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The role of adjusted massive transfusion protocols in emergency preparedness for mass casualty incidents

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Thesis

THE ROLE OF ADJUSTED MASSIVE TRANSFUSION PROTOCOLS IN EMERGENCY PREPAREDNESS FOR MASS CASUALTY INCIDENTS

by

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ABSTRACT

Background

In the United States, trauma is the leading cause of death for individuals less than 40 years of age. Massive hemorrhage and coagulopathy are known contributors to trauma mortality. Mass shooting incidents (MSIs) are a unique source of major trauma which can strain hospital resources. Various strategies to reduce the blood product requirements for the management of massive hemorrhage have been studied. Some of these strategies have been used in the management of recent MSIs. It is unknown what protocols are in place for managing resource scarcity in mass shooting incidents at trauma centers across the country.

Objective

This is a proposed cross-sectional study to investigate the protocols that trauma centers have in place for emergency response to mass shooting incidents. This study hypothesizes that the implementation of an adjusted massive transfusion protocol (MTP) for mass shooting incidents is not universal practice in trauma centers.

Methods

This study will consist of a brief outreach period to the American College of Surgeons (ACS) network, local and state trauma committees followed by the distribution of an electronic survey to all verified trauma centers. Distribution of the survey will be focused on the existing ACS database of verified trauma centers as they reflect the different geography and city size served by trauma departments across the United States. The survey response will first determine which trauma centers have an emergency response plan (ERP) in place for MSIs. For institutions with an ERP in place, additional questions will gather nominal and categorical data on the features of those protocols, specifically looking at adjusted massive transfusion protocols. Demographic data will be analyzed using descriptive statistics. Nominal and categorical data will be analyzed using chi-square statistics. Demographic data may be used for subgroup analyses.

Conclusion

Mass shooting incidents are the most common mass casualty event in the United States with the frequency and intensity increasing over time. The major cause of death from gunshot wounds in the first 24 hours is from massive hemorrhage. Adjusted massive transfusion protocols are an important strategy to manage massive hemorrhage in a MSI. Recommendations for emergency preparedness to manage mass shooting incidents have been made. However, there has been no large scale study to understand what practices are currently in place. By identifying areas with low levels of preparedness, we may be able

to direct resources to reduce disparities in outcomes and overall mortality from mass shooting incidents.

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LIST OF ABBREVIATIONS

AABB .....Association for the Advancement of Blood and Biotherapies

ABC .....Assessment of Blood Consumption

ACS.....American College of Surgeons

aPTT..... Activated Partial Thromboplastin Time

bMTP ..... Balanced Massive Transfusion Protocol

COVID-19..... Coronavirus Disease

CRASH-2..... Clinical Randomization of an Antifibrinolytic in Significant Hemorrhage

DCR ..... Damage Control Resuscitation

EM.....Emergency Medicine

EMS .....Emergency Medical Services

ERP .....Emergency Response Plan

FAST..... Focused Assessment with Sonography in Trauma

FC..... Fibrinogen Concentrate

FFP .....Fresh Frozen Plasma

GSW.....Gunshot Wound

INR..... International Normalized Ratio

IRB.....Institutional Review Board

ISS.....Injury Severity Score

ITACTIC.....Implementing Treatment Algorithms for the Correction of Trauma-Induced Coagulopathy

MATTERs..... Military Application of TXA in Trauma Emergency Resuscitation

MSI ..... Mass Shooting Incident

MTP ..... Massive Transfusion Protocol

OR .....Operating Room

PCC ..... Prothrombin Complex Concentrate

PROMMTT.....Prospective, Observational, Multicenter, Major Trauma Transfusion Trial

PROPPR.....Pragmatic, Randomized, Optimal Platelet and Plasma Ratios trial

PT .....Prothrombin Time

PTT .....Partial Thromboplastin Time

RBC..... Red Blood Cell

RCT..... Randomized Controlled Trial

REDCap .....Research Electronic Data Capture

RISC..... Revised Injury Severity Classification Score

ROTEM..... Rotational Thromboelastometry

SALT.....Sort, Assess, Life-Saving Interventions, Treatment/Transport

START .....Simple Triage and Rapid Treatment

TASH ..... Trauma Associated Severe Hemorrhage Score

TBSS .....Traumatic Bleeding Severity Score

TEG .....Thromboelastography

TIC .....Trauma Induced Coagulopathy

TRISS.....Trauma Injury Severity Score

TXA ..... Tranexamic Acid

UK..... United Kingdom

US ..... United States

VHA ..... Viscoelastic Hemostatic Assay

INTRODUCTION

Background

Major trauma is the leading cause of death in people less than 40 years of age globally. Massive hemorrhage and coagulopathy are known contributors to trauma mortality. Trauma induced coagulopathy (TIC) is present in approximately one third of all severely injured trauma patients and carries a 40% mortality rate.[1]

Damage control resuscitation (DCR) is the standard of care for patients with massive hemorrhage.[2] This consists of balanced fluid and blood product administration while achieving hemostasis and preventing acidosis, hypothermia and hypocalcemia.

Mass shooting incidents are a unique source of major trauma that can overwhelm a healthcare system. Firearm injuries are more likely to present with massive hemorrhage, placing them at increased risk of TIC.[3] The sudden increase in patient volume requiring simultaneous blood transfusion would very likely cause an unexpected spike in demand for blood products.

Emergency response plans (ERPs) for mass casualty incidents have become standard practice for healthcare systems with significant federal support since September 11, 2001.[4] These plans are designed to address and prevent challenges to the healthcare system when emergency departments face a sudden surge of critically injured patients.

As mass shooting incidents are the most common mass casualty event in the United States (US), emergency preparedness for these situations is paramount. [5]

Statement of the Problem

Massive transfusion protocols (MTPs) are designed to streamline the delivery of blood products to a trauma patient. In the instance of a sudden increase in demand for blood products, such as a mass shooting incident, an adjusted MTP may need to be implemented to preserve blood supply. At this point in time, it is not well understood if hospital systems have adjusted massive transfusion protocol as part of emergency response plans for mass shooting incidents.

Hypothesis

The implementation of an adjusted MTP for mass shooting incidents is not universal practice in trauma centers.

Objectives and specific aims

The objective of this study is to understand the existing strategies for emergency preparedness that trauma centers have in place for blood product administration in the event of a mass shooting incident.

Specifically, this study aims to:

1. Identify where mass shooting incident emergency response plans have been implemented.
2. Characterize the use of adjusted massive transfusion protocols in emergency response plans for mass shooting incidents.
3. Compare trends in emergency preparedness by geography, population served, hospital capability, and level of government funding.

REVIEW OF THE LITERATURE

Overview

Major trauma is the leading cause of morbidity and mortality globally.[1] In the United States, trauma is the leading cause of death for individuals less than 40 years of age. Major trauma is defined by the injury severity score (ISS), which accounts for the severity and location of different traumatic injuries, and is strongly associated with morbidity, mortality and duration of hospital stay. An ISS greater than 15 is considered major trauma on the basis of a proven increase in mortality.

Coagulopathy and massive hemorrhage are known contributors to trauma mortality. Post-traumatic hemorrhage occurs through two main mechanisms. The first is bleeding from direct injury to blood vessels. In the case of injury to large-caliber arteries, massive hemorrhage and death can occur in minutes. However, major hemorrhage can also occur from the development of trauma induced coagulopathy (TIC). This involves secondary bleeding from widespread microvascular hemorrhage, not necessarily localized to the site of trauma. [1] Hypoperfusion secondary to volume loss causes extensive inflammation and endothelial injury. Endothelial shedding of heparins and thrombomodulin provoke endogenous anticoagulation. This results in the release of tissue plasminogen activator creating a pro-fibrinolytic state. In addition to volume loss, including plasma containing crucial coagulation factors, the complex and variable mechanisms of TIC must be understood to optimize transfusion goals for each patient.[6] Trauma induced coagulopathy is present in approximately one third of all severely injured trauma patients and carries a

40% mortality rate. Early identification and management of coagulopathy is paramount to reduce mortality.

Mass shooting incidents are a unique source of major trauma. Patients presenting with gunshot wounds (GSW) are more likely to have higher injury severity scores than non-GSW trauma patients. They are five times more likely to require blood transfusion and when compared to non-GSW trauma patients who also required transfusion, patients with GSW require 10 times more blood products.[3] Of all mass casualty events in the United States, mass shooting incidents are the most common and most closely tracked.[5] Prior to 1990, there were less than 4 mass shooting incidents per year and the decade with the highest number of total deaths was the 1980s with 150 fatalities. Since then, the frequency of these events has increased over time and the events themselves have become more deadly. There were 509 fatalities in the 2010s alone. Since 2015, there have been five to ten MSIs per year.[7] In addition to the number of fatalities, these events have also resulted in more injuries over time. In the 97 mass shooting incidents since 1982, there was an average of 7.5 fatalities and 7.7 injuries when the event was perpetrated with a handgun. In recent years, more events have been perpetrated with an assault rifle resulting in an average of 11.6 fatalities and 29.9 injuries per event.[8] This surge of patients with higher injury severity scores and higher likelihood to require blood transfusion can quickly overwhelm receiving emergency departments. Therefore, it is important to understand the current state of emergency response plans in healthcare

systems to maximize resource allocation and reduce mortality in these increasingly likely events.

Identification of Trauma Severity

Major trauma is defined by the injury severity score. However, the decision to initiate massive transfusion protocol (MTP) is based on key features of clinical presentation as they relate to traumatic hemorrhage. Scores to quantify the severity of traumatic hemorrhage have become a more objective tool for MTP justification. One such score is the trauma associated severe hemorrhage (TASH) score which factors in eight variables: hemoglobin, base excess, systolic blood pressure, heart rate, free intra-abdominal fluid, unstable pelvic fracture, open or dislocated femur fracture and gender.[9] Another, the traumatic bleeding severity score (TBSS) uses five variables: age, systolic blood pressure, positive focused assessment with sonography in trauma (FAST) exam, severity of pelvic fracture and lactate level. These two have the highest sensitivity and specificity but face a major challenge in the timeliness of laboratory results. Traditional laboratory testing may be sent upon patient admission but will not result fast enough to guide treatment decisions. Therefore, MTP in these cases is largely initiated prior to results of coagulation testing with scores being confirmatory. [10] A more rapid score is the assessment of blood consumption (ABC), a simpler model of the TASH score. The ABC score is based on four variables: penetrating mechanism, positive FAST exam, systolic blood pressure and heart rate. This has shown reasonably high sensitivity (75%) and

specificity (86%) for predicting massive transfusion requirements and is therefore the fastest quantifiable way to guide MTP.[9]

Management of Massive Hemorrhage – Balanced Resuscitation

Intervention for severely hemorrhagic patients is best approached through damage control resuscitation. This consists of balanced resuscitation, hemostasis, and prevention of acidosis, hypothermia and hypocalcemia. (Figure 1)

To address hypovolemic shock, aggressive fluid resuscitation was thought to be the best initial intervention for many decades. However, resuscitation with crystalloids alone has shown no survival benefit.[2] The administration of large volumes of crystalloids has been associated with increased incidence of tissue edema, abdominal compartment syndrome and worsening of metabolic acidosis secondary to hyperchloremia.[2] Colloid solutions are another option that can produce more rapid and persistent plasma expansion. However, neither have shown benefits in mortality. In addition, a retrospective analysis of the German Trauma Registry found that the presence of early traumatic coagulopathy was associated with the amount of intravenous fluids administered.[11] Ultimately, only blood product transfusion can reduce coagulopathy and improve tissue oxygenation.

