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American Association for the Surgery of Trauma (AAST) / American College of Surgeons Committee on Trauma (ACS-COT): Clinical Protocol for Damage Control Resuscitation for the Adult Trauma Patient

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ABSTRACT:

Damage control resuscitation in the care of critically injured trauma patients aims to limit blood loss and prevent and treat coagulopathy by combining early definitive hemorrhage control, hypotensive resuscitation and early and balanced use of blood products (hemostatic resuscitation) and the use of other hemostatic agents. This clinical protocol has been developed to provide evidence-based recommendations for optimal damage control resuscitation in the care of trauma patients with hemorrhage.

LEVEL OF EVIDENCE: Therapeutic/Care Management; Level V.

TYPE: Algorithms / Guidelines / Clinical Protocol

KEYWORDS: Damage control resuscitation, hemorrhage, hemorrhagic shock, trauma, coagulopathy.

ABBREVIATIONS:

AAST: American Association for the Surgery of Trauma

ACS-COT: American College of Surgeons Committee on Trauma

ACS: American College of Surgeons

ATLS: Advanced Trauma Life Support

DOAC: direct oral anticoagulants

DCR: Damage control resuscitation

FAST: Focused Assessment with Sonography for Trauma

GCS: Glasgow Coma Score

MT: Massive transfusion

MTP: Massive transfusion protocol

NTDB: National Trauma Data Bank

PROPPR Trial: Pragmatic, Randomized Optimal Platelet and Plasma Ratio trial

PROMTT Trial: Prospective Observational Multicenter Major Transfusion trial

PRBC: packed red blood cells

RCT: Randomized controlled trial

REBOA: Resuscitative endovascular balloon occlusion of the aorta

ROTEM: rotational thromboelastometry

SBP: Systolic blood pressure

TBI: Traumatic brain injury

TEG: thromboelastography

Introduction

Hemorrhage is the leading cause of preventable death among injured patients. [1] Damage control resuscitation (DCR) describes the comprehensive care provided to minimize blood loss until definitive hemostasis is achieved, treat life-threatening injuries and to prevent/treat the lethal cycle of hypothermia, coagulopathy, acidosis and hypocalcemia. [2,3] Modern DCR significantly increases survival with the ultimate goal of zero preventable deaths after injury. [4]

Protocol Rationale and Goals:

Partners from the AAST and the ACS-COT established a work group to create this clinical protocol. The work group conducted a literature review to identify prospective and retrospective studies related to Damage Control Resuscitation in trauma patients. These studies were reviewed by members of the group, and consensus recommendations were generated based on current literature and expert opinion **(Figures 1 and 2)**. This Clinical Protocol has been reviewed and approved by the AAST Board of Managers and the ACS-COT Executive Committee.

The clinical protocol and evidence-based algorithm presented here is based on best available evidence from national and international guidelines (**Table 1**) and the consensus of experts on this panel. However, treatment decisions regarding management in trauma patients should be individualized for each patient and do not exclude other treatment strategies as being within the standard of care. Ultimately, the responsibility to implement treatment decisions rest with the treating physician at bedside in the intensive care unit.

Evidence Base: Brief Summary

Indications for DCR

Numerous characteristics have been used to identify trauma patients likely to require massive transfusion (MT), with associated high mortality risk.

Blood Pressure

Hypotension (defined as SBP<90mmHg) has been shown to predict the need for MT, with each 10mmHg increase associated with a 26% decrease in MT likelihood. SBP<90mmHg may be too restrictive for certain populations, with recommendations to expand the hypotension definition to include mild (100-110 mmHg), moderate (90-100 mmHg), or severe (< 90 mmHg). [5] Age-stratified SBP benchmarks may be useful. [5,6] The National Expert Panel for Field Triage suggests using SBP < 110 mmHg for age > 65 years. [7] Other protocols suggest adding heart rate <60bpm or >100bpm to this screening criteria in order to refine early identification of high-risk elderly trauma patients. [6] In other studies, heart rate alone did not predict the need for MT on multivariate regression analysis, and thus has not been recommended. [8]

Shock Index

Given the limitations of using SBP as a sole criterion, others have examined use of the shock index (HR/SBP) to predict MT, and it was recently included in the National Field Triage Guidelines. [9] A systematic review of SI for MT prediction after trauma identified 0.9 as an ideal cut-off, but acknowledged that using SI > 1 is easier to calculate and may be a safe, feasible, reproducible standardized screen. [10] Given the strength of the data for SI as a triage tool, the latest National Field Triage Guidelines recommend use of HR > SBP as a practical and rapid means of capturing patients with an SI > 1, including this as a "Red Criteria" associated with a 'high risk of serious injury'. [7] In a retrospective analysis of nearly 2,500 severely injured patients, SI modified for age (age x SI), or including mean arterial pressure (MAP) rather than SBP (modified SI = HR/MAP), did not improve the sensitivity/specificity of the tool, with SI > 0.95 associated with sensitivity 56% and specificity 88% for MT. SI utility is most compromised in patients with pre-existing comorbidities (diabetes, coronary artery disease, hypertension). [11] For prehospital SI, the cut-off for acceptable accuracy in predicting MT is higher than SI obtained in the trauma center. Additionally, the combination of pre-hospital and trauma center SI was only marginally more accurate than trauma center SI alone. [12]

End Tidal CO2 (EtCO2)

