

## Original Article

## Evaluation of massive transfusion protocol practices by type of trauma at a level I trauma center

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## ABSTRACT

**Purpose:** To evaluate massive transfusion protocol practices by trauma type at a level I trauma center.  
**Methods:** A retrospective analysis was performed on a sample of 76 trauma patients with MTP activation between March 2010 and January 2015 at a regional trauma center. Patient demographics, transfusion practices, and clinical outcomes were compared by type of trauma sustained.  
**Results:** Penetrating trauma patients who required MTP activation were significantly younger, had lower injury severity score (ISS), higher probability of survival (POS), decreased mortality, and higher Glasgow Coma scale (GCS) compared to blunt trauma patients. Overall, the mortality rate was 38.16%. The most common injury sustained among blunt trauma patients was head injury (36.21%), whereas the majority of the penetrating trauma patients sustained abdominal injuries (55.56%). Although the admission coagulation parameters and timing of coagulopathy were not significantly different between the two groups of patients, a significantly higher proportion of penetrating trauma patients received high plasma content therapy relative to blunt trauma patients ( $p < 0.01$ ).  
**Conclusion:** Despite the use of the same MTP for all injured patients requiring massive transfusion, significant differences existed between blunt trauma patients and penetrating trauma patients. These differences in transfusion characteristics and outcomes following MTP activation underscore the complexity of implementing MTPs and warrant vigilant transfusion practices to improve outcomes in trauma patients.

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## Introduction

Hemorrhage due to trauma accounts for approximately 50% of deaths within 24 h of injury.<sup>1</sup> Massive transfusion protocols (MTPs) have been enacted at hospital centers to effectively restore total blood volume in a proportion which mimics the actual blood volume lost within a span of 24 h. MTP is defined as transfusion of at least 10 packed red blood cells (PRBCs) within a 24 h period in a setting of uncontrolled hemorrhage.<sup>2</sup> In the setting of traumatic injury with massive blood loss, transfusion of blood may occur in a

short period of time. In these instances, administration of blood products in a 1:1:1 ratio aims to replete intravascular volume and prevent the onset of the triad of death consisting of coagulopathy, hypothermia and acidosis which, in turn, carries a very high mortality.<sup>3,4</sup> Implementation of MTP is crucial to resuscitation efforts, as it reduces coagulopathy and mortality in trauma patients.<sup>5,6</sup>

Despite comprehensive research demonstrating the influence of MTP in improving patient outcomes, a wide disparity exists across trauma centers in terms of MTP implementation and effectiveness.<sup>2</sup> The application of a standard MTP across all trauma patients, regardless of injury type or other patient-based characteristics, may partially explain the differences in implementation and effectiveness across trauma centers. Because the optimal ratio of transfusion of blood products still remains controversial, different transfusion practices may be warranted based on the type of trauma sustained.<sup>7,8</sup>

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As there are significant variations in the magnitude and distribution of damage to tissues, the injury patterns and responses to resuscitation are different in blunt and penetrating trauma patients.<sup>9</sup> These differences illustrate why MTP may need to differ according to injury type.

Alternatively, the current universal MTP may be appropriate for both blunt and penetrating traumas. This study adds to the limited body of research by retrospectively examining if patients admitted to a level I trauma center with a blunt or penetrating trauma and who received blood transfusions through MTP activation differed in terms of characteristics and outcomes. With the goal of improving outcomes for trauma patients following MTP activation, evaluating these differences between blunt and penetrating trauma patients provides insight into the optimal recognition and management of blood transfusions and helps inform the discussion as to whether a universal MTP across injury types is appropriate.

## Methods

Nassau University Medical Center (NUMC) is a 502 bed, Level I trauma center located in Nassau County, New York. Nassau County is included in the New York City metropolitan statistical area with a population of approximately 1.36 million. NUMC is a tertiary care and safety net institution for the region and admits 1500 to 1700 trauma patients per year. In this retrospective study, NUMC's trauma registry was used to identify all trauma patients who received blood transfusions through MTP activation between March 2010 and January 2015. The study protocol was approved by NUMC's Institutional Review Board. Patients who died before receiving blood transfusion through MTP activation and patients who were transferred from other hospitals were excluded from the study population.