Balanced resuscitation is now guided by the initiation of one liter of crystalloid infusion followed by prompt initiation of massive transfusion protocol. MTP is defined as 10 units of packed red blood cells (RBC) within a 24 hour period or the equivalent critical

administration threshold of at least 3 units within one hour. [12] The emphasis of resuscitation has shifted to replacement of lost blood volume with equivalent blood products.[13]

Over the past ten years, research in this area has explored the ideal ratio and minimum total blood products required to reach adequate volume for a recovering trauma patient. Although there is still a lack of consensus on ideal blood product ratios, two large scale studies in 2013 and 2015 provided the basis for a recommendation of 1:1:1 ratio of plasma : platelets : red blood cells in MTP. The prospective, observational, multicenter, major trauma transfusion (PROMMTT) trial was performed at ten level one trauma centers in the US. [14] A total of 905 patients who met the inclusion criteria of survival for 30 minutes after admission and transfusion of at least 3 total units of blood products within 24 hours were analyzed. In-hospital mortality was compared through a multivariable time-dependent Cox-model. Ratios of plasma : RBC and platelets : RBC were analyzed separately. Investigators found for both plasma and platelets that patients who received ratios less than 1:2 were 3 to 4 times more likely to die than patients with ratios of 1:1 or higher. This was most significant in the first six hours when exsanguination was the primary cause of death. After completion of this study, the question remained whether there was mortality difference between administration of 1:1:1 or 1:1:2 ratios of blood products.

The pragmatic, randomized, optimal platelet and plasma ratios (PROPPR) study sought to answer this question in the form of a randomized controlled trial (RCT). [15] From August 2012 to December 2013, the PROPPR team enrolled a total of 680 severely injured patients who arrived at twelve level one trauma centers in the United States and Canada. Patients were eligible if they were above age 15, had been received directly from the injury scene, required highest trauma level activation, were predicted to require MTP by ABC score or clinician judgement and received at least one unit of blood products within the first hour of treatment. They were then randomized with initial physician blinding to either receive a container of blood products in the 6:6:6 or 6:6:12 ratio of plasma : platelets : RBC. All patients received platelets first followed by alternating units of RBC and plasma. Patients outcomes were then compared on the basis of 24-hour and 30-day mortality. Investigators found no significant difference in mortality at 24 hours or 30 days. However, sub-analyses of time to hemostasis and cause of death found that more of those in the 1:1:1 group achieved hemostasis and less died specifically from exsanguination in the first 24 hours.[15] While the PROPPR study provides the best evidence to guide blood component transfusion ratios, there are several limitations which make it difficult to apply universally to the severe trauma population. One criticism is that the study suffers from survivor bias. In order to be enrolled, patients had to survive pre-hospital transport and the average of 26 minutes for randomization and receipt of blood products. A total of 11,185 patients were screened with only 680 enrolled. This skew towards the moderately severe trauma patients is also reflected in the average injury severity score of participants. On a scale of 1-75, the average participant of the PROPPR

study had an ISS of 26. While any score greater than 15 is considered serious, there is considerable variability between those presenting with scores between 26 and 75. For this reason, the evidence to adhere to a strict 1:1:1 ratio of blood components is not sufficient. In practice, clinicians following a fixed ratio MTP may find it reasonable to follow either a 1:1:1 or 1:1:2 ratio without concern for increased mortality with less plasma or platelet use.

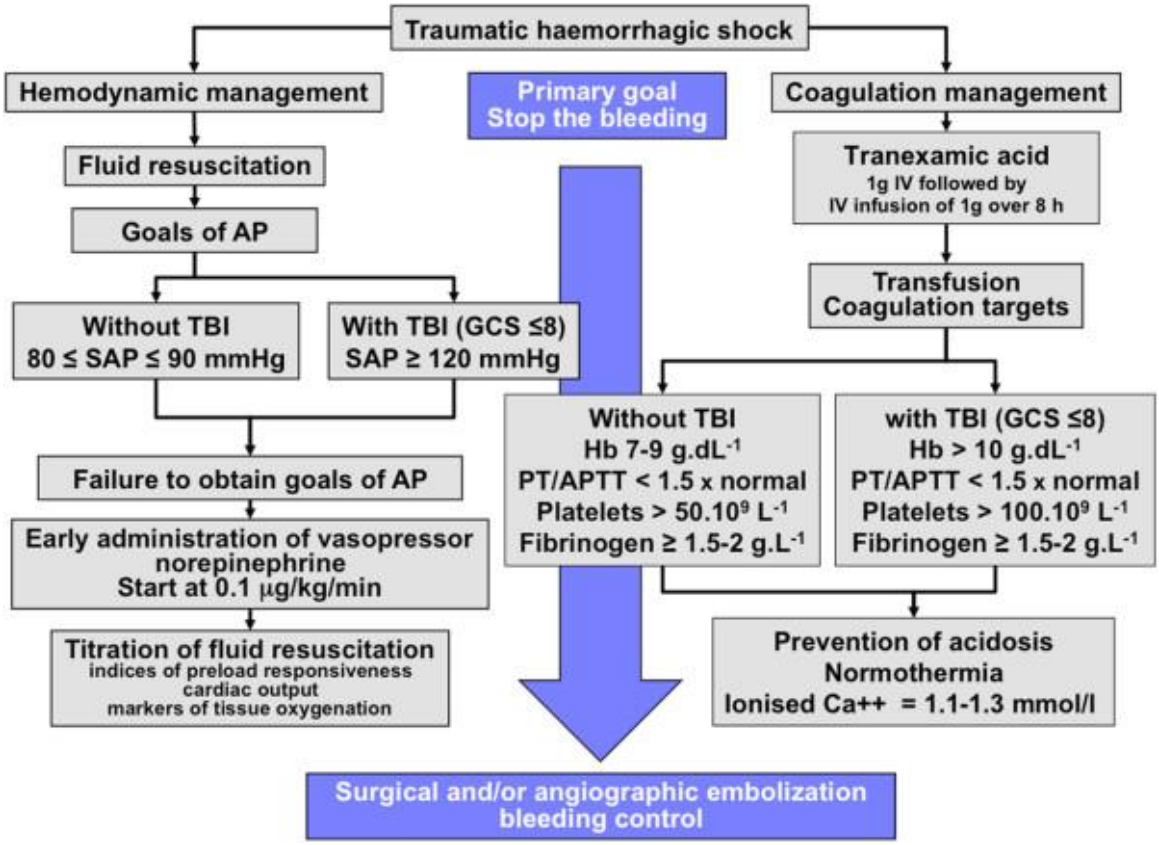


Figure 1: Flowchart of initial management of traumatic hemorrhagic shock[2]

Management of Massive Hemorrhage – Hemostasis

The second component of damage control resuscitation and management of TIC is hemostasis. Without intervention to address coagulopathy, achievement of hemostasis has historically required intervention from trauma surgery or interventional radiology. More recently, damage control resuscitation has incorporated a number of strategies to promote hemostasis prior to the operating room (OR), thereby decreasing overall blood transfusion requirements and improving the ability to achieve mechanical hemostasis.

One adjunct that has been investigated for universal use in trauma patients with massive hemorrhage is tranexamic acid (TXA). As hyperfibrinolysis has been recognized as a contributor to TIC, the use of an antifibrinolytic agent such as TXA was investigated. TXA is currently only approved for use in heavy menstrual bleeding and hemophilia. However, off-label use in MTP and hyperfibrinolysis has been studied over the past ten years. [16] In 2010, the Clinical Randomization of an Antifibrinolytic in Significant Hemorrhage (CRASH-2) team performed a randomized, double-blind controlled trial to investigate the efficacy of TXA in trauma patients with significant hemorrhage.[17] This was a global study, conducted in 274 hospitals across 40 countries. A total of 20, 211 participants were randomly assigned within eight hours of injury to either receive tranexamic acid or a matching placebo. These groups were then compared via 30-day mortality, further parsed by cause of death (bleeding, vascular occlusion, multiorgan failure, head injury, other). Investigators found that both all-cause mortality and death specifically from bleeding was significantly reduced in the TXA group.

A follow up study from the CRASH-2 team then investigated the time dependent component to TXA use.[18] Mortality differences were compared based on TXA administration in less than one hour, one to three hours and greater than three hours. This sub-analysis found that the risk of death due to bleeding after TXA administration was significantly reduced in both the <1 hour and 1-3 hour groups, with the <1 hour group being more significant. Rather than finding no difference in the greater than 3 hour group, investigators found that administration of TXA greater than 3 hours after injury seemed to increase the risk of death due to bleeding. This evidence bolstered the utility of TXA in trauma patients with the recommendation that it only be administered in the first three hours after injury.

Shortly after, the Military Application of Tranexamic Acid in Trauma Emergency Resuscitation (MATTERs) trial examined the use of TXA in combat injury. [19] This retrospective review of United States and United Kingdom (UK) trauma registries gathered data on TXA use in a surgical hospital in southern Afghanistan. A total of 896 patients were included on the basis of receiving at least one unit of packed RBC. The use of TXA was compared in the total cohort and a sub-analysis was performed on those who received massive transfusion. Mortality was compared at 24 hours, 48 hours and 30 days. Other data collected included the presence of post-operative coagulopathy and the rate of thromboembolic complications. This study corroborated that TXA use decreased overall mortality, most significantly in those requiring MTP. This mortality benefit was found up

to the 48 hour mark, supporting a decreased risk of death specifically from exsanguination. Patients in this trial were more likely to have a source of penetrating trauma compared to the CRASH-2 cohort which was 67% blunt trauma. In addition, patients in the MATTERs study had higher injury severity scores reflecting that TXA use is even more important as injury severity increases. Investigators did note that rates of thromboembolic events such as deep vein thrombosis and pulmonary thrombosis were increased in the TXA group but did not feel that the sample size was sufficient to assess this as an independent risk of TXA. The recommendation was instead made to monitor both hypo and hypercoagulable states after TXA administration. These studies provided the foundational evidence for the benefits and risks of TXA use in massive hemorrhage. This led to the integration of off-label use of TXA into protocols for prehospital, emergency department and surgical resuscitation.

Once the safety and efficacy of TXA was studied in trauma patients, focus shifted to the use of TXA to reduce blood transfusion requirements. If hemostasis can be achieved faster, less blood should be lost and therefore less transfusion required. El-Menyar et al. conducted a retrospective review of trauma patients from January 2017 to September 2018 to determine the blood transfusion requirements of matched patients who did or did not receive TXA. [20] Patients were included if they were transfused within four hours of admission and then compared to a TXA-treated patient matched by age, sex, injury severity score, head abbreviated injury score, prehospital heart rate and systolic blood pressure. The median amount of blood transfusion was greater in the control group (eight

units) compared to the TXA group (three units). The requirement of massive blood transfusion was also higher in the control group. There was no significant difference in mortality rates. Similar to the MATTERs study, investigators found a higher rate of venous thromboembolism without reaching statistical significance. This suggests that early administration of TXA could be highly useful if incorporated as a strategy to reduce blood product requirements in massive hemorrhage.

