The effects of a data driven maximum surgical blood ordering schedule on preoperative blood ordering practices

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Objective: The maximum surgical blood ordering schedule (MSBOS) provides guidelines for pre-operative pre-transfusion testing for elective surgical procedures. This study compared blood ordering and utilization during the period when the MSBOS was created by achieving consensus between the blood bank and the various surgical specialties, and after the introduction of an MSBOS created by using department-specific red blood cell (RBC) transfusion data (data driven MSBOS, dMSBOS).

Methods: The dMSBOS was created by analyzing 12 months of RBC transfusion data for each procedure across a regional health system. Pre-transfusion testing and the RBC crossmatch:transfusion (C:T) ratios at 8 of the hospitals were compared between the 12 month period before the dMSBOS was introduced, and the 15 months after its introduction.

Results: There were significant reductions in the median monthly number of type and screens not associated with RBC crossmatches (10,714 – 10,061; p < 0.0001) and the median number of type and screens associated with RBC crossmatches (10,127 – 9,349; p = 0.0014) on surgical patients after dMSBOS implementation. There were significant decreases in the median number of monthly RBC units crossmatched (2,981 – 2,444; p < 0.0001) and transfused (890 – 791; p < 0.0001) to surgical patients after implementing the dMSBOS. The overall system-wide C:T ratio trended down after dMSBOS implementation (from 3.34 to 3.17, p = 0.067).

Discussion: Crossmatching fewer RBC units facilitates more efficient management of the blood bank’s inventory.

Conclusion: The dMSBOS was effective in reducing the extent of unnecessary pre-transfusion testing before surgery and reduced the number of RBCs that were crossmatched for specific patients.

KEYWORDS
Red blood cell; ordering; MSBOS; pre-operative; pre-transfusion; testing; surgical; crossmatch

Introduction

The American Society of Anesthesiologists and the American College of Critical Care Medicine have emphasized the need to reduce both unnecessary pre-operative blood testing and ordering of red blood cell (RBC) units [1,2]. Implementing a hospital-based patient management (PBM) program can help identify ways of achieving these goals. Pre-transfusion testing and the preparation of RBCs for transfusion require time and have a cost associated with them; appropriate pre-operative testing and RBC ordering practices can ensure that the patient has the necessary testing completed prior to the procedure, which can prevent delays in providing RBCs, and thus, the surgery. The maximum surgical blood ordering schedule (MSBOS) was created to help ensure the completion of necessary pre-transfusion testing prior to a surgical procedure in order to prevent delays. It was also intended to eliminate unnecessary preoperative testing, hence effecting a cost savings, and to reduce the number of RBC units that are crossmatched for specific patients thereby improving the efficiency of managing the blood bank’s inventory.

Prior to the development of the MSBOS, the pre-operative ordering of blood products was based on the surgeon’s estimation of the patient’s need for intraoperative transfusion [3]. First described in 1976, the MSBOS was created in order to provide guidelines and recommendations for preoperative pre-transfusion testing and RBC ordering [3]. This original MSBOS was based on developing a consensus between the various surgical specialties and the hospital blood bank, which, over time, has not reflected changes in clinical practice nor actual blood use. Now, with the development of medical informatics, a data driven MSBOS (dMSBOS) can be created using department-specific RBC utilization data obtained from an anesthesia and/or laboratory information management system [4]. A dMSBOS’ recommendations are not only based on institution specific data, but can also include every surgical procedure performed at that institution. One example of a dMSBOS included information from
53,526 patients for 135 surgical procedures. The implementation of this dMSBOS led to a 38% reduction in preoperative blood orders, which translated into an annual cost savings of USD137,223 [5].

A dMSBOS based on specific patient blood utilization data was recently created at a multi-hospital regional health care system. The aim of this study was to compare RBC ordering and utilization before and after the introduction of the dMSBOS using the crossmatch:transfusion (C:T) ratio, a measure of how often crossmatched RBCs are actually transfused, and to determine whether the dMSBOS has reduced the extent of perioperative blood testing and ordering.

