Changes in blood product utilization in a seven-hospital system after the implementation of a patient blood management program: A 9-year follow-up

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Objectives: To analyze changes in red blood cell (RBC), platelet (PLT), and plasma transfusion volumes 9 years after the implementation of a multifaceted patient blood management (PBM) program across multiple hospitals.

Methods: Between fiscal years 2007 and 2015, the annual transfusion volumes for seven hospitals in a regional healthcare system were analyzed by hospital, and between 2014 and 2015, by four service lines including emergency department, intensive care unit (ICU), medical/surgical ward, and operating room at each hospital. The number of units of RBCs administered to transfused recipients on the wards and in ICUs was also enumerated.

Results: For these seven hospitals combined, there was a 29.9% reduction in the number of RBCs transfused between 2007 and 2015, a 24.8% reduction in plasma units, and a 25.7% reduction in PLT units. The two largest hospitals saw some of the largest reductions in RBC transfusions (40.1, 25.1%), and plasma transfusions (26.1, 33.8%), and one of those hospitals had a 49.5% reduction in PLT transfusions. Smaller-sized hospitals also had reductions in transfusion volumes, while some volumes increased at hospitals when new or expanded clinical services were introduced. The number of RBC units per transfused recipient was generally between 1.5 and 2 units on the wards and slightly higher in the ICUs.

Discussion: Although the overall volume of transfusions has generally decreased at each hospital site over time, the appropriateness of the administered transfusions cannot be evaluated by these data.

Conclusion: The system-wide implementation of a PBM program has reduced transfusion volumes.

Keywords: Patient blood management, Operating room, Red blood cell, Platelet, Plasma, Reduction, Intensive care unit, Emergency department, Ward

Introduction

Patient blood management (PBM) is an evolving concept that takes a multimodal approach to optimizing patients such that allogeneic transfusions might be avoided, and if not, providing the smallest effective dose of the product as guided by the available evidence.1

The most fundamental element in the implementation of a hospital-based PBM program is the availability of high-quality evidence to guide the practice. For example, having evidence-based transfusion thresholds in place is an important benchmark to gage a potential recipient’s need for a transfusion. Recently several well-designed randomized controlled trials (RCTs) have demonstrated the lack of superiority of liberal transfusion strategies compared to restrictive strategies in a variety of different patient populations including those in the intensive care unit (ICU),2 post hip replacement surgery,3 in acute gastrointestinal bleeding,4 cardiac surgery,5,6 and patients with sepsis.7 Similarly lower doses of platelets (PLTs) have been shown to be effective in preventing spontaneous bleeding in hematology/oncology patients.
The evidence base for the use of plasma in RCTs and observational trials is also beginning to accumulate.10–13

Implementing these transfusion thresholds can be done through education sessions with blood product prescribers,13 and reinforced using electronic prompts in the computerized physician order entry system (CPOE) that indicate when a patient might not require a transfusion based on their recent laboratory values.14 These alerts have been successful in reducing some transfusions that do not appear to be evidence based.15–17 Electronic alerts can also be useful in alerting surgeons when their patients are anemic before surgery so that the etiology of the anemia can be diagnosed and perhaps pharmaceuticals administered to increase their hemoglobin concentration thus obviating the need for RBC transfusion.18 Periodic electronic feedback to orthopedic surgeons indicating the percentage of their patients that have transfused and the number of RBC units transfused per patient in a graphic format has also reduced the number of transfusions,19 as has the routine use of tranexamic acid in these cases.

