ORIGINAL ARTICLE

Usage of Blood Products in Multiple-Casualty Incidents

The Experience of a Level I Trauma Center in Israel

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Objective: To predict how much blood will be needed based on the number of injured patients arriving after a multiple-casualty incident.

Design: A retrospective study evaluating data collected in 18 consecutive terrorist attacks in the city of Tel Aviv between January 1997 and February 2005.

Setting: A large, urban trauma center.

Patients: A total of 986 patients in 18 events.

Main Outcome Measures: Number of packed red blood cell (PRBC) units transfused per patient.

Results: A total of 332 U of PRBCs were transfused. Half of the PRBC units were administered as massive transfusions to 4.7% of the patients. The number of PRBC units transfused per patient index (PPI) was related to incident size (mean [SD], 0.70 [1.60] to 1.50 [1.60]). The most frequent major blood group transfused was type O (50%). Half of the units of PRBCs were supplied during the first 2 hours.

Conclusions: One unit of blood per evacuated victim is sufficient in a small multiple-casualty incident and 2 U is sufficient in a large multiple-casualty incident. Half of the PRBC units should be blood group O.

Arch Surg. 2008;143(10):983-989

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MULTIPLE-CASUALTY INCIDENTS (MCIs) as a consequence of terrorist attacks have become frequent in the world in recent years. These attacks, mostly committed by suicide bombers, pose a great challenge to the daily routine of already busy trauma centers. The special injury patterns in terrorist bombing attacks have been described previously.[1] The diagnostic, therapeutic, and administrative principles in the management of these incidents have also been previously detailed in the literature. However, the issues of blood utilization and blood bank preparedness in the setting of MCIs have not been explored, and thus guidelines regarding these aspects of MCI management have not been established.

See Invited Critique at end of article

Since blood transfusions are relatively common in trauma victims, it would be expected that MCIs are associated with a sudden, unexpected flood of orders for blood products, which poses a great burden on blood bank capabilities. Because very little data on the actual utilization and timing of blood products in the setting of MCIs are available, the objective of the current study was to describe the pattern of blood administration during MCIs. In addition, general recommendations for blood bank operations under MCI conditions were determined.

Our study describes the experience of the Tel Aviv Sourasky Medical Center (TASMC) during 18 urban MCIs between 1997 and 2005. The data presented depict the ordering and transfusion of blood and blood components in relation to blood groups and timing of transfusion, analyzed by type and size of MCI. The purpose of this study is to predict how much blood will be needed based on the number of injured patients arriving after an MCI.

METHODS

MULTIPLE-CASUALTY INCIDENTS

Multiple-casualty incidents resulting from terrorist attacks that occurred in the vicinity of Tel Aviv between 1997 and 2005 were reviewed. An MCI was defined as any incident leading to the evacuation of more than 10 liv-

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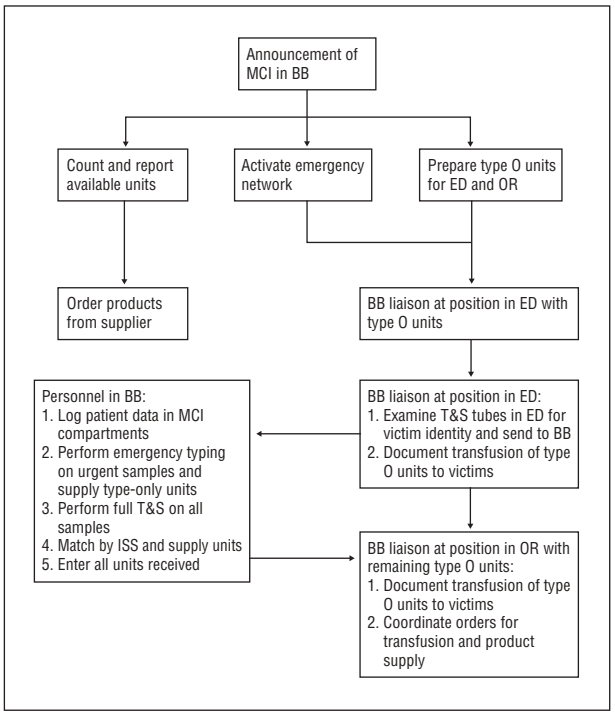

Figure. Blood bank standard operating protocol during a multiple-casualty incident (MCI). BB indicates blood bank; ED, emergency department; ISS, injury severity; OR, operating room; and T&S, type and screen.

ing victims to the Yitzhak Rabin Trauma Division of TASMC.[2] Some patients were evacuated to other level I and level II hospitals and are not included in this report. The destination of patients was determined by the emergency medical teams on the field. The MCIs were subgrouped according to 2 factors: (1) size, defined by the number of injured, evacuated, and admitted patients, respectively; and (2) type of scene (ie, confined vs open space).