Methods

The original, consensus-type MSBOS used by this multi-hospital regional healthcare network was created by obtaining consensus between the hospital blood bank and various surgical specialties on the extent of pre-transfusion testing and/or RBC crossmatching required for each procedure. This consensus-type MSBOS included 3084 procedures across 16 different surgical specialties.

The dMSBOS was created using data from all surgical procedures within this multi-hospital regional healthcare network over a 12 month period (January 2014–December 2014). For each procedure, the number of RBC units transfused during the procedure was recorded. These data were used to calculate the frequency at which patients undergoing specific procedures required RBC transfusion. This percentage was then used to create the dMSBOS guidelines. In the dMSBOS, each surgical procedure is listed in one of three categories. Category 1 includes surgeries where ≤5% of patients undergoing that procedure during the 12 month data collection period received RBC transfusion. The dMSBOS recommends no preoperative testing for the procedures listed in Category 1. Category 2 includes surgeries where between >5% and ≤25% of patients undergoing that procedure during the 12 month data collection period received RBC transfusion. The dMSBOS recommends a pre-operative type and screen (T&S) as the only pre-transfusion testing necessary for the procedures listed in Category 2. Finally, Category 3 includes surgeries where >25% of patients undergoing that procedure received RBC transfusion. The dMSBOS recommends performing a T&S and then crossmatching the median number of RBC units that were transfused during the 12 month data collection period for Category 3 surgeries (Table 1).

To compare the effectiveness of the dMSBOS on reducing the C:T ratio and the number of pre-operative T&Ss performed, data were collected during two periods. From September 2014 to August 2015 (12 months), pre-operative testing and RBC ordering was conducted according to the original, consensus-type MSBOS. The dMSBOS was introduced to eight hospitals within the healthcare system in September 2015, and its effect was studied for 15 months ending in November 2016. The following data were retrospectively obtained from the hospital blood bank’s electronic database and the hospital system’s electronic medical records for each surgical procedure during the two study periods: (i) the number of preoperative T&S where an RBC crossmatch was not subsequently ordered, and the number of preoperative T&S where RBC crossmatches were subsequently ordered, (ii) the number of RBC units crossmatched for patients undergoing the specific procedure, and (iii) the number of RBC units actually transfused to these patients during their hospital admission. The number of RBC units crossmatched and the number of RBC units transfused during their hospital admission were then used to calculate the C:T ratio for each procedure by dividing the total number of crossmatched RBCs by the number that were transfused. The C:T ratios before and after the introduction of the dMSBOS were further analyzed according to surgical specialty, specific hospital within the healthcare system, and the month in which the procedure took place.

Statistical testing was performed using the Mann–Whitney test (Prism version 7, Graphpad, La Jolla, CA, U.S.A). This study protocol was approved by the University of Pittsburgh’s quality improvement board, which is a division of the institutional review board.

| Table 1. The three categories of recommendations in the dMSBOS and some examples of the most commonly performed procedures in each category. |
|-------------------------------------------------|-------------------------------------------------|
| MSBOS category | Representative procedures |
| (1) No preoperative testing needed ≤5% of patients undergoing that procedure during the 12 month data collection period received RBC transfusion | Bronchoscopy, Laparoscopic abdominal hysterectomy, Laparoscopic ventral hernia repair |
| (2) Type and screen only >5% to ≤25% of patients undergoing that procedure during the 12 month data collection period received RBC transfusion | Coronary artery bypass graft, Craniotomy, Femur open reduction internal fixation, Laparotomy, Microvascular Free Flap, Total Laryngectomy |
| (3) Type and Screen with RBC Crossmatch >25% of patients undergoing that procedure during the 12 month data collection period received RBC transfusion | Heart Transplant (crossmatch 4 RBC units), Liver Transplant (crossmatch 4 RBC units), Splenectomy (crossmatch 3 RBC units), Tumor Debulking (crossmatch 2 RBC units) |
Results

Eight hospitals in a regional healthcare system were included in this study. These hospitals ranged from small community hospitals to large academic and tertiary care centers. Table 2 shows representative demographic data for each of these hospitals for the calendar year 2015. At seven of the eight hospitals, 60–77% of the procedures performed were outpatient (patient not admitted to hospital after surgery) in nature. The remaining cases were inpatient (patient admitted to the hospital after surgery) in nature. At one hospital, 49% of the procedures were outpatient in nature.

