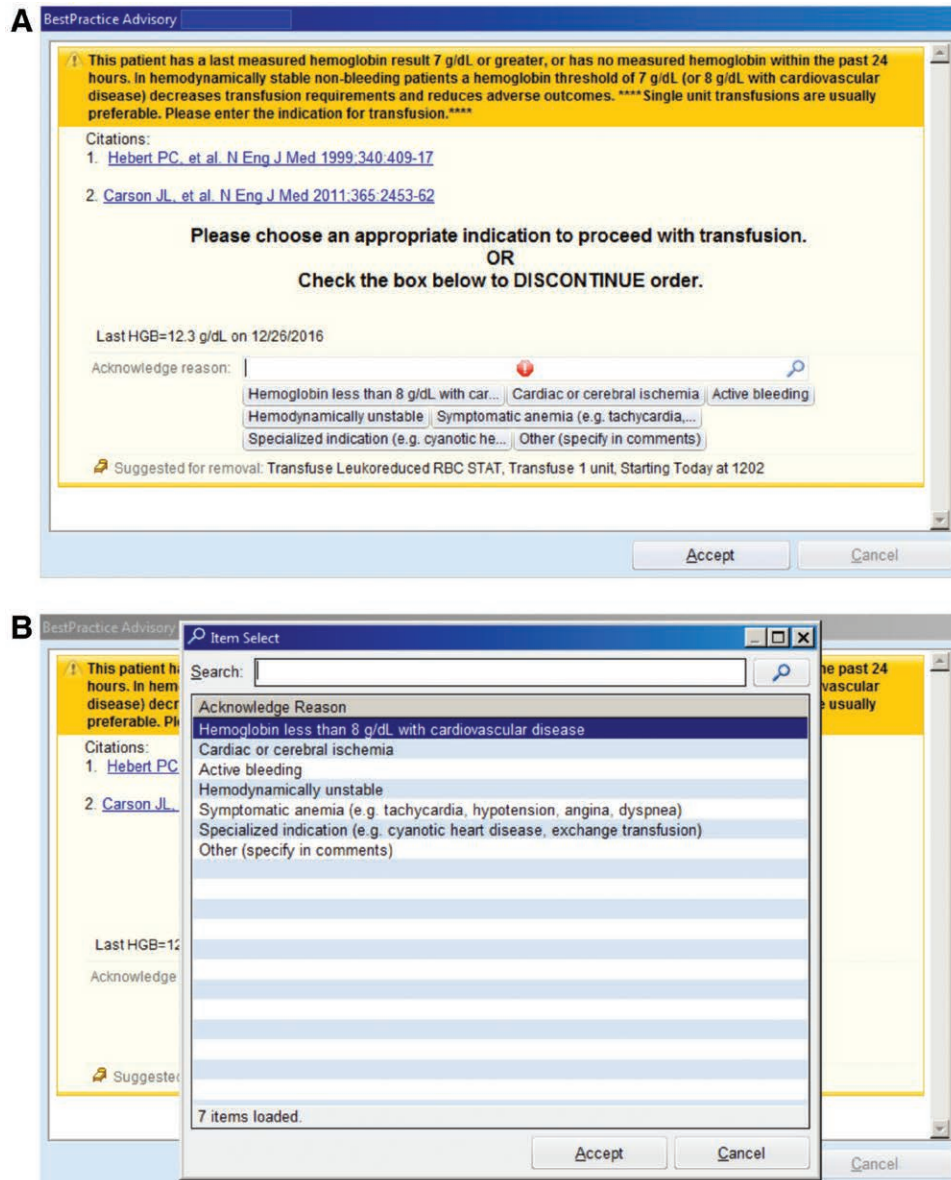
After adopting (harmonizing) standardized transfusion guidelines across the health system, we began an educational campaign at the other four hospitals, again covering all methods outlined in table 1. We also implemented the Epic electronic record across all five hospitals between 2014 and 2016, which included customized transfusion order sets for adults, pediatrics, and neonates, for the four different blood components, or 12 order sets in all. Considering that each of these includes a “prepare” and a “transfuse” order, 24 order sets were created.

