Effect of Pre-Hospital Use of the Assessment of Blood Consumption Score and Pre-Thawed Fresh Frozen Plasma on Resuscitation and Trauma Mortality

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BACKGROUND: Early blood product resuscitation reduces trauma patient mortality from hemorrhage. This mortality benefit depends on a system that can rapidly identify actively bleeding patients, initiate massive transfusion protocol (MTP), and mobilize resources to the bedside. We hypothesized that process improvement efforts that identify patients early and mobilize appropriate blood products to the bedside for immediate use would improve mortality.

STUDY DESIGN: Pre-implementation, MTP activation was at the discretion of the trauma surgeon, and only PRBCs were immediately available. In June 2016, the Assessment of Blood Consumption (ABC) score was incorporated in our pre-hospital triage process, and a process for thawed plasma to be available was developed. We performed a retrospective review of patients who were hypotensive on arrival or had MTP activated. We compared mortality and MTP component ratios 15 months pre- vs 15 months post-implementation.

RESULTS: Activations of MTP increased 6-fold, while the specificity of the process remained the same. In patients receiving MTP, appropriate blood product transfusion ratios increased 44%. Overall and penetrating trauma mortality improved by 23% and 41%, respectively. When divided by the Injury Severity Score (ISS), penetrating trauma mortality decreased by 65% for the ISS subgroup 15 to 24 and by 38% for ISS subgroup $\geq$ 25. Length of stay, ICU length of stay, and readmission rates were not significantly different.

CONCLUSIONS: Delivery of balanced blood product resuscitation is essential to confer mortality benefits. Process improvement directed at early recognition of the hemorrhagic patient, immediate product availability, and product delivery to the bedside for transfusion allows for mortality reduction without increased resource use. (J Am Coll Surg 2019;228:141−147. © 2018 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Trauma remains the fourth highest cause of death in the United States, and hemorrhage accounts for up to 40% of trauma-related deaths.[1-5] Trauma patient mortality from hemorrhage is reduced by initiating early blood product resuscitation and minimizing crystalloid resuscitation.[6-11] This mortality benefit depends on a system that can rapidly identify hemorrhaging patients, initiate massive transfusion protocol (MTP), and mobilize resources to the bedside.[12,13] The American College of Surgeon (ACS) Trauma Quality Improvement Best Practices recommends use of the Assessment of Blood Consumption (ABC) score to identify patients at risk for hemorrhage and initial MTP cooler delivery within 10 minutes of MTP activation.[14,15] Additionally, balanced blood product resuscitation is superior to high volume packed red blood cell resuscitation.[7,11,16-19] However, implementing these best practices can be challenging due to perceived resource requirements.

Disclosure Information: Nothing to disclose.

Received October 3, 2018; Revised November 10, 2018; Accepted November 12, 2018.

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https://doi.org/10.1016/j.jamcollsurg.2018.11.005
ISSN 1072-7515/18

Abbreviations and Acronyms

ABC = Assessment of Blood Consumption score
ACS = American College of Surgeons
ED = emergency department
EM = emergency medicine
EMS = emergency medical services
FFP = fresh frozen plasma
ISS = Injury Severity Score
MTP = massive transfusion protocol
PI = process improvement
PRBC = packed red blood cells
TEG = thromboelastogram

Shafi and colleagues[20] demonstrated that compliance with recommended practices at trauma centers is associated with decreased risk of death. On review of practices at our trauma system at an American College of Surgeons (ACS) level II trauma center, we determined that early and balanced blood product resuscitation was delivered to less than 50% of hypotensive trauma patients. Delays in MTP activation and lack of thawed plasma availability resulted in patients receiving excessive crystalloid and unbalanced blood product resuscitation. We hypothesized that process improvement (PI) efforts to identify hemorrhaging patients before arrival and earlier mobilization of appropriate blood products to the bedside would improve resuscitation and mortality.