Numerous recent reports reveal the utility of low EtCO2 (<26-28.5mmHg in adults) in the prehospital setting, emergency room, [13] and intraoperatively, [14] in predicting need for MT and mortality in trauma. [15] In one study, prehospital EtCO2 was a better predictor of mortality than SBP or SI, [15] and in another initial EtCO2 effectively predicted poor outcome including when controlling for mechanism and ISS. [16] These associations have been confirmed in TBI, [17] and for non-intubated, non-full trauma activation patients. [18]

The physiologic underpinnings of EtCO2 utility have been confirmed by correlating EtCO2 in the emergently intubated trauma patient with noninvasive measures of cardiac output, [19] showing that the PaCO2-EtCO2 difference is closely associated with outcome, [17] Importantly, EtCO2 cannot be used to rule-out severe injury. [20]

Initial Trauma Center History and Physical Exam Components: Age, Sex, Mechanism Pattern, FAST, GCS

Age greater than 55 has been shown to be predictive of worse hemorrhage, particularly retroperitoneal, for patients with otherwise similar injury complexes and characteristics. [8] Sex was included in several tested models, but was not shown to be predictive, though it has been included in historical composite scores. [5,8,11] Injury severity and pattern has been shown to be predictive of the need for damage control surgery in military/civilian populations. [21] Penetrating mechanism was significant on multivariable analysis of factors predictive of MT in combat casualties, but not consistently reproduced in the civilian literature. [22] Unstable pelvis fractures have been shown to be significantly associated with increased risk of MT. [8] Finally, each exam region which is positive on an initial FAST exam is associated with an increased risk of MT. [8] GCS was evaluated in one study, and was not significantly associated with MT on multivariate analysis. [8]

Laboratory Values

Biochemical measures of end organ perfusion (lactate, base deficit) and measures of coagulopathy are most promising in identifying patients who would benefit from DCR. In a retrospective cohort study conducted to develop a 'trauma bleeding severity score', increasing initial lactate (stratum <2.5, 2.5-5, 5-7.5, >7.5 mmol/L) was associated with an odds ratio of 4.3 for need for MT. [8] In a retrospective review of 6,347 patients, combination of prehospital lactate (with cut-offs 2.5 and 4mmol/L) with the ACS activation criteria would have resulted in a reduction in over-triage by 7.2% with an increase in under-triage of only 0.7%. [23] In a single-institution retrospective cohort study, elevated lactate, acidemia and/or base deficit were more predictive than SBP or SI for the need for damage control thoracic surgery for penetrating trauma. [24] Base deficit is also included in the highest performing composite score, the 'massive transfusion score'. [25] Decreased pH alone was not predictive on multivariate analysis. [5]

Markers of trauma-induced coagulopathy, including viscoelastic testing (TEG, ROTEM), and INR have been shown to be predictive of need for DCR, but their practical utility as inclusion criteria has been limited by lack of generalized availability and result time, with INR taking on average 66 minutes to obtain in one study. [8] Point-of-care (POC) INR correlated with rapid-TEG and transfusion requirement (POC INR >1.5 associated with OR: 6 for MT), while being less costly than TEG. [26] PTT was predictive only on univariate analysis, and has similar time limitations to laboratory based INR. [5] Platelet count was not predictive of MT requirement, likely due to the fact that even a normal platelet count may be insufficient after trauma. [8]

Composite Scores

Composite scores to predict need for MT (**Table 2**) can be useful, but some have been shown to be no better than clinician 'gestalt'. Many scoring systems fail in patients with pelvic hemorrhage, and some scores (RABT, TASH, mTICCS) include pelvic fracture. [27] The Massive Transfusion Score (MTS) is the only score developed since the initiation of the balanced resuscitation era but its sensitivity and specificity is still limited. [27] Scores which rely on laboratory values are limited by the delay required to obtain these results. There is ongoing research on embedding scoring systems in mobile-phone based clinical decision support systems. [28]

Interventions / Therapies

Airway Management

In patients with compromised airway, rapid sequence intubation with volume resuscitation and lower doses of sedatives to prevent cardiovascular collapse is recommended. [29,30] Given the known association with adrenal insufficiency, there is ongoing research into the appropriateness of etomidate. A RCT in a mixed critically ill population, and a multi-center retrospective study in trauma patients both failed to show any association of etomidate use with significant changes in hemodynamics or patient outcomes as compared to propofol and ketamine or a mix of these agents. [31,32]

Volume Resuscitation

Massive Transfusion Protocol (MTP) Activation

Rapid diagnosis and treatment of acute hemorrhage, trauma-induced coagulopathy and hemostatic defects in trauma is life-saving. [33] MTP implementation decreases mortality in trauma, with mortality benefit attributed to appropriate blood product transfusion ratio, time to transfusion, and other system improvements. In a planned sub-analysis of the PROPPR trial, each one minute delay in MTP activation was associated with a 5% increase in mortality, independent of product ratios administered. [34] A recent meta-analysis (14 RCTs; n=3201) reported that MTP significantly reduced overall mortality (OR 0.71, CI 0.56 – 0.90). MTP is currently recommended in the care of trauma patients with hemorrhage. [35]

Transfusion Ratio 1:1:1 (plasma:platelets:red blood cells)

The PROPPR trial confirmed fewer 24-hour deaths due to exsanguination with early administration of blood products in a 1:1:1 vs. 1:1:2 ratio. [36] A 2021 meta-analysis (5 RCTs; n=1757) reported a high platelet:PRBC ratio significantly improved 24 hour (OR 0.69, 95% CI 0.53-0.89) and 30-day (OR 0.78, 95% CI 0.63-0.98) mortality. [37] The 2014 TQIP guidelines recommend between 1:1:2 and 1:1:1 transfusion, the 2017 EAST guidelines recommend 1:1:1 transfusion, and the 2019 European guidelines recommend 'at least' a 1:1:2 ratio. [38–40] A 2021 secondary analysis of the PROMTT trial revealed that a higher ratio (>3:4) of plasma:platelet:PRBC transfusion during DCR was associated with improved survival. [41] A 2021 retrospective study at 17 trauma centers showed plasma:PRBC or platelet:PRBC ratio ≤ 1:1.5 was associated with significantly increased hospital mortality (OR 2.81, p<0.001) in patients who received ≥ 20 units of PRBCs by 24 hours. [42]

