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Experience with uncrossmatched blood refrigerator in emergency department

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ABSTRACT

Background Uncrossmatched packed red blood cell (PRBC) transfusion is fundamental in resuscitation of hemorrhagic shock. Ready availability of uncrossmatched blood can be achieved by storing uncrossmatched blood in a blood bank refrigerator in the emergency department (ED), but could theoretically lead to inappropriate uncrossmatched use.

Methods This retrospective study was performed at a level I trauma center from January 2013 to March 2014. Possibly inappropriate transfusion was defined as patients who received at least one unit of blood from the ED refrigerator and no more than two units of PRBC in the first 24 hours. Deaths within the first 24 hours were excluded. Patients who received blood from the ED refrigerator who received ≤2 units total in 24 hours were compared with those who received >2 units.

Results 158 adults received blood from the ED refrigerator. 140 (88.6%) were trauma patients. 37 (23.4%) received massive transfusion (MT). 42 (26.6%) deaths were excluded. 29 patients received ≤2 units and 87 received >2 units in the first 24 hours. The ≤2 units group had a higher systolic blood pressure (116 mm Hg vs. 102 mm Hg, p=0.042), lower base deficit (6.4 mEq/L vs. 9.4 mEq/L, p=0.032), higher hematocrit (34% vs. 30%, p=0.024), lower rate of MT protocol activation (27.6% vs. 58.6%, p=0.005), and lower rates of transfusion of fresh frozen plasma (17.2% vs. 54.0%, p=0.001) and platelets (13.8% vs. 39.1%, p=0.012). Appropriately transfused patients were more likely to have evidence of shock with active, non-compressible hemorrhage. Potentially inappropriate uses were more likely in patients either without evidence of hemorrhage or without signs of shock.

Discussion Storing uncrossmatched blood in the ED is an effective way to get PRBCs transfused quickly in hemorrhaging patients and is associated with a low rate of unnecessary uncrossmatched transfusion. Provider education and good clinical judgment are imperative to prevent unnecessary use.

Level of evidence Level III, therapeutic.

INTRODUCTION

Hemorrhage is the most common cause of possibly preventable death in trauma patients within the first 48 hours of injury. Emergent, life-saving transfusion is necessary in 5% to 8% of trauma activations.[1–8] Due to the time needed for a crossmatch to be performed, many patients requiring emergent transfusion will receive uncrossmatched blood until crossmatched units become available.

Immediate availability of uncrossmatched blood is therefore paramount to resuscitation in hemorrhagic shock. This can be achieved in multiple ways, such as placing the blood bank or a satellite branch of the blood bank within close physical proximity to the emergency department (ED), or having a "runner" bring uncrossmatched blood to trauma activations. Another alternative, as used at our institution, is to stock uncrossmatched blood in an ED blood bank refrigerator that can be accessed directly by nursing personnel.

A theoretical disadvantage to use of an ED blood bank refrigerator is that it becomes easier for bedside clinicians to access uncrossmatched units, which could lead to unnecessary transfusion in both trauma and non-trauma patients. Blood transfusion is not without risk. Transfusion of a single unit of packed red blood cells (PRBCs) intraoperatively in general surgery patients increased risk of mortality, morbidity, pneumonia, and septic shock.[9] Transfusion has also been shown to be an independent risk factor for ventilator-associated pneumonia, with a dose–response effect.[10] Uncrossmatched transfusion has additional risk: since clinically significant alloantibodies will be present in 6% to 10% of the population, uncrossmatched transfusions increase the risk of immediate as well as delayed transfusion reactions.[4 11]

The purpose of this study is to describe our experience with the use of an ED blood bank refrigerator and identify factors associated with inappropriate use.

METHODS

This Institutional Review Board-approved retrospective study was performed at a 945-bed American College of Surgeons-verified level I trauma center and tertiary care center from January 2013 through March 2014. All adult patients, including trauma and non-trauma patients, who received at least one unit of uncrossmatched blood from the ED refrigerator were identified using the blood bank database. Because there is no standard definition of what constitutes inappropriate transfusion of uncrossmatched blood, for the purposes of this study we chose to define "possibly inappropriate transfusion" as any patient who received at least one unit of uncrossmatched PRBCs from the ED refrigerator and no more than two units of PRBCs in total (crossmatched or uncrossmatched) within the first 24 hours. Massive transfusion was defined as requirement of at least 10 units of PRBCs within 24 hours.