The purpose of the study was to determine if implementation of the ABC score in the pre-hospital setting and maintaining thawed plasma improved outcomes at a level II trauma center. The results of this study demonstrate that process improvement methodology can be used to implement hemorrhagic trauma resuscitation best practices and improve mortality without a significant increase in resource use.

METHODS

This was a retrospective evaluation of prospectively collected data at University of Colorado Hospital (UCH) from March 1, 2015 to August 31, 2017. The Colorado Institutional Review Board reviewed this study and granted exemption on the basis that this was not human subject research because patients were treated with approved diagnostic and therapeutic procedures according to generally accepted standards of care.

Study setting

UCHealth University of Colorado Hospital (UCH) is an ACS and Colorado State verified level II trauma center that cares for injured patients across the Rocky Mountain region. Located in Aurora, CO, the 670 inpatient-bed trauma center admits more than 1,400 injured patients per year and serves as a specialty resource facility for the Rocky Mountain region. The trauma faculty is composed of 10 surgeons in the section of Trauma, Acute Care Surgery, and Surgical Critical Care. There is always an attending trauma surgeon in the hospital.

Patients identified by the emergency department charge nurse as severely injured according to prespecified physiologic, anatomic, and mechanistic criteria trigger trauma team activation. Activations indicate the need for a senior and a junior general surgery resident, an attending trauma surgeon, a primary and secondary nurse, a respiratory therapist, 2 emergency medicine residents and an emergency medicine attending to present to the trauma bay immediately. The team is present at the time of patient arrival and directs the initial evaluation and resuscitation of the patient.

Baseline massive transfusion protocol activation process

Before June 1, 2016, activation of MTP was at the discretion of the attending faculty (trauma surgery or emergency medicine). If the attending thought that MTP was indicated at the time of the patient's initial evaluation in the trauma bay, the primary nurse would call the blood bank to activate the MTP. The initial blood cooler contained 5 units of nonirradiated, type O packed red blood cells (PRBC). After preparation and delivery of the first blood cooler, the blood bank would thaw fresh frozen plasma (FFP). Thawing required approximately 30 to 45 minutes. This thawed FFP would be included in the second blood cooler. The second cooler contained 5 units PRBCs, 5 units AB negative FFP, and 1 platelet apheresis unit (PLT), equivalent to approximately 6 "units" of platelets. Additional coolers had the same contents as the second cooler unless specific products were requested by providers. Pharmacologic adjuncts (such as tranexamic acid) were not part of this protocol and were used at attending provider discretion.

Implementation of Assessment of Blood Consumption criteria and inclusion of plasma in initial blood cooler

A new MTP activation process was implemented June 1, 2016. Emergency medical services (EMS) calls the emergency department triage phone with a patient report. The emergency department charge nurse calculates an ABC score (Table 1) based on the EMS report of mechanism, blood pressure, and heart rate.[15] Three of the 4 components of the ABC score can be assessed before patient arrival in the trauma bay. A score of 2 or greater triggers the charge nurse to call the blood bank to activate MTP

Table 1. Activate Massive Transfusion Protocol if Two or More Conditions Exist

Systolic blood pressure $\leq$ 90 mmHg
Heart rate $\geq$ 120 beats per minute
Penetrating torso injury
+ Focused assessment with sonography for trauma (FAST)

before patient arrival. The first blood cooler is prepared and delivered to the trauma bay while the patient is transported to the hospital. Upon patient arrival, signs of hemorrhage are confirmed, and blood is immediately available for transfusion. Providers may also order MTP at their discretion, even if ABC criteria are not met. If the patient did not initially meet ABC criteria per EMS report, but then meets ABC criteria at the time of arrival (with the inclusion of the Focused Assessment with Sonography for Trauma [FAST] data), MTP is activated at that time.

