ORIGINAL ARTICLE

An Emergency Department Thawed Plasma Protocol for Severely Injured Patients

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Importance: In an effort to expedite delivery of plasma for patients requiring massive transfusions, US medical centers began keeping thawed plasma (TP) in their blood banks (BBs), markedly reducing time to release of plasma; however, the time to transfusion was still excessively long.

Objective: To expedite delivery and transfusion of TP through implementation of an emergency department (ED) protocol.

Design and Setting: Retrospective cohort study in an American College of Surgeons–verified level I trauma center.

Participants: Using the Trauma Registry of the American College of Surgeons database, we evaluated all adult trauma patients admitted from June 1, 2009, through August 31, 2010, who arrived directly from the scene, were the institution's highest level trauma activation, and received at least 1 U of red blood cells and 1 U of plasma in the first 6 hours after admission. The protocol was initiated in February 2010 by giving 4 U of AB plasma to patients in the ED. Patients were then divided into 2 groups: those admitted 8 months before (TP-BB) and 8 months after implementing TP location change (TP-ED).

Main Outcome Measures: Primary outcome was time to first unit of plasma. Secondary outcomes included 24-hour blood use and 24-hour and 30-day mortality.

Results: A total of 294 patients met the study criteria (130 in the TP-BB group and 164 in the TP-ED). Although the patient demographics were similar, TP-ED patients had greater anatomical injury (median Injury Severity Score, 18 vs 25; $P=.02$) and more physiologic disturbances (median weighted Revised Trauma Score, 6.81 vs 3.83; $P=.008$). The TP-ED patients had a shorter time to first plasma transfusion (89 vs 43 minutes, $P<.001$). The TP-ED protocol was associated with a reduction in 24-hour transfusion of RBCs ($P=.04$), plasma ($P=.04$), and platelets ($P<.001$). Logistic regression identified TP-ED as an independent predictor of decreased 30-day mortality (odds ratio, 0.43; 95% CI, 0.194-0.956; $P=.04$).

Conclusions: We demonstrated that implementation of an ED-TP protocol expedites transfusion of plasma to severely injured patients. This approach is associated with a reduction in overall blood product use and a 60% decreased odds in 30-day mortality.

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HEMORRHAGE IS THE LEADING cause of death within the first hour of arrival to a trauma center and one of the leading overall causes of death in trauma patients (30%-40%).[1,2] Of these hemorrhagic deaths, patients with a trauma-induced coagulopathy account for more than 50%, and the presence of trauma-induced coagulopathy correlated with a 3-fold increase in mortality.[3-5] On arrival to trauma centers, at least 25% of severely injured patients are already coagulopathic and thrombocytopenic.[4,6] When this group of patients receives effective higher ratios of plasma and platelets, a marked reduction in mortality has been observed.[7] These findings have led to the evolution and promotion of damage control resuscitation.[8] Damage control resuscitation aims to rapidly address hemorrhage and coagulopathy through permissive hypotension, minimization of early crystalloid use, and immediate provision of high ratios of plasma–red blood cells (RBCs).[3]

See Invited Critique at end of article

Early transfusion of RBCs is already a core element of trauma resuscitation, with most trauma centers storing uncrossmatched RBCs in their emergency departments (EDs). However, few centers store plasma in their EDs, making it difficult to achieve high plasma-RBC ratios early in the resuscitation of severely injured patients. By only having RBCs and crystalloids available in the ED, low plasma-RBC ratios are observed, which are associated with worsening coagulopathy and increased mortality.[3]

