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Hemorrhagic Shock

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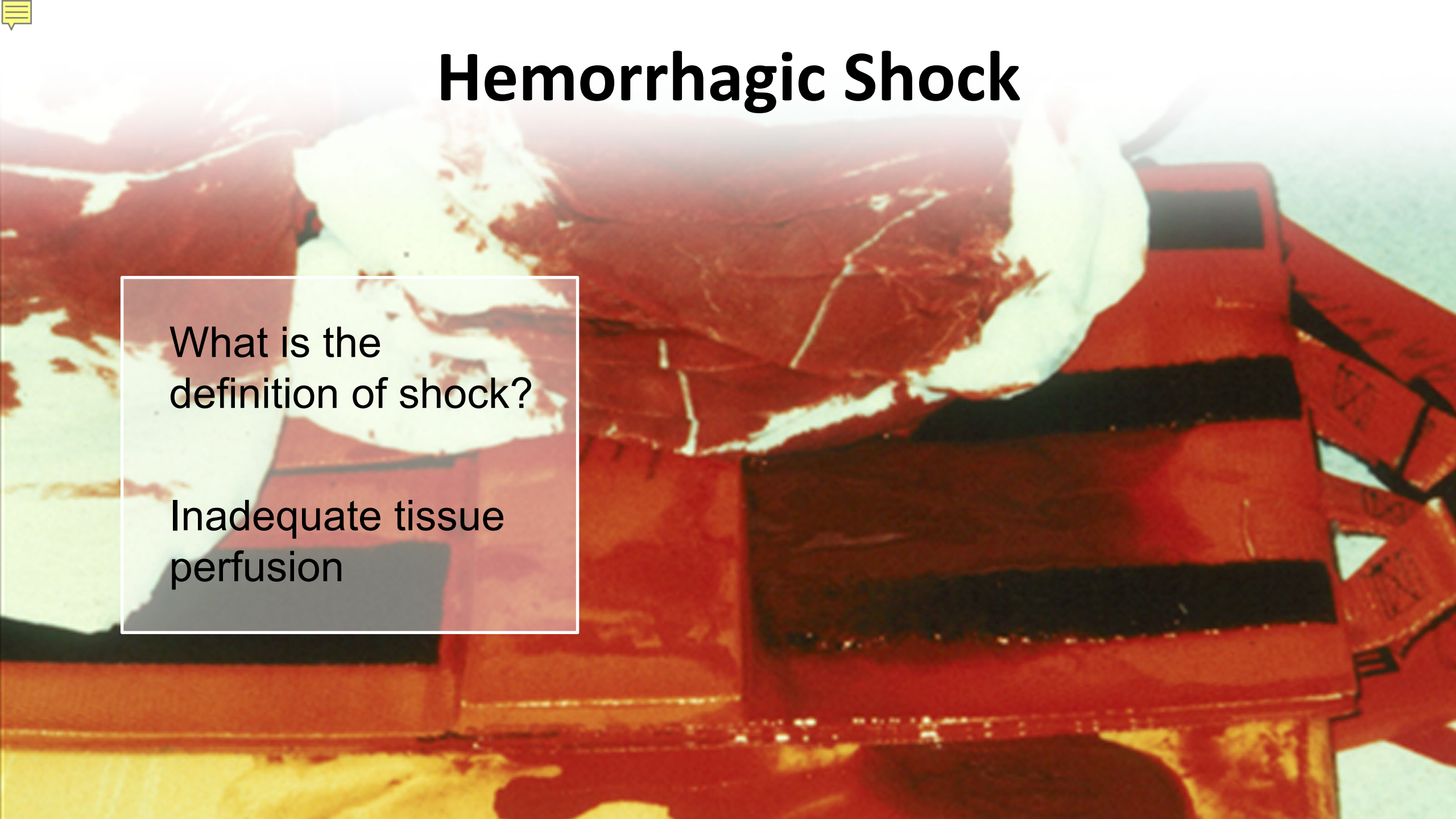
Objectives

At the conclusion of this presentation the participant will be able to:

- Define hemorrhagic shock.
- List common causes of hemorrhagic shock in the trauma patient.
- Recognize the signs and symptoms of hemorrhagic shock.
- Explain the importance of early control of hemorrhage in trauma patients.
- Describe initial management of hemorrhagic shock.
- Describe ongoing evaluation of the trauma patient with hemorrhagic shock.