Demographic, clinical, and outcome data were obtained for each patient, including age, sex, whether or not the institution's massive transfusion protocol (MTP) was activated, and etiology of hemorrhage. For trauma patients, results of a focused assessment with sonography for trauma (FAST) examination, presence of a pelvic fracture, admission Glasgow Coma Scale (GCS) score, Abbreviated Injury Scale score for head, and Injury Severity Score (ISS) were obtained. Clinical data obtained included admission heart rate (HR), systolic blood pressure (SBP), respiratory rate, pH, partial pressure of carbon dioxide, partial pressure of oxygen, lactate, base deficit, hematocrit, and if fresh frozen plasma (FFP), platelets, and cryoprecipitate were transfused. Outcome data collected included 24-hour and inpatient mortality and disposition from the ED.

We first compared 24-hour survivors with non-survivors. However, to eliminate survival bias in those patients who received ≤2 units in 24 hours, we excluded the 24-hour non-survivors from further analysis, as they would possibly have had a larger transfusion requirement had they survived. We then compared the ≤2 units group (the "possibly inappropriately transfused" group) with the >2 units group.

Patients who were identified as "possibly inappropriately transfused" were identified and their charts obtained. Based on clinical documentation and nursing flow sheets, we determined whether the patient met the activation criteria for the institutional MTP and the number of Assessment of Blood Consumption (ABC) Score criteria that was met. The authors then performed detailed chart review and adjudicated a consensus on whether transfusion of uncrossmatched blood was appropriate based on the clinical scenario.

Groups were compared using t-tests without assumption of equal variances, and Fisher's exact or χ^2 tests as appropriate. Welch's t-test was used for t-tests of unequal variances as determined by Levene's test for equality of variance. Statistical analyses were performed using SPSS V.23 statistical software. Significance was set at $p<0.05$.

RESULTS

There were 158 adult patients who received at least one unit of uncrossmatched blood from the ED refrigerator during the study period (table 1). The median age was 50, and 61.4% were male. A significant majority were trauma patients (140, 88.6%); however, several non-trauma patients received uncrossmatched transfusion from the ED refrigerator, including six patients with gastrointestinal (GI) bleeds, five patients with ruptured abdominal aortic aneurysms (AAAs), three obstetric or gynecological patients, two medical patients with anemia, one postoperative head and neck surgery patient, and one postoperative general surgery patient. Twenty-six of the 158 (16.5%) were victims of penetrating trauma. Use of uncrossmatched blood coincided with activation of the institution's MTP in 56.3% of cases. Of the trauma patients, the median ISS was 24 and the median GCS score was 11.

Forty-two of 158 patients died within 24 hours (table 2). Twenty-six (61.9%) of these deaths were from hemorrhagic shock, eight (19.0%) from catastrophic brain injuries due to blunt trauma, four (9.5%) from gunshot wounds to the head, and four (9.5%) from prehospital trauma-related cardiac arrests. Compared with 24-hour survivors, non-survivors used significantly more uncrossmatched ED refrigerator blood (median of 2 units vs. 1 unit, $p<0.001$) as well as overall total PRBC units (median of 7 units vs. 4 units, $p=0.046$), and had a higher overall rate of massive transfusion (35.7% vs. 19.0%, $p=0.028$).

Table 1 Demographics of all patients receiving uncrossmatched blood from ED refrigerator

Patients receiving any uncrossmatched red blood cells in the ED (n)	158
Age, median (range)	50 (16–91)
Sex	97 male (61.4%)/ 61 female (38.6%)
Penetrating	26 (16.5%)
Massive transfusion protocol activations	89 (56.3%)
Etiology	
Trauma	140 (88.6%)
Gastrointestinal bleeds	6 (3.8%)
Abdominal aortic aneurysms	5 (3.2%)
Gynecology-related	3 (1.9%)
Medical anemia	2 (1.3%)
General surgery-related	1 (0.6%)
Ear, nose and throat-related	1 (0.6%)
Injury Severity Score*, median (range)	24 (2–75)
Glasgow Coma Scale score*, median (range)	11 (3–15)
ED fridge units transfused (n)	292
ED fridge units transfused (n), median (range)	2.0 (1–6)
Total units transfused in 24 hours (n)	1172
Total units transfused in 24 hours (n), median (range)	4.0 (1–55)
Patients who received >10 units (n)	37 (23.4%)

*Trauma patients only.
ED, emergency department.