### **Computerized Provider Order Entry with Clinical Decision Support**

Modeling the system described by Goodnough *et al.*,<sup>27</sup> we implemented a best practice advisory (BPA) in the computerized provider order entry (CPOE) system at

the main campus (JHH) for RBCs in April 2013. This advisory was built with logic to check the last measured Hb value, with an alert triggering if the Hb was greater than or equal to 8 g/dL or if Hb had not been measured within the past 24 h. A year later, the BPA was changed to trigger with a Hb greater than or equal to 7 g/dL. This change was implemented after we recognized that about one third of all RBC transfusions in the hospital were occurring with preceding Hb concentrations between 7 and 8 g/dL. The alert message also included a Choosing Wisely recommendation to administer single-unit RBC transfusions to patients who are not actively bleeding and are hemodynamically stable.<sup>6</sup>

In September 2015, BPAs were implemented across the entire health system, including the operating rooms and procedural areas, for RBCs, plasma, and platelets. The BPA for RBCs and the indications to proceed with the RBC order are shown in figure 1. Active bleeding was a choice to transfuse outside of typical guidelines, which, for example, allowed intraoperative transfusion to occur unimpeded after acknowledging this reason. The BPA only fires one time per day, for any given blood component ordered by any one provider, to allow unimpeded ordering upon subsequent orders of the same product by the same provider. The BPAs included a laboratory value threshold for utilization review, based on our harmonized transfusion guidelines. These BPAs also served an educational purpose by showing the ordering provider the health system’s approved transfusion guidelines. Our plasma BPA is based on the last measured international normalized ratio (INR) results. It calls for a threshold of greater than or equal to 1.5 for actively bleeding patients, with a recommendation threshold of greater than or equal to 1.7 for patients undergoing surgery or invasive procedures.<sup>28</sup> A platelet BPA based on a platelet count threshold of greater than or equal to 50 K also was implemented.



**Fig. 1.** Computerized Provider Order Entry alerts. (A) When an erythrocyte (RBC) order is placed, an interruptive best practice advisory (BPA) is triggered if the preceding hemoglobin (Hb) value is greater than or equal to 7 g/dL or has not been measured in the previous 24 h. If the preceding Hb is less than 7 g/dL, then no BPA is triggered and the order is placed unimpeded. After acknowledging the BPA, the provider can either cancel the order or proceed by choosing a reason (B) to override the BPA and transfuse RBCs. These reasons are taken from the health system's transfusion guideline policy.

### Data and Value Analytics: Dashboards and Transfusion Guideline Compliance Reports

Under the guidance of the PBM Clinical Community, we created dashboards and reports that we have recently described.<sup>29</sup> Dashboards show the big-picture changes in blood utilization for the entire health system and for each hospital, whereas reports show individual providers' transfusion guideline compliance rates and allow comparison to peers within their own specialty (fig. 2). We created these provider-specific reports using blood management dashboards built on a Qlikview (Qlik, USA) business intelligence platform.<sup>29</sup> We found the method of greatest

impact for peer comparison to be the rank-order bar graph with provider names visible within departments, but not between departments.<sup>30</sup> A green-yellow-red color scheme correlated with preceding Hb values of less than 7 g/dL, 7 to 7.9 g/dL, and greater than or equal to 8 g/dL, respectively.<sup>31</sup> The reports also compared the percentages of 1-unit and 2-or-more-unit RBC orders among providers.<sup>29</sup> For plasma, green and red were used for preceding INR values of greater than or equal to 1.5 and less than 1.5, respectively.<sup>32</sup> For platelets, green and red were used for preceding platelet counts of less than 50,000, and greater than or equal to 50,000, respectively.<sup>33</sup>



**Fig. 2.** Two provider-specific departmental blood utilization reports are shown for a 1-month period for the Department of Internal Medicine (top two panels) and the Department of Orthopedic Surgery (bottom two panels). On the x-axis is the number of erythrocyte (RBC) units attributed to each attending physician. Physicians are identified by their numeric identification code on the y-axis. This type of report is sent to each department within the hospital. The proportion of RBC orders is shown according to whether they were for 1 or 2 or more units (left figures) and by the preceding hemoglobin value (right figures) by color coding (green = Hb < 7 g/dL; yellow = Hb 7 to 7.9 g/dL; red = Hb ≥ 8 g/dL). Both departments have a low rate of 2-or-more-unit RBC orders; however, the Department of Internal Medicine has a much larger proportion of RBC orders with a Hb trigger < 7 g/dL. Data were acquired from the Epic (USA) computerized provider order entry system. HGB = hemoglobin; Prov = provider.