Whole Blood

Warm, fresh whole blood was associated with a mortality benefit compared to blood component therapy in the military setting. Whole blood combined with component therapy was associated with improved survival in ACS-TQIP data (n=2785) compared to component therapy. [43,44] Two prior systematic reviews concluded no difference in mortality or product usage, but that whole blood use is safe and feasible. [45,46] A prospective observational study in 14 trauma centers (n=1623) reported significantly decreased 24-hour mortality (14 vs. 32%) and a 48% reduction in hospital mortality. [47] Two large multicenter RCTs are ongoing to determine whether whole blood resuscitation should be standard of care in hemorrhagic shock. [48,49] The Joint Trauma System consensus statement states that whole blood is the 'resuscitation product of choice for the treatment of hemorrhagic shock for all casualties at all roles of care'. [50] Institutions which develop whole blood programs are recommended to also develop a plan for identifying and supporting patients at risk of isoimmunization (i.e. Rh- patients), particularly females who may go on to childbearing. [51]

Isotonic Crystalloid Resuscitation

Improved outcomes are noted with blood product compared to crystalloid resuscitation after trauma, both in-hospital and prehospital settings. [52] A secondary analysis of the PROPPR study revealed each additional 500mL of crystalloid administered in the first 6-hours of hospital-based resuscitation was associated with a 9% increase in ARDS, but number blood products received was not predictive of ARDS. [53] The latest Tactical Combat Casualty Care guidelines for fluid resuscitation include the statement that 'crystalloids and hextend are no longer recommended as fluid resuscitation options in hemorrhagic shock'. [54] During the first 24 hours of resuscitation of the severely injured trauma patient, use of balanced crystalloid solutions (e.g. Lactated Ringers, Plasmalyte) vs. normal saline was associated with improved acid/base status and less hyperchloremia. [55] However, in TBI, normal saline is recommended. [56]

Venous Access

Guidelines recommend two 18 gauge or larger peripheral intravenous catheters. If not possible, intraosseous (IO) and central venous access are recommended . [57,58] A single institution prospective observational study of the resuscitation of trauma patients undergoing emergency department thoracotomy revealed attempts at IO access to be as fast as PIV attempts, and twice as likely to be successful. [59]

Hypotensive Resuscitation

Two systematic reviews concluded significant mortality benefit associated with hypotensive resuscitation. [60,61] A 2011 RCT compared intraoperative MAP goal of 50mmHg or 65mmHg in patients in hemorrhagic shock undergoing emergency surgery. This report demonstrated less post-operative coagulopathy and short-term mortality in the lower MAP goal group, but was terminated early as it was underpowered to detect the primary endpoint of 24 hour mortality. [62] A 2015 RCT comparing goal SBP 70 to 110mmHg in the pre-hospital setting, without access to blood product resuscitation, showed improved mortality for blunt trauma patients with the lower SBP goal. [63] It is important to note that several studies targeting lower blood pressure goals during resuscitation have been unable to meet the proposed "hypotensive" comparison cohorts. This makes comparison of "hypotensive" and "normotensive" resuscitation difficult. The observed benefits observed in the "hypotensive" group might be more reflective of restrictive fluid strategies rather than truly lower blood pressure. Furthermore, patients with TBI were excluded from the above studies, given the data suggesting worse outcomes in patients with TBI who experience hypotension. [60]

Resuscitation Adjuncts

Prevent and Treat Hypothermia (T < 36º C)

Continuous measurement of sublingual, tympanic, or urinary bladder catheter temperature is recommended, [64] and invasive monitors (e.g. esophageal, bladder) more closely approximate core temperature (i.e. intravascular). [65] Hypothermia is independently associated with increased blood product needs and mortality in trauma patients, and aggressive correction mitigates this increased mortality. [66,67] Evidence-based algorithms include active re-warming for anyone with T

< 37º C. However, if a tourniquet is in place, warming the extremity beyond the tourniquet is not recommended. [64,68]

Of note, therapeutic hypothermia has been explored for TBI, however, two recent systematic reviews / meta-analyses and one international RCT failed to show consistent evidence of benefit on neurologic outcome or mortality. [69–71] Thus, therapeutic hypothermia for TBI is not recommended.

Reverse Anticoagulation when Present

Trauma patients with pre-injury anticoagulation have increased mortality. [72] Recommendations exist for all patients with serious or life-threatening bleeding to undergo reversal, though mortality benefit from reversal is not consistently demonstrated. [73,74] Prothrombin complex concentrate has been shown to be effective for reversal of both vitamin K antagonists and DOACs, and offers the advantage of decreased volume administration; minimal data exist for outcomes for drug-specific DOAC reversal. [75] Patient history re indications for use and time of last dose are necessary, with consideration for re-initiation upon stabilization and cessation of hemorrhage. A 2022 multicenter severe TBI study did not find antiplatelet or anticoagulation reversal to be associated with mortality benefit. [76]