To facilitate the early achievement of higher plasma-RBC ratios, many trauma

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centers have implemented massive transfusion (MT) protocols.[9-12] Trauma centers that have implemented MT protocols have reported improved survival after implementation. These outcomes seem to be closely correlated with the early achievement of higher plasma-RBC ratios.[10] Although these MT protocols vary extensively from one trauma center to another, those centers reporting the most marked changes in survival are those that have implemented concurrent thawed plasma (TP) programs.[10,13,14] In addition to an associated reduction in mortality, centers that developed TP programs concurrent with their MT protocols have demonstrated reductions in time to first plasma transfusion and reduction in the overall number of blood and components transfused.[10,13,14] Before having TP readily available for release, blood banks (BBs) had to thaw their frozen plasma inventories (fresh frozen plasma [FFP] or plasma frozen within 24 hours of collection [FP24]) before the plasma could be packaged and delivered to the trauma team. Such strategies easily add up to a 30-minute delay on the first unit of plasma transfused.[15]

We have had TP stored in our BB for more than 20 years and have advocated for the early use of plasma as a primary resuscitation product for patients in hemorrhagic shock.[8,11,16] However, a recent performance improvement audit noted that although physicians were requesting and ordering plasma early (through activation of our MT protocol), actual transfusion of the first unit of plasma in MT protocol patients was often delayed by 60 minutes or longer. To expedite delivery and transfusion of plasma, we recently implemented a TP-ED program by placing 4 U of thawed AB plasma in the ED emergency release blood refrigerator. We hypothesized that having TP in the ED would (1) reduce time to first plasma transfusion, (2) reduce 24-hour blood product use, and (3) reduce mortality rates.

METHODS

STUDY SETTING

The University of Texas Health Science Center at Houston and the Memorial Hermann Hospital institutional review boards approved this study. Memorial Hermann Hospital is an American College of Surgeons–verified level I trauma center that is the primary teaching hospital for the University of Texas Health Science Center. Memorial Hermann Hospital is 1 of only 2 level I trauma centers in Houston, the fourth largest city in the United States. The hospital is an 800-bed facility within the Texas Medical Center and is home to the John S. Dunn Helistop, the busiest heliport for its size in the United States. The trauma center admits more than 6000 trauma patients annually, with the most severely injured cared for in the 25-bed shock trauma intensive care unit.

When clinically indicated, the MT protocol is activated. To do so, the trauma attending physician contacts the Memorial Hermann Hospital BB, states his or her name, the patient's name, the patient's sex and approximate age, and that he or she would like to activate the MT protocol. A blood type and screening sample is sent immediately to the BB. The ED technician delivers the blood type and screening sample and retrieves the first cooler of blood (6 group O RBC units and 6 group AB TP units) and 1 package of aphaeresis platelets. The products are delivered to the patient's bedside (ED, operating room, or interventional radiology department). As soon as typing is complete, type-specific products are released for subsequent coolers. The second and subsequent coolers contain 6 type-specific RBC units and 6 type-specific plasma units along with 1 aphaeresis platelet unit. Once hemostasis is declared by the surgeon and anesthesiologist, the MT protocol is discontinued and products are administered based on clinical and laboratory evaluation.

Beginning February 1, 2010, our institution began placing TP in the ED (TP-ED). Two jumbo group AB TP units were added to the ED refrigerator (at 1°C-6°C) to accompany the 4 group O-negative RBC units already kept there. Such availability allows for the immediate transfusion of products in a 1:1 plasma-RBC ratio. The products are evaluated by BB staff during each shift, assessing whether the products have reached their shelf life (or will in the next 24 hours). Those TP units that have been thawed for 96 hours at the time of inspection are returned to the BB to avoid expiration (120 hours after thaw). As units are transfused, the BB is notified by telephone and these products are replaced immediately. Before February 2010, all TP products were kept in the BB (approximately 20-30 U of various blood groups). Our BB is on the same floor as our ED, and a round-trip between the BB and ED is less than 3 minutes. All TP is derived from FFP. All blood products are provided by the Gulf Coast Regional Blood Center. In the ED refrigerator, we store only jumbo (group AB) TP units from male donors. For those units kept in the BB, all group A and O plasma units are from male donors. However, groups B and AB are from both male and female donors because of the limited number of products acquired from these less common blood types.