While TXA can address the end of the coagulation cascade, preventing fibrinolysis of clots that have already formed, it cannot aid the body in achieving hemostasis if other clotting factors have been lost. To understand the current state of a patient's blood volume and coagulation cascade, traditional laboratory testing would include the obtainment of hemoglobin, hematocrit, platelet, prothrombin time (PT), partial thromboplastin time (PTT), and fibrinogen values. However, these tests are not rapid and therefore may not provide much utility in the initial activation of massive transfusion protocol. The use of viscoelastic hemostatic assays (VHAs) may provide this necessary information on the coagulation cascade in a more timely manner.

Viscoelastic hemostatic assays can provide a holistic view of ex vivo clotting within fifteen minutes. The two most-studied systems are thromboelastography (TEG) and rotational thromboelastometry (ROTEM).

Thromboelastography displays a graphic interpretation of the initiation, strength and lysis of a clot. (Figure 2) Measurements taken are time to clot initiation – reaction time (R), time to reach a threshold of clot strength - kinetics time (K), slope of clot building - alpha angle (alpha), maximum clot strength - maximum amplitude (MA), clot strength at x minutes (Ax) and degree of thrombolysis at x minutes (LYx). Abnormalities in these variables are associated with specific coagulopathies. For example, prolonged R time is indicative of coagulation factor deficiency, while reduced clot strength at ten minutes (A10) and maximum amplitude (MA) can be indicative of thrombocytopenia or hypofibrinogenemia. [21]

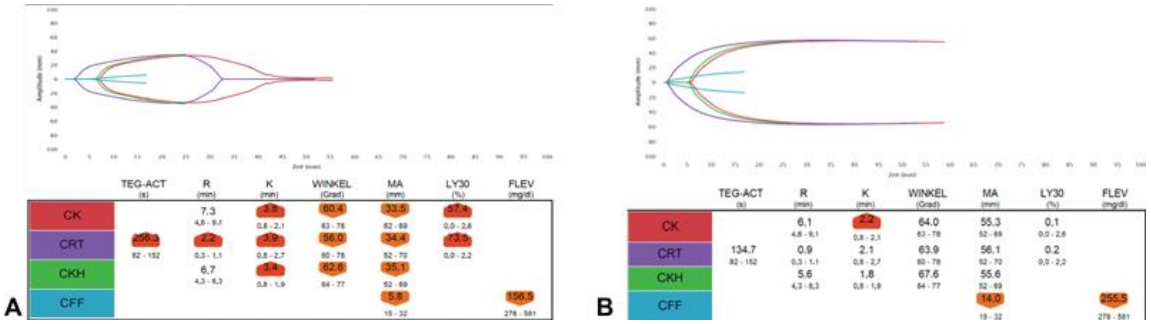


Figure 2: Example of a TEG tracing before and after treatment of hyperfibrinolysis[6]

Rotational thromboelastometry also produces a graphic display of the initiation, strength and lysis of a clot but can be targeted to various aspects of the coagulation cascade. (Figure 3) The EXTEM assay is specific for the extrinsic pathway measuring the activation of clot formation by tissue factor. Measurements include clotting time (CT), clotting factor time (CFT), clot strength at x minutes (Ax) and maximum clot formation (MCF). INTEM is specific for the intrinsic pathway measuring the activation of clot formation via the contact phase while FIBTEM evaluates the fibrinogen contribution to

clot formation. Other available assays include HEPTEM for evaluation of heparin effect and APTEM for evaluation of thrombolysis reversal. Similar to TEG, abnormalities in these pathways can be used to identify coagulopathies. For example, reduced A10 on the FIBTEM assay is indicative of hypofibrinogenemia while reduced A10 on the EXTEM assay suggests thrombocytopenia. In this way, single ROTEM tests can be more specific than results that would require combination of multiple TEG values. However, there has been no evidence suggesting superiority in clinical use of one system over the other.[3]

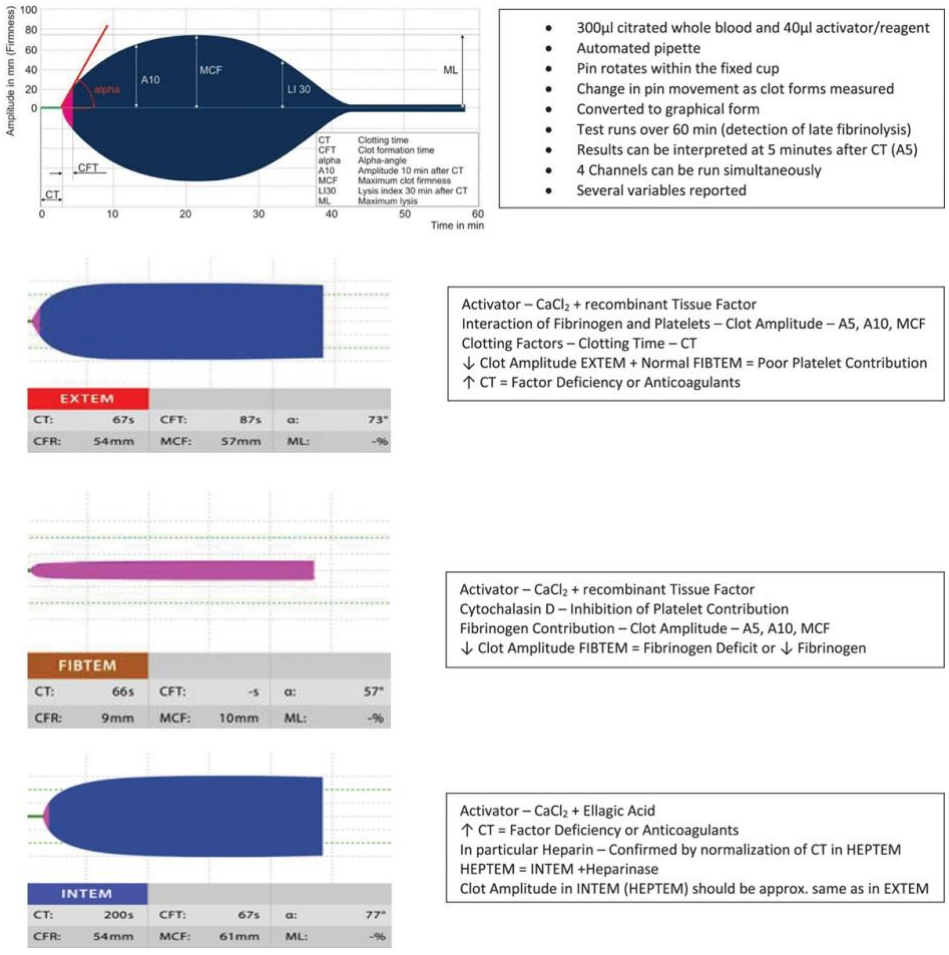


Figure 3: Example of a ROTEM including EXTEM, INTEM and FIBTEM tracings[22]

Viscoelastic testing provides benefit in the production of highly specific and time sensitive results. A traditional coagulation panel consists of PTT or activated partial thromboplastin time (aPTT), PT and international normalized ratio (INR). PT is used to measure the extrinsic pathway clotting time while PTT is used to measure the intrinsic pathway. The INR is an adjusted measurement of the PT to standardize specifically for warfarin therapy and aPTT is adjusted to monitor heparin therapy. TEG and ROTEM variables provide a more specific view of the coagulation cascade, allowing clinicians to identify deficiencies not only in the intrinsic or extrinsic clotting pathways but including fibrinogen activity and time for fibrinolysis. [23]

In addition to being highly specific, TEG and ROTEM provide a clear time benefit. A 2014 study found that early rapid-TEG values, such as activated clotting time, were available within five minutes, while later values, such as slope of clot building and maximum clot strength, were available within fifteen minutes. This was in comparison to traditional coagulation panel testing being available in 48 minutes. All TEG values were comparable to traditional laboratory testing (PT, PTT and platelet count) and equally as predictive of needs for blood product transfusion. [24] These objective measurements can be impactful in shortening time to hemostasis by identifying the target for hemostasis management. This can then result in a decreased requirement for blood products. The ability to rapidly repeat these assays to evaluate patient response to resuscitation can also be a useful tool to triage the need for further surgical or interventional hemostatic procedures.

Guided by data from VHAs, research has begun to investigate the use of coagulation factor replacement in severe trauma patients as a strategy to reduce blood product requirements. One such strategy is the administration of fibrinogen concentrate or cryoprecipitate. Fibrinogen is a mandatory compound in the coagulation pathway. In patients with severe blood loss, fibrinogen has been found to deplete faster, more reaching critically low concentrations more rapidly than other coagulation factors.[13] When coagulation pathways are under stress to correct massive hemorrhage, supplementation of fibrinogen can prevent it from becoming a limiting factor. Fibrinogen concentrate (FC) is derived from plasma, does not require allogeneic matching, has a long shelf-life and does not require thawing.[9] In 2013, Wafaisade et al. conducted a matched-pairs analysis of patients in the German Trauma Registry to determine if administration of fibrinogen concentrate was associated with improved outcomes. [25] A total of 294 pairs were compared by blood transfusion requirements, rates of thromboembolism, multiple organ failure and mortality at 6 hours and 30 days. Investigators found that early administration of fibrinogen concentrate was associated with significantly lower 6-hour mortality. Mortality at 30 days was not different between the two groups suggesting that cause of death in these patients was prevented in the early stages of acute hemorrhage but did not extend protection for the development of multiple organ failure. There was no significant difference in the amount of RBC administered to each group. This study provided modest evidence for the use of FC but not for its universal use to reduce blood transfusion requirements. A 2017 study by Innerhofer et al.

compared the use of fibrinogen concentrate as replacement for fresh frozen plasma (FFP). This study was terminated early because 52% of patients in the FFP group required rescue therapy and increased need for massive transfusion compared to 4% of the fibrinogen concentrate group. Therefore, the use of fibrinogen concentrate was continued for patient benefit.[9] This suggests that fibrinogen concentrate can not only reduce plasma requirements but outperform plasma in improving outcomes for trauma patients.

Cryoprecipitate is the condensed solution of fibrinogen, factor VIII, factor XIII, fibronectin and von Willebrand factor that results from centrifuging plasma. Similar to non-universal blood products, cryoprecipitate must be matched to blood type and thawed.[9] Although cryoprecipitate contains high concentrations of fibrinogen, there are no reports suggesting significant benefit for trauma patient mortality. [13] The difference between the two for the critically bleeding trauma patient lies primarily with feasibility of rapid administration. Studies in 2015 and 2016 found that it was feasible to administer fibrinogen concentrate within one hour of hospital arrival to 96% of patients, while it was feasible to administer cryoprecipitate within 90 minutes of hospital arrival to only 85% of patients.[9] Since then, research has continued to show use of either agent as an alternative to plasma.