Correct Acidosis

Correction of acidemia is feasible in injured patients, and, when lactate is used as a proxy, correction improves outcomes. [77] The primary means of correcting acidosis is hemorrhage control and blood product resuscitation. [78] Sodium bicarbonate to correct acidemia in trauma is not well-studied, data and consensus from critically ill patients in general suggest no utility in patients with a pH > 7.2, and questionable utility below this. [79] Hyperchloremic metabolic acidosis secondary to normal saline infusion is not an indication of ongoing resuscitation needs, but rather iatrogenesis to be avoided and allowed to self-correct when it occurs. [55]

Treat Hypocalcemia (Target Ca(2+) > 1 or 1.2 mmol/L)

Hypocalcemia is common in injured patients and is associated with increased transfusion requirement, coagulopathy, and mortality. [80] Military guidelines recommend maintaining Ca(2+) > 1-1.2 mmol/L with administration of 1gm calcium with the first unit of blood product, and at least after four units. [68] Calcium gluconate (4gm IV over 4hrs) was safe and effective at raising Ca(2+) > 1 mmol in multisystem critically ill trauma patients (10% developed mild hypercalcemia). [81] Others simply recommend giving ‘early’ calcium supplementation. [82] There are no prospective trials demonstrating improved outcome with hypocalcemia correction, and a recent retrospective cohort analysis did not show improved outcomes. [83]

Correct Trauma-Induced Coagulopathy

Coagulopathy is associated with worse outcomes in trauma, and modern DCR techniques including whole blood and 1:1:1 blood product transfusion are effective at minimizing its development. [84] In addition to prevention, research is ongoing regarding optimal means of monitoring, and correcting trauma-induced coagulopathy once developed, and assessing impact on patient outcomes.

A single-center 2016 RCT reported less use of blood products and improved 28 day survival for patients whose resuscitation was guided by TEG compared to conventional coagulation measurements (INR, platelet, fibrinogen). [85] While some recommend TEG-guided resuscitation, a 2021 multi-center RCT (ITACTIC) found no difference in clinically important outcomes between resuscitation guided by TEG compared to conventional coagulation tests. [86] In patients with TBI, a 2021 systematic review/meta-analysis, primarily driven by subgroup analysis of ITACTIC data, concluded TEG/ROTEM guided resuscitation in this population 'may' improve outcome. [87]

Tranexamic Acid (TXA)

TXA administered within 3-hours of injury resulted in improved mortality across civilian and military settings, in patients with both extra- and intracranial hemorrhage. [88,89] Additional TXA in those with fibrinolysis by viscoelastic testing may be helpful. The Targeted Action for Curing Trauma Induced Coagulopathy (TACTIC) systematic protocol recommends additional TXA if rapid TEG clot lysis at 30minutes (LY30) > 10%. [90] Others recommend more liberal TXA use, citing its cost-effectiveness and safety, thus recommending early and empiric treatment. [91] Data for TXA use in isolated TBI are mixed, with one systematic review concluding no clinical benefit and 'probably' no harm, and one recent multicenter prospective cohort study finding increased mortality in isolated TBI with pre-hospital TXA administration. [92,93]

Vasopressors

Retrospective data suggest worse outcomes among patients with hemorrhagic shock who are treated with vasopressors, with some data suggesting under-resuscitation and hypovolemia as contributing factors. [94,95] A 2017 systematic review concluded there is insufficient evidence to make recommendations, with studies showing harm reported to be compromised by bias. [96] European guidelines recommend vasopressors to maintain target arterial pressure in addition to fluids in the setting of life-threatening hypotension, and inotrope administration in the presence of myocardial dysfunction. [38] The 2019 AVERT-Shock trial confirmed that low-dose vasopressin in patients with hemorrhagic shock significantly decreased the use of blood products, with no difference in mortality. [97] Of vasoactive agents, vasopressin is best studied, driven by the physiologic rationale that endogenous arginine vasopressin is shown to be deficient in hemorrhaging patients, and the low-doses studied hypothesized to replace endogenous hormone, without promoting excessive vasoconstriction. [97] A 2020 review recommends a nuanced approach, including vasopressors in the management of hemorrhagic shock when vasoplegia is perceived to be contributing to hypotension. [98]

Hemorrhage Control

Compressible Hemorrhage

Tourniquet use has been shown to decrease hemorrhagic shock and improve mortality after major limb trauma, with low rates of complications (most common transient nerve palsy). [99] Junctional tourniquets have been shown to be safe and to effectively compress junctional vessels, but their clinical utility and impact on patient outcome is poorly studied. [100] Hemostatic dressings have been shown to be safe and superior to non-impregnated dressings for hemorrhage control, and may be associated with a decrease in transfused products when used for pre-peritoneal pelvic packing. [101] Data demonstrating improved outcome, including reduced transfusion requirements and mortality, are lacking for pelvic binder use. [102] Nonetheless, given the ability to decrease the size of the pelvis in unstable fractures, and thus theoretically promote tamponade of hemorrhage, as well as a reassuring safety profile, reviews of management of unstable pelvic fractures consistently recommend their use. [103] Emphasis has been made on correct placement over the greater trochanters. [104] Furthermore, commercially designed products may be more effective than 'sheeting', however this data is also weak. [105]

Noncompressible Hemorrhage

A multi-organization joint statement acknowledged the lack of high-grade evidence for improved trauma outcomes with REBOA use compared to standard treatment. The statement recommends REBOA use only by experienced clinicians within a system which includes mature quality assurance mechanisms and immediate access to definitive hemorrhage control maneuvers. Additionally, recommendations included <15 minutes for Zone I and <30 minutes for Zone III deployment. [106] A 2021 systematic review further supports this conclusion, finding existing data for REBOA too heterogeneous in indication to allow for recommendations for routine use, while acknowledging favorable outcomes as compared to resuscitative thoracotomy. [107] In 2022, the AAST REBOA study group published evidence suggesting improved outcomes with REBOA as compared to resuscitative thoracotomy in pelvic hemorrhage, but these data are retrospective with associated confounding by indication. [108]