Patient data were retrospectively collected from 2 sources. The computerized MCI database for the emergency department (ED), which registered each patient admitted to the ED, enabled us to retrieve patients' medical charts and their review. Other clinical data were retrieved from the hospital trauma registry. Collected data included analysis of the scene itself, mechanism of attack, number of injured and evacuated patients, and the type and severity of injuries.

BLOOD BANK MCI PROTOCOL

The blood bank has a standard operating protocol by which it abides whenever a notification of an MCI is received. The standard operating protocol relates to recruiting and positioning of personnel, reporting on existing supplies and ordering required inventory, shifting of work priorities during the event, handling victim samples (including a designated "compartment" in the computer system), and issuing of blood products. The **Figure** depicts the flow of events at the blood bank that starts immediately after notification of the occurrence of an MCI. Application of the complete protocol occurs when a large number of casualties are expected to arrive at TASMC. Recruitment of additional personnel and ordering additional blood products from the supplier all depend on the reported size of the MCI, the time of day, and the current packed red blood cell (PRBC) and component inventory at the blood bank.

Blood bank data on MCIs occurring since 1997 were retrieved from the computer. A detailed record review was performed on all data between 1997and 2001 by date and time of MCI, as MCI victim data were included among routine records. Because the system was upgraded in 2001 and the data on MCIs were compartmentalized, patient follow-up and merging of all blood bank data specifically on MCI victims is possible. The current system allows gathering data on MCI patients who receive an arbitrary unique patient number on admission and later when they have been positively identified, their known name is matched to a permanent patient ID number. This gives a complete set of data as well as ensuring patient safety.

All analyses of blood bank data used the complete data on 18 MCIs between 1997 and 2005. Details on sample type and screen (T&S), number of blood products transfused, and the timing of transfusion for each victim were retrieved.

DATA PROCESSING AND STATISTICAL ANALYSIS

Data were collected using Microsoft Excel 2004 (Microsoft Corporation, Redmond, Washington) and processed by SAS version 9.1 for Windows (SAS Institute, Cary, North Carolina), and they are presented as mean (standard deviation) or percentage, as appropriate. The Mann-Whitney nonparametric test was used for comparison between MCI categories regarding all parameters. Statistical significance was stated for P values $<.05$.

Two main indices were defined and calculated in this study: (1) the ratio between admitted and evacuated patients per incident and (2) the ratio of PBRC units transfused per hospitalized (admitted) patient index or PPI.

RESULTS

MCI CHARACTERISTICS

Complete data were available on 18 of 19 MCIs that occurred between 1997 and 2005 in the Tel Aviv area, all of which were caused by terrorist attacks. A total of 986 individuals were injured in 18 events; of these MCI victims, 498 (50.5%) were evacuated to TASMC; of those, 251 were admitted (50.4%). Victims not evacuated to TASMC were sent to neighboring level I and level II hospitals situated within a 30-km radius of TASMC. All calculated data refer only to patients who were evacuated to TASMC.

The mean number of evacuated and admitted patients per incident was 27.6 (17.0) (range, 3.0-64.0) and 13.9 (9.8) (range, 3.0-38.0), respectively. The mean evacuation to admission ratio was 0.56 (0.24) (range, 0.2-1.0).

Sixteen incidents were a result of suicide bombing attacks (SBAs). Of the total incidents, 9 of the SBAs (56.3%) occurred in confined spaces and 7 in open spaces (43.7%), generating 179 and 53 admissions, respectively. The remaining 2 were gunshot attacks producing 19 admissions. The evacuation to admission ratio for closed space, open space, and gunshot injuries were 60%, 50%, and 40%, respectively.

