CHAPTER 6

Introduction of a massive transfusion protocol: a before-and-after study in a level 1 trauma center

L.M.G. Geeraeds Jr
S.J.M. Kamphuis
E. Caldwell
T. Greenfield
M.J.A. Parr
G. Tweeddale
D. Rosenfeld
S.K. D’Amours

Submitted 2013
Abstract

Background
Outcome after massive transfusion following major trauma may be improved by using a massive transfusion protocol facilitating rapid resuscitation with blood products. The aim was to evaluate the effects of the introduction of a massive transfusion protocol (MTP) on patient outcome in a civilian level I trauma center.

Methods
A retrospective before-and-after study was performed in trauma patients over an 8-year period. Patients who had received a massive transfusion (≥10 units of packed red blood cells in the first 24 h) following introduction of the MTP (in 2006) were compared to a historical control group.

Results
Between the MTP group (n=45) and the pre-MTP group (n=52) there were no differences regarding mortality (at 24 hours and until hospital discharge), ICU stay, ventilator days and total hospital stay. No differences were found between the amounts of units packed red blood cells, fresh frozen plasma and platelets administered (at 24 hours and total amount). The intervals until administration of the first blood product did not differ. In the MTP group there were less infections 28.9 % vs. 51.9% (P=0.022).

Conclusions
Introduction of a MTP in our civilian level 1 trauma center was not associated with improvement of outcome or reduction of blood product usage. The decrease in infections after the introduction of the MTP must be attributed to other factors of trauma patient care that may have improved over time. Updating of our MTP is in progress. Opportunities for performance improvement (compliance monitoring) as well as other options to facilitate massive transfusion and/or prevent coagulopathy in trauma need to be investigated while awaiting results on prospective studies on blood component transfusion strategies.
Introduction
Worldwide, nearly 1 in 10 deaths are due to trauma, and hemorrhage accounts for 30 to 40% of trauma deaths. Hemorrhage is consistently the second most common cause of death in trauma, second only to central nervous system injury.\textsuperscript{1,2} Moreover, hemorrhage is recognized as the leading cause of preventable death in the first 24 hours after admission.\textsuperscript{3} In severely bleeding trauma patients, (surgical) control of hemorrhage is a time-critical priority. Simultaneously, circulating blood volume and coagulopathy need to be restored. Massive transfusion of blood products can be life-saving in trauma.\textsuperscript{4,5} In military trauma, massive transfusion occurs in 8-16% of trauma admissions. In contrast, massive transfusion in civilian trauma is needed in only 1% to 3% of trauma admissions.\textsuperscript{2,6} Thus, even in the busiest civilian trauma centers, the number of patients requiring massive transfusion may not exceed 100 per year.\textsuperscript{6} Because of the rarity of the event, the complexity and the hectic circumstances of treating exsanguinations in trauma, massive transfusion protocols (MTP) are used. These protocols are empirically based since the exact amount of lost blood volume is large but unknown. An MTP should provide for early delivery and administration of packages of blood products facilitating empirical transfusion of packed red cells (PRBC), fresh frozen plasma (FFP) and platelets (PLTs) in fixed ratio's in order to restore blood volume, perfusion, oxygenation while reversing coagulopathy, acidosis and hypothermia.\textsuperscript{7-9} And, if followed correctly, a MTP assures that a sufficient attempt has been made in order to justify the use of recombinant factor VIIa (rFVIIa).\textsuperscript{7} MTP's may improve outcome.\textsuperscript{10-12} Also, MTPs may reduce the volume of blood products used\textsuperscript{12,13} and the number of complications, such as infections\textsuperscript{14} that are associated with massive transfusions.\textsuperscript{15} In a survey that was published in 2006 it appeared that MTP exists at a relatively small number of large and well organized trauma centers.\textsuperscript{7} We studied the impact of the introduction of a MTP in our (urban) civilian level 1 trauma center.
Patients and methods

Study design
The research protocol was approved by the Sydney South West Area Health Service Human Research Ethics Committee. A retrospective, before-and-after cohort study was performed within Liverpool Hospital, Australia, a level 1 trauma center and teaching hospital serving over 800,000 people in south western Sydney. Trauma patients who underwent massive transfusion after introduction of the MTP (February 2006-December 2009) were compared to trauma patients who received massive transfusion during a time period before the introduction of the MTP (January 2002-January 2006). Massive transfusion was defined as having received ten or more units of PRBC within 24 hours of admission and the first blood product within six hours after admission.