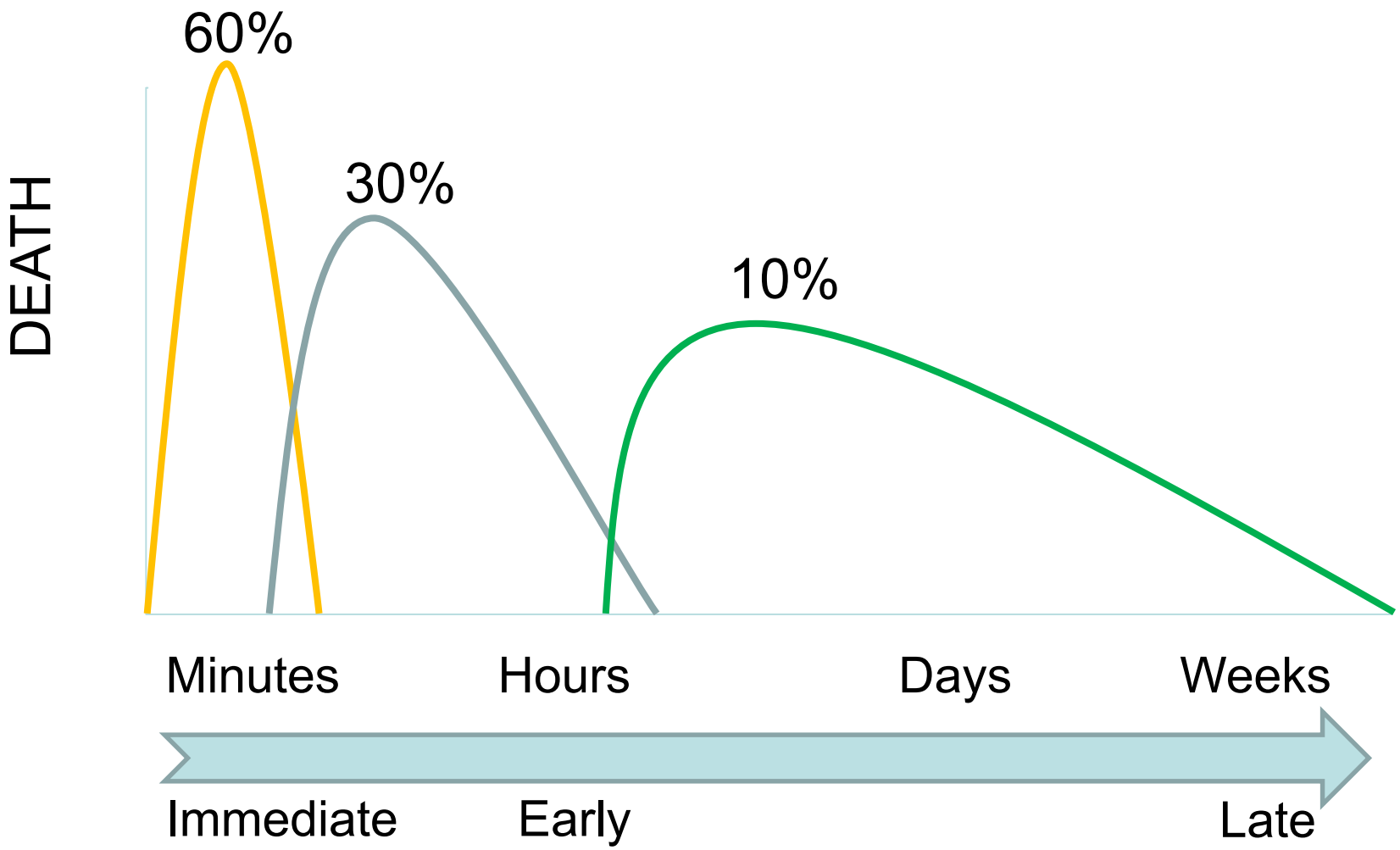
Hemorrhagic Shock



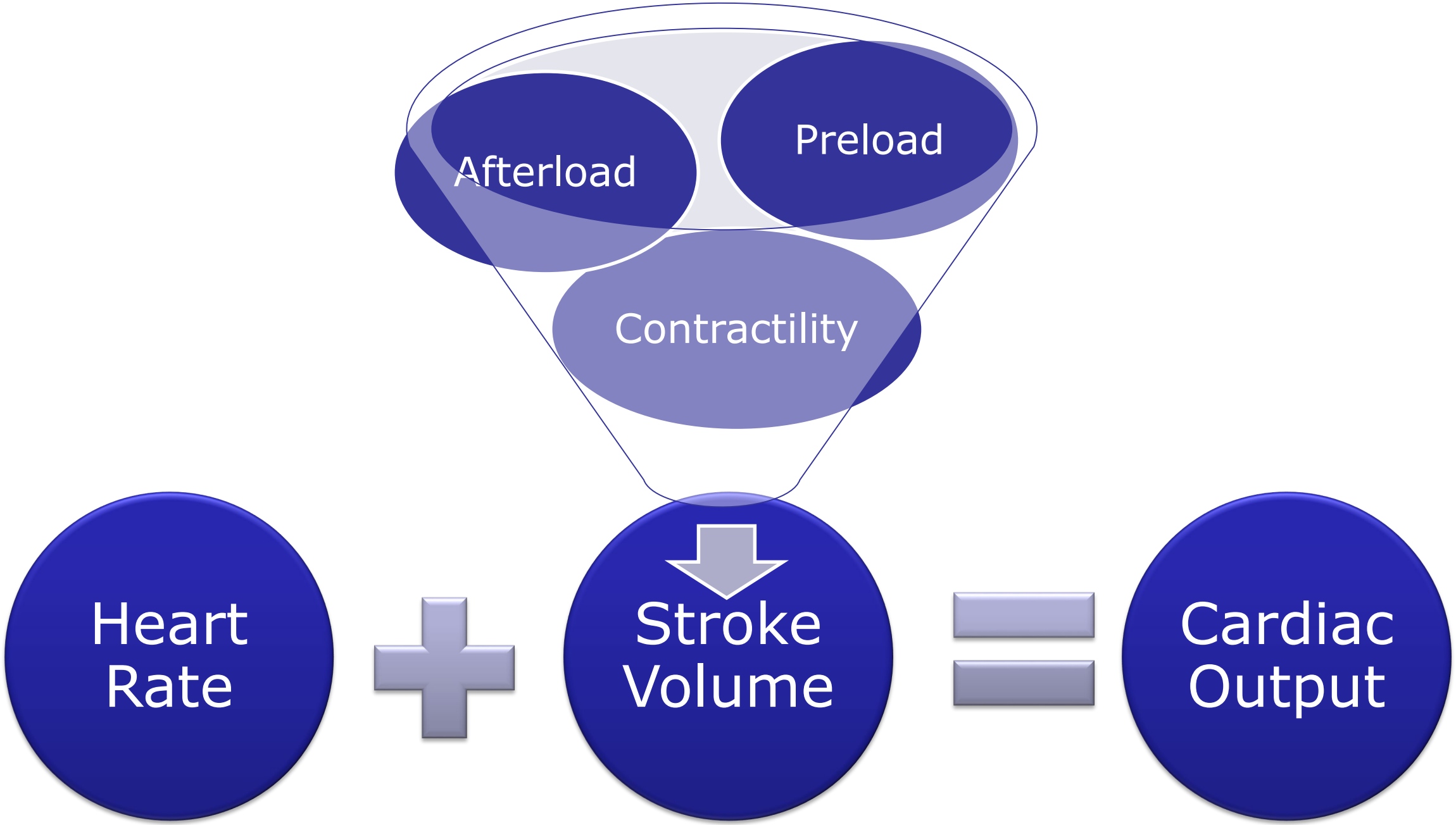
What is the definition of shock?

Inadequate tissue perfusion

Historic Trauma Trimodal Death Distribution



Sobrino & Shafi, 2013


Afterload
Preload
Contractility
Heart Rate
Stroke Volume
Cardiac Output

Injuries Associated with Massive Hemorrhage

- Chest
  - Aorta
  - Vena Cave
  - Hemothorax
- Abdomen
  - Spleen
  - Liver
- Pelvis
- Long bone
  - Femur
  - Humerus
- External bleeding
  - Various external sources such as the scalp
  - Don’t forget to exam the posterior surfaces!

Don’t underestimate the bleeding from soft tissue injury

Confounding Factors

- Patient's age
- Pre-existing disease/meds
- Severity of injury
- Access to care
- Golden hour
- Duration of shock
- Amount of prehospital fluid
- Presence of hypothermia

Classic Signs & Symptoms of Shock

- Changing mentation/confusion
- Rapid shallow breathing
- Hypotension
- **Tachycardia**
- Weak Pulse
- **Cool, clammy, skin**
- Prolonged capillary refill
- Narrowed pulse pressure
- Decreased urine output

Hemorrhagic Shock

Classes of Shock

PARAMETER	CLASS I	CLASS II (MILD)	CLASS III (MODERATE)	CLASS IV (SEVERE)
Approximate blood loss	<15%	15–30%	31–40%	>40%
Heart rate	↔	↔/↑	↑	↑/↑↑
Blood pressure	↔	↔	↔/↓	↓
Pulse pressure	↔	↓	↓	↓
Respiratory rate	↔	↔	↔/↑	↑
Urine output	↔	↔	↓	↓↓
Glasgow Coma Scale score	↔	↔	↓	↓
Base deficit[a]	0 to –2 mEq/L	–2 to –6 mEq/L	–6 to –10 mEq/L	–10 mEq/L or less
Need for blood products	Monitor	Possible	Yes	Massive Transfusion Protocol

[a] Base excess is the quantity of base (HCO_3^-, in mEq/L) that is above or below the normal range in the body. A negative number is called a base deficit and indicates metabolic acidosis.

Data from: Mutschler A, Nienaber U, Brockamp T, et al. A critical reappraisal of the ATLS classification of hypovolaemic shock: does it really reflect clinical reality? *Resuscitation* 2013,84:309–313.

Heart Rate and Blood Pressure

Heart rate

- Assess for rate and quality.
- Check central vs distal.
- A rapid heart rate and poor skin signs should be considered shock until it can be ruled out.

Blood pressure

- Does not define shock.
- Can be normal until class 3 of hemorrhagic shock.
- An increase in BP does not mean there is an increase in cardiac output.

Pulse Pressure / Respiratory Rate

- Pulse Pressure
  - Narrowed pulse pressure suggests significant blood loss.
  - Result of increasing diastolic pressure from compensatory catecholamine release.
- **Watch for a trend!**

100/60 100/64 100/68 100/74

- Respiratory rate
  - Increased rate of breathing can occur for various reasons.
  - Rule out respiratory cause:
    - Tension pneumothorax
  - Can be normal until class 3 of hemorrhagic shock

Urine Output and Mental Status

Urinary Output

- Used to monitor renal perfusion and guide resuscitation efforts.
  - 0.5 mL/kg/hr
- Better indicator than BP.
- Hematuria can indicate retroperitoneal bleeding.

Changes in mental status

- One of the first signs of shock.
- Indicator of perfusion.
- Could be affected by drugs and alcohol.
- Hypoxia or head injury until proven otherwise.