PATIENT AND INJURY CHARACTERISTICS

The injury severity score (ISS) of admitted patients was mild (ISS 1-8) in 61.5%, intermediate (ISS 9-15) in 17.5%,

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Table 1. Blood Type Testing, ISS, and Transfusion of PRBC Units According to Size of MCI

	Size of MCI			
	<25	≥25		
	No. of Patients Admitted (n = 15)[a]	No. of Patients Admitted (n = 3)[a]	Total No. of Patients Admitted (N = 18)[a]	*P* Value
Samples sent for T&S, No.	144	862	230	<.001
Mean (SD)	9.6 (5.8)	8.6 (25.7)	12.7 (12.6)	
PRBC units transfused, No. (%)	147 (44.3)	185 (55.7)	332	<.001
Mean (SD)	9.8 (15.0)	61.6 (77.0)	18.4 (35.8)	
Untested (blood group O±) PRBC units transfused, No. (%)	23 (15.7)	62 (33.5)	85 (25.6)	.04
Mean (SD)	1.5 (4.4)	20.6 (26.1)	5.3 (12.9)	
Mean (SD) ISS	11.8 (7.3)	12.6 (4.1)	12.0 (6.8)	.80

Abbreviations: ISS, injury severity score; MCI, multiple-casualty incident; PRBC, packed red blood cell; T&S, type and screen.
[a] Number of MCIs.

and severe (ISS ≥16) in 20.0% of patients. The mean ISS per incident was 12.0 (6.8) (range, 4-33). The mean ISS was not statistically different when comparing the size of events (*P*=.80; **Table 1**). The mean number of evacuated victims (per MCI) from confined-space scenes was significantly higher than from open-space scenes (mean, 36.4 [17.0] vs 20.1 [15.0] patients per incident, respectively; *P*=.04). The mean number of admitted patients per MCI from confined-space scenes was also significantly higher than from open-space scenes (20.3 [9.9] vs 7.5 [4.8], respectively; *P*=.001).

Patients were admitted or released according to the severity of injury; any patient needing a transfusion was admitted. Twelve of 251 patients (4.7%) met the criteria for massive transfusion, defined as more than 10 PRBC units within 24 hours after injury. All patients requiring a massive transfusion had been injured in an SBA in which the number of evacuated patients exceeded 25. The female to male ratio was 1:1. All were admitted to the intensive care unit (100%) and had a mean ISS of 15.0 [18.0] (range, 4-66). Eleven were urgently operated on (91.7%) on arrival. Of the 12 patients requiring massive transfusion, 3 died (25%). The massive transfusion group received 180 (54%) of the 332 PRBC units transfused in MCI patients.

BLOOD SAMPLES AND PRBC TRANSFUSION DURING MCIs

Table 1 depicts the data on testing and transfusion of PRBC units during all 18 MCIs. A total of 230 blood samples were sent for T&S with 2 tubes of blood samples per patient in accordance with the medical center guidelines that mandate that no transfusion be given before 2 separate samples are typed for each patient to ensure patient identity and safety of transfusion.

A total of 332 PRBC units were transfused, 85 of which were untested type O (25.6%) (Rh-positive and Rh-negative) units. The mean number of untested units of blood transfused was 5.3 (12.9) U (range, 0-50 U) per incident. Samples sent for T&S, total number of PRBC units transfused, and untested type O units of blood transfused were compared by size of MCI (Table 1). The means were significantly different, implying that the workload on the blood bank is significantly increased in an MCI with more than 25 admissions. With respect to transfusion of PRBC units, there was a 6-fold increase in the number of units transfused per MCI when more than 25 victims were admitted.

Since untested type O PRBC units are usually transfused when time is of the essence and conditions are critical, we looked at the number and fraction of type O units that were given during MCIs. A significant difference was demonstrated between smaller and larger MCIs (Table 1), suggesting that the number of victims treated simultaneously, if not the severity of the wounds, leads to transfusion of blood before testing.

NUMBER OF PRBC UNITS TRANSFUSED PER PATIENT

To try to predict the number of PRBC units transfused after an SBA, the number of PRBC units tranfused per admitted patient ratio (PPI) was calculated. The PPI describes the average number of PRBC units that were given to an admitted patient per incident. The average PPI was 1.36 for confined space, 1.66 for open space, and 0.05 for gunshot injury. The average PPI for all SBA was 1.20 (1.60). A statistically significant difference was found between larger MCIs (≥25 evacuated patients) and smaller MCIs (<25 evacuated patients) (**Table 2**). The PPI was not influenced by the place where the SBA took place (open or confined space).