Massive transfusion protocol
After a series of face-to-face meetings with specialists in trauma surgery, intensive care, anesthesiology, hematology and the blood bank, a MTP was established aiming at a more standardized approach in case of massive blood loss en need for transfusion. The MTP became active on February 1, 2006. The MTP could be activated by a specialist doctor or registrar calling the blood bank to state that the MTP was activated. Also, noting the administration of 10 units of PRBC to a single patient within 24 hours, or 5 units of PRBC within 3 hours, blood bank staff could activate the MTP if not otherwise advised. The MTP provided for empirical administration of FFP and PLTs (one pooled bag consists of four single donor platelet units) after the first 6 units of PRBC. Criteria for the use of rFVIIa were embedded in the MTP. A diagram of the complete MTP used in Liverpool Hospital is shown in Figure 1.
Figure 1. Massive Transfusion Protocol (Reproduced with permission of the Department of Trauma Services, Liverpool Hospital)

Guidelines for Massive Blood Transfusion

Definition: Replacement of the blood volume within 24 hours, i.e. 10 units of red cells, or replacement of 50% of blood volume within 3 hours (i.e. 5 units).

Activation of protocol:
1. By medical specialist or registrar calling Blood Bank on 85020 and stating "I am activating the massive blood transfusion protocol (MTP)."
2. By blood bank staff after 10 units of red cells are issued to a patient within 24 hours, or 5 units within 3 hours.

Collect blood:
- Urgent group and crossmatch
- Urgent baseline FBC
- Urgent baseline PT, aPTT, thrombin time, fibrinogen, D-dimers.

Avoid hypothermia:
- Use an appropriate blood warmer
- Keep the patient warm using external warming devices as appropriate
- Maintain a warm environment

Avoid hemodilution
- 6 units of red cells will be released
- Use freshest blood available
- Crossmatched blood if available (takes 40 minutes), otherwise uncrossmatched group O blood (takes 5 minutes; reaction risk 0.5%). After 6 units of group O blood are transfused, group O will continue to be issued.
- The use of microaggregate filters is not advised
- Give further red cells to maintain a Hb > 80 g/L (HCT > 25%)

Avoid coagulopathy, if bleeding continues, for each 6 units of red cells give:
- 4 units of FFP empirically (takes 15 minutes)
- 1 unit of pooled platelets empirically (any group is acceptable)

Repeat above hematology blood tests after transfusion of 6 units of red cells or each batch of coagulation factors:
- Give a further 4 units of FFP if PT/aPTT are > 1.5 x mid-normal (i.e. aPTT > 45 s)
- Give 10 units of cryoprecipitate if fibrinogen < 1 g/l
- Give 10 ml 10% calciumchloride IV if these clotting factors are given
- Give at least 1 unit of pooled platelets if platelet count is < 75*10⁹ / l

Monitor acid-base state for acidosis
Guidelines for Massive Blood Transfusion

Clinical monitoring:
- Clinical signs of coagulopathy may require further empirical blood product replacement before test results are available
- Use Blood Product Tally Sheet to record products given and timing of blood tests

Criteria for the use of recombinant Factor VIIa (rVIIa):
- Bleeding continues despite the above conventional therapy and
- All attempts to control bleeding by surgery or embolization have been taken, and
- In general: at least 10 units of red cells, 2 pooled platelets, 10 FFP and 10 units of cryoprecipitate have been given and
- The specialist has consulted the hematologist on call and they agree that the coagulopathy cannot be otherwise corrected.

The dose rVIIa (Novoseven) is 90 microgram/kg, but will be rounded to the nearest vial size (1.2 mg; none should be wasted). Vials are kept in the blood bank and will be issued on hematologists approval

Other measures to consider:
- Protamine sulphate as an antidote to standard unfractioned heparin if there is heparin activity.
- Vitamin K and prothrombin complex concentrate as antidotes to warfarin.
- The use of anti-fibrinolytic agents (tranexamic acid, aprotinin) if there is evidence of excessive fibrinolysis.
- The use of desmopressin (0.3 microgram/kg in 50 ml over 30 minutes) in patients with platelet dysfunction.