Prothrombin complex concentrate (PCC) has been proposed as another early intervention to improve coagulation. Similar to cryoprecipitate, PCC is derived from plasma and contains concentrated levels of factors II, VII, IX and X. The administration of fibrinogen

concentrate alone or in combination with PCC has resulted in significant improvement of fibrin polymerization and shorter clotting time.[13] In 2010, Schochl et al. studied the use of fibrinogen concentrate and prothrombin complex concentrate in trauma patients who had received at least five units of RBC within 24 hours. Use of FC and PCC was guided by ROTEM, one of the first applications of a VHA to guide an alternative approach to massive transfusion protocol. If maximum clot firmness was <10mm on fibrin based testing, fibrinogen concentrate was given as the first line hemostatic therapy. If clotting time on EXTEM was greater than 1.5 times normal, PCC was administered. Lack of improvement in subsequent EXTEM measurement was then the indication for platelet administration. Mortality rates from these patients was then compared to the mortality rate predicted by their trauma injury severity score (TRISS) and revised injury severity classification score (RISC). Of 131 patients, 102 (78%) were managed successfully with only FC and/or PCC. Transfusion of platelets was avoided in these patients with a significant reduction in observed mortality compared to both TRISS and RISC predicted rates. This study found that coagulation management without point-of-care guidance was not superior to VHA guided FC and PCC administration to reduce platelet use. However, the investigators did not provide an analysis of the effects of FC and PCC administration on RBC requirements. In 2011, the same team conducted another retrospective analysis of trauma patients to determine if the use of VHA-guided administration of FC or PCC had an effect on RBC requirements.[26,27] This analysis compared patients that were treated with FC and/or PCC but did not receive platelets to those who received platelets but no FC or PCC. Investigators found that patients in the FC-PCC group required significantly

less RBC transfusion and subsequent infusion of platelet concentrate. Mortality rates were comparable between the groups. This provided stronger evidence that use of FC and/or PCC could reduce the requirements for overall blood product transfusion.

When considering a coagulation factor approach to hemostasis, it is important to include factor XIII. Factor XIII is found in plasma and is responsible for cross-linking fibrin to stabilize clot firmness and prevent fibrinolysis. Trauma patients that present with higher injury severity scores have been found to have factor XIII levels decrease by almost 20% from the time of injury to hospital admission.[6] However, none of the aforementioned adjuncts for coagulation factor replacement other than plasma contain factor XIII. Therefore, these patients may need factor XIII concentrate available as a VHA guided adjunct to improve hemostasis. In perioperative settings, current guidelines suggest the use of VHAs for factor XIII monitoring and replacement when levels fall below 30%. This has not yet been studied in trauma patients but may warrant protocol development as VHA guided resuscitation becomes more prevalent.

Damage Control Resuscitation with a Limited Blood Supply

In situations where demand for blood products may overwhelm the available supply, such as mass shooting incidents, the use of VHA guided resuscitation may aid in resource allocation.

It is becoming more widely accepted in both emergency and surgical settings that VHAs are uniquely poised to improve outcomes in TIC compared to traditional coagulation testing. The use of tranexamic acid, fibrinogen concentrate and prothrombin complex concentrate all have individual evidence for reducing blood transfusion requirements but can be further guided by the use of point of care coagulation testing. One of the earliest evaluations of VHA-guided resuscitation was a Cochrane review in 2011. [28] Afshari et al. conducted a systematic review of randomized clinical trials that compared transfusion guided by TEG or ROTEM to transfusion guided by clinical judgement and/or standard laboratory tests. A total of nine randomized controlled trials were reviewed with a total of 776 participants. Of these initial studies, VHA-guided resuscitation had no significant effect on overall mortality. However, there was a significant reduction in the requirements of both platelets and fresh frozen plasma. This initial evidence for the utility of VHAs in damage control resuscitation spurred more research in the field.

In 2016, Winearls et al. conducted a literature review to compare the risks and benefits of a fixed ratio MTP compared to VHA guided resuscitation.[22] The benefits of a fixed ratio MTP were based on the PROMMTT and PROPPR trials as discussed prior. Over the past decade, implementation of MTPs has clearly improved survival in traumatic hemorrhage. However, the primary criticism for these studies is that all receiving facilities may not be able to achieve the same high standard of blood product availability, namely delivery of requested blood products within 10 minutes. For example, a follow up study of blood product delivery in UK trauma centers found a median time of 68 minutes to delivery of

plasma and greater than 2 hours for delivery of cryoprecipitate and platelets. When applying this to the US healthcare system, it may be likely that level one trauma centers could keep up with the timely administration of blood products in the PROPPR trial but lower-level trauma centers may be more vulnerable to time delays and blood product shortages. Therefore, only resource rich environments would be likely to see the improved survival from a fixed ratio MTP. In discussing VHA guided protocols, Winearls et al. noted a lack of data comparing the performance of VHA-guided algorithms for coagulation factor replacement to a fixed ratio MTP for trauma patients. Many hospitals that have integrated VHA use have done so in conjunction with an existing MTP, thereby preserving the strategy with a known initial mortality benefit and adding in a VHA targeted approach to damage control resuscitation.

Bainbridge et al. provided an example of this gradual adoption of VHA use with a retrospective analysis in 2021. This group analyzed the effect of implementation of a ROTEM guided protocol on existing fixed ratio MTP and coagulation management.[29] They found that in the one year following implementation of point of care ROTEM in their emergency department, it was utilized in 23.6% of trauma patients with 42% of those patients having an ISS >25, indicating greater implementation of ROTEM in patients with higher severity. Overall blood product usage between pre- and post-intervention groups had no significant difference. However, when the use of RBC, FFP, platelets and cryoprecipitate in the first 24 hours of hospital arrival were compared, there was a reduction in absolute percentage of patients who received FFP and platelets, while

there was an increase in those who received cryoprecipitate, reflecting a more targeted resuscitation approach. In addition, there was a significant decrease in the use of cryoprecipitate in those without a ROTEM sample, supporting the conclusion that with VHA data available, the arbitrary administration of coagulation factors is reduced. An interesting secondary outcome measured by this group was a cost comparison of blood transfusion products before and after ROTEM implementation. Investigators found a 25% reduction in overall blood product costs, reflecting a source of beneficial cost savings with the adoption of this new equipment. An example of the ROTEM guided protocol used in this study can be found in appendix A.

Also published in 2021, the Implementing Treatment Algorithms for the Correction of Trauma-Induced Coagulopathy (ITACTIC) study compared the implementation of VHA guided protocols across Europe.[30] This was a multicenter randomized controlled trial, including seven major trauma centers, with use of either TEG or ROTEM to reflect feasibility of both machines at different sites. A total of 396 patients either received either fixed ratio MTP guided by traditional laboratory testing or VHA guided MTP with outlined parameters for each site to follow when deciding to administer additional platelet, fibrinogen, plasma or antifibrinolytic therapies. Investigators found that patients in the VHA guided group were more likely to receive additional coagulation factors and receive them faster than the fixed ratio group. However, there was no difference in overall blood product usage or overall mortality. Interestingly, there was a significant reduction of mortality in the VHA guided group for those with traumatic brain injury, a

cause of at least 25% of deaths in critically bleeding patients and 50% of all trauma deaths. Therefore, the conclusions of the study are mixed. One notable limitation to generalizability is that 75% of these patients had MTP initiated either pre-hospital or within the first 10 minutes of arrival, making the incidence of coagulopathy less common. Similar to the PROMMTT and PROPPR studies, the timely MTP administration may not be feasible in all areas, where VHA guided resuscitation would then be more helpful.

Existing Literature

Massive Hemorrhage Management in Mass Shooting Incidents

Whether in resource rich or poor environments, mass shootings pose a rare but unique challenge for emergency and trauma departments. Patients presenting with GSW are more likely to have higher injury severity scores and require massive transfusion than non-GSW trauma patients. In the United States, the frequency of MSIs and number of casualties per incident has increased over time. In the past 30-40 years, the average number of persons injured in a single MSI who would then require immediate emergency department care has varied from 7.7 to 29.9 injuries depending on the type of gun used.[8] The Association for the Advancement of Blood and Biotherapies (AABB) Interorganizational Task Force on Domestic Disasters and Acts of Terrorism recommended an initial estimate of three group O RBC units per admission in a disaster. However, this suggestion was made in 2008 when MSI were more likely to be perpetrated with a handgun and had a lower median number of injuries. In addition, this

recommendation was made before the PROMMTT and PROPPR trials and made no recommendation for the estimated requirements for plasma or platelets. [31] Depending on the size of the city, number of trauma centers and number injured per event, the surge of patients with higher injury severity scores and higher likelihood to require blood transfusion can quickly overwhelm receiving emergency departments. Therefore, it is important to review more recent events to understand newer recommendations and how responders have acted to identify areas for improvement.

As the frequency of mass shooting incidents continued to rise in the early 2000s, responders also noticed increased severity of injuries with the use of semiautomatic weapons. One devastating example of this was in Newtown, CT where the perpetrator fired more than 150 rounds in less than 5 minutes, resulting in 26 immediate fatalities and 2 injured. After this incident Jacobs et al. published The Hartford Consensus in 2013 with the first set of recommendations for reducing mortality in a modern MSI.[32] The organizations represented in this consensus conference were the American College of Surgeons, Federal Bureau of Investigation, Prehospital Trauma Life Support, Committee on Tactical Combat Casualty Care, Major Cities Police Chiefs Association and the International Association of Fire Chiefs – Emergency Medical Services. Representatives of these organizations developed a succinct description of the necessary response to a mass shooting incident: THREAT. This acronym stands for threat suppression, hemorrhage control, rapid extrication to safety, assessment by medical providers and transport to definitive care. Many of the recommendations made were for prehospital

care, namely hemorrhage control training for civilians and law enforcement officers and integration of response between police, fire and emergency medical services (EMS). However, an important standard was set at this time. The study team concluded that for all future MSIs, after action evaluation should be completed specifically to measure the success of emergency response planning and identify areas for improvement based on the causes of preventable deaths.

A few years later in 2017, the Las Vegas, Nevada community experienced the deadliest mass shooting in modern United States history. In this single event, there were 58 fatalities and 869 injured.[33] Thirteen hospitals received approximately 620 patients, 250 via ambulance and the rest via private vehicle. Of those transported by ambulance, 200 (80%) arrived within one hour. This quickly overwhelmed the system and a major challenge identified was the supply of blood products. Therefore, in 2018, Lozada et al. published a study describing the blood component usage during this event and compared it to prior MSI reports. Within the first 24 hours, a total of 474 blood products were administered. This was comprised of 278 RBC, 151 plasma, 45 platelets, and 25 cryoprecipitate reflecting a plasma : platelet : RBC ratio of 0.54:0.81:1. In the next 14 hours, an additional 700 blood components were mobilized from the United Blood Services and The American Red Cross and civilians flocked to donate blood products, 137 units of which ultimately went to waste. Compared to previous MSIs, the relative amount of plasma each patient received was less than those in the terrorist attacks on Paris in 2015 at 0.7:0.44:1 and 2016 night club shooting in Orlando at 0.64:0.50:1. In

addition, investigators attributed the ability to administer the platelets was limited to one hospital, a level one trauma center, whereas the other hospitals in the area were unable to keep up the same platelet ratio. Despite the next day mobilization of additional blood products and public donation, much of the need for transfusion passed in the first 24 hours. Therefore, the investigators concluded that emergency preparedness, rather than reactivity, would have been the only way to improve their MTP supplies.