TIMING OF TRANSFUSION OF PRBC UNITS AND BLOOD COMPONENTS

The timing of transfused PRBC units and blood components is presented in **Table 3**. More than half of 332 PRBC units (53.3%) were given during the first 2 hours after admission, which is when ED triage, emergency treatment, and transfer to the operating room (OR) occur. This is also the time of intense pressure and the greatest workload on blood bank personnel. The mean demand for PRBC units was 4.6 (10.6) U in the first hour, and 5.6 (10.4) U in the next hour. Table 3 also depicts data on

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Table 2. Ratio of Number of Units of PRBCs to Patient According to Size and Type of Incident

	Type of Scene		No. of Evacuated Casualties	
	Confined Space	Open Space	<25	≥25
PPI[a]	0.9 (1.2)	1.5 (2.0)	0.7 (1.6)	1.5 (1.6)
P value	NS		.04	

Abbreviations: NS, nonsignificant; PPI, ratio of packed red blood cell units transfused per hospitalized (admitted) patient index; PRBCs, packed red blood cells.

[a]When PPI was calculated for evacuated patients, no difference between a small (<25) or large (≥25) number of multiple-casualty incidents was noted.

Table 3. Timing of Product Transfusion After Admission

	No. of Hours of Product Transfusion After Admission[a]		
Blood Product	0-2	>2-12	>12-48
PRBCs, U (n = 332)	53.3	22.0	24.7
FFP, U (n = 92)	19.0	63.0	18.0
Platelets (n = 72)	25.0	41.6	33.4
Cryoprecipitate (n = 148)	13.5	56.8	29.7

Abbreviations: FFP, fresh frozen plasma; PRBCs, packed red blood cells.

[a]Data are given as percentages.

transfusion of fresh frozen plasma (FFP), platelets, and cryoprecipitate.

Unlike the transfusion of PRBC units, which serves as a lifesaving or resuscitation treatment, blood components are usually an adjunct and are most often transfused 2 or more hours after the beginning of the event. Despite the lack of statistical significance (likely due to small sample size), one-half to two-thirds of plasma, platelet, and cryoprecipitate units were transfused between hours 3 and 12, when the victims are either still in the OR or were already transferred to the general care ward or intensive care unit. About one-third is transfused between 12 and 48 hours to correct dilutional or consumptive coagulopathy.

The TASMC blood bank has an inventory of 450 U of FFP daily. The total number of FFP units transfused during all MCIs was 92 (4.8 [7.3] U per incident; range, 0-23 U). The blood banks keep 30 U of platelets daily. The total number of platelet units transfused in all MCIs reached 72 U (4.0 [7.7] U per incident; range 0-24 U) and three-quarters of the units were transfused after the second hour after admission. The inventory of cryoprecipitate for our hospital is 80 U. The total number of cryoprecipitate units transfused in all incidents was 148 U (8.2 [15.7] U per incident; range, 0-50 U). No shortage of the different blood components (FFP, platelets, or cryoprecipitate) was encountered in any of the incidents.

TRANSFUSION OF PRBC UNITS BY MAJOR BLOOD GROUP

The distribution of PRBC units transfused by major blood groups is detailed in **Table 4**. Type O Rh-positive and type O Rh-negative units were given in 57.0% of PRBC transfusions. All untested type O PRBC units were transfused within the first hour following the MCI. It is noteworthy that no shortage of blood was experienced except for 1 (large) incident in which a shortage of type O Rh-negative units was temporarily anticipated but was immediately resolved by the emergency delivery of blood from the supplier.

COMMENT

The safe and timely provision of blood products is of crucial importance in the prevention and mitigation of morbidity and mortality due to traumatic injuries. In this study, the usage of blood in the treatment of civilian casualties resulting from terrorist attacks in 18 urban MCIs, both in open and closed spaces, was analyzed retrospectively and assessed the effect of transfusion therapy on blood banking services and the treatment of victims in the setting of an MCI.

The data show that patient injuries were similar, regardless of MCI location or size. The mean ISS per incident was 12 (6.8) (range, 4-33). The mean ISS was not statistically different when comparing the size of events, $P = .80$ (Table 1). Our assumption that bigger incidents might be associated with a higher ISS could not be established according to our data. Although the average ISS was higher in the large MCI group, it did not reach statistical significance. That might be explained by the high variability of injuries, which is much unexpected in these situations as reflected by a high standard deviation. It is unclear if the increasing amount of blood used per patient when the MCI is a larger event is owing to more serious injury not captured by ISS methodology, to longer time until definitive operation and control of blood loss, or to generalized confusion and inappropriate triage that leads to too many severely injured patients being sent to the same trauma center. The emergency medical teams in the field determined the evacuation destination of patients. Since the TASMC is the only level I trauma center in Tel Aviv, most of the severely injured patients were evacuated to our hospital. Although this might form a sample bias, we believe that it represents a true picture of events for which a level I trauma center should be prepared.