Twenty-four-hour non-survivors were also more likely to have the MTP activated (71.4% vs. 50.9%, $p=0.029$). The etiology of hemorrhagic shock (trauma vs. non-trauma) was not significantly different for either group.

Twenty-four-hour non-survivors were subsequently excluded, and the remaining 116 grouped by the total number of units of PRBC received in the first 24 hours (≤2 vs. >2). There were no statistical differences in demographics between these two groups (table 3). The clinical data are summarized in table 4. The ≤2 units group had a statistically significantly higher admission SBP (116 mm Hg vs. 102 mm Hg, $p=0.042$), a lower partial pressure of oxygen (86 mm Hg vs. 148 mm Hg, $p=0.001$), a lower admission base deficit (6.4 mmol/L vs. 9.4 mmol/L, $p=0.032$), a higher admission hematocrit (34.0% vs. 30.0%, $p=0.024$), a lower rate of MTP activation (27.6% vs. 58.6%, $p=0.005$), a lower rate of FFP transfusion (17.2% vs. 54.0%, $p=0.001$), and a lower rate of platelet transfusion (13.8% vs. 39.1%, $p=0.012$). There was no statistical difference in pH or lactate. Although not statistically significant, the ≤2 units group had a lower admission HR (94 vs. 105, $p=0.093$) and lower cryoprecipitate transfusion rate (3.4% vs. 17.2%, $p=0.069$).

Inpatient mortality was not different between groups. Patients in the >2 units group were more likely to be transferred to the operating room or angiography from the ED (60% vs. 41%, $p=0.029$).

The charts of the 29 patients in the ≤2 units group were reviewed by the authors. Of these, 18 (62.1%) met the institution's MTP activation criteria (table 5), but only 4 of these 18 (22.2%) actually had the MTP activated. The MTP was activated on an additional four who did not meet the criteria. Six patients (20.7%) met two or more variables of the ABC Score, and four of those patients (66.7%) also met the institution's MTP criteria. On review of documentation, 19 (65.5%) were determined by the authors to have received appropriate uncrossmatched

Table 2 Transfusion data based on 24-hour survival

	Died within 24 hours	Survived 24 hours	P values
n	42	116	
Emergency department fridge units received, median (range)	2 (1–6)	1 (1–4)	<0.001
Total units received in 24 hours, median (range)	7 (1–32)	4 (1–55)	0.046
Received ≥10 units in 24 hours	15 (35.7%)	22 (19.0%)	0.028
Massive transfusion protocol activated	30 (71.4%)	59 (50.9%)	0.029
Etiology			
Trauma (vs following)	36 (85.7%)	104 (89.7%)	0.572
Abdominal aortic aneurysms	4	2	
Medical anemia	0	2	
Gastrointestinal bleeds	2	4	
Gynecology-related	0	3	
Ear, nose and throat-related	0	1	
General surgery-related	1	0	

transfusions based on available information and description of the clinical scenario.

DISCUSSION

Resuscitation of hemorrhagic shock requires uncrossmatched PRBCs to be readily available. Need for uncrossmatched transfusion in the ED is one of the strongest predictors of the need for massive transfusion in trauma.[1 12 13] Our institution's rate of massive transfusion following uncrossmatched blood transfusion from our ED refrigerator was 23.4%, which is slightly lower than the published rate of 30% by Inaba *et al*.[1]

Overall, patients who received blood from the ED refrigerator had a 24-hour mortality rate of 26.6%, confirming that as a cohort they are at significantly increased risk of early death. However, patients needing two units or less in the first 24 hours were less likely to have a clinical picture of shock as demonstrated by a higher mean SBP. Their mean HR was lower but did not reach statistical significance, correlating with other studies that have shown that blood pressure is more predictive than HR for the need for massive transfusion.[5 14 15] A lower base deficit and a higher hematocrit were also observed, but are not clinically relevant, as these lab values would not be available immediately during resuscitation.