In July 2015, we began sending these provider-level reports out monthly at the main campus (JHH), and quarterly at the other four hospitals, to the Vice Presidents of Medical Affairs (VPMAs) and to each department chair, who disseminated the reports to attending physician members in their department. An example of this report is shown in figure 2.

**“Why Give Two When One Will Do?” Choosing Wisely Campaign**

After closely monitoring Hb transfusion thresholds for RBC transfusions for approximately 2 yr at the main campus, we recognized that the threshold (Hb trigger) was often guideline-compliant but that many orders were routinely placed for two RBC units, resulting in a higher-than-evidence-based Hb target after the transfusions. This presented a substantial opportunity to reduce RBC utilization. In April 2015, a “Why Give Two When One Will Do?” campaign was launched in an effort to reduce RBC overuse.<sup>34</sup> A communications campaign was begun with newsletter articles and screensaver messages showing the American Association of Blood Banks (AABB) Choosing Wisely aims,<sup>6</sup> which advocate single-unit RBC transfusions in hemodynamically stable, nonbleeding patients. This campaign was deemed necessary given that multiunit RBC orders were extremely

common in three of our hospitals (~66%), and somewhat common in the other two (20 to 40%).

**Other Interventions**

The various methods used to reduce unnecessary transfusions are summarized in table 1. The educational curriculum encouraged use of antifibrinolytic medications (e.g., tranexamic acid) for orthopedic surgeries, the early diagnosis and treatment of preoperative anemia before elective surgery (when feasible), and other changes in practice such as minimizing phlebotomy-related blood loss for laboratory tests by using smaller blood-collection tubes, using in-line blood return devices, and reducing routine daily tests in stable hospitalized patients.<sup>35</sup> Autologous blood salvage (cell salvage) was also encouraged for specific cases such as transplant, cardiac, and major orthopedic and spine surgeries. Point-of-care testing also was encouraged (e.g., thromboelastography) to reduce blood utilization in cardiac, transplant, and major vascular surgery at the main campus (JHH), but the other four hospitals did not have thromboelastography available. Anesthetic methods (normothermia, controlled hypotension, autologous normovolemic hemodilution) and surgical techniques (topical hemostatic agents, newer cautery systems, and minimally invasive and robotic approaches) also were encouraged.<sup>36,37</sup>

## Data Analysis

The number of patients included in this report was based on available data and no *a priori* power calculation was conducted. All measured outcomes of interest were assessed at monthly intervals, and the changes over time were analyzed. For statistical analysis, the baseline pre-PBM time period was considered to be FY2014 (July 1, 2013 to June 30, 2014), and the post-PBM time period was considered to be FY2015, FY2016, and the first six months of FY2017 (July 1, 2014 to December 30, 2016). Because some 2014 data were missing for Hospital 5 owing to a change in the electronic health record (EHR), we used the first four months of available data (July to October 2014) as the baseline, after annualizing by a threefold multiplier. We assessed changes in blood utilization using all units/all patients (including those not transfused), because nontransfused patients are important in a PBM program. Results are reported as number of units per 1,000 discharged patients.<sup>27</sup> Blood and cost savings were calculated by comparing the most recent year (FY2017) to the FY2014 baseline. We used actual acquisition costs for the three blood components and not the activity-based costs,<sup>9</sup> which include estimated overhead costs. Proportions were compared by chi-square tests. Changes in blood utilization were analyzed by one-way ANOVA.  $P < 0.05$  (two-tailed design) was considered statistically significant. All analyses were done using JMP ver. 12.1.0 (SAS Institutes, USA).