In addition to implementation of the ABC score, our blood bank concurrently began stocking thawed plasma so that the first cooler now contains: 5 units of PRBC, 5 units of FFP, and 1 unit of apheresed platelets. The PRBC and FFP are administered in alternating fashion. This was implemented to improve RBC: FFP ratios by making FFP immediately available. Under the new protocol, the second cooler now does not include platelets. Concurrent with this project we began using thromboelastogram (TEG)-based resuscitation outside of the initial 1 to 2 hours of ratio-based transfusion. The new process of triage for activating massive transfusion based on the prehospital report and summary of blood product administration are summarized in Figure 1.

Process improvement

All MTP changes underwent review and approval by a multidisciplinary process improvement committee. Our EMS systems and emergency department staff fielding EMS calls received directed education on the components of ABC scoring. All staff involved in trauma received education on the new process. The ABC score was

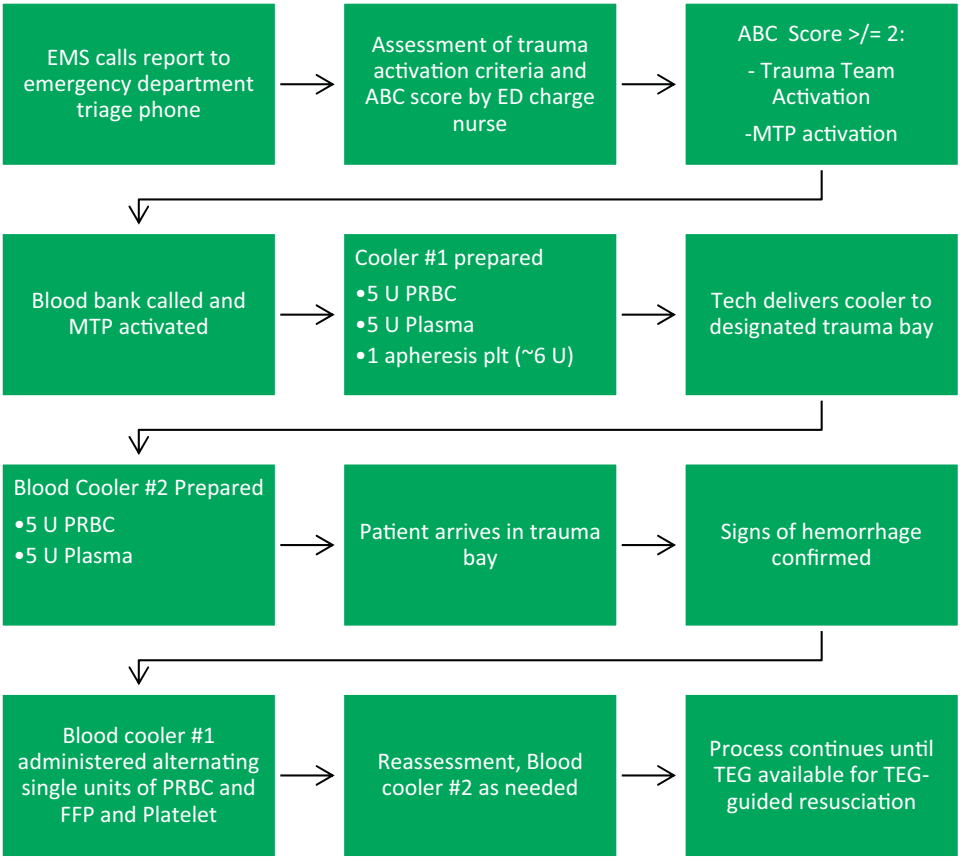

Figure 1. New massive transfusion protocol process. ABC, Assessment of Blood Consumption; ED, emergency department; EMS, emergency medical service; FFP, fresh frozen plasma; MTP, massive transfusion protocol; plt, platelet; PRBC, packed red blood cells; TEG, thromboelastogram.

incorporated into a "pocket card," which could be easily attached to providers' badges, and these cards were disseminated to emergency department and trauma surgery staff, faculty, physician assistants, and residents. Structured and directed educational conferences, morbidity and mortality conference presentations, and individual provider education were performed. In addition, case-by-case issues were addressed in our process improvement committee meetings. Our trauma nurse coordinators reviewed every MTP activation, and a dashboard was created to evaluate compliance. Ongoing performance was reviewed in real time at conferences and meetings.