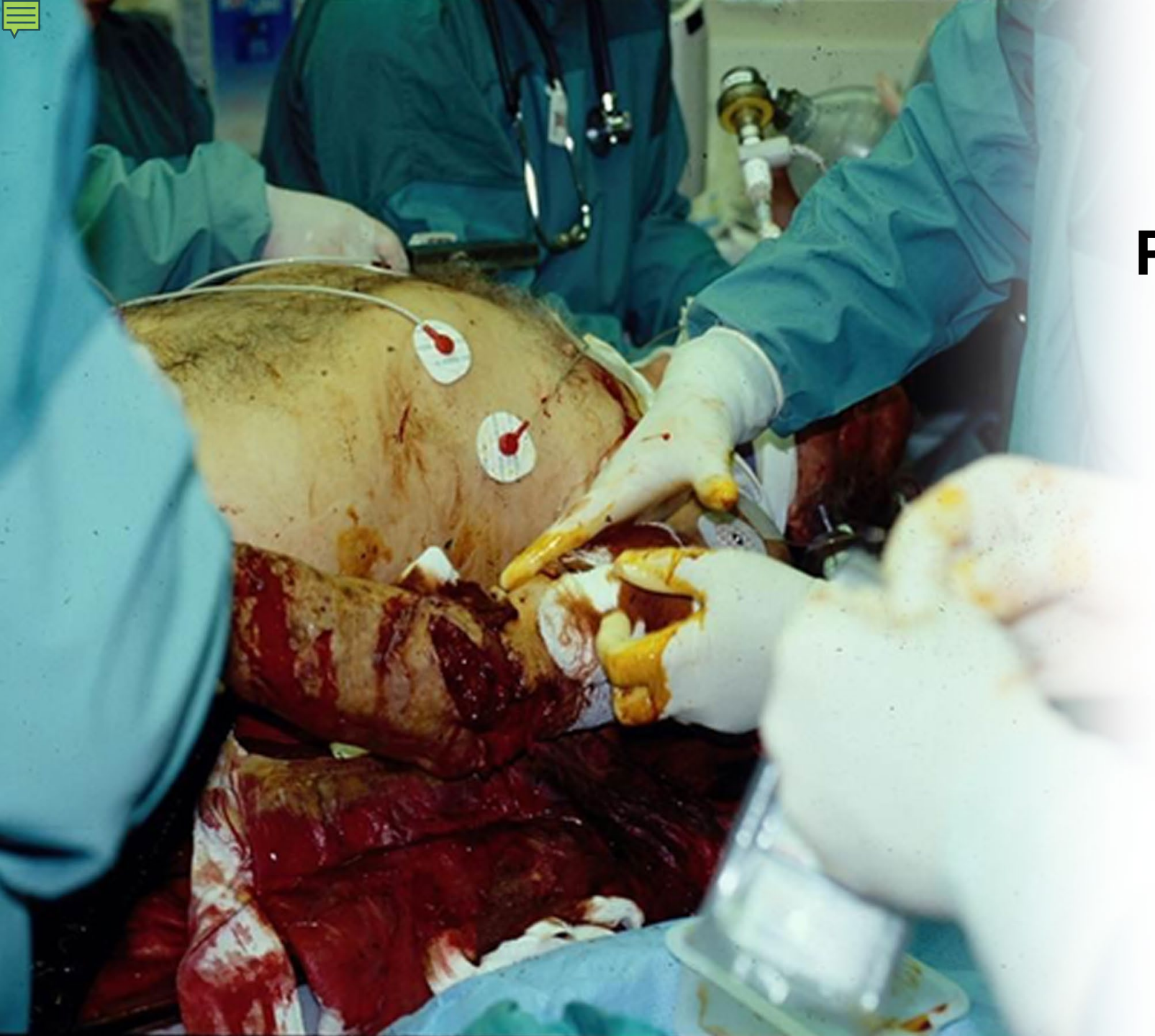
Base Deficit (BD)

- Sensitive measure of inadequate perfusion
- Normal range -3 to +3
- Performed as part of an ABG
- Admission BD correlates to blood loss
- Worsening BD:
  - Ongoing bleeding
  - Inadequate volume replacement

Blood Gas Values		
↓ pH	7.250	
pCO_2	35.3	mmHg
pO_2	77.7	mmHg
Acid Base Status		
↓ $cHCO_3^-(P)_c$	14.9	mmol/L
↕ $cBase(B)_c$	-11.1	mmol/L
↕ $cBase(Ecf)_c$	-10.9	mmol/L
Electrolyte Values		
cK^+	4.6	mmol/L
cNa^+	140	mmol/L
↓ cCa^{2+}	1.11	mmol/L
$cCa^{2+}(7.4)_c$	1.03	mmol/L
cCl^-	107	mmol/L

Hemorrhagic Shock

Assessment



Assessment

Primary Assessment

- Airway
- Breathing
- **Circulation**
- Disability
- Exposure

Diagnostic Tools

- Focused Abdominal Sonography for Trauma (FAST)
- Chest X-ray (CXR)
- Pelvic X-ray
- Diagnostic peritoneal lavage (DPL)
- Computed Tomography (CT)

Shock Index (SI)

- SI = HR / SBP
- Elevated early in shock
- Normal 0.5 - 0.7
- SI > 0.9 predicts:
  - Acute hypovolemia in presence of normal HR & BP
  - Marker of injury severity & mortality
  - Post-intubation hypotension
- Caution in Geriatrics
  - May underestimate shock due to higher baseline SBP
- Uses
  - Prehospital use → triage
  - Predict risk for mass transfusion

Hemorrhagic Shock

Treatment

Treatment

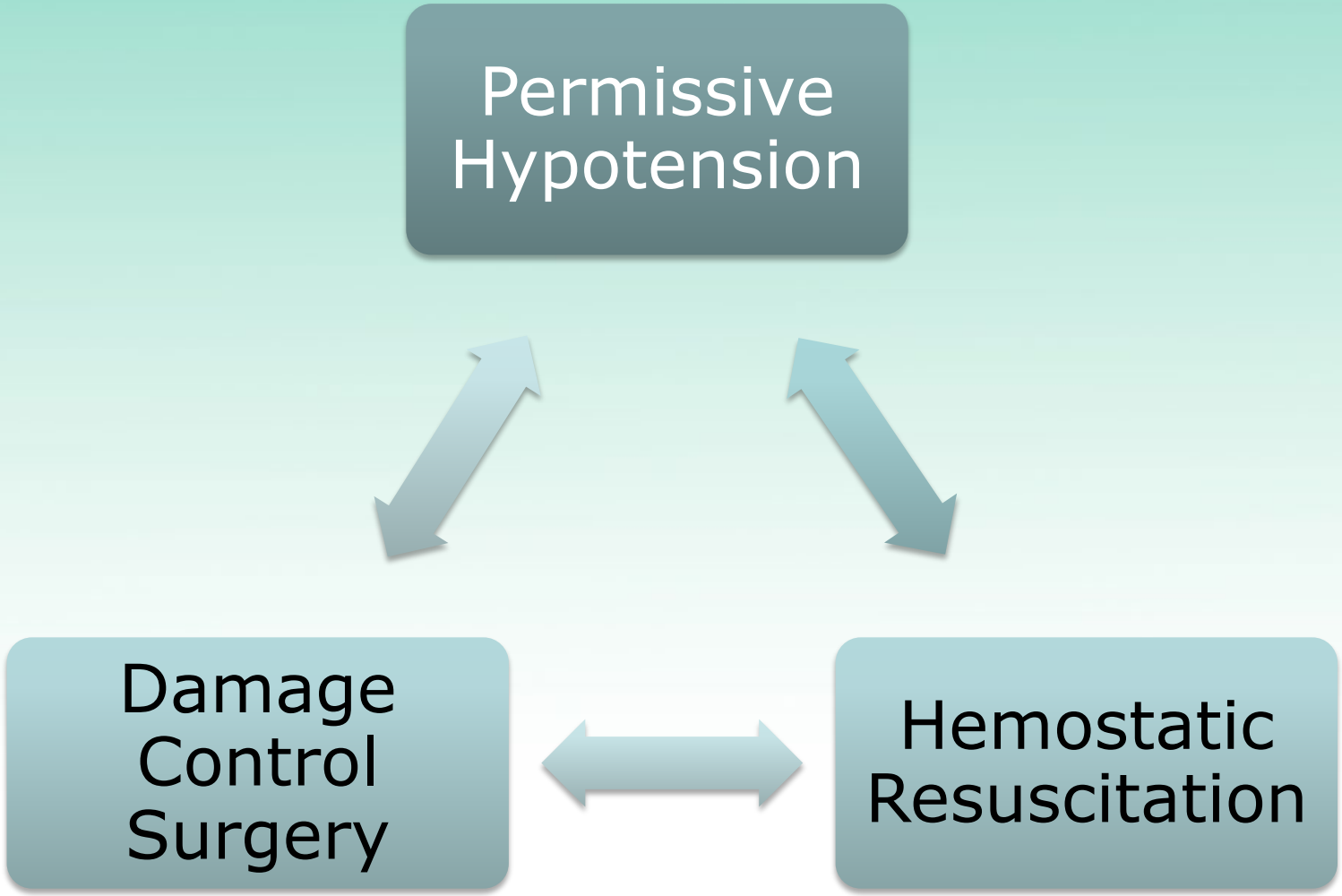
ATLS:
After 20 years of high-volume fluid resuscitation

- Chasing tachycardia
- Using Crystalloid > Blood
- Little evidence of improved survival

Current consensus:
Damage Control Resuscitation

- Permissive Hypotension
- Hemostatic Resuscitation
- Damage Control Surgery

Damage Control Resuscitation



Permissive Hypotension

- Restricted fluid administration
- Avoid “popping the clot”
- Accepting limited period (< 2 hours) of suboptimum end organ perfusion
- Titrate to Mean Arterial Pressure (MAP)