SELECTION OF PARTICIPANTS

Using the institution's Trauma Registry of the American College of Surgeons database, we evaluated all adult trauma patients admitted from June 1, 2009, through August 31, 2010, who (1) arrived directly from the scene, (2) were the institution's highest level trauma activation, and (3) received at least 1 U of RBCs and 1 U of plasma in the first 6 hours after admission. Patients who were younger than 18 years, had burn wounds on more than 20% of total body surface area, or who died within 30 minutes of arrival in the ED were excluded from this study. Patients were then divided into 2 groups: those admitted 8 months before (TP-BB) and 8 months after implementing TP location change (TP-ED).

DEFINITIONS AND OUTCOMES

We evaluated standard demographic data, including age, sex, race, and mechanism of injury. In addition, injury scores, such as initial Glasgow Coma Scale (GCS), weighted Revised Trauma Score (w-RTS), and Injury Severity Score (ISS), were recorded. The w-RTS is a physiology-based scoring system that incorporates the initial GCS score, systolic blood pressure, and respiratory rate.[17] These values are then coded and weighted and range from 4 (normal) to 0 (poor) for each variable (yielding a high of 7.841 and a low of 0). The Abbreviated Injury Scale (AIS) is an anatomical injury scoring system that quantifies injuries in various body regions from a score of 1 (minor injury) to 6 (nonsurvivable). A patient's ISS is calculated by summing the squares of the 3 highest AIS scores in 3 different body regions (values range from 1-75). *Massive transfusion* was defined as 10 U or more of packed RBCs in the first 24 hours after injury.

The *ED vital signs* were defined as the initial set of vital signs captured and documented in the trauma bay. All patients had a single comprehensive ED laboratory panel obtained shortly

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Table 1. Demographics and Injury Data

Demographic	Median (IQR)[a] TP-ED (n = 164)	TP-BB (n = 130)	*P* Value
Age, y	33 (23-50)	37 (24-52)	.27
Male sex, %	71.8	80.0	.07
White race, %	59.1	54.7	.39
Blunt mechanism of injury, %	75.1	62.8	.01
Admission GCS score	6 (3-14)	13 (3-15)	.04
Admission SBP, mm Hg	105 (84-126)	98 (85-120)	.31
Admission pulse, /min	107 (91-128)	102 (88-124)	.28
w-RTS	3.83 (2.93-7.11)	6.81 (2.93-7.84)	.008
Head AIS score	0 (0-3)	0 (0-2)	.005
Chest AIS score	3 (0-3)	0 (0-3)	<.001
Abdomen AIS score	2 (0-4)	0 (0-3)	<.001
ISS	25 (16-32)	18 (12-30)	.02

Abbreviations: AIS, Abbreviated Injury Scale; GCS, Glasgow Coma Scale; IQR, interquartile range; ISS, Injury Severity Score; SBP, systolic blood pressure; TP-BB, thawed plasma in blood bank; TP-ED, thawed plasma in emergency department; w-RTS, weighted Revised Trauma Score.

[a] Data are presented as median (IQR) unless otherwise indicated.

after arrival. The results of these laboratory tests were used for populating the ED laboratory value data fields through an electronic medical records data query. Although all ED laboratories and vital signs are standardized and performed at a uniform time (time zero), repeat laboratory values and intraoperative and postoperative laboratory values are not. These tests are performed as the patient's status dictates and are often missing, especially with early deaths. As such, we did not capture these variables in our database. We defined *ED crystalloid administration* as the sum of all normal saline, lactated Ringer, and other crystalloid solutions received while in the ED. We defined *ED blood products* (RBCs, plasma, and platelets) as those products received while in the ED. The *24-hour blood product calculations* were defined as the total number of products received 24 hours from time of arrival to the hospital. These products included blood in the trauma bay, in the operating room, and postoperatively up to the 24-hour postadmission time point.

The primary outcome of interest was time to first unit of plasma transfusion, which was defined as the time from arrival at our trauma center to the time the first unit of plasma was administered. Time to first unit of RBCs was defined in a similar fashion. Secondary outcomes included 24-hour blood product use (RBCs, plasma, platelets, and cryoprecipitate), 24-hour mortality, 30-day mortality, and hemorrhage-related mortality.