Outcomes measures

The primary outcome of interest was mortality of patients who were hypotensive on first recording in the trauma bay and/or required activation of MTP. Hypotension was defined as a systolic blood pressure $\leq$ 90 mmHg. Hypotensive patients who did not have MTP activated were included in the study population in order to capture patients who did not have MTP activated before implementation of the protocol, but who likely would have had MTP activation after protocol implementation. Patients who had no initial signs of life and were declared dead within 10 minutes of arrival to the trauma bay were excluded, as were patients who underwent resuscitation for significant burns.

Secondary outcomes included whether patients actually received massive transfusion and compliance with balanced blood product resuscitation. Massive transfusion was defined as $\geq$4 units in 1 hour for the first 4 hours or $\geq$10 units in the first 6 hours after arrival. Balanced blood product resuscitation compliance was defined as between 1:1:1 and 2:1:1 PRBC:FFP:platelet unit, all with a 20% margin of error.

Resource use was evaluated by collecting overall inpatient length of stay, intensive care unit (ICU) length of stay, and readmission rates from our trauma patient database. Readmission was defined according to Colorado State Trauma registry inclusion criteria, which states that readmissions are patients who were discharged after inpatient admission, return to the facility, and are hospitalized for a missed diagnosis, complication, failure of conservative management, or iatrogenic injury.

Normally distributed continuous variables were summarized by reporting the mean and SD and compared using the Student's *t*-test. Mann-Whitney U test was used for nonparametric continuous data. Proportions were compared using a chi-square or Fisher's exact test, as appropriate. A value of $p < 0.05$ was considered statistically significant. The R Project for statistical computing was used for all data analysis (3.5.0).[21]

Table 2. Patient Demographics

Characteristic	Pre-hospital (n = 24)	Post-hospital (n = 95)	p Value
Age, y, mean (SD)	40 ± 3	39 ± 3	0.70
Sex, n (%)			0.88
Male	21 (88)	82 (86)	
Female	3 (12)	13 (14)	
Injury Severity Score, n (%)			0.37
0 to 8	1 (4)	13 (14)	
8 to 15	3 (13)	20 (21)	
15 to 24	5 (21)	15 (16)	
>25	15 (62)	47 (49)	
Mechanism, n (%)			0.08
Penetrating	17 (71)	49 (51)	
Blunt	7 (29)	47 (49)	

RESULTS

Demographics

During the study period there were 119 patients with hypotension and/or MTP activation, 24 pre-implementation and 95 post-implementation. There were no differences in demographics between the pre-implementation and post-implementation groups including age, sex, ISS breakdown, and mechanism of injury (Table 2).

Massive transfusion

In the 15 months pre-implementation there were 15 MTP activations in 24 hypotensive patients (63%). Of the 15, 6 patients (40%) received massive transfusion. Of the 6, 2 patients (33.3%) received balanced blood product transfusion ratios. From pre- to post-implementation, MTP activations increased 6-fold to 93 of a possible 95 hypotensive patients (98%). Of the 93, 39 patients (41.9%) received massive transfusion. Of the 39 patients receiving massive transfusion, balanced blood product transfusion ratios were given in 30 patients (76.9%) (Table 3). The proportion of patients in the

Table 3. Massive Transfusion and Balanced Blood Product Ratio Compliance

Variable	Pre-hospital	Post-hospital	p Value
MTP activations, n	15	93	n/a
MTP received, n (%)	6 (40)	39 (41.9)	0.89
Appropriate MTP received, n (%)	2 (33.3)	30 (76.9)	0.03*

*Statistical significance at $p < 0.05$.
MTP, massive transfusion protocol; n/a, not applicable.