BP Measurements

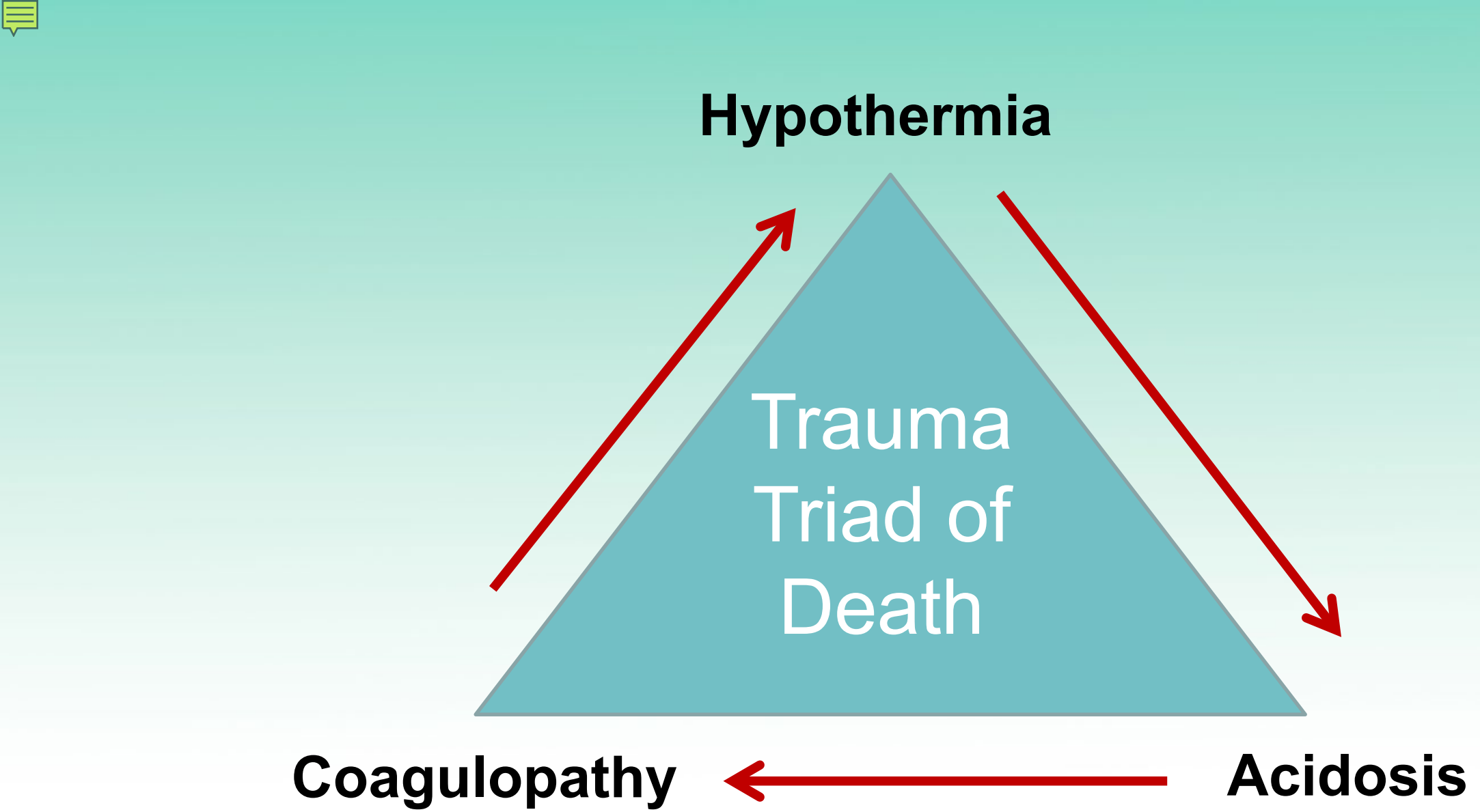
Systolic	Diastolic	Pulse Pressure	MAP
120	80	40	93
115	75	40	88
110	75	35	87
105	70	35	82
100	70	30	80
95	65	30	75
90	60	30	70
85	55	30	65
80	50	30	60
75	50	25	58
70	45	25	53
65	40	25	48
60	35	25	43

Normal MAP 70-100

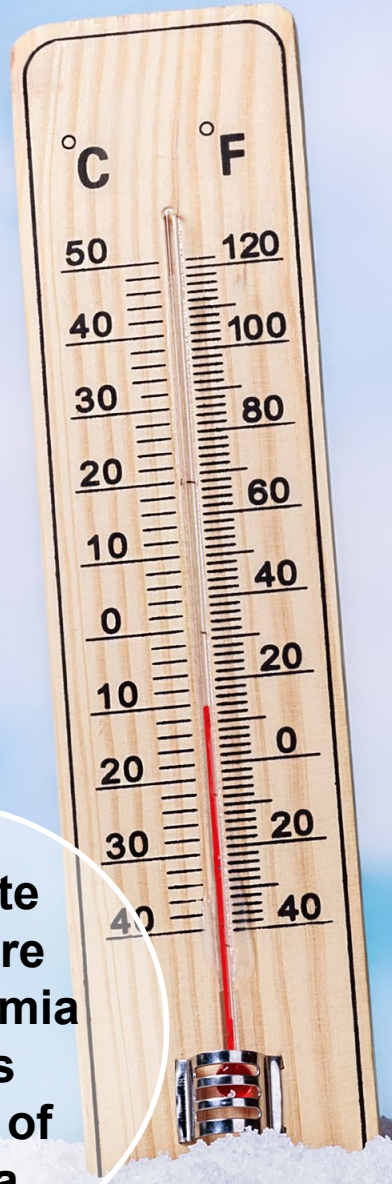
Coming Soon? **New Target MAP 50-70**

Hemostatic Resuscitation

- Early diagnosis in ED
- 1:1:1 ratio (pRBC to Plasma to Platelets)
- Use of the following products:
  - Cryoprecipitate
- Minimal crystalloids
- Stop the bleeding


Hypothermia
Trauma
Triad of
Death
Coagulopathy
Acidosis

Hypothermia



Moderate To Severe Hypothermia Occurs In <10% of Trauma

Defined:

- Core Temp < 35C (95F)

Action:

- ↓ coagulation factors
- ↑ platelet dysfunction

Classification:

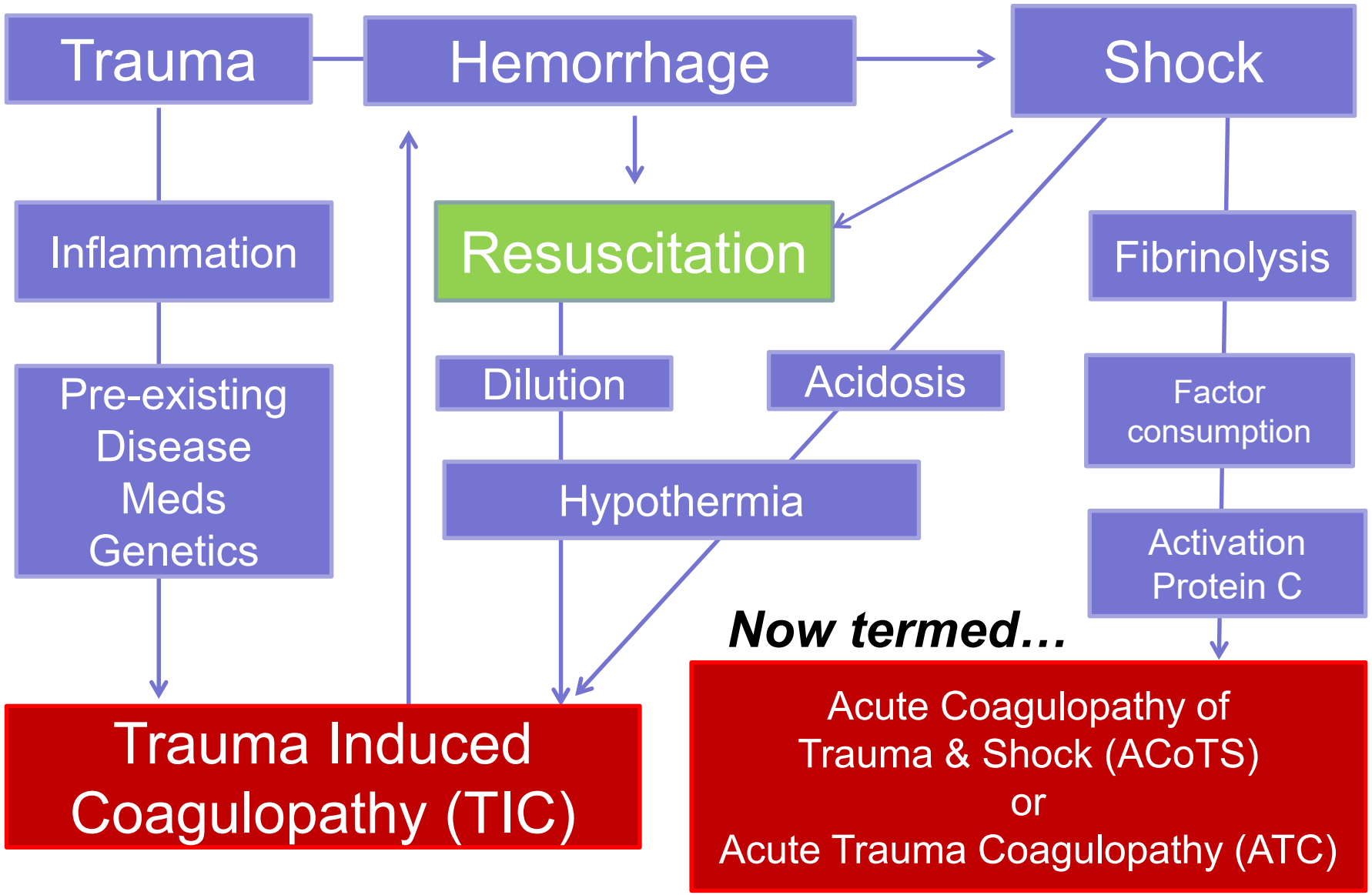
- Mod 32-34 C (90-93 F)
- Severe <32 C (< 90 F)
  T < 32C = 100% mortality in the face of trauma