## Results

The characteristics of the five hospitals, including the yearly number of blood components transfused, are given in table 2. Hospitals 1 and 2 have major teaching affiliations and a greater number of residents and medical students. Hospital 1 is the largest center and utilized 67.9% of all health system RBC units, 83.3% of all plasma units, and 89.7% of all platelet units during the 2014 baseline year. Four of the five hospitals have a labor and delivery service.

Changes in blood utilization for all five hospitals combined are shown in table 3. Across the health system, comparing the most recent year (2017) to the baseline time period before PBM (2014), the changes in blood utilization are as follows. The percentage of patients transfused decreased for RBCs from 11.3 to 10.4%, for plasma from 2.9 to 2.2%, and for platelets from 3.1 to 2.7%, ( $P < 0.0001$

for all three). The number of units transfused per 1,000 discharged patients decreased for RBCs by 19.8% ( $P < 0.0001$ ), for plasma by 38.9% ( $P = 0.0002$ ), and for platelets by 15.6% ( $P = 0.04$ ). Multiunit RBC transfusion orders decreased by 49% ( $P < 0.0001$ ), which coincided with our “Why Give Two When One Will Do?” campaign. The percentage of RBC orders with a preceding Hb greater than or equal to 8 g/dL decreased by 34.7% over time ( $P < 0.0001$ ), while plasma orders with an INR less than 1.5 decreased by 9.1% ( $P < 0.0001$ ), and platelet orders with a platelet count greater than or equal to 50 K decreased by 3.4% ( $P = 0.02$ ). Some 41.1% of all plasma (30,212 of 73,564 units) and 49.9% of all platelets (35,342 of 70,770 units) were given to those patients receiving 10 or more RBC units over their hospital stay. For the five-hospital health system, changes in blood utilization over the entire study period are illustrated in figure 3.

Considering only the patients who were transfused each specific blood product, the average number of RBC units per patient given RBCs decreased from  $4.0 \pm 6.5$  to  $3.5 \pm 4.9$  (by 14.6%;  $P < 0.0001$ ). The average number of plasma units per patient given plasma decreased from  $6.1 \pm 14.9$  to  $4.6 \pm 13.5$  (by 25.1%;  $P = 0.0014$ ). The average number of platelet units per patient given platelets decreased from  $5.1 \pm 8.1$  to  $4.8 \pm 8.1$  (by 4.9%;  $P = 0.002$ ).

For each of the five individual hospitals, changes in blood utilization are shown in the Supplemental Digital Content (<http://links.lww.com/ALN/B527>; tables 1–5). The most notable changes were the decrease in multiunit RBC transfusion orders and RBC utilization in units per patient in all hospitals, except for Hospital 2. Plasma utilization decreased significantly in two of the five hospitals, including the largest hospital (Hospital 1). Platelet utilization decreased in four hospitals (only one with statistical significance), and was unchanged in the fifth hospital. Compared to the baseline year 2014, the annualized blood acquisition cost savings for 2017 was \$2,120,273/yr, representing an approximate 400% return on investment for our PBM efforts.

## Discussion

Using the methods described here and a health system-wide clinical community approach to promote a PBM program, we effectively reduced overall blood utilization and blood

**Table 2.** Characteristics of the Five Hospitals in the Health System

Hospital	No. of Beds	Admissions per Year	Outpatient Visits	Births per Year	Teaching Affiliation	Personnel	RBC/Plasma/Platelet (units)*
Hospital 1	998	49,829	595,655	2,054	Major	9,781	36,223/17,063/16,307
Hospital 2	428	22,647	440,400	1,303	Major	3,041	5,358/1,553/621
Hospital 3	256	19,606	138,057	3,550	Minor	1,433	4,509/633/218
Hospital 4	246	11,466	93,405	3,437	Minor	1,531	2,447/158/165
Hospital 5	235	13,668	110,793	0	Minor	1,506	4,755/1,059/858

Data from The American Hospital Association (<http://www.ahadataviewer.com/QuickReport/default.aspx>, accessed December 12, 2016).