There were 76 trauma patients who received blood transfusions by MTP activation. The study population consisted of 58 patients with blunt trauma and 18 patients with penetrating trauma. All of the inpatient admissions and outpatient clinic records related to the traumatic injuries were reviewed. Patient demographic data and variables such as admission vitals, mechanism of injury, injury severity score (ISS), coagulation parameters, blood products transfused, Glasgow coma scale (GCS), hospital length of stay, and disposition were collected from the trauma registry and the blood bank. The probability of survival was obtained from the trauma registry data using Trauma One (Lancet technology) software.

MTP is indicated under one of the following circumstances at NUMC: Class IV shock (>2L loss) with no imminent end,  $\geq 6$  units of RBCs issued over a 4 h period, and/or a score  $>2$  using the assessment of blood consumption (ABC) based on the following criteria: penetrating mechanism, heart rate  $\geq 120$ , systolic blood pressure  $\leq 90$ , or a positive focused assessment with sonography in trauma. Upon MTP activation, the blood bank releases 2–4 units of uncross-matched Group O, and provides RBC and plasma with platelets in order to maintain a ratio of 6:6:1 RBCs:plasma:platelets respectively. Additionally, each subsequent packet consists of this ratio along with additional products such as cryoprecipitate as needed or based on patient's coagulation profile.

Descriptive statistics were performed on all study variables for the entire sample and then stratified according to whether a patient had a blunt or penetrating trauma. Continuous variables were summarized as means  $\pm$  standard deviations. Categorical variables were summarized as frequency distributions and percentages. To examine differences between blunt trauma patients and penetrating trauma patients, Pearson's Chi squared test or Fisher's exact test was used for categorical variables while Student's *t*-test or Mann-Whitney *U* test was used for continuous variables. The two

groups were considered statistically significant on each examined variable if  $p < 0.05$ . All analyses were performed with SAS 9.4.

## Results

From March 2010 to January 2015, the NUMC trauma unit had 3848 admissions with complete data available for review. Out of these patients, 76 met this study's inclusion criteria. In the entire cohort of trauma patients with MTP activations, the average age was  $42.3 \pm 22.1$  years, with men constituting 81.58% of the population. The mean ISS was  $30.31 \pm 18.6$ . The overall mortality for MTP activations, for both injury types, was 38.16% ( $n = 29$ ). Table 1 compares demographic characteristics of the total population with those sustaining blunt and penetrating trauma. Relative to patients sustaining blunt traumas, patients sustaining penetrating trauma were significantly younger ( $27.44 \pm 8.61$  vs  $46.84 \pm 22.97$  years;  $p < 0.0001$ ), had higher GCS ( $12.77 \pm 4.53$  vs  $8.86 \pm 5.45$ ;  $p = 0.00720$ ), lower ISS ( $19.05 \pm 7.71$  vs  $33.41 \pm 16.69$ ;  $p < 0.0001$ ) and increased probability of survival ( $0.87 \pm 0.20$  vs  $0.54 \pm 0.35$ ;  $p = 0.0005$ ).

The distribution of trauma type differed by race. For instance, 52.63% ( $n = 40$ ) of the total study sample receiving MTP was White. However, White patients consisted 5.56% ( $n = 1$ ) of the penetrating trauma group and 67.24% ( $n = 39$ ) of the blunt trauma group. Conversely, 19.74% ( $n = 15$ ) of the sample population was African-American, yet, African-Americans consisted of 8.62% ( $n = 5$ ) and 55.56% ( $n = 10$ ) of the blunt trauma and penetrating trauma groups respectively. There were no statistical differences between blunt trauma and penetrating trauma patients on variables indicating admission vitals (systolic blood pressure, heart rate, respiration rate) upon emergency department arrival as well as on variables denoting base deficit and blood pH. Mortality however did statistically differ between patients sustaining blunt trauma (48.28%) and patients sustaining penetrating trauma (5.56%).

Fig. 1 illustrates the injury mechanism by trauma type. The most prominent injury mechanism among blunt trauma patients was motor vehicle crash (43.00%) followed by pedestrians struck (36.00%) and falls (16.00%). Among penetrating trauma patients, gunshot wound was the most frequent injury mechanism (61.00%) followed by stab wounds (22.00%). The specific injuries documented in relation to the type of trauma sustained are presented in Fig. 2. Head injury was the most common injury sustained in patients with blunt trauma whereas the majority of patients with penetrating trauma sustained abdominal injuries (36.21%;  $n = 21$  vs 55.56%;  $n = 10$  ( $p < 0.001$ )). Extremity injuries were seen in 18.97% ( $n = 11$ ) of blunt trauma patients in comparison to 22.22% ( $n = 4$ ) of penetrating trauma patients. Chest injuries were slightly higher in blunt trauma compared to penetrating trauma patients (18.97%;  $n = 11$  vs 11.11%;  $n = 2$ ). External injury was only observed in a single blunt trauma patient (1.72%).