Data collection
Trauma patients that had a massive transfusion were identified through the Liverpool Hospital trauma registry and the blood bank registry. Clinical, laboratory and outcome parameters were extracted as well as time-interval and transfusion data by using the mentioned registries, individual patients notes and the electronic patients files. Infection was defined as an established clinical or culture positive diagnosis of infection. Abdominal compartment syndrome (ACS) was defined as a sustained intra-abdominal pressure above 20 mmHg associated with new organ dysfunction or organ failure.16 Multiple organ dysfunction syndrome (MODS) was defined as dysfunction or failure of three or more organs.17 Interval time was
measured from time point of admission (arrival in the Emergency Department (ED)) to the time point of administration of the first blood product. Data sets were checked for completeness before statistical analysis.

**Statistical analysis**
Data are presented as mean ± SD or as median plus range. For normally distributed data the Student’s t-test was used to compare groups. Comparisons for categorical data were performed using $\chi^2$ analysis. In case of skewed distribution of data, the Mann-Whitney U test was used. (SPSS 16, Chicago, IL). Statistical significance was set at P values <0.05.
Results

Study Groups
During the period of January 1 2002 until December 31 2009, a total of 20,725 patients were admitted to the trauma service. Of those patients, 8401 were categorized as major trauma patients. A total of 97 patients met our study inclusion criteria for massive transfusion (1.15%). In the time period before introduction of the MTP, 52 patients were identified (preMTP group). In the time period after introduction of the MTP, 45 patients were identified (MTP group).

Patient group characteristics
Both groups were comparable regarding age, gender, mechanism of injury, injury severity score, systolic blood pressure, pulse rate and temperature upon emergency department arrival (Table 1). Upon hospital admission, there were no differences between groups regarding pH, Hb and platelet count, and the administered volume ofprehospital fluids.

Table 1. Characteristics upon admission of trauma patients that required massive transfusion before and after the introduction of a massive transfusion protocol

<table>
<thead>
<tr>
<th></th>
<th>preMTP (n=52)</th>
<th>MTP (n=45)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>39 ± 18</td>
<td>43 ± 20</td>
<td>0.28</td>
</tr>
<tr>
<td>Male (%)</td>
<td>82.7</td>
<td>75.6</td>
<td>0.75</td>
</tr>
<tr>
<td>Blunt (%)</td>
<td>86.5</td>
<td>77.8</td>
<td>0.37</td>
</tr>
<tr>
<td>ISS</td>
<td>42.3 ± 15.3</td>
<td>38.7 ± 15.8</td>
<td>0.25</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>106 (0-175)</td>
<td>88 (0-175)</td>
<td>0.07</td>
</tr>
<tr>
<td>Pulse (beats per minute)</td>
<td>114 (72-177)</td>
<td>122 (0-180)</td>
<td>0.48</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>35.7 ± 1.2</td>
<td>35.5 ± 1.2</td>
<td>0.38</td>
</tr>
<tr>
<td>pH</td>
<td>7.14 ± 0.17</td>
<td>7.15 ± 0.17</td>
<td>0.63</td>
</tr>
<tr>
<td>Hb (g/L)</td>
<td>113 ± 24</td>
<td>112 ± 24</td>
<td>0.88</td>
</tr>
<tr>
<td>Platelet count (x10⁹/L)</td>
<td>186 (24-434)</td>
<td>219 (45-452)</td>
<td>0.24</td>
</tr>
<tr>
<td>Pre-hospital fluid volume (mL)</td>
<td>450 (0-4000)</td>
<td>300 (0-5700)</td>
<td>0.85</td>
</tr>
</tbody>
</table>

PreMTP: before massive transfusion protocol; MTP: after massive transfusion protocol. ISS: injury severity score; SBP: systolic blood pressure; Hb: hemoglobin level.
Outcomes and complications
Mortality at 24 hours after admission did not differ between the preMTP group and MTP group: 30.8% versus 31.1% (P=0.91). Mortality until hospital discharge was not different between groups (38.5% versus 44%; P=0.55; Table 2). No differences were found regarding the number of ICU days, ventilator days and hospital days. Also, the incidence of abdominal compartment syndrome and MODS between groups was similar. However, the incidence of infections was significantly lower in the MTP group when compared to the preMTP group (28.9% versus 51.9%; P=0.02; Table 2).