The principles of PBM can also be applied in many surgical settings. Using cell salvage to recover shed blood can reduce the need for allogeneic RBCs in certain high blood loss surgeries,20 while the use of tranexamic acid had markedly reduced the need for RBC transfusion following many different types of procedures, especially orthopedics.21–23 Eliminating pre-operative autologous donations of RBCs, pre-operative hemoglobin optimization, use of point of care testing, and extensive physician education are all integral components of PBM in surgery.24 The development of an algorithm based on anesthesia information management systems data to help determine the extent of pre-operative pretransfusion testing that is needed for individual patients can also help guide practice in an evidence-based manner, and potentially reduce unnecessary transfusions.25 Reducing the amount of waste in the operating rooms (ORs) and throughout the hospital is another important component of PBM, and can be achieved through some simple interventions such as using posters to alert physicians to the problem of waste and affixing cardboard tags to each unit issued to the OR indicating the outdate of the unit and its proper storage conditions.26

Many of the above mentioned PBM initiatives have been implemented in a regional, multi-hospital healthcare system in a step-wise manner beginning in 2007 (Table 1). It was expected that there would be reductions in blood product usage across the healthcare system as the PBM program evolved and became more widely implemented throughout the system’s hospitals. However, it was not clear whether the reductions in transfusions would occur at all seven hospitals, or whether the reductions would come from only several services at some of the larger-sized hospitals that had historically transfused large quantities of blood. The goals of this study was to identify which hospitals had experienced the largest reductions in blood use after implementation of these PBM initiatives, and which if any clinical services had not yet fully realized the full benefits of PBM thereby indicating where additional resources and education should be focused.

### Methods

This retrospective review of blood product usage before and during the implementation of a variety of PBM initiatives was conducted at seven hospitals in a regional, multi-hospital healthcare system (Table 2). All of these hospitals are serviced by a centralized transfusion service (CTS) that manages the

| Year | Event |
|------|-------|
| 2007–2008 | Ad hoc PBM committee created to investigate feasibility of implementing PBM initiatives |
| 2009 | Electronic feedback to orthopedic surgeons on the number of RBC transfusions and the percentage of patients transfused initiated |
| 2011 | Pilot study of automated alerts to surgeons and family doctors on anemic pre-operative patients initiated |
| 2012 | System-wide PBM committee formally created and funded |
| 2013 | Phase 1 of blood product waste reduction campaign initiated |
| 2014 | Pre-operative autologous donation prevention campaign initiated |
| 2015 | Additional automated alerts about potentially unnecessary transfusions in the CPOE initiated |

See text for specific references.
transfusion service for each hospital and maintains a centralized database of patient transfusion records.27

The institutions included in this analysis ranged from large, quaternary-care academic hospitals to small community hospitals, including a center that specialized in women’s health. All hospitals utilize the same CPOE and laboratory information system (Cerner, Kansas City, MO). One of these hospitals was added to the system in 2009 (see below). No specialist pediatric hospitals were included in this analysis.

To determine the effect of PBM implementation on blood product use, the total number of RBC, plasma, and PLT transfusions that had been transfused at six of the hospitals between fiscal year (i.e., 1 July–30 June) 2007 and 2015 was extracted from the CTS’ recipient database. Note that as the majority of the PLTs transfused throughout this healthcare system are whole blood PLTs, the number of whole blood PLT equivalents is reported herein: the number of transfused apheresis PLTs was multiplied by five (as one apheresis PLT unit is considered equivalent to five whole blood PLT units) and then added to the number of transfused whole blood PLTs. A seventh hospital was added to the system in 2009. Prior to 2009 this hospital, and its blood bank, had been under a completely different administration than the other six hospitals and its transfusion volumes before 2009 are not available. For the purposes of calculating the combined overall rate of change in blood products transfused between 2007 and 2015 for these seven hospitals, the number of blood products transfused at this hospital in 2009 was added to those transfused in 2007 at the other six hospitals, as 2009 was the first year in which hospital 7 was part of this healthcare system and the CTS. The hospital location to which each product was issued was retrieved from the patient databases maintained by the healthcare system’s quality department, and analyzed by quarter (i.e., 3-month period) for the 2014 and 2015 fiscal years. For the purposes of comparing blood utilization between these hospitals, the hospital location to where each product was issued was grouped into four categories: medical/surgical ward, OR (this also included units issued to pre- and post-operative recovery areas as well as those units issued directly to the ORs themselves. Procedures performed in interventional radiology or gastroenterology suites were not included.), emergency room (ER), and ICU (all types of adult ICUs including cardiac, transplant, neurology, trauma, etc., were included). To normalize the number of blood products issued to these four hospital locations, the number of blood products transfused to these four locations were divided by the quarterly number of admissions to medical/surgical wards, quarterly number of procedures performed in the OR, quarterly number of ER visits (regardless of whether the patient was subsequently admitted to the hospital or was discharged home), and the quarterly number of ICU admissions, respectively, for each hospital during fiscal years 2014 and 2015. This normalization thus accounted for differences in the number of patients treated and the number of transfusions administered at each hospital. The number of RBC units administered in these four hospital locations was also normalized for the number of recipients who actually received RBC transfusions, thereby providing an estimate of the number of RBC units administered per transfused recipient.