Overall, the outcomes from the Las Vegas incident were better than expected.[34] Of the 58 fatalities, 31 died at the scene, 22 were dead on arrival, 4 died within 12 hours and 1 died at 36 hours. This was attributed to lessons learned from prior events such as application of direct pressure and effective tourniquets in the field, rapid hospital transport, protocols for damage control resuscitation and rapid triage to the operating room where all available trauma surgeons were mobilized. Other factors contributing to low hospital morality, such as the event being on a Sunday night just before evening shift change, where the maximum number of healthcare providers were in the building, and blood banks having just been stocked for the coming week, were fortuitous. In addition, Las Vegas is a very well-resourced city with multiple trauma centers and a unique military-civilian partnership for medical training.[35] The early administration of plasma and platelets, despite not being at ideal ratios, likely contributed to the decreased loss of life in the first 24 hours. The use of TXA, viscoelastic hemostatic assays or coagulation factors other than cryoprecipitate were not reported.

In 2019, a mass shooting incident in El Paso, Texas resulted in 23 fatalities and 23 injuries.[36] Qiao et al. published the management of this incident, specifically the use of ROTEM guided resuscitation, and compared the transfusion statistics to other MSIs. During the El Paso incident, two hospitals received a total of 27 patients. Of those, 15 were transported to the level one trauma center with ROTEM capability. Five patients were administered TXA upon arrival, three had ROTEM guided resuscitation, and two required MTP in the first 24 hours. A total of 14 of the 15 patients at the level one trauma center underwent one or two surgical procedures for mechanical hemostasis shortly after arrival. Six patients required transfusion during their hospital stay for a total of 95 blood products used and a plasma : platelet : RBC ratio of 1:0.94:1.18. Of the fatalities, 19 died on scene, 3 died within 12 hours and 1 died greater than 30 days later. In comparison to other recent MSIs included in analysis, El Paso had the lowest number injured and the highest fatality rate (50%). However, this data is skewed by the high proportion of those who died on scene. Of those who reached the hospital, this fatality rate decreased to 8%, similar to the 6% found in Las Vegas. El Paso also had the lowest RBC:FFP ratio per admission, the closest to the 1:1:1 ratio, and the highest rates of platelet and cryoprecipitate transfusions.

Overall, the El Paso MSI was well prepared for and in-hospital success was the result of an established damage control resuscitation protocol, ROTEM monitoring of MTP, strategic placement of hemostatic agents (TXA, combat application tourniquets, QuickClot and HemCon) in a centrally designated hallway, full blood bank support with

rapid release of frozen products, and rapid triage to operating rooms with available trauma surgeons mobilized. In this incident, the major loss of life was pre-hospital and likely the result of the use of an assault rifle at close range. Only prevention of the incident itself could have improved the outcome for those who died on scene. For those who reached the hospital, the use of MTP adjuncts such as TXA, ROTEM and cryoprecipitate aided the team in the ideal management of trauma patients and reduced morbidity and mortality.

Since these recent events, teams who had experienced an MSI were invited to meet to form a consensus on emergency response planning. Goolsby et al. published the recommendations that came out of this in 2022.[37] A total of fifteen clinicians who had responded to an MSI in 2016 or later with 15 or more people killed or injured were included. The six mass shooting incidents represented were Orlando, FL (2016), Las Vegas, NV (2017), Sutherland Springs, TX (2017), Parkland, FL (2018), El Paso, TX (2019) and Dayton, OH (2019). Participants completed a three round Delphi process, first with a two-part survey and then with two rounds of site-specific presentations followed by discussion groups to generate consensus recommendations. The discussion groups were split by expertise: emergency medical services, emergency medicine (EM) and surgery. The themes identified and discussed were readiness training, community preparation, triage, communication, patient tracking, space expansion plans, staffing, military-civilian collaboration, clinical treatment best practices, documentation, family reunification, and after-action mental health. When discussing readiness training,

participants stressed that regular, recurrent training and exercises are essential to prepare for an MSI. These trainings should be interprofessional and interdisciplinary to include all medical staff, even if they don't care for trauma patients regularly. The recommendations for public education were built upon the previous work by the Hartford Consensus and Stop the Bleed campaign, once again identifying that if the public are trained they are willing and able to help with early hemostasis. Triage was identified as a dynamic and recurrent process. Specific recommendations for triage included that a mass shooting protocol should include anatomic triage (e.g. considering location of GSW and prioritizing patient care based on the potential lethality) rather than traditional triage protocols such as SALT (sort, assess, life-saving interventions, treatment/transport) or START (simple triage and rapid treatment). In addition, surgeons should assist with triage in the emergency department, particularly to identify appropriate patients for the OR. All groups agreed that improved education and current treatment protocols are needed for hemorrhage control and blood transfusion during MSIs. The EMS group specifically recommended better education and protocols for wound packing, airway techniques and whole blood administration. A final recommendation for federal support also included that military-civilian healthcare collaboration is helpful for MSI preparation and may facilitate rapid incorporation of additional clinical resources in an MSI response. Full recommendations provided from this consensus can be found in appendix B.

Massive Transfusion Protocols in Disaster Management

In 2020, Ramsey et al. conducted a retrospective review of mass casualty events that occurred between 1980-2020 to provide recommendations for estimated blood requirements.[38] The aim of this study was to examine how the previous AABB guidelines for estimated blood product administration compared to real utilization data from recent events. Although not limited to mass shooting incidents, this provided a focused review of the literature for estimated blood product requirements under the direction of damage control resuscitation. The team also noted that there were no significant differences in transfusion requirements for the majority of events included (bombings) compared to mass shooting incidents. Ramsey included 32 mass casualty events with blood utilization available and at least 50 RBC used per event. In these reports, the team specifically looked at the utilization rates of RBC, plasma, and platelets. They found that the maximum blood products transfused in the first 24 hours of an event were 382 RBC, 199 plasma, 45 platelets. The majority of blood products used in each event were administered at the highest-level trauma centers, likely reflecting the acuity of patients directed there. Reports were also stratified by era, defining MCEs after 2010 and one military study in 2008 as the balanced MTP (bMTP) era. Blood usage in the pre-bMTP era had higher utilization of RBC while in the bMTP era there was higher utilization of plasma and platelets. In addition, investigators found that mass shooting incidents had the highest utilization of platelets. Between these two eras, in-hospital mortality showed a favorable but not significant decrease from 5.5% in the pre-bMTP group to 3.5% in the bMTP group. This data resulted in a proposed update to the previous AABB guideline,

now stating that for a mass casualty incident emergency response plans should estimate a total of 3 RBC, 1 plasma and 0.25 platelet apheresis units per admission and direct supplies to the highest level trauma centers which would likely require 6 RBC, 4 plasma and 0.5 platelet apheresis units per admission. Each platelet apheresis unit discussed in this study would be equal to a 6 pack of platelets. The investigators acknowledge that the total estimates for each event are likely to be within the stores of regional blood centers but not of a single hospital. Therefore, an additional recommendation was made that although initial triage can be imprecise, transfusion services and blood centers should have early and ongoing access to patient triage and transport information to provide urgent blood component support where indicated.

A notable study to guide future research is that of Jacobs et al. in 2021.[39] This study examined the blood shortages experienced and changes to massive transfusion protocols in the coronavirus disease (COVID-19) pandemic. Although this was not an isolated mass casualty event, the COVID-19 pandemic is a prominent example of managing blood demand in a resource limited environment. Investigators distributed an 18-question survey to a total of 115 hospitals with known transfusion medicine departments and established MTP to understand whether those institutions had altered their MTP due to blood shortages and if so, what adjustments they had made. A total of 50 hospitals completed the survey, a 43% response rate. All responding institutions utilized a fixed ratio of blood products in their MTP, however, investigators noticed significant variability with a total of 19 different ratios used. At baseline, eight of the institutions

also used VHAs to guide their MTP. As a result of the blood shortages in the COVID-19 pandemic, 10% of the institutions made alterations to their MTP and 10% had a plan for an altered MTP in place if their supplies were to worsen. Strategies to alter their MTP included decreasing the fixed ratio of plasma : platelets : RBC from 6:1:6 to 4:1:4, altering the release of platelets from one unit every cycle to every other cycle, issuing one half of the MTP cycle at a time and reducing the number of RBC units by half after the third cycle. Given the low response rate and variability among the respondents, this survey cannot be considered generalizable. However, it provides a foundation to analyze what preparedness structures are in place when a surge in blood product demand overwhelms the available supply.

In the past decade, existing literature has focused on after action reports from MSIs, consensus statements for preparedness recommendations and retrospective reviews of blood product utilization. Optimal response to mass shooting incidents requires an emergency response plan that includes quantifiable hospital resources, plans for resource allocation and staff familiarity with best practices. To date, there has been no research performed to understand what hospitals have emergency response plans in place and what their protocols are. Moving forward, there is room to improve the understanding of how these recommendations have been implemented and how preparedness for a MSI may vary across the United States.

METHODS

Study Design

This descriptive study will use a survey-based study design to investigate the protocols that trauma centers have in place for emergency response to mass shooting incidents. This study will use self-reported data to identify where MSI emergency response plans have been implemented. For those centers with emergency response plans, further data will then be collected on key components of massive hemorrhage control such as community initiatives, triage, hemostatic agents, massive transfusion protocols, viscoelastic hemostatic assays and expansion of staffing, supplies and space. Ultimately, this study aims to compare trends in emergency preparedness for MSI by geography, city size, trauma center level designation and level of government funding. This study will be conducted over 6 months with a survey period of 3 months and 3 months allowed for data analysis.

Study Population and Sampling

The population for this study will be identified trauma centers. All trauma centers that have been verified through the American College of Surgeons will be included in the study. These trauma centers were selected as they have decided to undergo the voluntary verification of the ACS, demonstrating a commitment to high level care of trauma patients.[40] This database includes hospitals that hold Level I, Level II, Level III, Level IV and Level V trauma center distinctions, representing the heterogenicity of trauma centers in the United States. Individuals designated to receive the survey will be identified as the

point of contact for trauma level designation previously provided to the ACS. To the best possible extent, leaders in each institution associated with trauma level distinction will be made aware of this effort ahead of time to maximize the response rate. In addition, trauma centers outside of the ACS network will be invited to enroll in the study via materials distributed through their local or state trauma committees. A full list of inclusion and exclusion criteria can be found in table 1.