The transfusion characteristics of the study sample are illustrated in Table 2. Overall, 88.89% of the patients received plasma, 77.78% received platelets, and 27.78% received cryoprecipitate. The majority of patients received a higher ratio of plasma (61.11%) relative to RBC, where higher plasma content was defined as an RBC/FFP ratio  $<2$ . The proportion of patients who received plasma and platelets did not significantly differ between blunt trauma and penetrating trauma patients (Table 2). Relative to blunt trauma patients, significantly more penetrating trauma patients received high-plasma-content therapy (66.67% vs 59.26%;  $p = 0.0020$ ). Despite this finding, the mean number of RBCs, platelets, and cryoprecipitate units transfused did not significantly differ between the blunt and penetrating trauma patients.

Table 3 illustrates the study population's admission coagulation parameters. Overall, the study sample had a mean INR (International Normalized Ratio) of  $1.47 \pm 0.92$ , PT (Prothrombin Time) of

**Table 1**  
Demographic Characteristics by type of trauma.

Variable	Total sample (n = 76)	Blunt trauma (n = 58)	Penetrating trauma (n = 18)	p value
Age (mean ± SD)	42.25 ± 22.05	46.84 ± 22.97	27.44 ± 8.61	<0.0001*
Sex [n (%)]				0.107
Female	14 (18.42)	13 (22.41)	1 (5.56)	
Male	62 (81.58)	45 (77.59)	17 (94.44)	
ISS	30.01 ± 18.60	33.41 ± 16.69	19.05 ± 7.71	<0.0001*
GCS (Mean ± SD)	9.78 ± 5.48	8.86 ± 5.45	12.77 ± 4.53	0.0072*
Race [n (%)]				<0.0001*
White	40 (52.63)	39 (67.24)	1 (5.56)	
African-American	15 (19.74)	5 (8.62)	10 (55.56)	
Hispanic	18 (23.68)	13 (22.41)	5 (27.78)	
Asian	1 (1.32)	0 (0.00)	1 (5.56)	
Other	2 (2.63)	1 (1.72)	1 (5.56)	
Hospital LOS	22.04 ± 38.72	23.41 ± 42.83	17.35 ± 19.23	0.5739
ICU LOS (Mean ± SD)	8.79 ± 10.28	9.62 ± 10.60	6.29 ± 9.06	0.2499
Probability of Survival (POS)	0.62 ± 0.35	0.54 ± 0.35	0.87 ± 0.20	0.0005*
ED SBP	108.98 ± 44.70	108.16 ± 44.16	111.61 ± 47.59	0.7773
ED RR	16.78 ± 7.37	16.04 ± 7.51	19.29 ± 6.48	0.1104
ED temperature	93.90 ± 15.02	92.69 ± 17.31	97.39 ± 1.66	0.3175
ED HR	97.35 ± 32.22	95.5 ± 34.78	103.33 ± 21.84	0.3712
pH	7.22 ± 0.15	7.21 ± 0.17	7.26 ± 0.11	0.2851
Base Deficit	8.35 ± 6.35	9.00 ± 6.63	6.45 ± 5.17	0.2772
Mortality [n (%)]	29 (38.16)	28 (48.28)	1 (5.56)	<0.0001*

Note: SD = standard deviation, LOS = length of stay, ICU = intensive care unit, ISS = injury severity score, GCS = Glasgow Coma Scale, ED RR = Emergency room respiration rate, ED SBP = Emergency room systolic blood pressure, ED HR = Emergency room heart rate, \**p* < 0.05 is considered significant.

16.14 ± 3.34 s, and PTT (Partial Thromboplastin Time) of 35.86 ± 16.83 s. The admission coagulation parameters were not significantly different between blunt and penetrating trauma patients. Similarly, no significant difference was observed between blunt trauma and penetrating trauma patients in terms of the proportion of patients that were coagulopathic within 1 h, between 1 and 2 h, and between 2 and 12 h as illustrated in Table 4. Out of the 46 patients who were coagulopathic within the first 12 h, 27 (58.69%) became coagulopathic within 1 h of admission.