Acidosis

- **Effects:**
  - Altered hemostasis
  - Myocardial depression
- **Correlates with:**
  - Depth of shock
  - Degree of tissue injury
- **Assessed**:
  - pH
  - Base Deficit
  - Lactate

- **pH** < 7.2
- **Initial BD ≥ 6**
  - Predicts transfusion
  - Increased ICU days
  - Risk for MSOF
- **Initial BD ≥ 7.5**
  - ↑ mortality

Trauma Coagulopathy Theory



Treatment Goals

- Provide adequate ventilation (Airway)
- Provide adequate oxygenation (Breathing)

Circulation

- Stop the bleed
- Retore circulating volume
- Involve a surgeon
- Transfer to appropriate level of care!!

Mechanical Means for Controlling Hemorrhage

- Direct pressure
- Packing the wound
- Splinting long bone fracture
- Operative intervention
- Angioembolism

For more information on “Stop the Bleed” initiative, please visit: www.stopthebleed.org

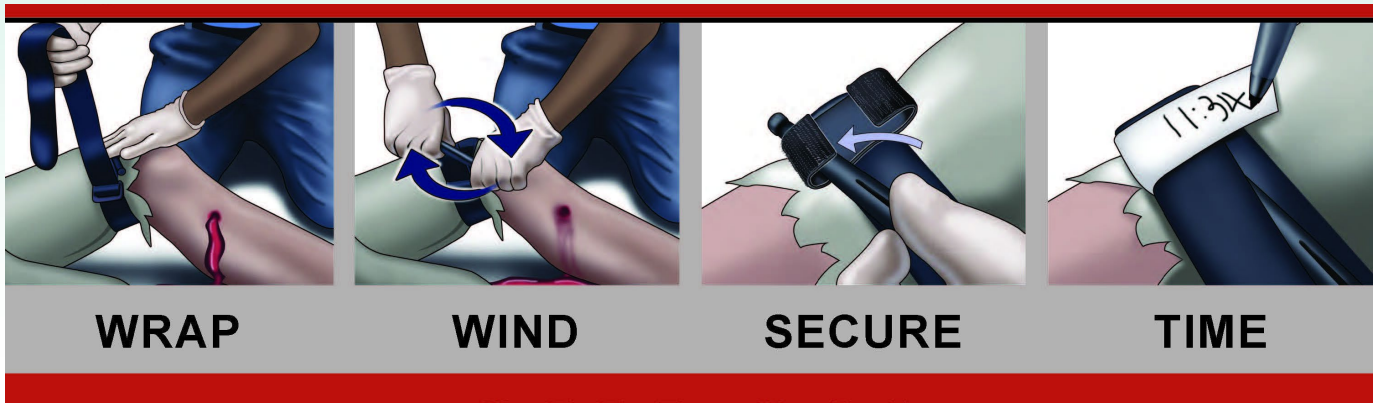
Mechanical Means for Controlling Hemorrhage

Pelvic Binders or a Sheet

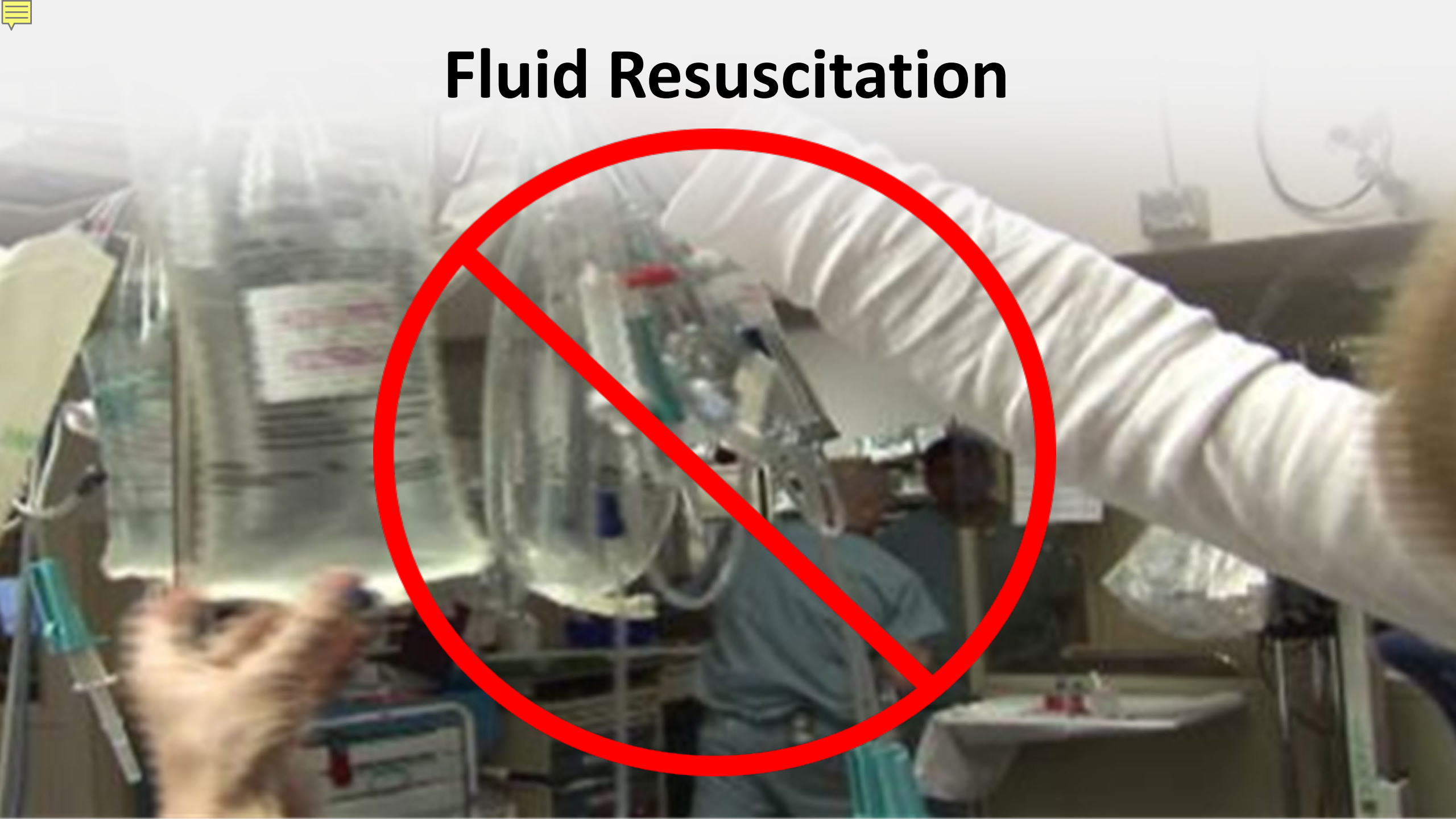
- Reduces pelvis volume
- Tamponade effect