No shortage of blood was experienced and the standard operating protocol employed at TASMC has served its purpose of supplying blood in a safe and timely fashion. Use of the standard operating protocol allowed for a smooth flow of work at different sites including the blood bank, ED, and OR. This implies that if a facility has a sufficient supply of blood products and applies a protocol similar to the TASMC protocol, shortages should be rare in MCIs.

At the time the blood bank receives MCI notification, 3 types of activities occur simultaneously: (1) a count of existing free PRBC units inventory and ordering from the supplier; (2) activation of the recruitment network (ie, notifying the blood bank director and the designated liaison[s] who decide how many people should be brought in from home based on the reported size of the

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Table 4. Distribution of PRBC Units Transfused in All MCIs by Major Blood Groups

	Blood Group								All Blood Groups
	A+	A–	B+	B–	*AB*+	AB–	O+	O–	
Total No. of PRBC units in all MCIs, No. (%)	93 (28.0)	0	36 (10.8)	8 (2.4)	6 (1.8)	0	137 (41.3)	52 (15.7)	**332** (**100**)
Mean (SD) No. of PRBC units per MCI (range)	5.2 (20) (0-55)	0	2.0 (4.1) (0-12)	0.4 (1.8) (0-8)	0.3 (1.3) (0-6)	0	7.6 (16.6) (0-46)	2.9 (17.5) (0-39)	18.4 (35.8)
Required inventory[a]	60	10	40	10	20	5	60	10	**215**
Frequency in Israeli donor population (%)[b]	38	4	16	2	6	1	30	3	**100**

Abbreviations: MCI, multiple-casualty incident; PRBC, packed red blood cell.
[a] Calculated by the size of the MCI, type of hospital, and distance from the supplier.
[b] Unpublished data from the MDA (Israeli Magen David Adom [the national blood supplier]), Central Blood Collection Center (January 2005).

MCI, time of day, and number of personnel at the blood bank at the time); and (3) preparation of type O blood units in a container to be brought by the liaison to the trauma triage room in the ED. The responsibility of the liaison in the ED is to supervise sample collection for T&S transfer samples to the blood bank, supply and record each unit of type O blood transfused into victims, and then to perform the necessary tests.

A recipient may receive blood from 1 of 3 "pathways": (1) as emergency type O immediately on arrival from the container held by the blood bank liaison in the ED; (2) as a "type and immediate spin only" after the blood type has been verified on 2 separate samples (but the screening test for unexpected antibodies has been omitted), which takes approximately 10 minutes from first blood specimen tube's arrival to blood issuance; and (3) after a full T&S has been performed, which takes approximately 45 minutes. A full T&S test and an immediate spin crossmatch (to verify a major blood group match between the patient and unit of PRBCs) is the default procedure for each sample and is routinely applied, unless otherwise specified by the ordering physician on a special form. Obviously, if a patient has been transfused by type only, a full screen is performed and the physician is notified of the result as soon as it is available. Of note, owing to our protocol of double sampling and T&S testing before transfusion of each patient, no mistransfusion has occurred in any of the MCIs.

Approximately 1 hour after the start of an MCI, admitted victims have been resuscitated and are being transferred to the OR. At this time, the liaison from the ED or a second designated liaison goes to the OR area with the remaining type O units to be dispersed as necessary. At this point, the main activity of the liaison shifts from primarily supervising correct sample collection to coordinating the demands of the surgical and anesthesiology teams within the ORs and the blood bank, along with physically delivering blood units to the different operating rooms. In most cases, the liaison(s) has completed both ED and OR tasks within 1 to 2 hours after the start of the MCI and returns to the blood bank to join the staff. The distribution of transfused PRBC units by major blood groups is detailed in Table 4. Type O Rh-positive and O Rh-negative were given in 57.0% of PRBC transfusions, whereas their combined frequency in the Israeli donor population is 33.0% (Table 4). The difference is accounted for by 85 PRBC units (25.6%) that were administered without a complete T&S testing, as shown in Table 1. Interestingly, all untested type O PRBC units were transfused within the first hour following the MCI. The transfusion of approximately 16.0% (3.0% in the Israeli population) type O Rh-negative PRBC reflects the guideline to transfuse untested Rh-negative blood only to females of reproductive age. There was a large MCI that occurred in a club where many young women were injured.