STATISTICAL ANALYSIS

Continuous data are presented as medians and interquartile range (IQR), with comparisons between groups performed using the Wilcoxon rank sum (Mann-Whitney) test. Categorical data are reported as proportions and, wherever appropriate, tested for significance using the χ^2 or Fisher exact test. The primary data analysis evaluated time to first unit of plasma transfused, blood product use, and mortality. A secondary analysis included the effect on those receiving MT. All statistical tests were 2-tailed, with $P < .05$ set as significant. STATA statistical software, version 10.0 (Stata Corp), was used for analysis.

Purposeful regression modeling was then used to construct a multivariate logistic regression model evaluating 30-day mortality. This modeling was performed using the technique of purposeful selection of covariates described by Hosmer and Lemeshow.[18] Clinically sound and independent variables were then chosen, including age, sex, ISS, w-RTS, ED laboratory values, 24-hour fluid administration, and transfusions. After this, the variables were entered into stepwise regression that selected 4 variables of significance (ISS, w-RTS, base deficit, and mechanism of injury). These variables were then applied to a multivariate logistic regression analysis evaluating these 4 variables and TP.

A multivariate linear regression model was then performed evaluating blood and blood component transfusions as a continuous variable. A multivariable logistic regression model was constructed to evaluate receipt of specific volumes of products. The variables included in the multivariate analyses were anatomical injury (ISS), physiologic injury (w-RTS), and tissue or metabolic injury (base deficit). In an effort to minimize the risk of falsely identifying significant results with multiple comparisons, all variables were prespecified and judged a priori to be clinically sound.

RESULTS

DEMOGRAPHIC AND BASELINE DATA

A total of 6997 trauma patients were admitted to our facility during the 16-month study period. Of these, 1833 were major trauma activations (highest level activation criteria). A total of 1539 were excluded, leaving 294 patients who met the enrollment criteria. There were 164 patients in the TP-ED group and 130 in the TP-BB group. The demographics and injury scoring for these patients are given in **Table 1**. Although basic demographics were similar between those admitted during the 2 periods, patients in the TP-ED group were more physiologically (w-RTS) and anatomically injured (ISS) on arrival. Median head, chest, and abdominal AIS scores were higher in the TP-ED group compared with the TP-BB group. However, no difference was found between the TP-ED and TP-BB groups for face AIS score (median [IQR], 0 [0-2] and 0 [0-0], respectively; $P = .07$), extremity AIS score (0 [0-3] and 0 [0-3], respectively; $P = .74$), or external AIS score (0 [0-0] and 0 [0-0], respectively; $P = .08$). Admission laboratory values, obtained as part of the routine trauma panel value, are given in **Table 2**. Admission laboratory values were also similar, with the exception of rapid thromboelastography values. These differences in demographics and coagulopathy are not surprising given that our inclusion criteria biased against the TP-ED group. Many severely ill patients who did not receive a unit of plasma before they died were excluded from the TP-BB group.

TRANSFUSION AND OUTCOME DATA

Although median times to the first unit of RBCs were similar between the 2 groups, time to first unit of plasma was significantly less in the TP-ED group (**Table 3**). Although trends toward less product transfusions were observed for RBC and plasma, the TP-ED group had less transfusion of cryoprecipitate in the first 24 hours of admission. Consistent with this, TP-ED had a significantly lower MT rate. In addition, the median crystalloids in the ED were 2.0 L (IQR, 1.5-2.6 L) in the TP-ED group compared with 3.0 L (IQR, 1.9-3.1 L) in the TP-BB group ($P = .11$). Because this appears to be a clinically meaningful reduction in fluids, this may represent a type II

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Table 2. Admission Diagnostic Testing and Laboratory Results[a]