## Discussion

This study evaluated the differences in massive transfusion practices by trauma type at a regional trauma center. The results illustrate that significant differences exist in transfusion practices by trauma type (i.e., blunt trauma or penetrating trauma) despite the trauma center's universal massive transfusion protocol. These

findings may assist in the development of strategic resuscitative transfusion practices that can be based on type of trauma.

As expected, baseline characteristics were significantly different between the blunt and penetrating trauma patients. The notably younger age of the penetrating trauma patients relative to blunt trauma patients may be partially due the increased prevalence of gang violence in the region which generally involves a younger population (Table 1). Our results on basic differences in characteristics are consistent with a previous study by Rowell et al.<sup>9</sup> The penetrating trauma patients had significantly higher GCS, lower ISS, and increased probability of survival compared to blunt trauma patients. These findings can be attributed to the basic differences in injury patterns that have been extensively studied. For instance, multi-cavitary bleeding as seen in blunt trauma is a much more formidable foe compared to penetrating injury where a bleeding is often localized and managed by direct control.<sup>10,11</sup>

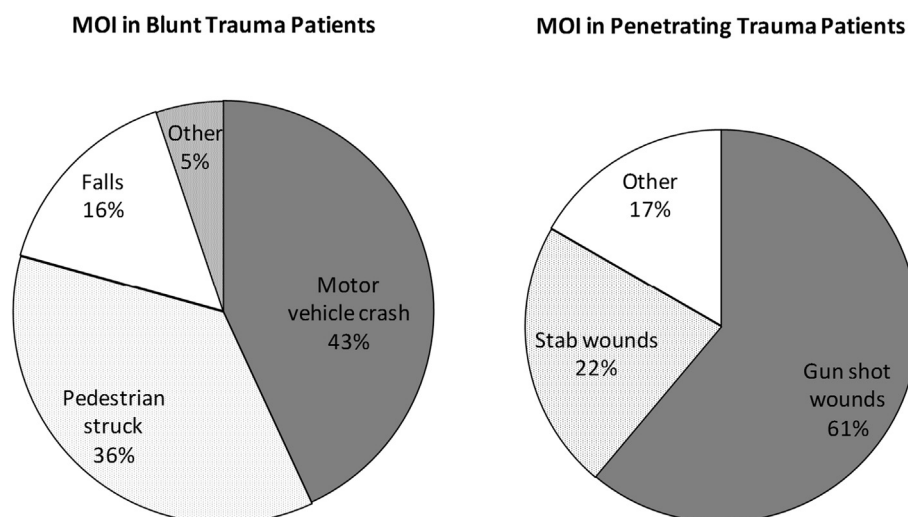


Fig. 1. Mechanism of injury by type of trauma. Pie charts illustrating the mechanism of injury by type of trauma sustained in 76 trauma patients with MTP activation.

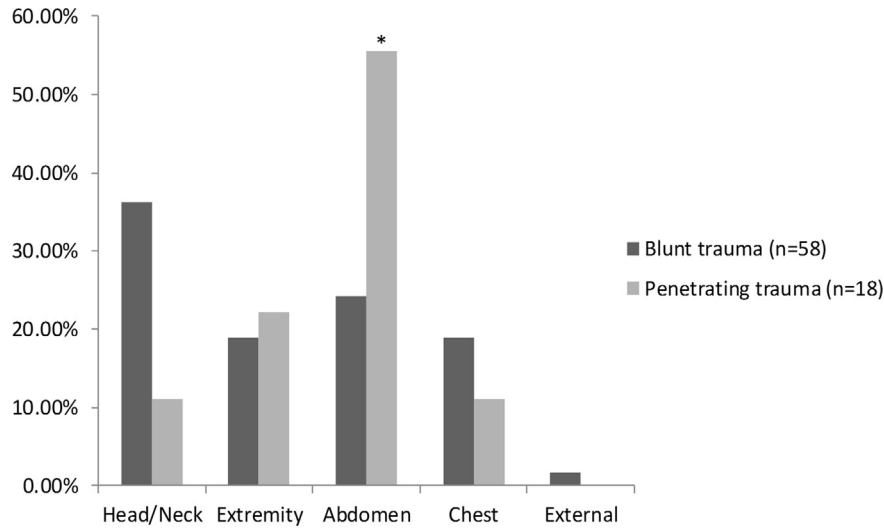


Fig. 2. Distribution of major injuries by type of trauma. Bar graph illustrating the pattern of major injury by type of trauma sustained in 76 trauma patients with MTP activation.