Inclusion:
• Trauma centers verified by the ACS • Non-ACS verified trauma centers that have self-selected for inclusion in the study per notification via local or state announcements
Exclusion:
• Institutions that do not carry a current trauma level distinction from the ACS, local or state oversight • Institutions that are unable to provide a reliable point of contact for the 6 month study period

Table 1: Inclusion and Exclusion Criteria

The ACS Report on America's Trauma System was used as a reference for determining the proper sample size. Per this report, there are approximately 2000 trauma centers in the United States.[41] Within this network, it is more likely that level one trauma centers would have an established MTP and less likely that lower-level trauma centers would have this protocol in place. Therefore, to calculate the sample size these institutions were split into three groups by trauma level: level one, level two and three, and level four and five. A contingency table with a small Cohen's effect size of 0.21, two degrees of freedom, beta level of .20 and alpha level of .05 was used to determine an estimated sample size of 219 participants.

The database of ACS verified programs currently has 588 members to which this study invitation would be distributed. The study from Jacobs et al. conducted during the COVID-19 pandemic had a similar design with a 43% response rate.[39] It is reasonable to assume that response rates would be higher for a study conducted within an established network and not during an active pandemic. Therefore, this study design will assume a 60% response rate resulting in an estimated 352 responses from this database. This is still well above the estimated sample size needed for this study.

Recruitment

Prior to the start of this study, all trauma centers verified by the ACS will be contacted to confirm the best point of contact for the duration of the six-month study. In addition, points of contact for local and state trauma committees will be notified to disseminate materials for awareness of this initiative. Trauma centers outside of the ACS network will be invited to enroll in the study via these materials from the local or state trauma committees. The confirmed listserv for ACS verified trauma centers will be the primary mode of survey distribution and follow up. A centralized email address for the study team will be provided on the materials provided through local and state networks for respondents who choose to self-select their institution for inclusion. Upon verification of the best point of contact for that site, a personalized link will be sent to avoid duplication in responses.

Intervention

This study will evaluate the prevalence of emergency response plans for mass shooting incidents. This will be done through an eight-question survey. All trauma centers enrolled in this study will be invited to complete the same initial survey. For those sites with an emergency response plan, an additional twenty questions will be asked to understand the components of that plan.

Study Variables and Measures

This survey will be constructed using the Research Electronic Data Capture (REDCap) platform. The questions were developed by the authors to assess whether institutions have emergency response plans in place for MSIs and if so, what those emergency response plans contain.

An initial survey of eight questions will aim to collect the demographic characteristics of each site and understand if they have an emergency response plan for mass shooting incidents in place. Demographic data will include geographic location, city size, trauma center level designation and level of government funding based on facility type (i.e. for-profit, nonprofit, federally owned). Specific details can be found in Appendix C.

For those institutions who answer “Yes” to having an emergency response plan for a MSI, they will be prompted to complete an additional twenty questions. These questions will be organized into 5 categories, condensed from the recommendations of the ACS

consensus published by Goolsby et al.[37] These categories are: community initiatives, triage, expansion (space, staff, supplies), hemorrhage control, and military-civilian collaboration. Further details on these subsequent questions can be found in Appendix C. Questions will be in multiple choice format with the most likely answers from literature review represented. Respondents will be able to select all that apply for questions that may have overlap in options. Each question will have an additional "other" option so that respondents can insert notes if they feel that a feature of their plan did not fit the available choices. The study team will review these other fields after the completion of the survey for recategorization, either under the scope of one of the existing question options or as a new option. For those willing, there will be an option to upload a de-identified file of their current emergency response plan for knowledge sharing purposes.

Data Collection

Utilizing the listserv confirmed by the ACS network, a personalized link for accessing the survey in the REDCap system will be sent to the point of contact for each institution. These personalized links prevent duplicate responses. Survey responses will be automatically uploaded and de-identified within the database. Survey collection will occur for approximately 3 months, allowing for sufficient time to gather data from each institution while avoiding a prolonged timeline.

Data Analysis

The collected survey data will be analyzed using SPSS statistical software. The demographics of each institution will be summarized in a table using descriptive statistics. Multiple choice questionnaire responses will be tabulated and reported as a frequency. Categorical data will be analyzed using chi-square statistics and may be stratified by demographics, specifically by geographical region, city size, trauma center level designation and level of government funding.

Timeline and Resources

This project will take place over 9 months. An initial 4-week period will be budgeted for Institutional Review Board (IRB) approval. Prior to survey distribution, 6-8 weeks will be budgeted for confirmation of points of contact in the ACS network and outreach to local and state trauma committees. Survey collection will occur for approximately 3 months, allowing for sufficient time to gather data from each institution while avoiding a prolonged timeline. The study team will then allow an additional 3 months for data analysis.

Resources will include one advisor who will advocate and provide clinical context to the project, one project manager to lead the initial period of outreach and coordinate study tasks, one research assistant to carry out study tasks and one analyst to conduct the final data analysis (Table 2).

Role	FTE
Clinical Advisor	0.10
Project Coordinator	0.25
Research Assistant	0.25
Data Analyst	0.25

Table 2: Study Personnel

Institutional Review Board

This study proposal will be submitted to the Boston University Medical Campus IRB for exempt determination. This project meets the definition of research as it is a survey being conducted to contribute to generalized knowledge. However, this project will not require full IRB review as the human subject interaction is limited to survey procedures. This study is of minimal risk and falls under the common rule exempt category 10.2.4.2.1.2 for survey methodology.

CONCLUSION

Discussion

Mass shooting incidents are the most common mass casualty event in the United States with frequency and intensity increasing over time. The major cause of death from gunshot wounds in the first 24 hours is from massive hemorrhage. There is a robust body of research supporting treatment strategies for massive hemorrhage, including best practices when supplies like blood products are in high demand. Although recommendations for emergency preparedness have been made, there has been no large-scale study to understand what practices are currently in place at trauma centers across the United States.

The lack of literature on preparedness for mass shooting incidents was identified by the American College of Surgeons in their 2016 survey on mass casualty incident management.[4] Without an understanding of what trauma centers currently have in place, disparities in treatment capabilities and opportunities for improvement cannot be identified. As seen in the management of previous MSIs, facilities benefit from military-civilian partnerships. Without data on where facilities need support, it is difficult to direct and strengthen federal resources prior to an unpredictable event.

Measuring the success of mass shooting incident management after an event is difficult. These events are by nature, unpredictable and devastating for the community. As acknowledged by the consensus recommendations in 2023, it is much better to intervene

and ensure best practices have been implemented prior to an event rather than identify system failures that led to preventable deaths after the fact. In addition, the strategies used for massive hemorrhage management do not only apply to mass shooting incidents. As seen with the COVID-19 pandemic, having emergency response plans that allow for flexibility while maintaining standard of care can be helpful for any resource limiting event.

The generalizability of this study may be limited to the United States. The scale and frequency of mass shooting incidents is a uniquely American problem. In addition, the healthcare system and geographic variation of trauma centers within the United States is hard to apply to other countries. However, domestic terrorism is a universal issue. Therefore, the identified preparedness strategies utilized in the United States can be helpful on a global scale, as seen with previous literature used from Australia and the European Union.

One limitation of this study would be selection bias. The primary recruitment for this study involves trauma centers within the ACS database. In pursuing ACS verification for their trauma level distinction, these facilities are more likely to be up to date on best practice recommendations and education distributed through the ACS network. These facilities may therefore have better preparedness plans in place than their non-ACS verified counterparts. This may also limit generalizability as the ACS network and standards only apply to the United States.

Another limitation is that the data will be self-reported. Therefore, the selection of the correct option to each question relies on the interpretation of that respondent. In an effort to mitigate this, the study will include “other” options so that respondents who are unsure as to which option may fit best can allow the study team to use a written response and categorize as they see fit. In addition, respondents will be encouraged to provide a de-identified version of their existing emergency response plan so that the study team can see the details if a selected response is in question.

The major obstacle anticipated in this study is response rates. In general, survey-based study designs anticipate at least a 20% dropout rate. This was included in the sample size calculations to ensure adequate power and generalizability. Efforts to improve response rates will also include the four to eight-week outreach period prior to study start and the support of the established ACS marketing team.

The advantages of this study are that it will be conducted through an established and trusted network. The feasibility of this study was proven by the last ACS survey in 2016, which can be viewed as a pilot for this larger scale effort. In addition, using an established database and electronic distribution will maximize access to respondents and ease of survey completion. Finally, this survey will be a foundational piece of literature on mass shooting incident preparedness, after which interventions for quality

improvement, standardization of care and future research on successful MSI response can be built.

Summary

In the United States, trauma is the leading cause of death for individuals less than 40 years of age.[1] Massive hemorrhage and coagulopathy are known contributors to trauma mortality. Mass shooting incidents are a unique source of major trauma. Patients presenting with gunshot wounds are more likely to have higher injury severity scores, require blood transfusion and require more blood products overall.[3] Strategies to manage massive hemorrhage in mass casualty events include the use of massive transfusion protocols, tranexamic acid, viscoelastic hemostatic assays and coagulation factor replacement. Responses to prior mass shooting incidents have been mixed with after action reports being the primary method of understanding the causes of preventable death. In the past ten years, members of the healthcare teams that have responded to recent MSIs in the United States have met to form a consensus as to best practices for emergency preparedness. These recommendations include pre-hospital interventions such as hemorrhage control training for civilians, recurrent interdisciplinary training drills, anatomic triage, standardized education and protocols for hemorrhage control and blood transfusion, and military-civilian healthcare collaboration.[37] The aim of this project is to understand the current protocols in place for MSI emergency preparedness at trauma centers across the United States. This data will be used to identify trends in preparedness and direct resources to institutions who either do not have a plan in place or have not incorporated the most recent ACS recommendations.