Table 2. Outcomes and complications of trauma patients that required massive transfusion before and after the introduction of a massive transfusion protocol

<table>
<thead>
<tr>
<th></th>
<th>preMTP (n=52)</th>
<th>MTP (n=45)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality within 24 h</td>
<td>30.8% (16)</td>
<td>31.1% (14)</td>
<td>0.91</td>
</tr>
<tr>
<td>Mortality until HDC</td>
<td>38.5% (20)</td>
<td>44% (20)</td>
<td>0.55</td>
</tr>
<tr>
<td>Ventilator days</td>
<td>3 (0-221)</td>
<td>3 (0-91)</td>
<td>0.73</td>
</tr>
<tr>
<td>ICU days</td>
<td>6 (0-233)</td>
<td>6 (0-91)</td>
<td>0.96</td>
</tr>
<tr>
<td>Hospital days</td>
<td>18 (0-626)</td>
<td>17 (0-323)</td>
<td>0.73</td>
</tr>
<tr>
<td>ACS</td>
<td>3.8% (2)</td>
<td>2.2% (1)</td>
<td>0.65</td>
</tr>
<tr>
<td>MODS</td>
<td>5.8% (3)</td>
<td>6.7% (3)</td>
<td>0.86</td>
</tr>
<tr>
<td>Infections</td>
<td>51.9% (27)</td>
<td>28.9% (13)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

PreMTP: before massive transfusion protocol; MTP: after massive transfusion protocol. HDC hospital discharge, ACS: abdominal compartment syndrome, MODS: multiple organ dysfunction syndrome

Use of blood products and administration of rFVIIa
The number of blood products that were administered within the first 24 hours and the total number of blood products used in the MTP-group did not differ from the amounts administered in the preMTP group (Table 3). There was no difference between the preMTP group and the MTP group regarding the administration of rFVIIa: respectively 25% vs. 28.9% (P=0.67; Table 3).
Table 3. Number of administered units of blood products at 24 hours to trauma patients that required massive transfusion after admission and during the total stay, before and after the introduction of a massive transfusion protocol

<table>
<thead>
<tr>
<th></th>
<th>preMTP (n=52)</th>
<th>MTP(n=45)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within 24 hours after hospital admission</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRBC</td>
<td>22 (10-105)</td>
<td>17 (10-48)</td>
<td>0.29</td>
</tr>
<tr>
<td>FFP</td>
<td>11 (4-52)</td>
<td>11 (3-34)</td>
<td>0.47</td>
</tr>
<tr>
<td>PLTs</td>
<td>8 (0-72)</td>
<td>12 (0-28)</td>
<td>0.21</td>
</tr>
<tr>
<td><strong>Total number of transfused products</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRBC</td>
<td>24 (10-255)</td>
<td>20 (10-65)</td>
<td>0.65</td>
</tr>
<tr>
<td>FFP</td>
<td>12 (4-105)</td>
<td>12 (3-63)</td>
<td>0.38</td>
</tr>
<tr>
<td>PLTs</td>
<td>8 (0-108)</td>
<td>12 (0-60)</td>
<td>0.26</td>
</tr>
<tr>
<td>rFVIIa</td>
<td>25% (13)</td>
<td>28.9% (13)</td>
<td>0.67</td>
</tr>
</tbody>
</table>

PreMTP: before massive transfusion protocol; MTP: after massive transfusion protocol. PRBC: packed red blood cells; FFP: fresh frozen plasma; PLTs: platelets, unit composed of 4 single donor units.

**Time interval**

The time intervals between admission and administration of the first blood product did not change following introduction of the MTP (Table 4).

Table 4. Time interval between emergency department arrival and administration of the first blood product in trauma patients that required massive transfusion, before and after the introduction of a massive transfusion protocol.