Table 2

Transfusions within 24 h by injury class (the data of “patients receiving” are expressed as n (%)).

Component/Transfusions	Total sample (n = 72 <sup>a</sup> )	Blunt trauma (n = 54)	Penetrating trauma (n = 18)	p value
<b>RBCs</b>				
Patients receiving	72 (100)	54 (100)	18 (100)	0.8411
Mean (range) No. of transfusions/units	10.33 (1–53)	11.65 (1–53)	7.94 (2–32)	0.1190
<b>Plasma</b>				
Patients receiving	64 (88.89)	49 (90.74)	16 (88.89)	0.8183
Mean (range) No. of transfusions/units	8.13 (1–52)	8.76 (1–52)	7.31 (1–20)	0.5489
Patients receiving low-plasma-content therapy (RBC/FFP ratio $\geq 2.0$ )	21 (29.17)	17 (31.48%)	4 (22.22)	0.0210*
Patients receiving high-plasma-content therapy (RBC/FFP ratio of $<2.0$ )	44 (61.11)	32 (59.26)	12 (66.67)	0.0020*
<b>Platelets</b>				
Patients receiving	56 (77.78)	46 (85.18)	13 (72.22)	0.3764
Mean (range) No. of transfusions/doses	2.36 (1–11)	2.52 (1–11)	1.69 (1–3)	0.2109
<b>Cryoprecipitate</b>				
Patients receiving	20 (27.78)	16 (29.63)	4 (22.22)	0.0021*
Mean (range) No. of transfusions/doses	1.95 (1–10)	1.56 (1–4)	3.5 (1–10)	0.0935
RBC/FFP	1.89 $\pm$ 1.63	2.00 $\pm$ 1.81	1.57 $\pm$ 0.91	0.3672
Mean total transfusion volume (mL)	5831.53 $\pm$ 4970.94	6277.41 $\pm$ 5205.71	4493.89 $\pm$ 4023.59	0.1894

Note: <sup>a</sup> 4 blunt patients with missing information regarding units transfusion with 24hrs were excluded, RBC = Red blood cell, FFP=Fresh Frozen Plasma,\*p < 0.05 is considered significant.

Table 3

Admission coagulation parameters by injury class.

Coagulation parameter	Total sample (n = 76)	Blunt trauma (n = 58)	Penetrating trauma (n = 18)	p value
INR	1.47 $\pm$ 0.92	1.50 $\pm$ 1.01	1.38 $\pm$ 0.43	0.645
PT	16.14 $\pm$ 3.34	16.03 $\pm$ 3.19	16.49 $\pm$ 3.86	0.619
PTT	35.86 $\pm$ 16.83	37.65 $\pm$ 18.20	30.18 $\pm$ 8.98	0.109

Table 4

Characteristics of coagulopathy by injury class.

Timing of coagulopathy	Total (n = 46)	Blunt trauma (n = 37)	Penetrating trauma (n = 9)	p value
Within first hour (acute)	27 (58.70%)	22 (59.46%)	5 (35.71%)	0.2086
Between 1 and 2 h (early)	7 (15.22%)	5 (13.51%)	2 (14.28%)	1.0000
Between 2 and 12 h (late)	12 (26.08%)	10 (27.03%)	2 (14.28%)	0.4713

Upon admission, penetrating trauma patients had a higher probability of survival relative to blunt trauma patients. Although the implementation of massive transfusion practices has improved overall survival in trauma patients, bleeding remains the cause of death in up to 40% of trauma cases<sup>1,2,12,13</sup> and mortality rates between 30% and 70% following massive transfusion are often reported.<sup>14,15</sup> The overall mortality (38.16%) for this study's population was in line with these estimates. However, mortality differed greatly when the sample was stratified by blunt or penetrating trauma; the mortality among blunt trauma patients was 48.28% relative to 5.56% for patients who sustained a penetrating trauma. This difference may partially be due to a significantly higher ISS in blunt trauma patients relative to the ISS of penetrating trauma patients ( $33.41 \pm 16.69$  vs  $19.05 \pm 7.71$ ;  $p < 0.0001$ ). The higher ISS among blunt trauma patients could be a result of the multiple injuries blunt trauma patients tend to have compared to the number of injuries for penetrating trauma patients.<sup>10</sup>