Early Surgical Intervention

Thoracic Injury

Data from the Vietnam War military experience, with validation in the civilian setting, suggests worse outcomes for patients with blunt or penetrating injury who have initial chest tube output

>1500cc and delay in thoracotomy. [109] The ATLS course suggests consideration for thoracotomy in patients with >1500cc output on initial placement, or >200cc/hr for 2-4 hours following placement. [57] Optimal damage control surgical principles, including packing and temporary thoracic closure, are still being defined. [110]

Abdominal Injury

In a 2018 retrospective analysis of 317 hypotensive trauma patients, FAST had a sensitivity of 62% and specificity of 83% for predicting the need for therapeutic laparotomy within six hours of trauma center arrival. [111]

High-quality data regarding when to employ damage-control rather than definitive surgery are lacking, and a 2021 systematic review confirmed inadequate evidence to draw conclusions regarding indication or effectiveness. [112] A single-institution RCT trended towards improved outcome with damage control laparotomy. [113] However, damage control surgery has also been associated with significant rates of intraabdominal infection, enterocutaneous fistula, and ventral hernia formation, including when compared to matched controls. [114] A 2016 report identified the following indications most highly associated with use of damage control surgery: injury pattern identified during operation, inability to control hemorrhage, greater volume of resuscitation required, severity of physiologic insult, and need for staged abdominal or thoracic wall reconstruction. [115] Published indicators were shown to be consistently used at the primary investigator's institution, but the impact on patient outcome is, as of yet, unpublished. [116]

Resuscitation Endpoints

While increased requirements for fluid, blood products, and vasopressors during initial resuscitation have all been shown to be associated with multiple organ failure in injured patients, the evidence supporting specific endpoints of resuscitation are limited. [53,117] Normalization of perfusion, as assessed by lactate and base deficit, has been suggested as a feasible endpoint which is meaningful in the majority of trauma patients, and is minimally confounded by pre-existing comorbidities or subsequent organ failure. [118] Capillary refill and cardiac/lung ultrasound (pulmonary edema, ventricular filling, IVC respiratory variability, cardiac function, etc.) are well studied in shock. [119,120] Though there is strong physiologic rationale for these in addition to other resuscitation endpoints (e.g. urine output), validating reports in trauma patients are limited.

Limitations

While an extensive literature review was conducted and current studies were evaluated by workgroup members, a formal evaluation of the level of evidence reviewed and the strength of recommendations provided are not included as part of this clinical protocol. We have provided references to formal DCR guidelines to provide this information (**Table 1**).

Conclusion

Hemorrhage is the leading cause of early mortality in severely injured trauma patients, and the core tenets of DCR have been confirmed to significantly decrease mortality. This clinical protocol provides evidence-based recommendations for optimal DCR for critically injured trauma patients with the aim of increasing the application of DCR care to patients across all levels of trauma care. Trauma centers should further customize this clinical protocol for their own institution and specific resource setting.

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Figure 1 Legend.

SBP – systolic blood pressure, HR – heart rate, EtCO2 – end tidal carbon dioxide, FAST – focused assessment with sonography for trauma, INR – international normalized ratio, TEG - thromboelastogram, MTP – massive transfusion protocol, PIV – peripherally intravenous line, MAP – mean arterial pressure, TXA – tranexamic acid.

Figure 1

Figure 1.
Clinical Protocol Summary Recommendations
Damage Control Resuscitation (DCR)

Inclusion Criteria
Recommend use of a composite of the following, selected for feasibility in ones' setting, to determine which patients may benefit from DCR: hypotension (SBP<90mmHg, and <110mmHg for persons >65 years), shock index (HR/SBP >1 or HR>SBP in adults), EtCO2 (<26-28.5mmHg), pelvic fracture, positive FAST, abnormal lactate, abnormal base deficit, point-of-care INR, or rapid-TEG.
Consider the Massive Transfusion Score as composite score with current strongest evidence-base.
Airway Management
In patients with compromised airway protection, intubation with rapid sequence intubation, after a brief period of volume resuscitation to prevent cardiovascular collapse when indicated, recommended.
Volume Resuscitation
Recommend initiation of an MTP with transfusion of whole blood if available, or component therapy in a 1:1:1 ratio. Balanced crystalloids (e.g. Lactated Ringers, Plasmalyte) when blood products not available.
Recommend two PIV >=18 gauge. If unable, intraosseous, and/or central venous access recommended.
Recommend selective use of hypotensive (SBP goal >70 mmHg or MAP goal >50 mmHg) resuscitation. Recommend against its use in trauma patients with known / suspected traumatic brain injury.
Resuscitation Adjuncts
Recommend continuous measurement of temperature, with invasive monitors (e.g. esophageal, bladder) when feasible, with active re-warming for anyone with T <37° Celsius.
Recommend reversal of pre-injury anticoagulation in unstable trauma patients.
Recommend early measurement and correction of ionized calcium.
Recommend early monitoring and correction trauma-induced coagulopathy.
Recommend vasopressor use only in the setting of perceived vasoplegia, 1st choice low-dose vasopressin.
Recommend TXA administration within 3h of injury in patients with hemorrhage, TEG guided re-dosing.
Hemorrhage Control
Recommend compression of hemorrhage as indicated: tourniquets, hemostatic packing, pelvic binders.
In non-compressible hemorrhage, recommend consideration of resuscitative endovascular balloon occlusion of the aorta where adequate clinician experience and quality assurance mechanisms exist.
Recommend early thoracotomy when chest tube output >1500cc on placement or >200cc/h for 2-4 h.
Recommend early laparotomy in unstable trauma patients with a positive FAST.
Recommend selective use of damage control surgery, with consideration for inability to control hemorrhage, ongoing resuscitation requirements, metabolic perturbations, or need for abdominal/thoracic wall reconstruction.
Resuscitation Endpoints
Recommend normalization of perfusion, as assessed by lactate/base deficit, as primary endpoint.