Because early initiation of the MTP is critical to reducing mortality in hemorrhage, uncrossmatched PRBC transfusion should prompt activation of the MTP. Therefore, the criteria used during the study period for ED refrigerator use (table 5) were the same as for activating our MTP, which included 14 different clinical and laboratory criteria. Protocols requiring weighing of variables, calculation of scores such as ISS, and dependence of laboratory values can lead to variability in MTP activation among providers.[2 16 17] This was also demonstrated in our study, as only one-third of the patients in the ≤2 units group who met the MTP criteria had it activated. Significantly more patients in the >2 units group had the MTP activated, but still barely over half (59%). This would suggest that providers were activating the MTP based on their own clinical judgment, not the established activation criteria.

Therefore, we reviewed the clinical scenarios of the 29 patients in the ≤2 units group, and concluded that uncrossmatched

Table 3 Demographic data by the number of uncrossmatched units received in 24-hour survivors

	≤2 units	>2 units	P values
Patients (n)	29	87	
Age, mean (SD)	50 (17)	47 (18)	0.365
Female	12 (41.4%)	35 (40.2%)	1.000
Penetrating	2 (6.9%)	17 (19.5%)	0.151
Trauma etiology (%)	24 (82.8%)	80 (92.0%)	0.171
Abdominal aortic aneurysms	0	2	
Medical anemia	2	0	
Ear, nose and throat-related	1	0	
Gastrointestinal bleeds	1	3	
Gynecology-related	1	2	
Injury Severity Score, median (range)	21.5 (2–34)	26 (4–50)	0.119
Glasgow Coma Scale score, median (range)	14 (3–15)	14 (3–15)	0.118
Abbreviated Injury Scale score, head, median (range)	0 (0–4)	0 (0–5)	0.905

Table 4 Clinical data in 24-hour survivors

	≤2 units	>2 units	P values
n	29	87	
Positive FAST	4 (14%)	26 (30%)	0.140
Pelvic fracture	7 (24%)	28 (32%)	0.336
Systolic blood pressure, mean (SD)	116 (33)	102 (31)	0.042
Systolic blood pressure ≤90	6 (21%)	33 (39%)	0.112
Heart rate, mean (SD)	94 (29)	105 (29)	0.093
Heart rate ≥120	6 (21%)	28 (33%)	0.248
pH, mean (SD)	7.3 (0.1)	7.2 (0.1)	0.238
PCO_2 (mm Hg), mean (SD)	44 (14)	44 (13)	0.959
PO_2 (mm Hg), mean (SD)	86 (69)	148 (118)	0.001
Lactate (mmol/L), mean (SD)	3.4 (2.7)	4.5 (3.3)	0.159
Base deficit (mEq/L), mean (SD)	6.4 (5.8)	9.4 (6.3)	0.032
Admission hematocrit (%), mean (SD)	34 (6)	30 (8)	0.024
Massive transfusion protocol activated	8 (28%)	51 (59%)	0.005
Received fresh frozen plasma	5 (17%)	47 (54%)	0.001
Received platelets	4 (14%)	34 (39%)	0.012
Received cryoprecipitate	1 (3%)	15 (17%)	0.069
Discharged alive	26 (90%)	73 (84%)	0.556

FAST, focused assessment with sonography for trauma; PCO_2, partial pressure of carbon dioxide; PO_2, partial pressure of oxygen.

Table 5 Institutional MTP criteria during the study period

Admission clinical criteria	Operating room clinical criteria	Laboratory criteria
SBP ≤70 mm Hg	Non-surgical hemorrhage	Base deficit >8
Crystalloid >4 L	EBL >150 cc/min	International Normalized Ratio >1.4
Estimated Blood Loss (EBL) >1000 cc		Prothrombin Time >18 s
SBP <90 despite 3.5 L crystalloid		Partial Thromboplastin Time >60 s
Temperature <34°C		Admission Hct <30
ISS >25		pH <7.1

Only one of the criteria had to be met for activation of massive transfusion protocol.
ISS, Injury Severity Score; SBP, systolic blood pressure.

PRBC transfusion was clinically indicated in 19 (65.5%) of those cases. We made several observations regarding the patients in this group. Of the 19, 17 had "stable" initial vital signs that became unstable, meeting either the HR or SBP criteria for the ABC Score. Three of those 17 met both. There were four positive FASTs, as well as four negative FASTs that had hemoperitoneum on CT scan requiring emergent operative management. There were also two patients with pelvic fractures, one with large hemothorax, one with a postoperative arterial bleed from a surgical site, and one with a penetrating neck injury with arterial bleed. Finally, there were two patients found to have a shock other than hemorrhagic (a blunt trauma patient with neurogenic shock and a cirrhotic with a GI bleed in septic shock).