There was a statistically significant 18% decrease in the median number of RBC units crossmatched per month on surgical patients during the consensus-type MSBOS period compared to the dMSBOS period (2981 and 2444, respectively, $p < 0.0001$) (Figure 1(A)). In addition, there was a statistically significant 11% decrease in the median number of RBC units transfused to surgical patients during their hospital admission per month between the consensus-type MSBOS period compared to the dMSBOS period (890 and 791; $p < 0.0001$) (Figure 1(A)).

The consensus-type MSBOS recommended a T&S only for 10.7% of the 3084 included procedures and a T&S with RBC crossmatching for 9.1%. This is in contrast to the recommendations of the dMSBOS, where a T&S only was recommended for 11% of the 3428 included surgical procedures, and a T&S with RBC crossmatching was indicated for 4%. Figure 1(B) shows the extent of preoperative pre-transfusion testing performed across the eight hospital healthcare network. There was a small but statistically significant 6.1% decrease in the median number of T&Ss performed on surgical patients per month between the consensus-type MSBOS period compared to the dMSBOS period (10 714 and 10 061, respectively, $p < 0.0001$). In addition, there was a statistically significant 7.7% decrease in the median number of T&S with RBC crossmatches performed on surgical patients per month between the period where the consensus-type MSBOS was utilized compared to the period after the introduction of the dMSBOS (10 714 and 10 061, respectively, $p = 0.0014$; Figure 1(B)). These data are also graphically depicted on a monthly basis in Figure 2.

There was a trend toward an overall reduction in the C:T ratio for all surgical procedures combined across the eight hospitals within the system between the period where the consensus-type MSBOS was utilized compared to the period after the introduction of the dMSBOS (3.34 and 3.17, respectively, $p = 0.067$). At six of eight hospitals, a trend toward a decrease in the C:T ratio occurred after implementing the dMSBOS was observed (Figure 3). Overall, the mean decrease in C:T ratio for these six hospitals was $0.23 \pm 0.15$; however,

Table 2. Demographics of each of the eight hospitals in a multi-hospital regional healthcare network system.

| Hospital                        | Outpatient cases | Inpatient cases | Total cases |
|---------------------------------|------------------|----------------|-------------|
| 156 Bed community hospital      | 5489 (72%)       | 2111 (28%)     | 7600        |
| 360 Bed specialty hospital/     | 11581 (60%)      | 7697 (40%)     | 19 278      |
| Academic center                 |                  |                |             |
| 272 Bed community hospital      | 4401 (73%)       | 1627 (27%)     | 6028        |
| 404 Bed tertiary care center    | 17516 (70%)      | 7560 (30%)     | 25 076      |
| 399 Bed tertiary care center    | 21789 (73%)      | 8074 (27%)     | 29 863      |
| 795 Bed tertiary Care/          | 19034 (49%)      | 19469 (51%)    | 38 503      |
| Academic center                 |                  |                |             |
| 517 Bed tertiary care/          | 18745 (63%)      | 10900 (37%)    | 29 645      |
| Academic center                 |                  |                |             |
| 249 Bed community hospital      | 18276 (77%)      | 5552 (23%)     | 23 828      |

Data from 2015 calendar year is shown. Outpatient cases were those where the patient was not admitted to the hospital following surgery. Inpatient cases were those where the patient was admitted to the hospital after surgery.