<table>
<thead>
<tr>
<th></th>
<th>preMTP (n=52)</th>
<th>MTP(n=45)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time interval (min)</strong></td>
<td>16 (2-333)</td>
<td>19 (1-218)</td>
<td>0.82</td>
</tr>
</tbody>
</table>

PreMTP: time period before massive transfusion protocol; MTP: massive transfusion protocol. Median with range.
Discussion

Massive transfusion is a life-saving element of the management of exsanguinating trauma patients.\textsuperscript{18} Massive transfusion protocols may facilitate the process of massive transfusion in trauma but scientific reports on the effects of MTP on, for instance survival and blood product usage do show contrasting results.

Survival

In our study, introduction of a MTP did not improve survival in massively transfused trauma patients. In a before-and-after study, Dente et al. found markedly improved survival at 24 hours after implementation of a MTP.\textsuperscript{10} However, in contrast with our MTP, the MTP implemented in the author’s institution was designed to achieve PRBC:FFP:PLTs ratio of 1:1:1 quickly by making use of routinely stored thawed plasma (6 units). Also, a designated ‘runner’ was used to continuously deliver packages of blood products to the patient area after pick-up at the blood bank. In another before-and-after study, O’Keeffe et al.\textsuperscript{13} found no difference in mortality after implementing a MTP using predefined transfusion packages (with 2 units of thawed plasma in the initial package). Also, Dirks et al.\textsuperscript{19} found similar results: no effect on mortality after introduction of a MTP that had increased blood product ratio’s and delivery times. As our MTP was instituted in 2006, it was not designed to aim at PRBC:FFP:PLTs-ratio of 1:1:1.\textsuperscript{20} Also, already thawed plasma was not available at our institution and our MTP did not provide for designated personnel to run to and from the blood bank. Since the early administration (simultaneously with the initial units of PRBC) of sufficient coagulation factors (FFP) may be of essence in massive transfusion,\textsuperscript{11,21} this may have been of influence on our results. More recent insights regarding the importance of timely, and thus early administration of sufficient FFP and platelets in addition to PRBC transfusion has allowed for refinement of MTP’s. This has resulted in the development of Trauma Exsanguination Protocols (TEP) that are characterized by extensive, proactive involvement of blood banks providing for rapid availability and delivery of blood products.\textsuperscript{12,22} For this purpose, thawed FFP is readily available in some (large) trauma centers.\textsuperscript{10,11,13} It may not be feasible and/or cost-effective for trauma centers with less exposure to exsanguinating trauma cases to keep thawed plasma and blood bank personnel at hand according to such protocols.
**Compliance**
Also, compliance to MTP’s can be problematic because of the rarity and the frequently hectic circumstances of the event of resuscitating an exsanguinating trauma patient. Cotton et al. demonstrated that only 27% of all TEP activations had full compliance during a performance improvement investigation but during this investigation, compliance could only be improved up to a maximum of 50%. Moreover, full compliance appeared to be an independent predictor of survival in this study. As there is a gap between administrative implementation of the MTP’s and the actual usage, it is advised that the evaluations of the effect of MTP’s should carefully take into account for the degree of compliance. Also, they found that 2.9% of trauma admissions triggered TEP during a two-year study period. Of the 8401 major trauma patients admitted to Liverpool Hospital during our eight-year study period, only 1.15% needed massive transfusion. The retrospective design of our study, which may be associated with an information bias, did not allow us to evaluate adherence to our MTP. But non-compliance to the protocol need to taken into account when interpreting our findings. Nevertheless, it will be challenging to improve performance by increasing protocol compliance when trauma teams are exposed to less than only one case a month. Adherence to a MTP might be more difficult in centers with less exposure to exsanguinating trauma and/or less blood bank resources.