\*Units transfused in 2014 (baseline year before the health system-wide Patient Blood Management Clinical Community began).

RBC = erythrocyte.

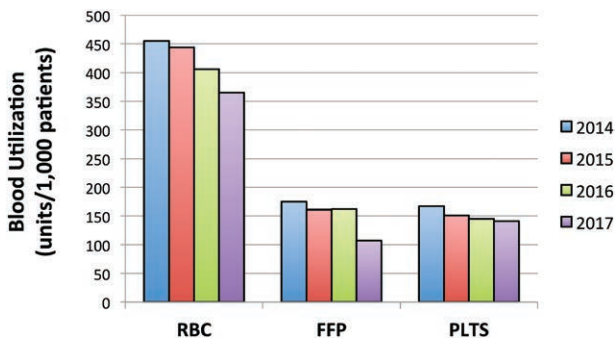
**Table 3.** Blood Utilization by Year for the Five Health System Hospitals Combined

Fiscal Year (No. of inpatients)	2014* (n = 117,444)	2015† (n = 117,690)	2016† (n = 116,741)	2017† (n = 58,732)	P Value
<b>RBCs</b>					
Utilization (units/1,000 patients)‡	455	444	406	365	< 0.0001
No. (%) of patients transfused	13,210 (11.3%)	12,950 (11.0%)	12,093 (10.4%)	6,088 (10.4%)	< 0.0001
No. (%) orders ≥ 2 units	12,038 (39.7%)	9,125 (30.2%)	5,560 (17.7%)	3,513 (20.2%)	< 0.0001
No. (%) orders for Hb ≥ 8g/dL§	10,023 (33.9%)	9,120 (30.9%)	7,822 (25.5%)	3,675 (22.1%)	< 0.0001
<b>Plasma</b>					
Utilization (units/1,000 patients)‡	175	161	162	107	0.0002
No. (%) of patients transfused	3,371 (2.9%)	3,037 (2.6%)	2,705 (2.3%)	1,262 (2.2%)	< 0.0001
No. (%) orders for INR < 1.5**	2,190 (40.6%)	1,888 (39.7%)	1,654 (37.7%)	877 (36.9%)	< 0.0001
<b>Platelets</b>					
Utilization (units/1,000 patients)‡	167	151	145	141	0.04
No. (%) of patients transfused	3,610 (3.1%)	3,355 (2.9%)	3,237 (2.8%)	1,572 (2.7%)	< 0.0001
No. (%) orders for PLTS ≥ 50 K††	2,646 (23.5%)	2,514 (22.8%)	3,062 (24.2%)	1,759 (22.7%)	0.02

\*Year 2014: baseline period, pre-patient blood management.

†Years 2015, 2016, 2017: post-patient blood management time period. 2017 includes 6 months (July 2016 to December 2016). ‡All units divided by all patients, including those who received no transfusions. §Orders with preceding Hb ≥ 8g/dL within 24h before order, or Hb missing (no Hb measured within 24h). \*\*Orders with preceding INR < 1.5 within 24h before order, or INR missing (no INR measured within 24h). ††Orders with preceding PLTS ≥ 50K within 24h before order, or PLTS missing (no PLTS measured within 24h).

Hb = hemoglobin; INR = international ratio; PLTS = platelet count; RBC = erythrocyte.



**Fig. 3.** Across the entire health system, for each of the three blood components, changes in utilization (number of units per 1,000 patients) are shown over time. FFP = fresh frozen plasma; PLTS = platelets; RBC = erythrocyte.

acquisition costs. Although methods of establishing PBM programs have been reported previously,<sup>15,27,38,39</sup> to our knowledge, this is the first description of methods used to implement a PBM program across multiple hospitals within a health system. Our methods also illustrate how anesthesiologists can be leaders in quality improvement, providing value both inside and outside of the operating rooms.