Table 4. Mortality Pre- to Post-Implementation

	Pre-implementation		Post-implementation		
Mortality	**n/N**	**%**	**n/N**	**%**	**p Value**
Overall mortality	10/24	41.6	18/95	18.9	0.02*
Penetrating mortality	8/17	47.1	3/50	6.0	<0.0001*
Blunt mortality	2/7	28.6	15/45	33.3	0.80

*Statistical significance at $p < 0.05$.

study who had MTP activated increased pre-implementation to post-implementation (15 of 24, 62% pre; 93 of 95, 98% post; $p < 0.00001$).

Mortality

Pre-implementation 30-day mortality was 41.6%, decreasing to 18.9% post-implementation ($p = 0.02$). When divided by mechanism of injury, penetrating trauma mortality decreased by 41% ($p < 0.0001$), and blunt trauma mortality increased, but this did not reach statistical significance (Table 4).

When divided by ISS, overall mortality was not significantly different for any ISS subgroup. Penetrating trauma mortality decreased by 65% for ISS subgroup 15 to 24 ($p = 0.04$) and by 38 % for ISS subgroup 25+ ($p = 0.03$). Blunt trauma mortality was not significantly different for any ISS subgroup (Table 5).

In patients who received MTP, mortality was 66% (4 of 6) pre-implementation and 33% (13 of 39) post-implementation ($p = 0.18$). Comparing mortality of those who did receive balanced blood product transfusion with those who did not, in the pre-implementation group, mortality was 0% (0 of 2) for patients who did receive balanced transfusion ratios compared with 50% (2 of 4) for those who did not ($p =$ n/a). Post-implementation mortality was 30% (9 of 30) for those who received balanced transfusion ratios compared with 44% (4 of 9) in those who did not ($p = 0.45$).

Mortality of all trauma admissions during the same time periods were 3.3% (19 of 576) pre-implementation and 3.7% (25 of 677) post-implementation ($p = 0.71$); trauma patients who received the highest level of trauma activation had a 10% (11 of 110) vs 10% (15 of 150) mortality ($p = 1.0$). Mortality of admitted trauma patients who received any blood product was 26% (13 of 50) pre-implementation and 15.5% (13 of 84) post-implementation ($p = 0.14$).

Length of stay and readmissions

Hospital length of stay did not change from pre-implementation to post-implementation (10.8 ± 13 days pre, 12.6 ± 19 days post, $p = 0.37$). For patients admitted to the ICU, length of stay in the ICU did not change pre- to post-implementation (7.1 ± 8.3 days

Table 5. Mortality by Injury Severity Score

	Pre-implementation		Post-implementation		
Injury Severity Score	**n/N**	**%**	**n/N**	**%**	**p Value**
Overall					
0 to 8	0/1	0	0/12	0	n/a
8 to 15	0/2	0	0/20	0	n/a
15 to 24	3/6	50	2/16	13	0.10
>25	7/15	47	16/47	34	0.38
Penetrating					
0 to 8	0/1	0	0/7	0	n/a
8 to 15	0/2	0	0/16	0	n/a
15 to 24	3/4	75	1/10	10	0.04*
>25	5/10	50	2/17	12	0.03*
Blunt					
0 to 8	0/0	0	0/5	0	n/a
8 to 15	0/0	0	0/4	0	n/a
15 to 24	0/2	0	1/6	17	n/a
>25	2/5	40	14/30	47	1.0

*Statistical significance at $p < 0.05$.
n/a, not applicable.

pre, 7.0 ± 10.6 days post, p = 0.46). There were no 30-day readmissions at our facility for either group.