Significance

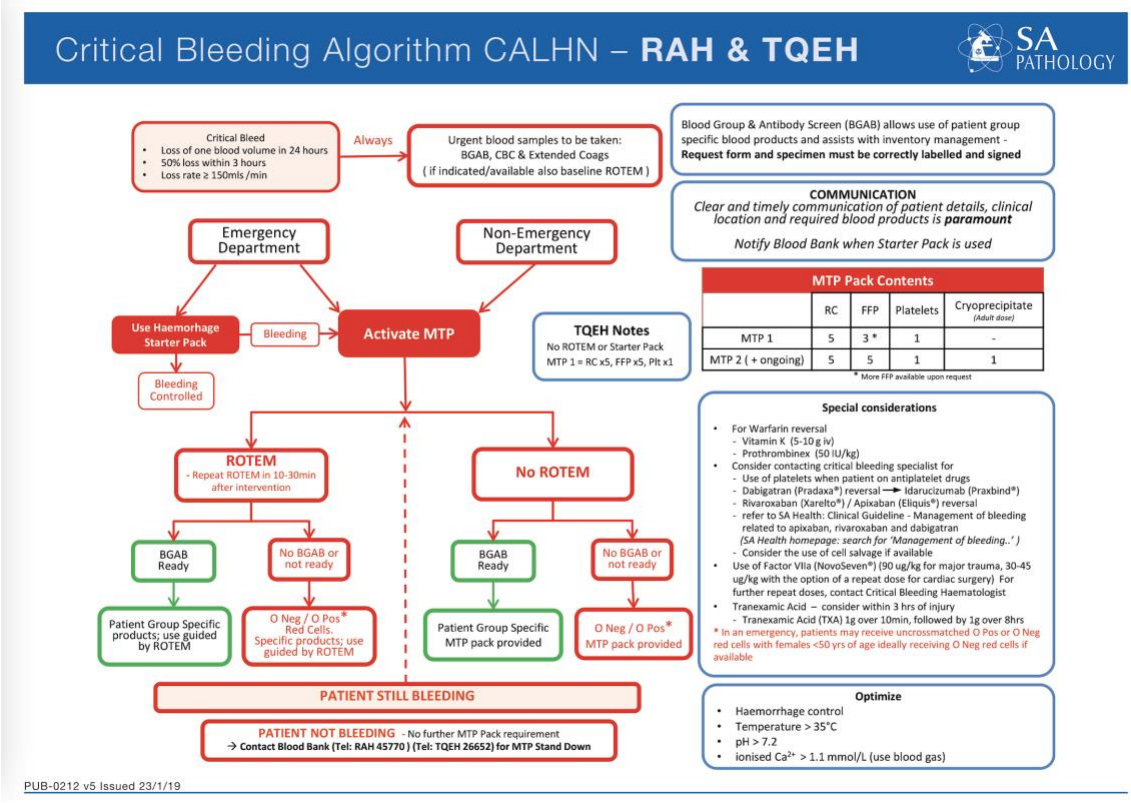
Death via gun violence is a public health problem. This study is designed to aid in reducing mortality from mass shooting incidents. By understanding the level of preparedness for MSIs at trauma centers across the United States, resources can be directed to improve disparities. Mass shooting incidents are unpredictable and every community is at risk. Therefore, it is important to ensure a standard of preparedness is met and assist centers that face barriers to implementing the most current recommendations. Literature over the past twenty years has shown that different mechanisms to improve hemostasis can reduce blood product requirements. This can be most significant for lower-level trauma centers and areas where blood supplies are less plentiful. However, these areas are the most likely to face cost barriers when attempting to implement new protocols. It is imperative to identify areas most in need so that resources can be provided and/or federal support under the umbrella of disaster preparedness and military-civilian collaboration can be established. In addition, this study will promote knowledge sharing among trauma centers. By sharing the features of protocols at different trauma levels, institutions can find opportunities for their own quality improvement and connect through the ACS network for support.

It is important to note that all of the protocols being investigated in this study apply to the treatment of patients once an MSI has occurred. The most significant action that can be taken to reduce mortality from gun violence is prevention. Recent efforts from the

American College of Surgeons Committee on Trauma have attempted to achieve consensus as to the best practices for violence prevention in the United States. (Appendix D). To achieve a significant reduction in mortality from mass shooting incidents, we must improve preparedness in conjunction with societal efforts to prevent gun violence.

APPENDIX A

Example of ROTEM guided MTP[29]



RAH ROTEM TRANSFUSION ALGORITHM FOR ADULT TRAUMA

Critical Bleeding for ROTEM (Only EXTEM and FIBTEM performed as default)

[Optimise: Temp > 36°C pH > 7.2 Ca (ion) >1 mmol/L Hb >70g/L Plt > 75 x 10^9/L]

How to read algorithm/Example:

Test Run Time (Check)

ROTEM	→	*RESULTS*	*DIAGNOSIS*	*TREATMENT*

5 min (Check) [Run the sample for at least 30 min to rule out hyperfibrinolysis – see below]

NORMAL ROTEM

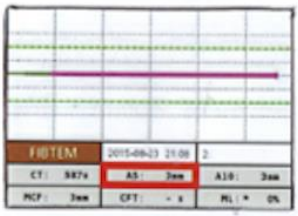
RESULTS	DIAGNOSIS	TREATMENT
EXTEM CT < 90s EXTEM A5 ≥ 40 mm FIBTEM A5 ≥ 10 mm EXTEM ML < 15 % (30 min)	Normal	Nil

Note: If ongoing bleeding – repeat ROTEM if no surgical cause found or after initial 4 units of packed red cells

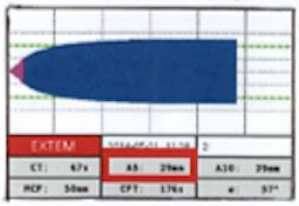
ABNORMAL ROTEMs: (SEE BELOW)

Contact Critical Bleeding Haematologist via switchboard or refer to roster

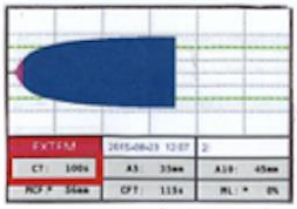
Repeat ROTEM 10 min after every intervention to assess response



RESULTS	DIAGNOSIS	TREATMENT
FIBTEM A5 ≤ 10 mm	Low Fibrinogen	Start FFP and give 1 Adult dose CRYO when available

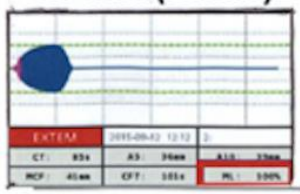


RESULTS	DIAGNOSIS	TREATMENT
EXTEM A5 < 40 mm AND FIBTEM A5 > 10 mm	Low platelets	Platelets 1 adult dose



RESULTS	DIAGNOSIS	TREATMENT
EXTEM CT ≥ 90s AND FIBTEM A5 > 10 mm	Low coagulation factors	FFP 2-4 units OR PCC 10 Units/kg

30 min (Check)



RESULTS	DIAGONSIS	TREATMENT
EXTEM ML ≥ 15%	Hyperfibrinolysis	Tranexamic Acid 1g IV

APPENDIX B

Recommendations for MSI Emergency Response Plans[37]

Themes	Prehospital Recommendations	Emergency Medicine Recommendations	Surgery Recommendations	Common Recommendations
Prior Training, Exercises, Readiness	Communities need to conduct regular drills and exercises involving participants at all response levels, including senior leadership. Mass shooting exercises should mirror actual events and what to expect.	"Train the way you fight" – create daily practices or training exercises that that reflect practice during an MSI. Include specific exercise activity related to the physical plant, such as transporting patients to and on elevators, mobilizing supplies from storage, and practicing space expansion.	Multidisciplinary education, training, and exercises should include all clinical units (e.g., ED, surgery, anesthesia, ICUs, stepdowns, blood bank) and providers of all levels (physicians, nurses, techs, trainees, and support staff).	**MSI drills and exercises should be conducted regularly and must includes all potential participants from support staff to senior leadership. MSI drills and exercises should be as realistic as possible and include all aspects of care delivery.**
		Trauma care training, like Advanced Truama Life Support (ATLS), is valuable for staff, especially those who do not regularly care for trauma patients.	Surgical specialties not traditionally involved in trauma care, but that could assist in emergency operative interventions, should be included in response training.	**Medical staff should undergo trauma and response training, as it is especially valuable for those who do not care for trauma patients regularly.**
Community Preparation of Bystander, Civilian, Law Enforcement	Specific education about seeking treatment and not overloading hospitals is also important.	Civilians can and do help with movement and evacuation of injured people. Training or information can help make this more successful.	Active shooting preparedness and response training should be more widely available to the public and include information about patient transportation by the public.Internet mapping programs should include noting a hospital as an ACS-designated trauma facility.	**Laypeople should receive prior education or immediate direction from web-based mapping programs about the appropriate hospitals to bring MSI patients for care.**
		Stop the Bleed education is beneficial for community preparation.	Stop the Bleed and tourniquet training should be widely implemented to the public and providers at all levels.	**Stop the Bleed education should be performed widely as an important part of community preparation**
Triage	Triage needs to occur at the site of mass shooting incidents (MSI).	Initial triage should take place prior to hospital entry. Triage should be a repetitive, iterative process.	Initial triage of critically injured patients should occur to prioritize access to the hospital and operating room (OR).	**Triage should be staged and iterative at the scene, emergency department, and to priortize operative care**
	SALT triage with consideration of anatomical gunshot wound injuries.	Mass shooting triage protocol should emphasize GSW injury pattern and mentation.		**A mass shooting triage protocol should include injury pattern and anatomic considerations**
		EM physicians and surgeons should triage together in the ED. Experienced physicians should perform triage.	A surgeon should remain in the ED to choose patients for the OR.	**Surgeons should assist with triage in the ED, particularly to identify appropriate patients for the OR**
Communications	Appropriate, effective, and frequent communication between the field, command and hospital	Direct communication between ED and scene is essential.	Frequent, direct communication between the hospital, law enforcement, and EMS is necessary .	**There must be effective communications from the scene, command center, and hospitals by all emergency response agencies.**
	Hospitals and healthcare systems must work/communicate together across the region		Regional hospitals should have a system to communicate and coordinate capacities and resources in real time.	**Coordinated hospital communications and capacity awareness should be available across a region.**
		Ensure modern, redundant ways to reach people for extra help. Use a group activation plan (such as WhatsApp, Everbridge, etc.) vs. individual texts/calls.	Hospitals should use immediate, redundant methods to contact staff.	**Hospitals should use immediate, redundant methods to reach staff during an emergency or MSI.**
Patient Identification and Tracking	Using Treatment Tags that include patient identifying bar codes could potentially facilitate patient tracking from field to hospital and subsequent patient documentation.	Consider a national tracking system,such as a national bar code plan, that could integrate across multiple EHRs, both pre-hospital and hospital.	Hospitals need a robust and redundant system to label and track identified and unidentified patients throughout a large MSI.	**A seemless system is needed to track patients accurately from the scene through definitive care and rehabilitation**
Space Expansion Plans		Hospitals should have plans to rapidly increase capacity and physical space during a mass shooting. Implement a routine protocol to move patients rapidly in and out of essential areas, such as resuscitation bays, so beds can be freed for others.	Shift patients internally without discharge to repurpose and open new spaces.	**Hospitals should plan to increase capacity rapidly, including moving patients internally without discharge, rapid emergency department and in-house discharges, and opening, flexing, or repurposing spaces.**
Staffing		Include law enforcement/security in staffing response to control access, maintain security, prevent a secondary attack.	Every department, including support services and leadership, must have the ability to rapidly surge and supply staff for mass shooting events.	**Staffing plans for MSI must include all categories of staff from hospital leadership to support services, not just clinical staff.**
Military-Civilian Collaboration		Military-civilian collaboration was helpful at sites with existing collaborative relationships.	When possible military healthcare facilities should be incorporated into civilian trauma systems to increase MSI capacities and capabilities.	**Creating military-civilian healthcare collaborations is helpful for MSI preparation, and may facilitate rapid incorporation of military clinical resources in an MSI response.**
Clinical Treatment	Better education and protocols for EMS clinicians about when, why, and how to use wound packing, airway techniques, and whole blood administration.		Up-to-date hemostatic transfusion protocols should be used in all mass shooting resuscitations.	**Improved education and current treatment protocols are needed for hemorrhage control and blood transfusion during MSIs.**
Medical Records (Documentation)	Consider abbreviated system of documentation such as paper tags or apps.	Alternate and redundant documentation mechanisms and "simple" fallbacks are needed.	EHRs should have a tool/template to rapidly document care for MSI patients and the ability to document at the bedside.	**Alternative methods of rapid documentation and orders should be established and practiced in advance.**
Family Reunification	Establishment of a family assistance center is critical and requires very rapid implementation.	Every community and hospital should have a coordinated family reunification plan.	Local governments, working with hospitals, should have a plan to rapidly identify victims and communicate with families.	**All local governments, in collaboration with local hospitals should have a family reunification/information plan included in their disaster and MSI plans.**
	Locate the family assistance center close to the incident site.	Designate a predetermined, nearby location where concerned family members can go (e.g. a convention		**Family reunification centers should be located near the incident site.**
Grieving and After-Action Mental Health	There should be a prospectively established process for mental health support that can be broken up into debriefing situations that include individuals with similar experiences.	Standardized grieving and debrief process is necessary.	All organizations should have active-outreach and perhaps anonymous mental health programs for providers and trainees after any MSI.	**Organizations should have have pre-existing mental health support systems, processes, and resources to assist staff affected by the MSI response.**