Descriptive statistics and linear regression models were calculated using GraphPad Prism software (version 5, La Jolla, CA). To determine the significance of the changes in blood products transfused over the 9 years of this study for all hospitals combined, two linear regression models were constructed: The first model included the total number of transfused products between 2007 and 2015 and excluded those that were transfused at the hospital that was added in 2009. The second model included the total number of blood products transfused between 2009 and 2015 at all hospitals (including those at the hospital added in 2009). In this way, the impact of the addition of the hospital in 2009 on the transfusion trends across all hospitals could be assessed. A $P$ value of <0.05 was considered statistically significant. The data collection protocol was approved by the Quality Improvement Board, which is a division of the University of Pittsburgh’s Institutional Review Board.

**Results**

The combined, overall number of blood products administered at these hospitals decreased between 2007 (including the 2009 transfusion volumes from the hospital that was added in 2009) and 2015 (Fig. 1); there was a 29.9% decrease in the number of RBCs transfused, a 25.7% decrease in the number of PLT units transfused, and a 24.8% reduction in the number of plasma units transfused. To determine the significance of these changes over time, two linear regression models were constructed. In the model that considered only the transfusions between
2007 and 2015 at the six hospitals that had been in the network since 2007, the reduction in the number of PLTs transfused over time was statistically significant ($P = 0.003$), as was the reduction in plasma transfusions ($P = 0.036$), and also the number of RBCs transfused ($P = 0.002$). In the second model, where all of the transfusions from all seven hospitals from 2009 to 2015 were considered, the reduction in the number of plasma units transfused ($P = 0.002$) and the number of RBCs transfused ($P = 0.005$) was significantly reduced, while the rate of PLT transfusion demonstrated a clear trend towards significance ($P = 0.068$). This indicates that the addition of this hospital in 2009 had an effect on the overall number of PLTs transfused, but not on RBCs or plasma transfusions.

Fig. 2 shows the trends for RBC, plasma, and PLT transfusion from 2007 to 2015 for the seven hospitals in this system. Some of the largest decreases in utilization occurred at the largest hospitals in the system; hospital 4 saw 40.6% ($P < 0.0001$), 26.1% ($P = 0.044$), and 49.5% ($P = 0.001$) decreases in RBC, plasma, and PLT transfusion, respectively, while hospital 5 saw a 25.1% ($P = 0.007$) and 33.8% ($P = 0.023$) decrease in RBC and plasma utilization, respectively. The latter hospital also has a cancer treatment center, thus its decrease in PLT usage between 2007 and 2015 was only $\sim 5\%$ ($P = 0.89$). Reductions in transfusion volumes were also seen at some of the smaller hospitals, such as hospital 6, where reductions...
of 35.6% \((P = 0.046)\) and 49.0% \((P = 0.01)\) in RBC and plasma utilization, respectively, were achieved. The PLT transfusion rate did not change significantly at this center between 2007 and 2015 (an increase of 2.11%, \(P = 0.67\)). Some hospitals also had increases in product usage that were not statistically significant, such as the 43% \((P = 0.55)\) increase in RBC transfusions at hospital 1 between 2007 and 2015. This gradual increase was likely due to the expanded range of surgical and ICU services offered at this hospital during the study period.