Mechanism of trauma differs significantly in the extent and magnitude of tissue damage it causes and can potentially influence the degree of hemorrhage and coagulopathy.<sup>9</sup> Strategic interventions to prevent acidosis, hypothermia, and coagulopathy are vital to control hemorrhage in a complex trauma resuscitation environment.<sup>16,17</sup> Existing literature demonstrates that about one third of patients are coagulopathic upon arrival to the hospital in various settings.<sup>18–20</sup> In our study population, 35.53% of the trauma patients were coagulopathic within the first hour of admission, and a majority of them were victims of blunt trauma (Table 4). NUMC has modified its MTP protocol to include tranexamic acid given the early onset of coagulopathy noted in its patient population. Several studies have reported that coagulopathy contributes to increased mortality in trauma patients.<sup>3,19</sup> The higher mortality rate noted in blunt trauma patients was likely due to a significantly higher ISS and resultant coagulopathy noted in the blunt trauma patients relative to those sustaining penetrating trauma. Others have reported admission coagulopathy rates of 24%–28% in patients requiring massive transfusions.<sup>19–21</sup> The higher incidence of admission coagulopathy in our study population compared to other reports may be due to inherent differences in basic study population characteristics such as ISS, mechanism of injury.

The findings revealed significant differences in the transfusion practices by injury type despite the universal MTP. For instance, the majority of blunt trauma patients were coagulopathic within 1 h of admission, yet, a significantly higher proportion of penetrating trauma patients received higher plasma content relative to RBC when compared to blunt trauma patients (Table 2). Furthermore, despite the MTP calling to attempt to closely maintain a RBC to plasma ratio of 1, this optimal ratio was not reached in either blunt trauma or penetrating trauma patients. The reason for this finding is unclear and merits further research, but may be due to individual physician practice preferences in blood transfusion based on trauma type.

The two trauma groups also had a similar RBC to FFP ratio as well as volume of blood products transfused, both noteworthy considering differences in mortality between the two groups and the findings of previous studies that the ratio of blood products transfused affects mortality.<sup>7,22–24,24,25</sup> Despite these similarities, a higher proportion of penetrating trauma patients received higher plasma content even though they had significantly lower ISS relative to blunt trauma patients.

A final noteworthy difference in the results was that the proportion of blunt trauma patients who received cryoprecipitate was significantly higher than the share of penetrating trauma patients who received cryoprecipitate. NUMC's MTP calls for transfusion of cryoprecipitate when laboratory test results indicate a fibrinogen level less than  $100 \text{ mg dL}^{-1}$  or at the third call

for an MTP. Although fibrinogen levels were not examined in this study, the preferential transfusion of plasma and cryoprecipitate by injury type may have contributed to the lack of significant differences in coagulation profiles between blunt and penetrating trauma patients, despite an uneven distribution of injury severity and characteristics.

The highly variable makeup of massive transfusion practices among trauma centers and the lack of universal practice guidelines results in paucity of comparative research.<sup>12,26</sup> While this study provides insights into how the characteristics and outcomes of patients with MTP activation differ according to trauma type, the results should be interpreted in the context of a number of limitations. Our retrospective study is limited by a lack of certain variables, such as admission platelet concentration and fibrinogen levels at various time points. Also, the data includes MTP activations that occurred immediately after the protocol implementation. Therefore, there was a window period where the protocol compliance would have been low, thus influencing our results. Survivor bias to some extent is also unavoidable. Moreover, the results are based on a single institutional experience and limited number of patients which impacts the generalization of these findings.

In conclusion, the characteristics of blunt and penetrating trauma patients who required MTP activation were significantly different. Despite a universal MTP, the transfusion practices were significantly different by trauma type. These differences in characteristics and outcomes after MTP activation underscore the complexity of implementing MTPs and substantiate the need for tailored MTPs by trauma type. The results add to the current literature on this subject and suggest a need for more institutional studies focusing on outcome measures and transfusion practices by trauma type upon MTP activation.

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