KEY

Agreement between all three sub-groups
Agreement between EM and Surgery sub-groups
Agreement between EMS and EM sub-groups
Agreement between EMS and surgery sub-groups

APPENDIX C

Proposed Survey Questions

Initial Survey
Demographics (select the best option)
1. Is your Institution a trauma center verified by the American College of Surgeons (ACS)? (yes) (no)
2. How would you describe your institution? a) Academic medical center/university hospital b) State, community, or city hospital c) Federal government/military facility d) Private, nonprofit e) Private, profit f) Other
3. What trauma center distinction does your institution hold? a) Level 1 b) Level 2 c) Level 3 d) Level 4 e) Level 5
4. Approximately how many beds does your institution have? a) >900 b) 751− 900 c) 601− 750 d) 451− 600 e) 301− 450 f) 150− 300 g) <150
5. In which state is your institution located? -Drop-down list of all states
6. What is the population size of the area your institution serves? a) >1 million b) 500,000 – 1 million c) 100,000 – 500,000 d) 50,000 – 100,000 e) <50,000
7. How would the area your institution serves be classified? a) Urban b) Suburban c) Rural

8. Does your institution currently have an approved emergency response plan for a mass shooting incident in place?
   (yes) (no)

Additional Emergency Response Plan (ERP) Questions
Community Initiatives
1. Does your institution have a plan in place to direct community members on how to seek treatment in the event of an MSI? -Yes (select all that apply) o Online announcements o Web based mapping programs o Public radio/television broadcasts o Ability to change highway signs -No -Other (comment)
2. Does your institution support community initiatives for education on massive hemorrhage control? - Yes (select all that apply) o Stop the Bleed program o Other bleeding control training (comment) -No -Other (comment)
3. How often does your institution hold training exercises for mass shooting incidents? -Biannually -Annually -Every 2-5 years -Every 5-10 years -This institution does not hold training exercises for mass shooting incidents -Other (comment)
4. Who is invited by your institution to participate in training exercises for mass shooting incidents? (select all that apply) -Senior leadership -Trauma surgery staff -Emergency department staff -Non-trauma trained hospital Staff -EMS -Fire -Police -911 operators -Blood bank staff -Civilians -This institution does not hold training exercises for mass shooting incidents

-Other (comment)
5. What departments are required to complete Advanced Trauma Life Support (ATLS) at your institution? (select all that apply) -Emergency department -Trauma surgery -Other surgery -Anesthesia -Intensive care unit -Stepdown unit -None -Other (comment)
6. Which clinical roles are required to complete Advanced Trauma Life Support (ATLS) at your institution? (select all that apply) -Physicians -Advanced practice providers (APP) -Nurses -Techs -Trainees -Ancillary support staff -None -Other (comment)
Triage
1. Where does your ERP designate triage to take place in an MSI? (select all that apply) -Pre-hospital scene -Separate designated pre-hospital site -Ambulance bay -Designated emergency department area -Trauma bay -No designated triage location -Other (comment)
2. What triage protocol are your staff expected to follow in an MSI? -SALT triage -START triage -Anatomic triage -No designated triage protocol -Other (comment)
3. Which clinical roles are designated to triage patients in an MSI? (select all that apply) -EMT -Paramedic -ED technician -ED Nurse -ED Provider (Physician or APP)

-Surgical Provider (Physician or APP) -No role designated for triage -Other (comment)
Expansion
1. What plan does your institution have in place to rapidly increase physical capacity during a MSI? (select all that apply) -Rapid discharge protocol -Internal patient movement to decompress essential areas -Designated internal EM surge areas -Designated internal OR surge areas -Rapid transfer protocol to direct stable patients to lower-level facilities -Diversion protocol -Emergency communication network with outlying trauma centers -No ability to emergently increase capacity -Other (comment)
2. What plan does your institution have in place to rapidly increase staffing during an MSI? (select all that apply) -Established phone call/text network -Established page network -Established email network -Designated communications officer -No plan in place to contact off-shift staff -Other (comment)
3. Which roles does your institution include in emergent staffing requests? (select all that apply) -Physicians -Advanced practice providers -Nurses -Techs -Trainees -Ancillary support staff -Security -No plan in place to contact off-shift staff -Other (comment)
4. What plan does your institution have in place to rapidly acquire additional supplies (i.e. blood products) during an MSI? (select all that apply) -Established emergency agreement with regional suppliers -Established emergency agreement with outlying hospitals -Electronic request network -Radio request network -Phone call/text request network -No plan in place to acquire additional supplies -Other (comment)

Hemorrhage Control
1. Are your pre-hospital services trained in the administration of tranexamic acid (TXA)? -Yes (select all that apply) o EMS o Police o Fire -No -Other (comment)
2. Are your pre-hospital services trained in the administration of whole blood? -Yes (select all that apply) o EMS o Police o Fire -No -Other (comment)
3. Are your pre-hospital services routinely trained in the best practices for bleeding control (i.e. Stop the Bleed, ATLS)? -Yes (select all that apply) o EMS o Police o Fire -No -Other (comment)
4. Does your blood bank currently have an approved Massive Transfusion Protocol in place? -Yes (select all that apply) o Fixed ratio MTP (i.e. 6 plasma : 6 platelets : 6 RBC) o Transfusion threshold based MTP (i.e. platelet threshold of 50,000/uL) o Point-of-care coagulation testing guided MTP (i.e. TEG, ROTEM) -No -Other (comment)
5. Does your institution currently have an adjusted MTP in place for MSI? -Yes(select all that apply) o Reduced fixed ratio MTP (i.e. 4:4:4) o Transfusion threshold based MTP o Point-of-care coagulation testing guided MTP -No -Other (comment)
6. What coagulation factors does your institution have available for massive hemorrhage control? (select all that apply) -Tranexamic acid -Fibrinogen concentrate -Cryoprecipitate

-Prothrombin complex concentrate -Factor XIII concentrate -None of the above -Other (comment)
Military-Civilian Collaboration
1. Does your institution have a military-civilian collaboration in place? -Yes, existing relationship in place for day to day operations -Yes, existing relationship in place for disaster use only -Collaboration plan in process -No, interested in military support -No, not interested in military support -Other (comment)
Emergency Response Plan
Please upload a de-identified version of your institution's current ERP for mass shooting incidents if you are willing to share the content with other trauma centers. (not required)

APPENDIX D

ACS Committee on Trauma Consensus Recommendations[42]

ACS NEWS

ACS-COT Firearm Strategy Team (FAST)

13 recommendations based on public safety principles

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Obtaining ownership

Principle: We believe those who are a danger to themselves or others should not be allowed to purchase or receive a firearm as a gift or as a transfer from another person.

1. A robust and accurate background check in accordance with federal law for all purchases and all transfers of firearms.

Firearm registration

Principle: A firearm should be transferred with registration in accordance to federal law 18 U.S.C. § 922[g][1-9] just as other properties are, such as vehicles or a home. This would include the private sale and the transfer of property that is bequeathed from an estate or among family members.

2. Firearm registration and the development/implementation of an electronic database for all registered firearms

Licensure

Principle: Certain classes of weapons with significant offensive capability are currently appropriately restricted and regulated under the National Firearms Act classification as class III weapons (eg fully automatic machine guns, explosive devices, and short-barreled shotguns).

3. A formal reassessment of the firearms designated within each of the National Firearms Act classifications

Education and Training

Principle: Responsible firearm ownership and use comes with significant responsibility and understanding of safe handling, care, and use.

4. Formal gun safety training that includes 4 vital safety rules for all new gun owners and hunter safety and safe gun handling education.
5. Direct adult supervision in the use of firearms for children <12 years. Indirect supervision for children between 12-18 years (if not state regulated).

Safe storage

Principle: Owners who do not provide reasonable, safe firearm storage should be held responsible for adverse events related to discharge of their firearm(s).

6. Owners provide safe and controlled storage of their firearms. Those who do not should be held responsible for adverse events related to discharge of their firearm(s).

Mandatory reporting/risk mitigation (Red Flag laws)

Principle: For individuals who are deemed an imminent threat to themselves or others, firearm ownership should be temporarily or permanently restricted based on due process.

7. For those deemed an imminent threat to self or others, programs to remove firearms from such persons should be standard as is done in Extreme Risk Protection Order policies, Red Flag laws, and federal law. Require specific due process measures for removal and return of firearms.
8. Treat mass shootings as terrorism; support/encourage domestic law-enforcement efforts and strategies.

Safety innovation and technology

Principle: Firearm ownership should be made safer through the use of innovative technology such as that used in automobile safety.

9. Develop firearm technology to significantly reduce the risk of self-harm, prevent unintentional discharge, and prevent unintended use by someone other than the registered firearm owner.

Funding for public health research

Principle: Research to understand health conditions underpins the modern practice of medicine and is essential to improve care and develop effective interventions for all health care conditions.

10. Federally fund research for firearm injury and injury prevention at a level commensurate with the burden of the disease without restriction.
11. Conduct research in a bipartisan manner. Broadly address firearm safety, violence intervention and control research; serious mental illness and firearm violence; and improving treatment of patients injured from firearms, among other issues.

Culture of violence

Principle: We all own the culture of violence. The same principle of freedom with responsibility applies to the manner in which mass killings are communicated to the public. We have concerns that the manner and tone in which information is released to the public and covered by the media likely leads to "copy-cat" mass killers.

12. Publicly eliminate the notoriety of the shooter and take an editorially muted approach to the coverage of these events.

Social isolation and mental health

Principle: Social Isolation combined with exaggerated depictions of violence, especially when targeted towards young men, likely contributes to violence in the US.[22]

(22. Council on Communications and Media. Media violence. Pediatrics 2009;124:1495-1503.)

- Cited Here

13. Encourage recognition of mental health warning signs and social isolation; when such warning signs are identified, immediate refer persons to appropriate mental health professionals.

For evident signs of violent ideation, thoughts, or actions encourage peers, teachers, and family to "see something, say something" and report to appropriate local and national law enforcement

These recommendations were developed by trauma surgeons and firearm owners to make firearm ownership safer for all Americans.

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