Fig. 3 shows blood product usage by quarter in the emergency departments (EDs) of these seven hospitals over the most recent 2 years. Each data point represents the number of transfusions per 1000 admissions to the ED, regardless of whether the patients were admitted or discharged. The blood product use in the EDs over the most recent 2 years was stable overall, and reflects the volume and acuity of the patients seen at each site. There is no disproportionate increase in the use of any of these products at any of the sites, and the number of transfusions per 1000 ED admissions ranged between 0 and 30 for all products and all sites. It is interesting to note that while PLT use in the ED at the largest hospital in this network (hospital 4) was relatively stable over the most recent eight quarters, there was a gradual decrease in plasma utilization despite it being an active level 1 trauma center. The rate of PLTs transfused in the ED of the hospital with the cancer center (hospital 5) was not higher than many of the other EDs; this is likely because the hematology patients who require a PLT transfusion are quickly admitted to the ward where their transfusion is administered.

Fig. 4 shows the RBC, PLT, and plasma utilization trends on medical and surgical wards in these seven hospitals. RBC and PLT utilization was relatively stable over the eight quarters analyzed, with higher RBC and PLT usage per 1000 patients at the hospital with the cancer center (hospital 5) compared to the other hospitals. Overall, plasma utilization was more fluctuant compared to RBCs and PLTs.

Fig. 5 shows the RBC, PLT, and plasma trends in the ORs of these seven hospitals. Similar to the utilization in the ED and on the medical/surgical wards, blood product transfusion rates over the most recent eight quarters were stable, and the transfusion rates range between 0 and 300 transfusions per 1000 admissions. The two hospitals with the greatest use of PLT and RBCs (hospitals 4 and 5) have the two busiest ORs.

Fig. 6 demonstrates the blood product usage in the ICUs at these seven hospitals, per 1000 ICU admissions. The transfusion rates were generally stable.
Figure 4  The number of RBC (A), PLT (B), and plasma (C) transfusions per 1000 medical and surgical floor admissions at eight hospital sites over eight quarters from 2014 to 2015.

Figure 5  The number of RBCs (A), PLTs (B), and plasma transfusions (C) per 1000 OR cases at eight hospital sites over eight quarters from 2014 to 2015.
with some sites showing decreases in usage. The number of transfusions per 1000 ICU patients was higher than the rate seen on the medical/surgical wards, or in the OR, or ED, ranging from 0 to 2500 transfusions per 1000 admissions.

While the above figures demonstrate the number of transfusions per admission, which estimates the number of patients who received a transfusion, Figs. 7 and 8 demonstrate the number of RBC units that the transfused patients on the medical/surgical wards and in the ICUs actually received. It is apparent that the ICU in the hospital with the cancer center (hospital 5) transfused many patients with the largest number of RBCs administered per recipient of any ICU in this healthcare network. This is likely related to the number of hematology/oncology patients treated in this ICU. Overall, and similar to the number of transfusions per 1000 patients, the number of transfused units per patient was also stable across the eight quarters. Additionally, the number of RBC units transfused per

![Figure 6](image1.png)

**Figure 6**  The number of RBCs (A), PLTs (B), and plasma (C) transfusions per 1000 ICU admissions at eight hospital sites over eight quarters from 2014 to 2015.

![Figure 7](image2.png)

**Figure 7**  RBC transfusions per transfused medical and surgical floor recipient at eight hospital sites over eight quarters from 2014 to 2015.
Discussion
The implementation of a multifaceted PBM program has vastly reduced the overall number of transfused blood products at these hospitals. The hospitals at which the PBM program has had the greatest impact in reducing transfusions were the two largest, although the smaller hospitals have also seen reductions since implementing the PBM program. There were no individual clinical services that transfused unusually large volumes for a sustained period of time during the eight quarters of fiscal year 2014 and 2015. Similarly, this study showed that in general, since the dramatic decrease in blood product usage that followed during the first few years after the implementation of the PBM program, blood product use has remained stable or has even continued to decrease over the most recent 2 years.