Our data show that a significant fraction of all PRBC units are transfused within the first 2 hours of an incident and that a majority are untested type O units, with significantly more used in larger MCIs. From the PPI calculated and presented in Table 2, one can use as a guideline 1 U of PRBCs per victim in small MCIs and 2 U per victim in larger incidents. Thus, trauma teams and transfusion medicine physicians can have a framework of how many units to order from the supplier immediately on notification of the event.

Despite the scarcity of data on actual transfusion in MCIs, data on supply for such victims from the Israeli Magen David Adom (the national blood supplier) show that 12% of the injured succumb at the site while many suffer mild injuries and stress. This leaves the mostly moderate and severely injured victims as candidates for blood transfusion. The number of PRBC units ordered from the supplier per civilian casualty in 2000-2002 was 6.5.[3] Thus, orders (and therefore supply) exceeded the actual demand by 3-fold.

Our article defines a new concept of PRBC units per patient ratio. Taking into account factors such as the uncertainty of the arrival of additional victims to the ED, the risk of second-hit explosions, and the chaotic atmosphere that might exist between both ED and emergency medical service teams, this index may be of practical value. It may assist both the medical manager of the incident and the blood bank in evaluating the number of PRBC units to be transfused. Multiplying a known index by the anticipated number of patients at the scene to be transferred to the ED may give a rough estimate of the number of needed transfusions. However, as reflected from the data, there is a considerable variation (range, 0-3.6; mean, 0.55 PRBC unit per evacuated patient) in this parameter among the 18 incidents described. This variation may be attributed to several factors. First, it should be made clear that aside from our hospital there are 2 additional level I trauma centers

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in a 10-mile radius that also received patients during the previously mentioned MCIs. Although there is an established policy for the emergency medical service teams regarding the regulation and distribution of patients with different levels of injuries, a certain amount of inequality seems to persistently exist, as the nearest hospital receives larger numbers of casualties sustaining more severe injuries in relatively short time periods. In addition, the injury pattern in open-space incidents differs from that observed in confined-space incidents, with the latter making up more than 50% of the SBAs described in our series.[4] Indeed, significantly more patients were eventually hospitalized after being involved in a confined-space MCI, therefore stressing their severity of injury and the anticipated need for blood transfusion. It appears from our data that the most powerful predictor of PRBC unit demand is the magnitude of the MCI, in terms of the number of evacuated casualties. Incidents from which more than 25 persons were transferred to the ED were associated with a significantly higher PPI, as well as with higher rates of admissions.

Therefore, taking into account the previously mentioned factors, the PPI may aid in providing a rough estimate of the expected demand for blood. There are several important lessons to be learned from our review. One important lesson is that the actual usage of blood is smaller than anticipated and ordered. Another lesson is that approximately 50% of the initial order of PRBC units on notification of an MCI should be type O units. These will most often be used during the first 2 hours for urgent transfusions, about half of which will be untested as shown by the current analysis. These numbers are significant for suppliers as well who may have to direct a limited supply of type O blood to a single medical center.

The amount of PRBC units transfused during the first 24 hours after admission merits further discussion. Our findings correlate with a report by Wudel et al,[5] who described patients transfused massively after blunt trauma. Farion et al[6] described the implementation of trauma care protocols in the early 1990s that resulted in increased survival of more severely injured patients while using less total numbers of units of PRBCs, but with 70% of all units of PRBCs being transfused within 24 hours of admission. In a retrospective analysis of all transfusions provided to acute trauma patients admitted to a large level I trauma center in the year 2000, Como et al[7] reported that only 62% were administered in the first day. However, many factors in these analyses may be confounding. First, none of the previously mentioned studies addressed the issue of MCIs. It may be prudent to assume an "economical" strategy in the setting of an MCI, limiting the amount of blood transfused in the first hours to those absolutely necessary, thus trying to avoid exceeding blood bank capabilities. Other modalities to limit transfusions, such as the use of a cell scavenger, might be difficult to institute since the technicians who operate them may be busy in other capacities such as working the pump machine, but these may be helpful if local resources allow their use.