Component	Median (IQR) TP-ED (n = 164)	Median (IQR) TP-BB (n = 130)	*P* Value
Positive FAST examination result, %	37.1	35.2	.77
Admission base deficit, mEq/L	5 (3-7)	5 (2-8)	.53
pH	7.32 (7.25-7.35)	7.30 (7.26-7.35)	.64
PT, s	15.4 (14.3-17.2)	15.0 (14.3-16.3)	.07
Platelet count, $\times 10^3/\mu L$	235 (277-182)	244 (197-299)	.24
Hemoglobin, g/dL	12.2 (10.7-13.9)	12.3 (10.9-13.8)	.47
rTEG-ACT, s	121 (113-128)	113 (105-121)	<.001
rTEG split point, min	0.7 (0.6-0.8)	0.6 (0.4-0.7)	<.001

Abbrevations: ACT, activated clotting time; FAST, focused assessment for the sonography for trauma; IQR, interquartile range; PT, prothrombin time; rTEG, rapid thromboelastography; TP-BB, thawed plasma in blood bank; TP-ED, thawed plasma in emergency department.

SI conversion factors: To convert base deficit to millimoles per liter, multiply by 1; to convert platelet count to $\times 10^9/L$, multiply by 1; to convert hemoglobin to grams per liter, multiply by 10.

[a] Data are presented as median (IQR) unless otherwise indicated.

Table 3. Primary and Secondary Outcome Data[a]

Variable	Median (IQR) TP-ED (n = 164)	Median (IQR) TP-BB (n = 130)	*P* Value
Time to first unit of RBCs, min	18 (11-73)	20 (10-72)	.85
Time to first unit of plasma, min	43 (21-106)	89 (48-192)	<.001
24-h RBC transfusions, U	5 (2-10)	6 (3-11)	.13
24-h Plasma transfusion, U	6 (3-11)	7.5 (4-14)	.08
24-h Platelet transfusion, U	12 (6-18)	12 (6-18)	.77
24-h Cryoprecipitate transfusion, U	0	0	.03
Massive transfusion rate, %	27.0	39.0	.04
24-h Mortality, %	9.7	6.9	.39
30-d Mortality, %	20.7	22.3	.74
Hemorrhage-related mortality, %	14.7	27.5	.21

Abbreviations: IQR, interquartile range; RBCs, red blood cells; TP-BB, thawed plasma in blood bank; TP-ED, thawed plasma in emergency department.

[a] Data are presented as median (IQR) unless otherwise indicated.

error. Univariate analyses demonstrated similar 24-hour and 30-day mortality between the groups.

No differences were found in length of stay (TP-ED: median [IQR], 17 [9-26] days vs TP-BB: 15 [7-27] days) or intensive care unit length of stay (6 [3-13] days vs 8 [3-16] days) between the groups. With respect to cause of death, no statistically significant differences were found between the groups. Hemorrhage-related mortality was seen in 14.7% of TP-ED patients and 27.5% of TP-BB patients. A total of 14.7% of deaths were attributed to respiratory failure or acute respiratory distress syndrome in the TP-ED group compared with 13.7% in the TP-BB group. Cardiovascular events accounted for 10.2% and 10.3% of deaths in the TP-ED and TP-BB groups, respectively. Although most deaths in both groups were attributed to traumatic brain injury (48.8% in the TP-ED group and 41.7% in the TP-BB group), deaths from multiorgan failure (2.9% vs 3.4%), sepsis (2.9% vs 3.4%), and withdrawal of care were also observed (5.8% vs 0%).

During the study period, a simultaneous quality improvement process was in place. In tracking the use and waste of TP during this time frame, only 3 U of jumbo AB TP were deemed "wasted" during this time frame. All of these units were during the TP-ED period and were attributed to not cycling the product out in a timely fashion. Although the protocol was to rotate the units out of the ED refrigerator at the beginning of day 4, these 3 U were not rotated out until late on day 4 or into day 5.