Comparing these utilization data over the past several years with that from the most recent National Blood Collection and Utilization Survey (NBCUS, data from 2011), the reductions in RBC transfusion that we have observed have also been noted nationally, with an 8.2% reduction in the number of transfused whole blood and RBC units noted in 2011 compared to 2008. As the reductions in RBC utilization in this healthcare system (at least at the two hospitals with the largest RBC transfusion volumes) seemed to accelerate after 2011, it will be interesting to compare these data with the next version of the NBCUS, which will feature data from 2013. The 2011 NBCUS data also revealed that PLT transfusions increased by 7.3% compared to 2008, however at least at one of the largest hospitals in this healthcare system, there was a reduction in PLT transfusions over this period, while the PLT transfusion rate remained relatively constant at the other hospitals. The plasma transfusion rate at the large hospital with a level 1 trauma center increased between 2008 and 2011, which was the opposite finding in the NBCUS report (a 13.4% decrease between 2008 and 2011). It is also interesting to note that the plasma use at the large tertiary care hospital with a level 1 trauma center decreased after 2010; perhaps the explanation lies in part with a shift away from the fixed blood product ratio resuscitation of trauma patients strategy towards a goal-directed therapy strategy where the results of laboratory testing guide the provision of blood products. The more widespread use of tranexamic acid in these patients has also likely reduced the number of blood products these patients receive.

It appears that the ORs are transfusing products in proportion to the number of patients treated and the acuity of the patient population. The two hospitals that transfuse the greatest number of products (hospitals 4 and 5) are those that have the largest volume of OR cases, and conduct the most complex surgeries. These trends are also present in the volume of transfusions performed in the ED at these two hospitals. It is also interesting to note that at hospital 1, with a large obstetrical patient population, a relatively large number of its ICU patients were transfused with at least one RBC (Fig. 6). Yet it is apparent from Fig. 8, that the actual number of RBC units administered per transfused ICU patient was low. This suggests that many of the ICU patients in this hospital received RBC transfusions, but with a small number of units per patient. Perhaps this reflects on the nature of postpartum hemorrhage management at this hospital. This finding is also present but to a lesser degree at some of the other hospital sites. In general though, it is encouraging to see that patients are receiving less than two units during each of their transfusion episodes (i.e., every time they are transfused) on the medical/surgical wards. The number of transfused units per transfused recipient is independent of the number of admissions or procedures, and can thus be compared between services and hospitals. The sudden upward trend to transfusing >2 RBCs per transfusion episode in the ICU at hospital 5 merits

Figure 8 RBC transfusions per transfused ICU recipient at eight hospital sites over eight quarters from 2014 to 2015.
Verdecchia ally recipient on the medical and surgical wards was gener-

Although the number of RBC units transfused per

were appropriate for the individual recipient.

determine if the transfusions that were administered

for the specific hospitals in this study, and no clear out-

ation volumes in a healthcare system with an advanced

useful in that it demonstrates the current blood utiliz-

implemented. However, the service line data are still

had the largest reductions after PBM was

before 2014, it is also not possible to see which services

largest reductions in blood products use occurred

in the healthcare network. Overall, the number of

products transfused has generally been reduced over

9 years, which is especially apparent at the hospitals

with the largest volume of transfusions. Some of

the smaller volume hospitals have also seen reductions

in the number of units transfused, and are also trans-

fusing small numbers of RBCs per transfusion episode.

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Ethics approval The data collection protocol was approved by the Quality Improvement Board, which is a division of the University of Pittsburgh’s Institutional Review Board.

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