**Amounts of blood products**
After the introduction of the MTP, no differences were found regarding the amounts of blood product used in our study. This is in contrast to the study of O’Keeffe et al. who found a significant decrease in PRBC, FFP and PLTs. Our MTP was not intended to reach PRBC:FFP:PLTs-ratio of 1:1:1 during massive transfusion. So, this could explain our findings since a possible beneficial effect of higher blood product ratios on outcome and blood product usage was noted in other studies. In contrast, Riskin et al. showed, in a before and after study, that introduction of a MTP did improve outcome but without changes in blood product usage. The improvement was attributed to the earlier (and expeditious) administration of PRBC, FFP and PLTs after the introduction of the protocol. In contrast, Scalea et al. found that early and aggressive use of FFP in trauma patients did not improve survival in a civilian setting. Because of the retrospective nature of our study, we were not able to retrieve data on the actual timing of the administration of blood products as FFP and PLTs in addition to PRBC. According to our MTP, FFP should be given to patients in ongoing bleeding only after administration of the first 6 units of PRBC. Also, already thawed FFP, as described in other MTP’s was not available on demand in our hospital. So, it
is possible that patients may not have received sufficient number of FFP in a timely fashion while transfusing PRBC. The time until administration of the first blood product was not reduced after the introduction of the MTP. Riskin et al.\textsuperscript{11} showed that introduction of a MTP reduced mean times to administration of the first unit of the PRBC, FFP and PLTs.

**Recombinant factor VIIa**
Recombinant factor VIIa (Novoseven®, NovoNordisk, Denmark) was introduced in Liverpool Hospital for trauma patients in February 2003 as a 'last resort' for the treatment of coagulopathy.\textsuperscript{26} In our study, no differences were found regarding the use of rFVIIa after the introduction of the MTP. Apparently, although the use of rFVIIa was more defined in the MTP, the clinical need for administration in massively transfused trauma patients did not decrease. Indirectly, introduction of the MTP may not have led to a decrease of cases with sustained bleeding due to coagulopathy.

**Hospital stay and complications**
We did not find any significant changes in ventilator days, ICU days or total days of stay. Cotton et al. did find a significant decrease in ventilator days after implementation of a MTP.\textsuperscript{14} Moreover, they found a reduction in ACS and MODS that was accompanied by a significant decrease in blood product usage after the introduction of a MTP. Our findings of a significant decrease in the number of infections after introduction of the MTP is consistent with the results of Cotton.\textsuperscript{14} However, since we found no other differences between groups, our finding can not be associated with the introduction of the MTP. Other factors of trauma care such as ICU care that have improved over the years may be accountable.

**Limitations and future directions**
As shown, our study has two limitations. Firstly, it comprises a single center, observational study with limited power. However, it may reflect common practice at similar civilian trauma centers since the incidence of massive transfusion in trauma is low. The primary goal of our study was to evaluate the possible effect on outcome and blood product usage following introduction of a MTP. The retrospective nature of our study did not allow for data collection of specific parameters such as the exact timing of the administration of all blood products. Due to the hectic circumstances of resuscitation, probably, those parameters can only be scored during real time monitoring in prospective study set-ups. Secondly, our protocol was introduced in 2006, just before the trauma community came to some new insights regarding
massive transfusion and hemostatic resuscitation.\textsuperscript{7,8,20} So, we aim at improvement by updating the MTP (in progress) together with prospective protocol compliance monitoring. In general, tools to predict massive transfusion in trauma need to be evaluated to rapidly identify patients that may need massive transfusion while awaiting results of prospective research on blood component transfusion strategies.\textsuperscript{27} Next to this, since exsanguination in trauma is a rare event, even in busy trauma centers, alternative and/or adjuvant treatment options during massive transfusion should be investigated that may be easier and/or more efficiently to apply. In an observational study, Schöchl \textit{et al.}\textsuperscript{28} reported a favorable survival rate while using mainly fibrinogen concentrate and prothrombin complex concentrate instead of FFP in hemorrhaging trauma patients. When prospectively proven to be of benefit, in this way, massive transfusion may become less dependent of instant blood product (thawed FFP, PLTs) availability, blood bank resources (including personnel) and demanding multidisciplinary, logistics and procedures that need to be followed only once in a while.

\textbf{Conclusions}

Introduction of a MTP in our level 1 civilian trauma center did not affect survival, blood product usage or the incidence of complications. Despite contrasting data on the effects of MTP in literature, we are updating the MTP to the latest insights. However, since treatment of exsanguinating hemorrhage is complex and exposure within civilian trauma centers is limited, compliance to any MTP, and thus effectiveness, will be challenging. Opportunities for performance improvement as well as other options to facilitate massive transfusion and/or prevent coagulopathy in trauma need to be investigated while awaiting the results of prospective research on blood component transfusion strategies.
References