Ten patients were determined to have received an uncrossmatched transfusion not clinically indicated. These included three blunt trauma victims with hypotension, but who had an HR <120 and no source of bleeding identified on initial assessment; two patients were transfused with uncrossmatched PRBCs to correct medical anemia; one blunt trauma patient had reported prehospital hypotension but a normal blood pressure on arrival; one patient had a gunshot wound to the abdomen with stable vital signs; one blunt trauma victim had an ascending aortic pseudoaneurysm with normal vital signs managed non-operatively; in the final instance, the obstetrician-gynecologist service used uncrossmatched refrigerator units for surgical bleeding during a cesarean section performed in the resuscitation bay for non-trauma-related fetal distress.

Since the study period, our institution has changed to the ABC Score for MTP activation as well as for uncrossmatched blood use. The ABC Score is easier to use due to it having fewer variables (4), all of which can be assessed within minutes of patient arrival.[2] Only 6 of the 18 patients in the ≤2 units group who met our institutional MTP criteria were ABC-positive, suggesting that had the ABC Score been implemented during the study period, less MTPs may have been called and less uncrossmatched blood may have been transfused.

Inappropriate transfusion was associated with a significant traumatic mechanism but absence of shock, and shock in non-trauma patients. Other forms of shock, such as sepsis, are more likely than hemorrhagic shock in the non-trauma population, and therefore use of uncrossmatched transfusion in the non-trauma population should be limited. However, it is important to note that there are non-trauma cases in which uncrossmatched transfusion in the ED is appropriate: in this study, six patients with AAAs and six patients with GI bleeds received blood from the ED refrigerator. Four (66.7%) of the six ruptured AAAs and two (33.3%) of the GI bleeds died within 24 hours.

Ultimately, good clinical judgment is required for appropriate use of uncrossmatched PRBCs stored in the ED and subsequent MTP activation. Patients should have evidence of ongoing non-compressible hemorrhage and evidence of shock. The ABC Score can guide this decision-making; however, it has only been validated to predict massive transfusion in trauma[2] and is limited in some cases of blunt trauma and all non-trauma, limiting its usefulness as institution-wide MTP activation criteria. At our institution, the ABC Score can be expanded to include significant hemoperitoneum not found with FAST, hemothorax, pelvic fracture, ruptured AAAs, and massive GI bleeds.

This study is limited due to its retrospective nature. There is no standard definition for what constitutes an inappropriate transfusion of uncrossmatched blood. Use of our definition (two or less units of RBCs transfused in 24 hours) resulted in a study group that was large enough to detect major differences, but was not large enough to determine possible risk factors for inappropriate uncrossmatched transfusion through statistical analysis. It is impossible to tell what percentage of these patients would have received an uncrossmatched transfusion in the absence of an ED refrigerator. Also, massive transfusion definitions have changed over time and use of other definitions would potentially change the comparisons. Furthermore, the data set obtained only collected initial vital signs and did not allow for the identification of patients who presented with normal vital signs, but were transient responders. Finally, our case review of the possibly inappropriately transfused patients is subjective and is limited by the quality of the available documentation.

In conclusion, an ED blood refrigerator is an effective way to provide easily available uncrossmatched blood for resuscitation of hemorrhagic shock. Receiving uncrossmatched blood from the ED refrigerator is associated with a high rate of early mortality. However, its accessibility could result in some instances of unnecessary use of uncrossmatched blood, which was unusual in this study (6.3%). Clinicians should use objective criteria when possible, but good clinical judgment remains essential. Patients who receive ED refrigerator blood and who require no more than two units in 24 hours do not necessarily represent cases of inappropriate use, but warrant review as part of blood bank quality assurance.

Contributors CTH: literature search, data collection, data interpretation, writing, critical revision. MT: literature search, data collection, data interpretation, writing, critical revision. DD: data analysis, critical revision. ZY: study design, data collection, data interpretation. JO'B: data collection, study design. DW: study design, data interpretation. AB: study design, data interpretation, critical revision, literature search. LB: study design, data interpretation, critical revision, data collection, literature search.

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