Although some have described PBM as giving the right dose of the right product to the right patient for the right reason, others believe that PBM is simply avoiding unnecessary transfusions. In reality, good blood management is just the good practice of medicine with regard to preventing and managing anemia, optimizing hemostasis to reduce or prevent hemorrhage, and promoting optimal blood conservation with a patient-centered focus.<sup>40–44</sup> PBM is also focused on patient safety. Although transfusion-transmitted viral infections are much less common than they were 20 or 30 yr ago, new emerging infectious agents (e.g., Zika virus

and babesiosis) are of great concern.<sup>45,46</sup> Furthermore, the top two causes of transfusion-related death—transfusion-related acute lung injury and transfusion-associated circulatory overload—occur at least 100-fold more commonly than HIV or viral hepatitis,<sup>47</sup> and more commonly than has been historically reported.<sup>48,49</sup>

As previously mentioned, the clinical community concept we describe as the structure behind our PBM efforts shares common principles with both the Choosing Wisely and the Perioperative Surgical Home campaigns, which aim to reduce unnecessary procedures by standardizing care and reducing variation in practice. The clinical community provided the infrastructure through which we accomplished these aims. Three critical features of the clinical community are the physician leadership, project management support, and robust data analytics. The Clinical Community Project Management Office (PMO) supports the clinical community with a project manager, data analytics, lean support, and other resources as appropriate to promote quality improvement. For example, even seemingly simple tasks of creating agendas, scheduling meetings, providing call-in numbers, and video conferencing login access, can be challenging without a dedicated support staff.

The other important feature that cannot be overemphasized in our program is the collection and analysis of high-quality data and its dissemination back to the providers to improve practice.<sup>16,17</sup> Physicians are a competitive group, and the rank-order bar graph with names promotes a competition among physicians to do better than their peers. There is some resistance, however, to the green, yellow, and red data representation, as clinicians claim their patients are exceptions to guidelines because of active bleeding, symptomatic anemia, or hypovolemia. For this reason, we carefully acknowledge on the reports that our transfusion guidelines

apply specifically to nonbleeding, hemodynamically stable patients. In fact, our dashboards have a filter to exclude transfusion episodes when the ordering provider indicates active bleeding, such as those episodes that commonly occur in the operating rooms. In our PBM program, we opted to invest time and money into data collection, analysis, and audits with feedback to providers rather than hiring a full-time transfusion safety officer for each of the five hospitals. We recently counted more than 600 physicians who receive our transfusion guideline compliance reports at regular intervals. Given the approximately 100,000 units of blood components that are transfused annually across the five hospitals, a large-scale data-driven approach with guideline compliance reports sent at regular intervals to providers was thought to be more effective and less expensive than hiring a TSO for each institution to review individual transfusions.

We would like to emphasize that without financial support, a PBM program is unlikely to succeed. This type of work cannot be accomplished on nights and weekends, and the people doing the primary work need salary support for dedicated nonclinical time. To justify the financial support for a PBM program, it is helpful to set targets for decreasing blood use and a return on investment to show the health system leadership that the resources can pay for themselves. This is especially true in light of the poor or nonexistent reimbursement for blood and blood components. Our current return on investment is about 400%, in terms of savings on blood acquisition costs.

One challenge that we recognize is the large number of massively transfused patients seen in an urban tertiary care center. This likely explains why two-thirds of all RBC units and 80 to 90% of all plasma and platelet units in the healthcare system were given at Hospital 1, which had the most massive transfusions. We also have shown that these patients consume a huge percentage of overall blood within the hospital.<sup>50</sup> Even with education and the use of CPOE with decision support (BPAs), the ability to alter blood utilization for services such as transplant, vascular, and cardiac surgery is less, especially when patients require major procedures such as extracorporeal membrane oxygenation, left ventricular assist device, and heart and lung transplants.<sup>50</sup> Even with these cases, however, autologous blood salvage (cell salvage) thromboelastography, and careful monitoring of Hb targets—not just triggers—are important. For example, we have seen massively transfused patients leave the hospital with a Hb level higher than is necessary. Accordingly, it is just as important to know when to stop giving blood in a massive transfusion as it is to know when to initiate the protocol. We also have recently reported that outcomes can be favorable even after massive transfusions.<sup>51</sup> The heterogeneity across hospitals for changes in blood utilization is to be expected, based on differences in case mix, as well as the proportion of patients who require massive transfusions.