SBP – systolic blood pressure, HR – heart rate, EtCO2 – end tidal carbon dioxide, FAST – focused assessment with sonography for trauma, INR – international normalized ratio, TEG - thromboelastogram, MTP – massive transfusion protocol, PIV – peripherally intravenous line, MAP – mean arterial pressure, TXA – tranexamic acid.

Figure 2

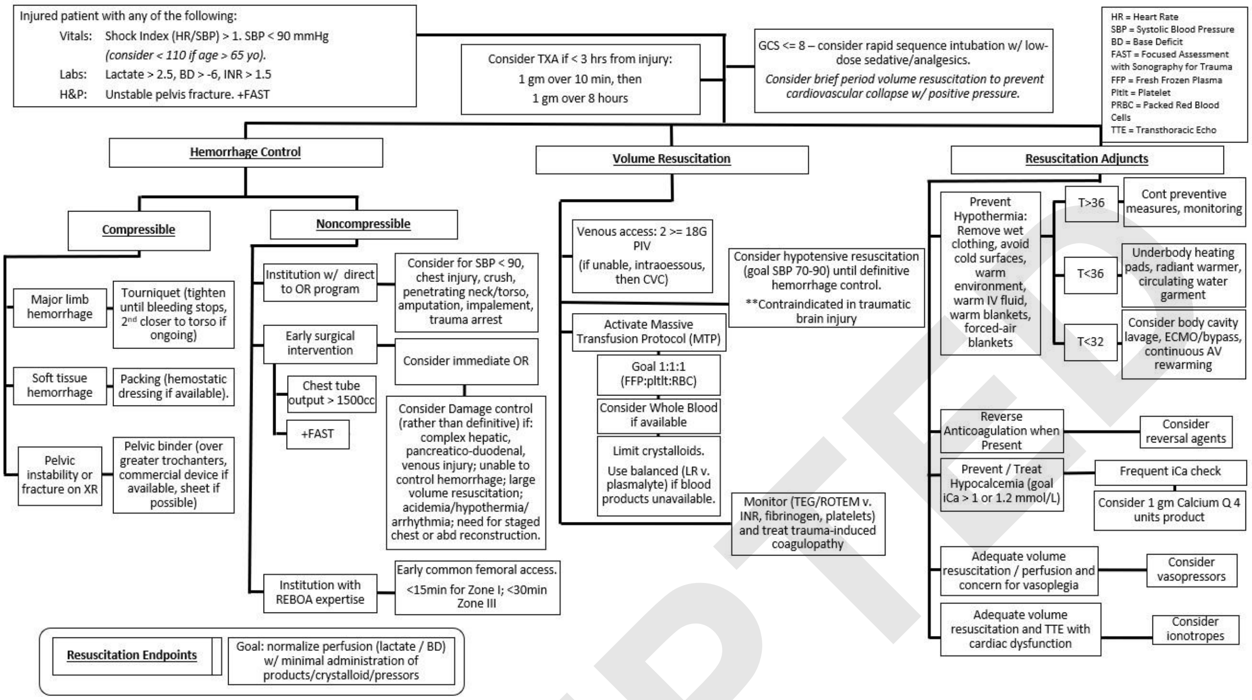

Injured patient with any of the following:
Vitals: Shock Index (HR/SBP) > 1. SBP < 90 mmHg
(consider < 110 if age > 65 yo).
Labs: Lactate > 2.5, BD > -6, INR > 1.5
H&P: Unstable pelvis fracture. +FAST
Consider TXA if < 3 hrs from injury:
1 gm over 10 min, then
1 gm over 8 hours
GCS <= 8 – consider rapid sequence intubation w/ low-dose sedative/analgesics.
Consider brief period volume resuscitation to prevent cardiovascular collapse w/ positive pressure.
HR = Heart Rate
SBP = Systolic Blood Pressure
BD = Base Deficit
FAST = Focused Assessment with Sonography for Trauma
FFP = Fresh Frozen Plasma
Pltlt = Platelet
PRBC = Packed Red Blood Cells
TTE = Transthoracic Echo
Hemorrhage Control
Volume Resuscitation
Resuscitation Adjuncts
Compressible
Noncompressible
Major limb hemorrhage
Tourniquet (tighten until bleeding stops, 2nd closer to torso if ongoing)
Soft tissue hemorrhage
Packing (hemostatic dressing if available).
Pelvic instability or fracture on XR
Pelvic binder (over greater trochanters, commercial device if available, sheet if possible)
Institution w/ direct to OR program
Consider for SBP < 90, chest injury, crush, penetrating neck/torso, amputation, impalement, trauma arrest
Early surgical intervention
Consider immediate OR
Chest tube output > 1500cc
+FAST
Consider Damage control (rather than definitive) if: complex hepatic, pancreatico-duodenal, venous injury; unable to control hemorrhage; large volume resuscitation; acidemia/hypothermia/ arrhythmia; need for staged chest or abd reconstruction.
Institution with REBOA expertise
Early common femoral access. <15min for Zone I; <30min Zone III
Venous access: 2 >= 18G PIV
(if unable, intraoessous, then CVC)
Consider hypotensive resuscitation (goal SBP 70-90) until definitive hemorrhage control.
**Contraindicated in traumatic brain injury
Activate Massive Transfusion Protocol (MTP)
Goal 1:1:1 (FFP:pltlt:RBC)
Consider Whole Blood if available
Limit crystalloids.
Use balanced (LR v. plasmalyte) if blood products unavailable.
Monitor (TEG/ROTEM v. INR, fibrinogen, platelets) and treat trauma-induced coagulopathy
Prevent Hypothermia: Remove wet clothing, avoid cold surfaces, warm environment, warm IV fluid, warm blankets, forced-air blankets
T>36
Cont preventive measures, monitoring
T<36
Underbody heating pads, radiant warmer, circulating water garment
T<32
Consider body cavity lavage, ECMO/bypass, continuous AV rewarming
Reverse Anticoagulation when Present
Consider reversal agents
Prevent / Treat Hypocalcemia (goal iCa > 1 or 1.2 mmol/L)
Frequent iCa check
Consider 1 gm Calcium Q 4 units product
Adequate volume resuscitation / perfusion and concern for vasoplegia
Consider vasopressors
Adequate volume resuscitation and TTE with cardiac dysfunction
Consider ionotropes
Resuscitation Endpoints
Goal: normalize perfusion (lactate / BD) w/ minimal administration of products/crystalloid/pressors