MT GROUP ANALYSES

Between the 2 groups, 44 patients in the TP-ED group (26.8%) and 50 in the TP-BB group (38.5%) received an MT. The groups were similar for age, sex, race, and mechanism of injury. However, the TP-ED patients arrived with more physiologic disturbances (median w-RTS, 2.93 vs 4.29; $P = .046$) and were more anatomically injured (median ISS, 32 vs 25; $P = .03$). In addition, the TP-ED group had lower hemoglobin levels (10.8 g/dL vs 12.3 g/dL [to convert to grams per liter, multiply by 10], $P = .04$) and more prolonged rapid thromboelastography activated clotting time (121 seconds vs 113 seconds, $P = .03$). All other laboratory values were similar between groups with the exception of admission prothrombin time, which was more prolonged (17.3 seconds vs 15.9 seconds, $P = .09$). These data further support that our study design led to the TP-ED group being more severely injured. This finding is the result of the TP-BB group having availability bias (delay in receiving at least 1 U of plasma) because all TP was stored in the BB. With respect to outcomes, the effect of moving the TP from the BB to the ED was associated with a significant reduction in time to first plasma transfusion in the MT patients (median time, 14 minutes vs 59 minutes; $P < .001$). No differences were found in mortality or transfusion volumes by univariate analyses.

MULTIVARIATE ANALYSES

Multivariate linear regression was then performed to evaluate the effect of TP in the ED on blood product use. When controlling for anatomical, physiologic, and tissue measures of injury and shock, TP-ED was associated with significant reductions in 24-hour RBCs (coefficient, −2.938; 95% CI, −5.683 to −0.193; $P = .04$), plasma (coefficient, −2.722; 95% CI, −5.365 to −0.079; $P = .04$), platelet (coefficient, −7.270; 95% CI, −10.849 to −3.691; $P < .001$), and cryoprecipitate transfusions (coefficient, −26.710; 95% CI, −45.798 to −7.622; $P = .007$). A multivariate logistic regression model was then constructed. After controlling for anatomical severity of injury (ISS), physiologic instability (w-RTS), shock (arrival base deficit), and mechanism of injury, TP in the ED was an independent predictor of decreased 30-day mortality (**Table 4**).

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Table 4. Multiple Logistic Regression Model Predicting 30-Day Mortality

Variable	Odds Ratio (95% CI)	*P* Value
Thawed plasma in ED	0.43 (0.194-0.956)	.04
Injury severity (ISS)	1.12 (1.070-1.174)	<.001
Physiologic status (w-RTS)	0.84 (0.694-1.012)	.07
Admission base deficit	0.99 (0.921-1.070)	.84
Blunt mechanism of injury	2.32 (0.608-8.825)	.22

Abbreviations: ED, emergency department; ISS, Injury Severity Score; w-RTS, weighted Revised Trauma Score.

COMMENT

Although TP has been used by some BBs for several decades, it first appeared in the 17th edition of the American Association of Blood Banks *Standards for Blood Banks and Transfusion Services* in 1996.[19] Thawed plasma is derived from either FFP (frozen within 8 hours) or FP24 (frozen within 24 hours). Once thawed and labeled TP, both FFP and FP24 may be used for an additional 96 hours past their traditional 24-hour postthaw shelf life. Centers using TP consider all 3 products (FFP, FP24, and TP) to be equivalent products with the exception of use in neonates (in whom FFP or FP24 must be used) and when higher levels of factors V and VIII are needed (in which case FFP should be used).[20] Moreover, the use of TP has been reported to provide acceptable levels of coagulation factors, reduce plasma waste, and be a cost-effective strategy for plasma use.[20-22] The current study evaluated the effect of moving TP to the ED, making the product immediately available for treating severely injured patients. After implementation of an ED-TP protocol, we noted a reduction in time to first unit of plasma transfusion, decreased 24-hour blood product use, lower MT rates, and a 60% reduction in 30-day mortality.