Other challenges that we faced in setting up a multihospital PBM program included the differing EHR systems that

were in use at the institutions, the transition to new EHR systems, and the ability to maintain “legacy” data from the old EHR system after the transition. Now that we have a complete transition to the Epic EHR across the entire system for ordering all transfusions, our data capabilities are improved. Another challenge was a reliable method of report distribution down to the provider level. We elected to delegate report distribution by using a chain-of-command approach, by sending them to the VPMA, who sends to the department chairs, and then to their departmental attending physician members. This top-down approach worked well because the VPMA has oversight and authority to support such quality improvement efforts. Another issue was how to determine cost avoidance when blood utilization decreased. We chose to use blood acquisition cost primarily, rather than the roughly fourfold higher activity-based cost of blood,<sup>9</sup> because we recognized that some, but not all, overhead costs are borne by the hospital. We do, however, recognize that these overhead costs exist and sometimes refer to both methods of cost assessment.

When we compared our PBM results with those from other institutions, for example the results of Goodnough *et al.*<sup>52</sup> at Stanford University Hospital (Stanford, California), our decrease in RBC utilization was less (19.8 *vs.* 42%). It should be recognized, however, that the baseline degree of RBC overuse was likely higher at Stanford, where 60 to 65% of RBC transfusions had a preceding Hb greater than 8 g/dL in 2008, and they were able to reduce it to 35 to 40% by 2011.<sup>40</sup> Our pre-PBM baseline degree of RBC overuse by these same criteria (table 3) was similar to Stanford's post-PBM overuse percentages. The likely explanation for these differences is that five of the eight randomized controlled trials supporting a restrictive transfusion strategy were published during or after 2011.<sup>18–25</sup> With this degree of high-quality evidence supporting PBM practices, blood utilization was likely already curtailed by the time our program began. Rates of massive transfusions and double-unit RBC orders also may have differed between institutions.

A few limitations to our study should be recognized. First, PBM programs are usually introduced in stages, as we described. It is therefore possible that we underestimated the actual blood savings because we had already introduced some degree of PBM to the main campus during what we call the pre-PBM period. It is also difficult to determine the relative contribution of individual blood conservation methods, when some methods began simultaneously (*i.e.*, BPAs and guideline compliance reports). Second, the progress we report is that from a single health system, and results in other centers may be different. The amount of blood savings likely depends on the baseline degree of transfusion overuse, which can vary substantially among centers. Third, most previous reports focus on RBCs, whereas we report all three major blood components. The issue here is that most of the evidence supporting transfusion triggers relies on studies comparing liberal and restrictive RBC transfusion.<sup>18–25</sup> No such

randomized controlled trial has been published for plasma, and only one, in the setting of oncology, for platelet transfusion.<sup>53</sup> Therefore, compared with Hb transfusion thresholds for RBCs, we have less evidence to support the INR and platelet count thresholds associated with adequate hemostasis. Finally, the percentage of plasma and platelets given outside the laboratory value thresholds changed by small amounts, while plasma and platelet utilization decreased substantially. It is possible that active bleeding or massive transfusion was the indication for these transfusions rather than abnormal laboratory values. In fact, almost half of all our plasma and platelet units went to patients given more than 10 RBC units, and the vast majority of these components were given at the main campus, where trauma, transplant, and major cardiac cases are prevalent.

In summary, we describe methods for implementing a comprehensive PBM program across five hospitals in our healthcare system using a clinical community approach. By working together collaboratively across disciplines, sharing best practices, and using high-quality data collection and feedback to promote evidence-based practice, we can reduce unnecessary transfusions and associated risks while decreasing costs. Such changes in healthcare delivery are examples of how we can increase the value of care we provide to our patients.

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## Competing Interests

Dr. Frank has received consulting fees from Haemonetics (Braintree, Massachusetts), Medtronic (Minneapolis, Minnesota), and Zimmer/Biomet (Warsaw, Indiana). All other authors declare no competing interests.

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