Figure 1. Overall preoperative blood ordering and pre-transfusion testing during the consensus-type MSBOS and dMSBOS periods for an eight hospital regional healthcare network. (A) The median number of RBC units crossmatched and transfused per month. Black columns represent the median number of RBC units crossmatched. Gray columns represent the median number RBC units transfused. Error bars indicate the 95% confidence interval. (B) The median number of preoperative tests ordered per month. Black columns represent the median number of T&Ss ordered. Gray columns represent the median number of T&Ss ordered including an RBC crossmatch. Error bars indicate the 95% confidence interval.
none of these decreases were statistically significant ($p \geq 0.17$ for all six of these hospitals). Of the two hospitals that had an increase in the C:T ratio after implementing the dMSBOS, both were small community hospitals, and the mean increase in C:T ratio for both of these hospitals was $0.20 \pm 0.06$. These increases in the C:T ratios were also not statistically significant ($p \geq 0.66$ for both hospitals).

The overall C:T ratios were evaluated for 12 different surgical specialties and Anesthesiology as a group before and after the introduction of the dMSBOS (Figure 4). Nine surgical specialties showed a trend toward a decrease in C:T ratio after the implementation of the dMSBOS; the mean reduction in the C:T ratio for these nine specialties was $0.49 \pm 0.54$ (Figure 4). Of these nine surgical specialties, Colon and Rectal surgery ($5.16$ and $3.25$, respectively, $p = 0.012$) and Orthopedic surgery ($3.02$ and $2.53$, respectively, $p = 0.007$). The remaining seven specialties with a reduced C:T ratio were Anesthesiology, Cardiothoracic,
General, Neurosurgery, Obstetrics and Gynecology, Plastic and Reconstructive, and Surgical Oncology, but these reductions were not statistically significant ($p \geq 0.91$ for each of these eight specialties). Four other specialties (Otolaryngology, Transplant, Urology, and Vascular) had an increase in C:T ratio after implementing the dMSBOS, but none of these increases were statistically significant ($p \geq 0.69$ for each of these four specialties).

**Discussion**

The MSBOS provides guidelines for preoperative pre-transfusion testing and RBC ordering. In the United States, the MSBOS’ recommendations are not lawful mandates, however, blood ordering that is in excess of the MSBOS’ recommendations often require justification to the blood bank [6]. With the increase in cost of blood products and related testing, and recognition of the adverse effects of transfusion, some institutions design their MSBOS based on institution-specific transfusion data. The regional health care system in this study constructed a dMSBOS based on specific transfusion data that was obtained over the course of one year. This dMSBOS was implemented across eight hospitals within a healthcare system, and the effects on perioperative blood ordering and transfusion were evaluated.

The dMSBOS at this health care system was effective in reducing the rate of pre-transfusion testing ordered on surgical patients, and also on the rate of RBCs that were crossmatched and transfused to these patients. It was less effective in reducing the C:T ratio. This latter result differs from other studies, which have found significant reductions in the C:T ratio following the implementation of a dMSBOS. Frank et al. found that a complex, institution-specific dMSBOS led to a 27% decrease in C:T ratio over a 17 month period at a single institution. Moreover, at that institution, there was a 38% decrease in the number of procedures where the MSBOS recommended any form of pre-transfusion testing [5]. This recommendation was based on the following criteria: <5% patients undergoing that procedure required RBC transfusion, median estimated blood loss $\leq 50$ ml, transfusion index $<0.3$, and no major bleeding risk [5]. This is similar to the Category 1 recommendation of the dMSBOS in the current study. In addition, Mahar et al. showed a decrease in procedure specific C:T ratio from an initial range of between 5 and 32 to a final range of between 0 and 1 following the implementation of a dMSBOS [7]. Furthermore, based on current literature, a C:T ratio of less than or equal to 2.0 is considered to be ideal [5,8,9], and this study revealed a system wide C:T ratio that was still above 2.0, although there was a decreasing trend noted after implementing the dMSBOS.