In an effort to expedite delivery of plasma for patients with substantial bleeding and those requiring MT, US medical centers have increasingly turned to TP programs.[23] By keeping TP in their BBs, time to release of plasma has been markedly reduced, allowing it to be provided (along with RBCs) with the first-batch MT of blood products. Investigators at Stanford University began storing 4 U of TP in their BB for their MT protocol in 2005.[14] They found that by making plasma available in the BB, time to first plasma transfusion was reduced from 254 to 169 minutes. Although the investigators had an MT protocol, this delay was still excessively long, and, not surprisingly, the ratios of products did not affect outcome. Similarly, investigators at the University of Alabama at Birmingham have argued that the improved survival associated with higher ratios is due to survival bias.[24] At their institution, this is likely true because they experience significant delays in plasma delivery as a result of availability bias. In other words, you cannot give what you do not have. Despite receiving their first unit of RBCs at 18 minutes, it was 93 minutes before the first unit of plasma was transfused. Again, it is difficult to achieve high ratios early and transfuse plasma rapidly in the absence of a TP protocol.

Despite having a mature MT protocol at our institution and a focus on earlier transfusion of plasma, an internal audit recently revealed that time to first unit of plasma was delayed by 60 to 75 minutes.[16] To address this, we implemented a TP protocol in which 4 U of group AB plasma were available in the ED/trauma bay refrigerator. After implementation, median time to first plasma transfusion was reduced from 89 to 43 minutes. Even more notable, time to first plasma transfusion among those receiving an MT was reduced from 59 to 14 minutes. The earliest plasma was infused 3 minutes after arrival. Time to first unit of RBC transfusion was similar across the groups and remained unchanged during the study period.

In 2006, Cotton et al[9,11] began a TP program in their BB to make plasma readily available for delivery in their MT protocol. This process involved keeping at least 10 U of group AB TP (and some group A plasma) available at all times. In addition to marked decreases in blood product use, the authors noted a decrease in mortality from 66% to 51%. Similarly, the Stanford group demonstrated a significant reduction in mortality (from 45% to 19%) after implementation of their TP program. By taking this concept from the BB to the ED, our study demonstrated marked reductions in MT rates and 24-hour blood product use. More importantly, this TP-ED protocol was associated with a 60% odds reduction in 30-day mortality.

Limitations to this study include the small sample size for each cohort and the retrospective design. Although the TP-ED group was identified in a prospective cohort, the comparison cohort (TP-BB) was identified using data collected via a trauma registry database and computerized patient medical records. In addition, a notable limitation is that based on the study design, the population is not homogenous and the cohorts are not identically matched, resulting in a bias against the TP-ED group. Specifically, our inclusion criteria required that the patient receive at least 1 U of plasma. Therefore, patients admitted before TP was stored in the ED would be expected to be less severely injured and less physiologically disturbed. Stated another way, because of delays in plasma delivery, many severely ill patients in the TP-BB group did not receive 1 U of plasma before they died and were excluded from the study. These same patients were, however, included in the TP-ED group because plasma was immediately available. The differences noted in univariate analyses were addressed with the use of multivariable regression strategies. Therefore, if an availability bias (often called "survival bias") were present, this would only strengthen our hypothesis and findings that suggest better outcome with the use of a TP-ED protocol.

Our study examined the effect of implementing a TP protocol in the ED. We demonstrated that an MT protocol expedites transfusion of plasma to severely injured patients. The TP-ED protocol was also associated with a reduction in overall blood product use and decreased MT rates. Moreover, this protocol was associated with a 60% odds reduction in 30-day mortality when controlling for admission injury severity and physiologic status. This finding may be the result of being able to provide a more hemostatic resuscitation immediately after arrival. Given the immediate avail-

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ability of plasma and RBCs and our recent findings, these blood products have replaced (at our institution) initial resuscitation using crystalloid-based strategies. However, a prospective, randomized trial is warranted to validate these findings.

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INVITED CRITIQUE

Stopping the Bleeding

Radwan and colleagues are leaders in the study and understanding of hemostatic resuscitation after injury. The principal finding of the present study[1] is that the availability of thawed plasma (TP) in the emergency department (ED) led to much earlier plasma administration in trauma patients who received blood and blood products compared with an earlier group of patients who received TP from the blood bank. Transfusion volumes of red blood cells, plasma, and platelets during the first 24 hours also were reduced in the TP-ED group.

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