Multiple-casualty incidents create a unique population of trauma patients. The fact that 5% of the patients receive more than 50% of the transfusions only amplifies the uniqueness of these patients. In addition, such events are characterized by a relative lack of personnel and technical capabilities for patient monitoring combined with missed diagnoses and the postponement of less urgent surgical interventions. Thus, scenarios in which excessive blood transfusions are administered to MCI patients are not a rarity.

Unlike PRBC transfusion that serves as a lifesaving or resuscitation treatment, blood components are usually an adjunct and are most often transfused 2 hours or more after the beginning of the event. One-half to two-thirds of plasma, platelet, and cryoprecipitate units were transfused between hours 3 and 12, when the victims are either still in the OR or already transferred to the general care ward or intensive care unit. About one-third of components are transfused between 12 and 48 hours to correct dilutional or consumptive coagulopathy. The massive transfusion protocol employed at the time of these MCIs did not include the more modern concept of early factor replacement. These old protocols would not begin factor replacement until after 6 U of PRBCs were transfused, while the modern approach is favoring a 1:1 ratio of PRBCs to FFP.

CONCLUSIONS

Most PRBCs are administered during the first 12 hours after admission. Although only 5% of the patients will require massive blood transfusions, those patients will receive 50% of the total number of units of PRBCs transfused. Blood bank operations must be coordinated with other medical teams dealing with an MCI. Timely flow of relevant data to the blood bank and application of the PPI might help initial estimates of the need for blood products.

Accepted for Publication: April 27, 2007.
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Author Contributions: Drs Soffer, Klausner, Schulman, Hareuveni, and Ben-Tal had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Soffer, Klausner, Bar-Zohar, Szold, Schulman, Halpern, and Ben-Tal. *Acquisition of data:* Soffer, Klausner, Bar-Zohar, Shimonov, Hareuveni, and Ben-Tal. *Analysis and interpretation of data:* Soffer, Klausner, Szold, Schulman, Halpern, Shimonov, Hareuveni, and Ben-Tal. *Drafting of the manuscript:* Soffer, Klausner, Bar-Zohar, Szold, Halpern, Shimonov, Hareuveni, and Ben-Tal. *Critical revision of the manuscript for important intellectual content:* Soffer, Klausner, Bar-Zohar, Szold, Schulman, and Ben-Tal. *Statistical analysis:* Soffer and Schulman. *Obtained funding:* Soffer, Klausner, and Halpern. *Administrative, technical, and material support:* Soffer, Klausner, Bar-Zohar, Szold, Schulman, Shimonov, Hareuveni, and Ben-Tal. *Study supervision:* Soffer, Klausner, Bar-Zohar, Szold, Schulman, Halpern, Shimonov, Hareuveni, and Ben-Tal.
Financial Disclosure: None reported.

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Previous Presentation: This study was presented at the 36th Annual Meeting of the Western Trauma Association; March 24, 2006; Big Sky, Montana.

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INVITED CRITIQUE

Accurate estimation of the need for blood products during MCIs is vital to providing these lifesaving resources when health care systems are under their greatest stress. In this era of terrorist activity, the most likely event will be a bombing, and thus we can learn a great deal from the experience gained in Israel where these incidents have been all too common. The article by Soffer et al provides a retrospective review of the use of PRBCs following 18 consecutive terrorist attacks in Tel Aviv between 1997 and 2005. They define a PRBC unit per admitted patient ratio index, which may be useful in planning the number of units of PRBCs to keep available for such events. More importantly, they also describe a standard operating procedure for notification and activation of the blood bank during an MCI that could be adapted for use by trauma systems throughout the world.

What's missing from this description of blood product needs, however, is the early use of coagulation factors such as FFP, platelets, and cryoprecipitate. More than 50% of the blood transfused was used by 5% of patients requiring a massive transfusion (>10 U of PRBCs within 24 hours). As acknowledged by the authors, during this study period their massive transfusion protocol did not initiate the transfusion of these factors until after 6 U of PRBCs had been transfused, and as a result patients did not receive factors until more than 2 hours after admission. Recent studies[1,2] have emphasized the need to transfuse FFP much earlier. Data from the management of combat casualties in Iraq have suggested administering a 1:1 ratio of PRBCs to FFP to those requiring a massive transfusion.[1,2] If these data are confirmed, this will have implications for blood banks to ensure the immediate availability of coagulation products in addition to PRBCs. Early administration of these products may minimize dilutional coagulopathy and ultimately reduce the number of PRBCs required. Further study in this area is clearly warranted to optimize planning for future events.

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Financial Disclosure: None reported.

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