Tourniquets

- Good outcomes
- Safe and effective



Fluid Resuscitation

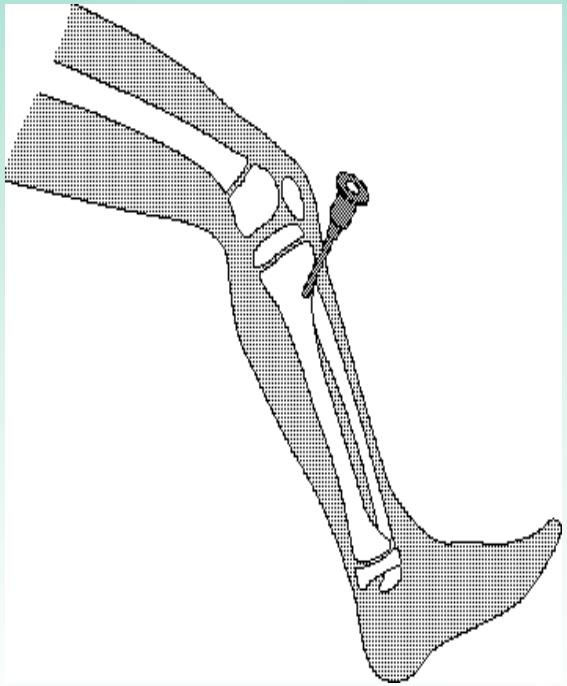


Principles of IV Access

- Fastest, simplest route best (antecubital or forearm)
  - Large bore, minimum 18g short catheter
  - Flow limited by IV gauge and length
  - Warm fluids to prevent hypothermia
- Consider Intraosseous (IO) ***early*** as rescue device
- Femoral or Subclavian/Internal Jugular are preferred central line sites

Intraosseous Devices

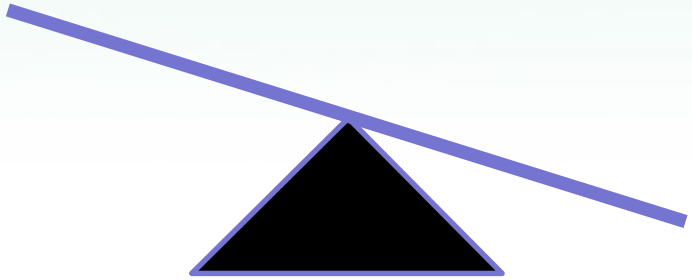
- Temporary access
- Children & adults
- Insertion can be done quickly
- Sites vary depend on the device
- Common site (lower leg and upper arm)
- Avoid fracture/injury sites
- Fluid/blood/meds can be administered
- Flow rates up to 6 L/hr with pressure bag
- Risk: extravasation → compartment syndrome



Fluid Administration Balance

Too little…

- Ongoing shock
- Continued acidosis
- Coagulopathy
- Myocardial dysfunction
- Renal failure
- Death



Too much…

- Increased bleeding
- Clot disruption
- Dilution coagulation factors
- Compartment syndromes
- Transfusion concerns
  - Inflammation
  - Immunosuppression
  - Transfusion Related Acute Lung Injury (TRALI)

Fluid Resuscitation Guidelines

- Class I
  - Body can compensate within 24 hours
  - Monitor for the need for crystalloids or blood products
- Class II
  - Crystalloid infusion required
  - Blood products may be needed
- Class III
  - Crystalloid infusion required
  - Blood products will be necessary
- Class IV
  - Aggressive management to avoid death
  - Institute the massive transfusion protocol

Limit crystalloids to 1 liter in adults

Crystalloids (Isotonic Solutions)

Balanced electrolyte solutions are similar to extra cellular fluid (ECF). Rapidly equilibrates across compartments.

Only 25% remains in IVS after 17 minutes!

NS vs. LR

Normal Saline

- Na,Cl
- Fluid of choice for blood
- Con:
  - Hyperchloremic acidosis
  - Retention/overload and electrolyte imbalance with large quantities

Lactated Ringers

- Na, Cl, K, Ca, Lactate
- Fluid of choice per ATLS
- Con:
  - Immune modulation

Blood Administration

Traditional Management	
Fluid	Blood
Give 2 Liters ↓ → Continue IV's wide open	PRBC 5-10 u ↓ Wait for labs ↓ Plasma ↓ Platelets

Emerging Management	
Fluid	Blood
Minimize	1:1 or 1:2 (Plasma: RBC) Protocolize ↓ Massive Transfusion Protocol

Massive Transfusion

- Best when guided by a protocol
- RBC's and Plasma must be warmed
- Monitor closely for coagulopathy or confounding factors:
  - Hypothermia
  - Acidosis
  - Hypocalcemia

- Protocol example: Assessment of Blood Consumption (ABC Score)
  - Pulse >120
  - SBP < 90
  - + FAST
  - Penetrating trauma to the torse

** Two more would indicate the need to activate the MTP*

Autotransfusion

- Consider for patients with massive hemothorax
  - Indicated for isolated chest injury
  - Diaphragmatic injury is a contraindication to autotransfusion
- Often requires an anticoagulant to be added (i.e. Sodium citrate)
- Do not delay definitive treatment to set up the autotransfuser
- Follow the manufacture's recommendations/ organizational policy for the device in your facility

Massive Transfusion Protocol (MTP)

Dr. Alex Guerrero, https://www.intertrauma.com

Advantages of Blood Products

	Packed Red Blood Cells	Plasma	Platelets
Action	Carries Oxygen No clotting factors Replenishes normal plasma and blood volume	Coagulation Factors	Aggregation
1 unit	~300 ml (Hct 55%)	~250 ml	~25 ml individual unit ~150 pooled unit
Dose	↑ Hgb by 1 g/dl ↑ Hct by 3 % In the non-bleeding pt	↑ coags by 2.5% (Need at least 4 u for significant change)	1 unit Apheresis (pooled) ↑ 25,000-50,000 per u
Storage	-4 C <u>Progression</u>: Emerg Uncrossmatched (immediate) Type Specific (20 min) Cross Matched (60 min)	<u>Non-Trauma Center</u> • Frozen • Thaw time • 2 u in 30 minutes <u>Trauma Center</u> • Room Temp • Good for 5 days • Monitor wastage	Room temp Agitated

Response to Resuscitation

	Rapid Responders	Transient Responders	Minimal or No Response
Vital Signs	Return to normal	Improves initially then deteriorates	No change
Blood Loss (Estimated)	< 15%	15 – 40%	> 40%
Blood products required	Low	Moderate to High	High
Blood preparation	Type and Crossmatch	Type Specific	Massive Transfusion
Operative Intervention/ Angioembolism	Unlikely	Likely	Immediate
Need for surgeon	Required	Required	Required

Assessment vs. Resuscitation Endpoints

Initial Assessment

- Mentation
- Skin Perfusion
- Pulse
- Blood Pressure
- Pulse Pressure
- Shock Index
- Urine Output