In spite of the reductions in pre-transfusion testing, it remains unclear how extensively the new dMSBOS has been adopted. Although the dMSBOS is available electronically in several easily accessed areas of the hospital system’s intranet and surgical booking software, a large portion of pre-operative blood ordering is conducted by surgical residents and fellows who might not know how to access the dMSBOS. In addition, regardless of the MSBOS’ recommendation, intraoperative blood ordering many times takes place as a result from a conversation between the surgeon and the anesthesiologist in the OR after the procedure has started. Efforts to increase awareness of the new MSBOS’ recommendations and to enhance staff awareness of how to access it will be undertaken to improve...
adherence to its recommendations. Furthermore, the dMSBOS’ recommendations are just that, and there is no process to evaluate the appropriateness of pre-operative pre-transfusion testing or RBC ordering outside of these recommendations.

In light of the continued relatively high overall C:T ratio after the implementation of the dMSBOS, several approaches have been undertaken in this healthcare system to improve the adherence to its recommendations. Lectures have been presented to various surgical specialties reminding them about the importance of using the MSBOS and that it can be easily accessed online in the operating room itself, a discussion of the MSBOS is presented as part of the curriculum of the nurse anesthesiologists, and the updated dMSBOS was supplied to the chairperson of each surgical specialty so that they could educate their faculty about its recommendations and how it can be accessed. In addition, the transfusion service staff and its medical leadership have been encouraged to take an active role in identifying cases where quantities of blood products greater than that recommended in the MSBOS have been ordered and to investigate the appropriateness of these orders. It is hoped that these ongoing efforts will result in greater compliance with the MSBOS and a reduction in the C:T ratios.

Another approach that has been shown to be effective in reducing blood utilization, beyond adherence to the MSBOS, is electronic remote blood issue (ERBI) [10]. These systems involve placing a refrigerator containing RBCs in locations remote from the hospital transfusion service near wards where transfusions are routinely administered, such as near the operating rooms. Members of the clinical team can obtain crossmatched RBC units from these refrigerators if their patients are eligible for the computer crossmatch (i.e. they have a current type and screen and no historical or current antibodies) at the time that the decision is made to administer the transfusion. Placing ERBI systems near the potential recipients has been shown, in combination with a clinical decision support system, to significantly reduce both the quantity of RBCs that were ordered but not utilized and also the mean pre-transfusion hemoglobin concentration [11]. Combining an ERBI system with a data-driven review of the MSBOS could provide an effective approach for the evidence based provision of RBCs for these patients.

This retrospective study has several limitations. First, this study was conducted in a single healthcare system, which had a consensus-type MSBOS in place for many years. Perhaps other institutions might have a different experience when implementing a MSBOS for the first time or when making changes to a pre-existing schedule. Additionally, for some patients seen in pre-surgery clinics, an anesthesiologist ordered the pre-transfusion testing, and in the operating room itself some RBC transfusions were attributed to the anesthesiologist not the surgeon. For these patients it was not possible to identify the nature of the surgery that they were undergoing, hence these orders were subsumed under the Anesthesiology category in Figure 4. Although some patients might have received RBC transfusions in the days following their surgery while recovering in ICUs or other post-operative hospital wards, the majority of the procedures performed throughout this healthcare system were performed on patients who were discharged from hospital on the same day following their surgery. Thus, the number of RBCs transfused to these surgical patients during their admission generally reflects the number that were administered either during or immediately after their surgery. The final limitation of this study lies in the MSBOS itself. This institution’s dMSBOS includes procedures under broad categories, and may need revision to include more detailed procedure descriptions. For example, all posterior spinal lumbar fusions are included under one category without specification of the number of levels being fused. This might be relevant if the number of RBC transfusions differs by the extent of the surgery.

This study demonstrated that a dMSBOS produced significant decreases in the extent of pre-transfusion testing and RBCs crossmatched and transfused to surgical patients across the eight hospitals of a large healthcare system although there was only a trend toward a reduction in the system’s overall C:T ratio. As awareness of the dMSBOS and its recommendations on the part of surgical teams grows, and as a more coordinated pre-transfusion testing effort is made in the operating room, an even greater impact on pre-transfusion testing is likely to prevail.

Disclosure statement

No potential conflict of interest was reported by the authors.

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