DISCUSSION

The results of this study demonstrate that process improvement efforts to decrease time to blood product availability and improved compliance with balanced blood product resuscitation improve mortality in trauma. Our efforts to implement ACS best practices resulted in a significant decrease in overall and penetrating trauma mortality. Overall hospital length of stay, ICU length of stay, and 30-day readmission rates were not affected. Although the ABC score may not be the perfect marker for MTP in the prehospital setting, it represents an easy-to-implement guideline that should be broadly applicable across trauma centers.[15,22,23] Smaller trauma centers with fewer resources may find the cost of implementation of ACS best practices to be daunting, but it is likely that these efforts will pay dividends in outcomes.

We acknowledge that trauma mortality is multifactorial, and therefore, the mortality benefit in this study cannot be independently linked to our efforts, as it is possible that other system improvements contributed to our improved outcomes during this time period. Notably, the patients most likely to benefit from improvements in MTP are penetrating trauma patients, who exsanguinate rapidly, but can often be salvaged with aggressive resuscitation until hemostasis is achieved. It was in this population that we saw the most significant decline in mortality. We cannot conclude whether the earlier activation of MTP or the increase in compliance with balanced resuscitation was more important. We would argue that both are vital because studies have demonstrated that both contribute to trauma mortality.[12,13,16] The benefits of balanced blood product transfusion have been clearly demonstrated, and a recent study concluded that delays in MTP activation and delivery of blood products are associated with increased time to hemostasis and increased mortality.[13] In an evaluation of the Pragmatic, Randomized Optimal Platelet and Plasma Ratios (PROPPR) dataset, "every minute of delay between the activation of MTP and the arrival of the first blood cooler, regardless of ratio, resulted in a 5% increase in the odds of mortality"; the authors further noted that "every effort should be made to decrease the time to recognition of the need for MTP and the time to administration of the first blood product."[13] One criticism of the noted equivalent mortality in the PROPPR trial is that patients receiving unnecessary blood product may have affected mortality. In our study, we found no change in our overall trauma admission mortality or our trauma activation mortality, and a nonsignificant decrease in mortality of trauma patients who received any blood product. This supports the belief that early, balanced blood product resuscitation is more beneficial than harmful and may truly improve mortality.

Implementation of processes to improve early and appropriate blood transfusions in trauma patients can be overwhelming. This requires negotiations with local blood banks, hospital administration, ED faculty and nursing, and trauma team providers. In order to ensure the most rapid availability of all necessary components, blood must either be stored in the ED or be mobilized via a triage trigger before patient arrival; likewise, thawed FFP should immediately be available, or thawing of FFP should begin before patient arrival. Emergency department-based blood storage remains a significant hurdle due to concerns over blood waste, loss of blood bank control over product administration, and administrative and regulatory issues surrounding equipment maintenance, monitoring, and staff demands. Blood storage in the ED and keeping a pool of thawed FFP may not be achievable at all institutions, especially outside of high-volume level I trauma centers. Our unique use of the ABC score to activate MTP based on pre-hospital report resulted in a shorter time to blood product availability without a significant increase in the proportion of patients who had MTP activated but did not ultimately need massive transfusion. This is how we addressed our time to blood product availability issue, and although we were unable to acquire granular data, our blood bank maintains that the new MTP process has not led to an increase in blood product waste. We also did not see a significant increase in inaccurate MTP activation and saw no changes in resource use (length of stay and readmission), despite the potential for a survival bias with improved mortality. This study provides data to support the maintenance of thawed FFP and early MTP activation as critical measures to improve trauma patient outcomes.

This study is limited by the fact that it was a single center study with a small number of patients. Lack of granular data concerning time to blood transfusion and blood waste is a limitation. Concurrent with implementation of this process improvement, we began using thermoelastogram (TEG)-guided resuscitation, which may have affected mortality. However, TEG results were not routinely immediately available, and patients generally received 2 or more coolers of blood product resuscitation before any TEG-based resuscitation.

CONCLUSIONS

In summary, process improvement directed at implementing ACS Trauma Quality Improvement Best Practices, including early recognition of the hemorrhagic patient, immediate product availability, and product delivery to the bedside for transfusion, allows for the associated improved resuscitation and mortality reduction without significant overtriage.

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