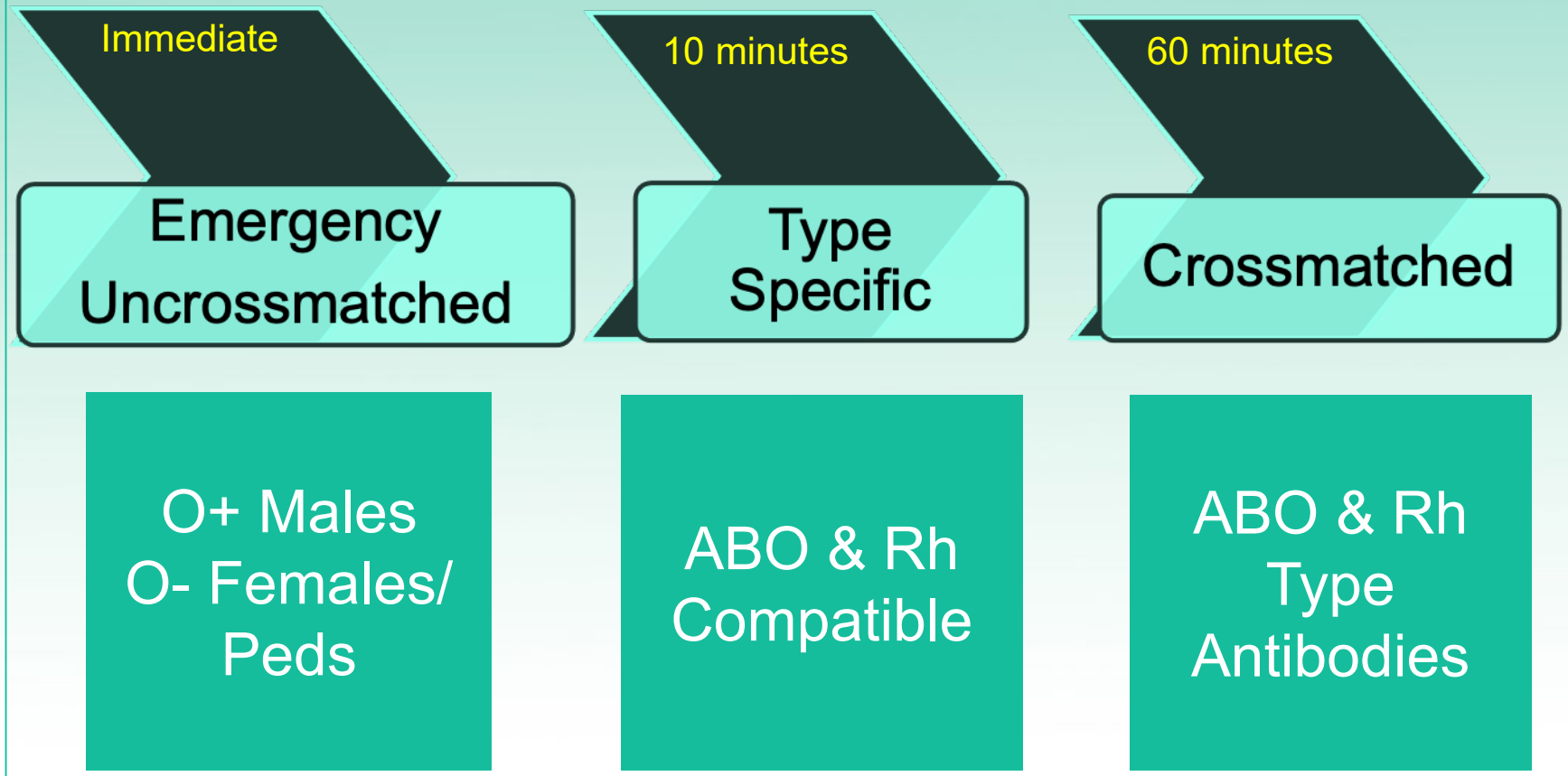
Resuscitation Endpoints

- pH
- Serum Lactate
- Base Deficit
- Hemodynamic stability
- Echocardiography
- StO2 (NIRS)

Hemorrhagic Shock

Laboratory Tests

Type and Crossmatch



Hemoglobin / Hematocrit

- Unreliable estimation of acute blood loss
- Lag time of several hours
- Baseline value for comparison only
- May be dilutional or falsely elevated

Arterial pH

Part of the arterial blood gas (ABG)

Acidosis - Serum pH < 7.20

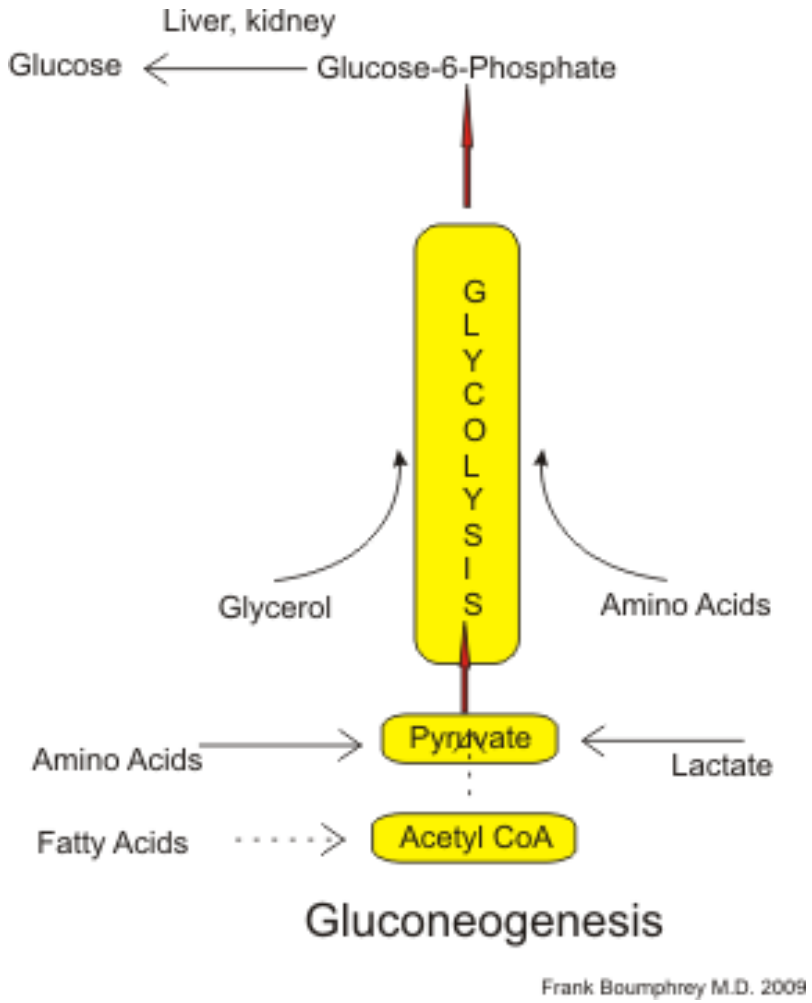
Ongoing Marker of Severe Physiologic Derangement

- Decreased cardiac contractility
- Decreased cardiac output
- Vasodilation and decreased BP
- Decreased hepatic and renal blood flow

Lactic Acid

- Lactate or “lactic acid” is a normal product of cellular metabolism.
- Lactate itself is NOT toxic to cells or tissue.
  - Normal level of venous lactate is < 2.2 mmol/L
- Initial response occurs due to shift to anerobic metabolism.
- Indirect measure of oxygen debt

Lactate Clearance:
Liver 60%
Kidney 30%
Heart ≈5%
Skeletal Muscle ≈5%



Wikipedia.org

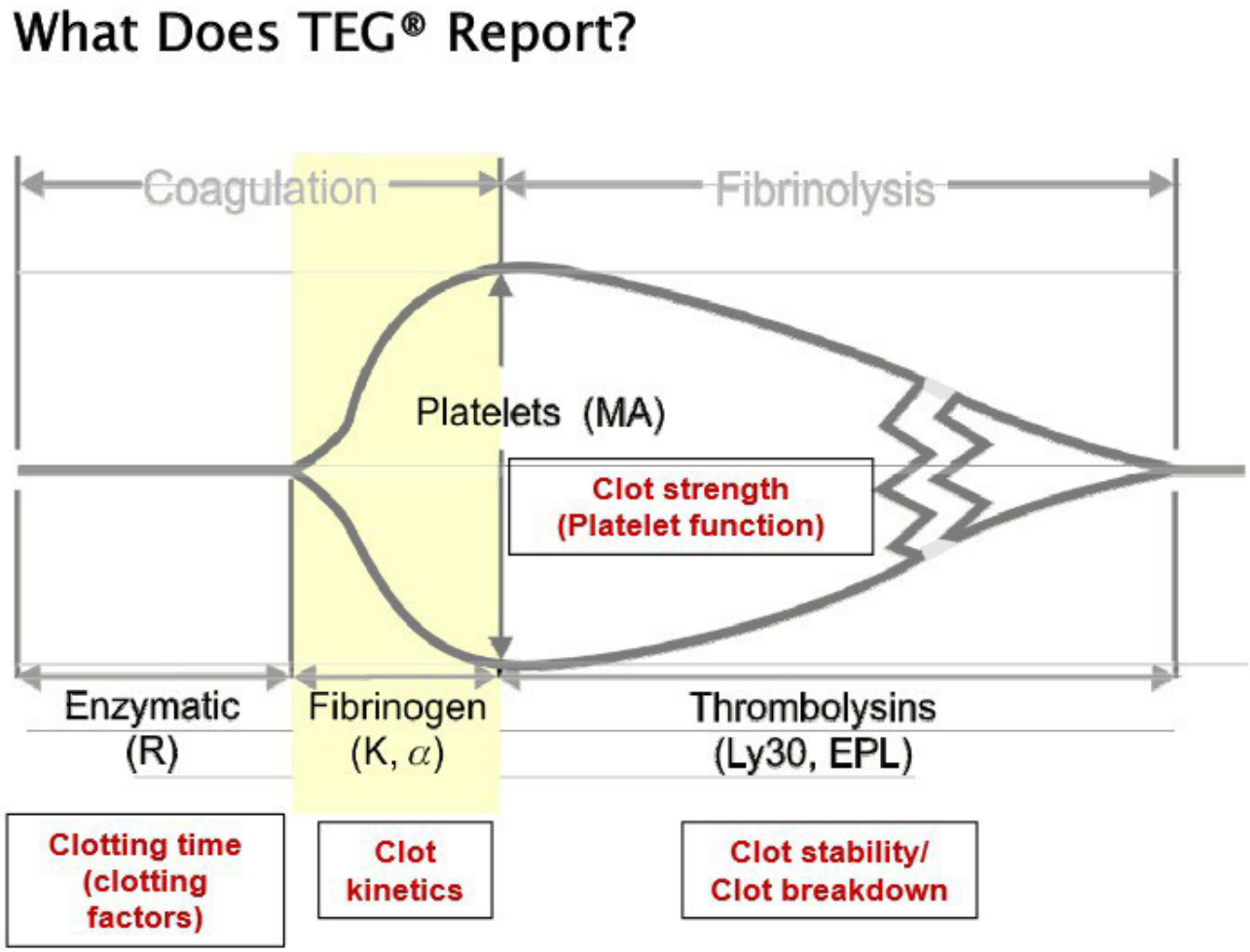
International Normalized Ratio (INR)