Table 1. National and International Guidelines for Damage Control Resuscitation

Organization	Guideline	Reference
Eastern Association for the Surgery of Trauma	Damage control resuscitation in patients with severe traumatic hemorrhage: A practice management guideline	Cannon JW, Khan MA, Raja AS, et al. J Trauma Acute Care Surg. 2017 Mar;82(3):605-617.
American College of Surgeons-Committee on Trauma	ACS TQIP Massive Transfusion in Trauma Guidelines.	https://www.facs.org/-/media/files/quality-programs/trauma/tqip/transfusion_guildelines.ashx
Joint Trauma System Clinical Practice Guideline	Damage Control Resuscitation (CPG ID:18)	https://jts.amedd.army.mil/assets/docs/cpgs/Damage_Control_Resuscitation_12_Jul_2019_ID18.pdf https://jts.health.mil/assets/docs/damage_control/DCR_QRG_2019-11-04.pdf
Joint Trauma System Clinical Practice Guideline	Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) for Hemorrhagic Shock (CPG ID:38)	https://jts.amedd.army.mil/assets/docs/cpgs/Resuscitative_Endovascular_Balloon_Occlusion_of_the_Aorta_(REBOA)_for_Hemorrhagic_Shock_31_Mar_2020_ID38.pdf
European Task Force for Advanced Bleeding Care in Trauma	The European guideline on management of major bleeding and coagulopathy following trauma: fifth edition.	Spahn DR, Bouillon B, Cerny V, et al. Crit Care. 2019 Dec;23(1):98.
National Institute for Health and Care Excellence (NICE)	Major trauma: assessment and initial management of major trauma. NICE Guideline NG39. Methods, evidence and recommendations. National Clinical Guidelines Centre. February 2016.	https://www.nice.org.uk/guidance/ng39/evidence/full-guideline-2308122833
American College of Surgeons-Committee on Trauma	National guideline for the field triage of injured patients: Recommendations of the National Expert Panel on Field Triage, 2021	Newgard CD, Fischer P, Gestring M, et al. Journal of Trauma and Acute Care Surgery 93(2):p e49-e60, August 2022.
Tactical Combat Casualty Care (TCCC) guidelines	Joint Trauma System TCCC Guidelines 2021. Standard of Care for the Modern Battlefield	https://www.deployedmedicine.com/market/11/content/40

Table 2. Scoring Systems to Predict Massive Transfusion

Score	Components of Score	Prediction Accuracy
MTS Massive Transfusion Score	SBP < 90 HR ≥ 120 FAST positive Penetrating mechanism Base deficit ≥ 6 INR ≥ 1.5 Hemoglobin < 11 g/dL	MTS > 1 = Sensitivity 93%, Specificity 20% MTS > 2 = Sensitivity 70%, Specificity 67% MTS > 3 = Sensitivity 40%, Specificity 87%
ABC Assessment of Blood Consumption Score	Penetrating mechanism = 1 FAST positive = 1 SBP ≤ 90 mm Hg = 1 HR ≥ 120 bpm = 1	**ABC Score ≥ 2** Sensitivity 69%; Specificity 82%
RABT Revised Assessment of Bleeding and Transfusion Score	Penetrating = 1 FAST positive = 1 Shock Index > 1 = 1 Presence of pelvic fracture = 1	**RABT Score ≥ 2** Sensitivity 78% Specificity 91%
TASH Trauma-Associated Severe Hemorrhage Score	SBP < 100 = 4; SBP 100-120 = 1 Heart rate > 120 = 3 FAST positive = 3 Hemoglobin <7 g/dL = 8 < 9 g/dL = 6 < 10 g/dL = 4 < 11 g/dL = 3 < 12 g/dL = 2 Base deficit < 10 = 4 < 6 = 3 < 2 = 1 Extremity or pelvic fractures: AIS score 3 or 4 = 3 AIS score 5 = 6 Male sex = 1	**TASH Score** Sensitivity 68% Specificity 82% Using a logistic function, the TASH score is transformed into the probability of an MT: TASH score < 9 points, <5% MT TASH score ≥ 16 points, > 50% MT TASH score ≥ 27 100% MT
mTICCS Modified Trauma-Induced Coagulopathy Clinical Score	Severity: trauma activation = 2 SBP < 90 mm Hg once = 5 SBP always > 90 mm Hg = 0 Extent of significant injuries: Head/Neck = 1 Upper Extremity = 1 Lower Extremity = 1 Torso = 2 Abdomen = 2 Pelvis = 2 Total possible score 2-16	**mTICCS Score** Sensitivity 78% Specificity 74%