- Test of clotting (extrinsic pathway)
- Internationally accepted method of reporting prothrombin (PT) results worldwide

Population	Value
Normal	0.8 - 1.2
Anticoagulant Use	2.0 - 3.0
Trauma	> 1.5 = coagulopathy

Thromboelastographic (TEG)

- Whole blood test
- Measuring hemostasis
  - Clot initiation to clot lysis
  - Net effect of your components



Hemorrhagic Shock

Other Considerations

Tranexamic acid (TXA)

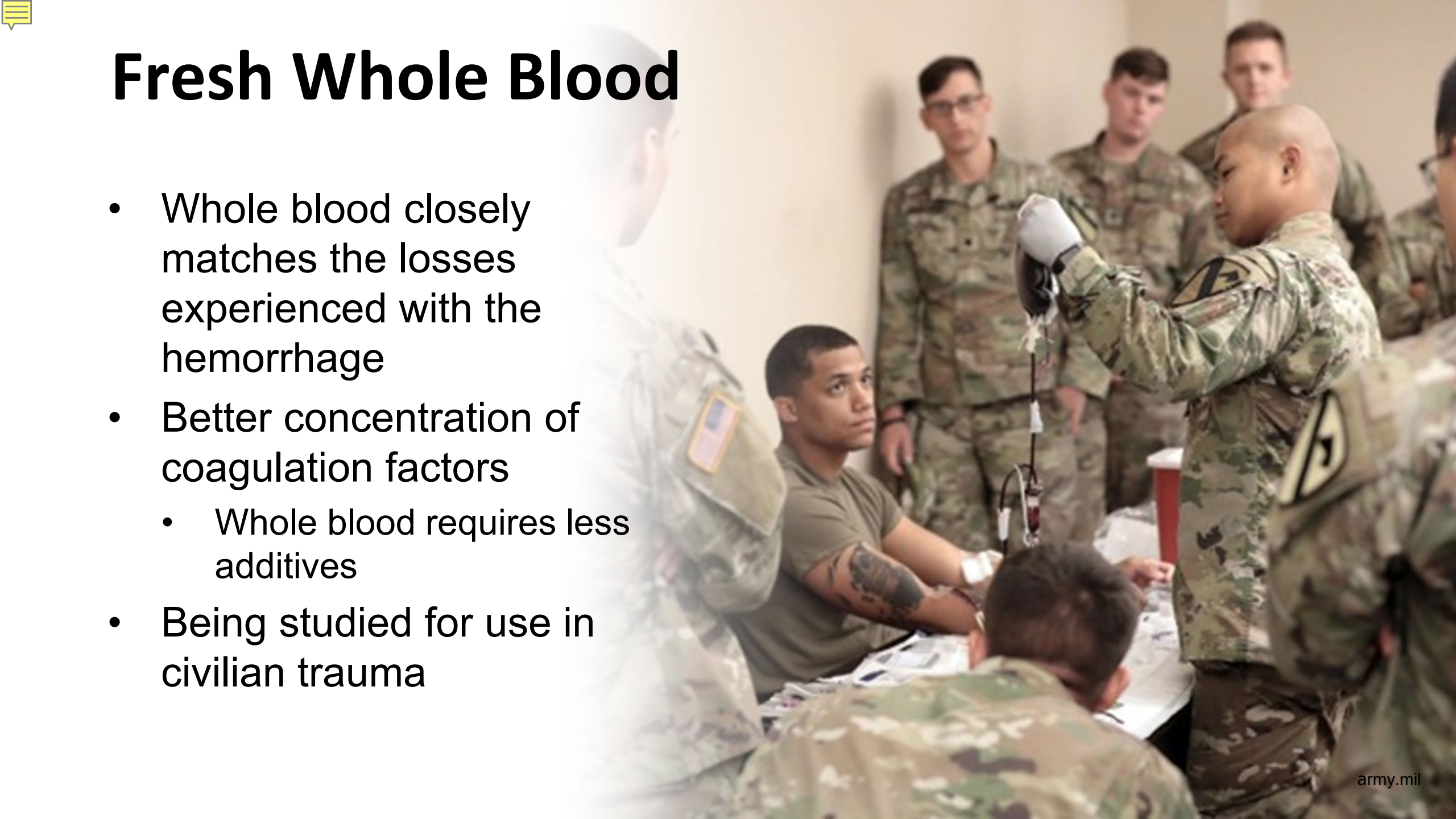
- TXA is an anti-fibrinolytic that inhibits both plasminogen activation and plasmin activity.
- This prevents clot break down and promotes new clot formation.
- Inexpensive ($80/dose) and proven safety profile.

Example of TXA Protocol

- Administer within 1-3 hours of injury
- 1 unit of blood
- 1 gram bolus of TXA
- 1 gram infusion over 8 hours

Fresh Whole Blood

- Whole blood closely matches the losses experienced with the hemorrhage
- Better concentration of coagulation factors
  - Whole blood requires less additives
- Being studied for use in civilian trauma



Recombinant Factor VIIa

- Off label use in trauma: Refractory bleeding in trauma
- Activates Extrinsic coagulation cascade
- Correct before use:
  - Hypofibrinogenemia
    - Cryoprecipitate
  - Thrombocytopenia
    - Platelets
  - Hypothermia
    - Correct Temperature
  - Acidosis
    - Consider Bicarbonate

- Include in the Massive Transfusion Protocol (Example)
  - Do not use too early or too late
  - Administer between 8 - 20 PRBC's
  - Recommended dose: 100 mcg/kg
  - Expensive:
    - 100mcg
      X 70kg =7,000mcg = $7,700
  - Repeated at 1–2 hour intervals if required

Fibrinogen Concentrate (FC)

- Produced from pooled human plasma
  - Standardized fibrinogen concentration per vial (900 – 1300 mg of fibrinogen)
- Key role in clot formation due to fibrin production
  - Conversion to fibrin is catalyzed by thrombin
  - Induces platelet activation and aggregation by binding to glycoprotein GPIIb/IIIa receptors
- Literature in trauma
  - Positive relationship between plasma fibrinogen levels and survival
  - Reduction in transfusion requirements
  - Dosing strategy of 2 – 4 grams utilized in TIC

Prothrombin Complex Concentrate (PCC)

- Mechanism
  - Replenishes vitamin K dependent clotting factors (II, VII, IX, X)
  - Promotes conversion of fibrinogen to fibrin and cross-linked fibrin clot formation
- Reduced thrombin formation
  - Expected when procoagulant activity is < 30%
  - Occurs with blood loss > 150 – 200% of estimated blood volume
- Fibrinogen in trauma
  - Inadequate fibrinogen levels due to dilutional effects
  - Hyperfibrinolysis
  - Fibrinogen synthesis inhibition
  - Fibrin polymerization interference

Near Infrared Spectroscopy (NIRS)

Skeletal muscle StO2

- Measures hemoglobin oxygen saturation in tissue
- Tracks systemic O2 delivery
- Continuously and Noninvasively
- Comparable results to BD and Lactate
  - Predicts MSOF
  - Predicts Mortality
  - Research ongoing as resuscitation endpoint

Summary

- Use an organized approach to assessing trauma patients
- Recognize the presence of shock
- Stop the bleeding
- Appropriate use of diagnostic tools
- Assess for coagulopathy early
- Limit the use of crystalloids to 1 liter
- Use a Massive Transfusion Protocol
- Use damage control resuscitation techniques