American Association for the Surgery of Trauma (AAST) / American College of Surgeons Committee on Trauma (ACS-COT): Protocol for Damage Control Resuscitation of the Trauma Patient

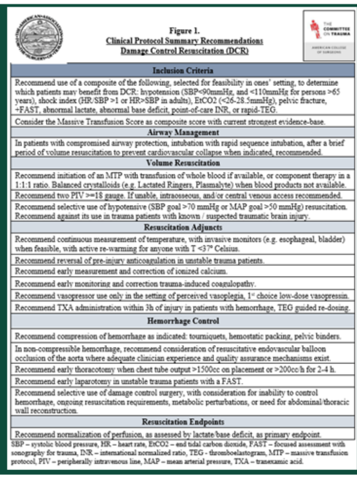
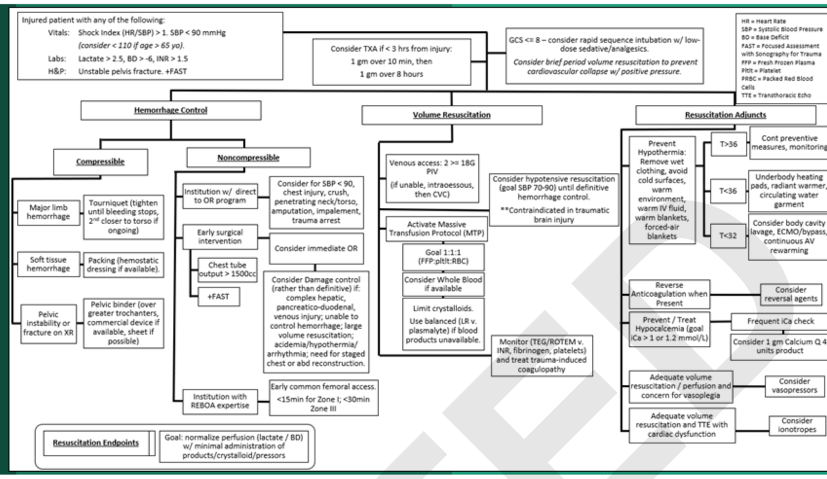


Figure 1.
Clinical Protocol Summary Recommendations
Damage Control Resuscitation (DCR)

Inclusion Criteria
Recommend use of a composite of the following, selected for feasibility in ones' setting, to determine which patients may benefit from DCR: hypotension (SBP<90mmHg, and <110mmHg for persons >65 years), shock index (HR/SBP >1 or HR>SBP in adults), EtCO2 (<26-28.5mmHg), pelvic fracture, +FAST, abnormal lactate, abnormal base deficit, point-of-care INR, or rapid-TEG.
Consider the Massive Transfusion Score as composite score with current strongest evidence-base.
Airway Management
In patients with compromised airway protection, intubation with rapid sequence intubation, after a brief period of volume resuscitation to prevent cardiovascular collapse when indicated, recommended.
Volume Resuscitation
Recommend initiation of an MTP with transfusion of whole blood if available, or component therapy in a 1:1:1 ratio. Balanced crystalloids (e.g. Lactated Ringers, Plasmalyte) when blood products not available.
Recommend two PIV >=18 gauge. If unable, intraosseous, and/or central venous access recommended.
Recommend selective use of hypotensive (SBP goal >70 mmHg or MAP goal >50 mmHg) resuscitation. Recommend against its use in trauma patients with known / suspected traumatic brain injury.
Resuscitation Adjuncts
Recommend continuous measurement of temperature, with invasive monitors (e.g. esophageal, bladder) when feasible, with active re-warming for anyone with T <37° Celsius.
Recommend reversal of pre-injury anticoagulation in unstable trauma patients.
Recommend early measurement and correction of ionized calcium.
Recommend early monitoring and correction trauma-induced coagulopathy.
Recommend vasopressor use only in the setting of perceived vasoplegia, 1st choice low-dose vasopressin.
Recommend TXA administration within 3h of injury in patients with hemorrhage, TEG guided re-dosing.
Hemorrhage Control
Recommend compression of hemorrhage as indicated: tourniquets, hemostatic packing, pelvic binders.
In non-compressible hemorrhage, recommend consideration of resuscitative endovascular balloon occlusion of the aorta where adequate clinician experience and quality assurance mechanisms exist.
Recommend early thoracotomy when chest tube output >1500cc on placement or >200cc/h for 2-4 h.
Recommend early laparotomy in unstable trauma patients with a FAST.
Recommend selective use of damage control surgery, with consideration for inability to control hemorrhage, ongoing resuscitation requirements, metabolic perturbations, or need for abdominal/thoracic wall reconstruction.
Resuscitation Endpoints
Recommend normalization of perfusion, as assessed by lactate/base deficit, as primary endpoint.

SBP – systolic blood pressure, HR – heart rate, EtCO2 – end tidal carbon dioxide, FAST – focused assessment with sonography for trauma, INR – international normalized ratio, TEG - thromboelastogram, MTP – massive transfusion protocol, PIV – peripherally intravenous line, MAP – mean arterial pressure, TXA – tranexamic acid.



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