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SOCIETY OF TRAUMA NURSES

Mechanism of Injury

Understanding the Kinematics of Trauma

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Objectives

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

- State how the fundamental principles of physics apply to various types of injuries
- Given a specific mechanism of injury, predict injury patterns

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Kinematics

- The study of basic physics concepts that dictate how energy affects the human body
- Allows prediction of injuries based on motion involved

Mechanism of Injury

Mechanism of injury (MOI) is the way in which traumatic injuries occur

Different MOIs produce injuries that may be isolated or occur in many body systems

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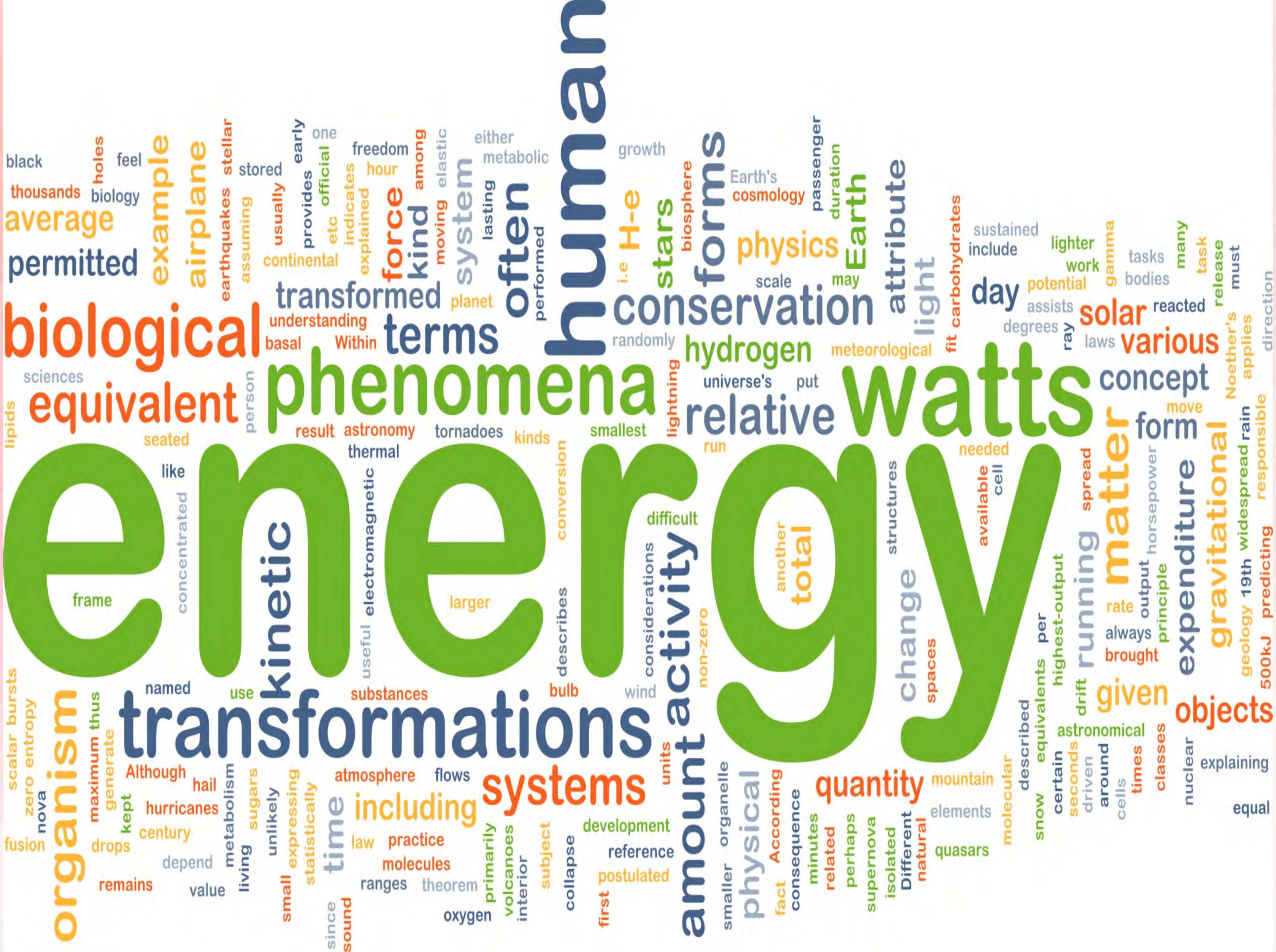

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TRAUMA…

excessive

ENERGY


Withholding of
Essential Energy
Oxygen
Water
Food

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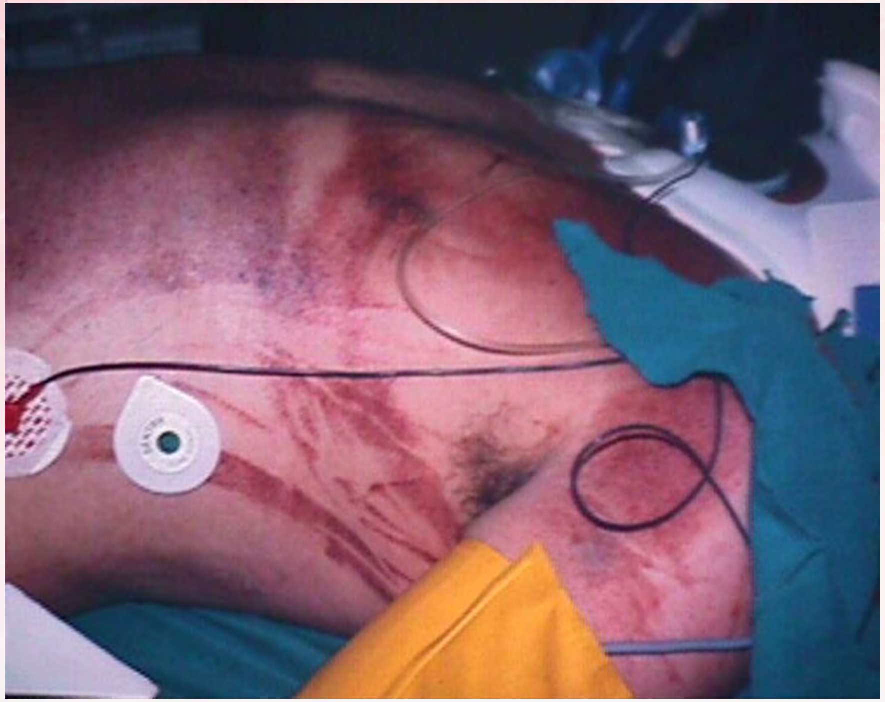

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TRAUMA…
excessive
ENERGY

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Energy Form

- **Kinetic**
  - Gravity
  - Acceleration / Deceleration
  - Object strikes body
  - Penetrating
  - Blast
- **Thermal**
- **Electrical**
- **Chemical**
- **Radiological**

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Blast

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Injury Phases of an Explosion

Primary injury

↓

Secondary injury

↓

Tertiary injury

↓

Quaternary injury

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Thermal

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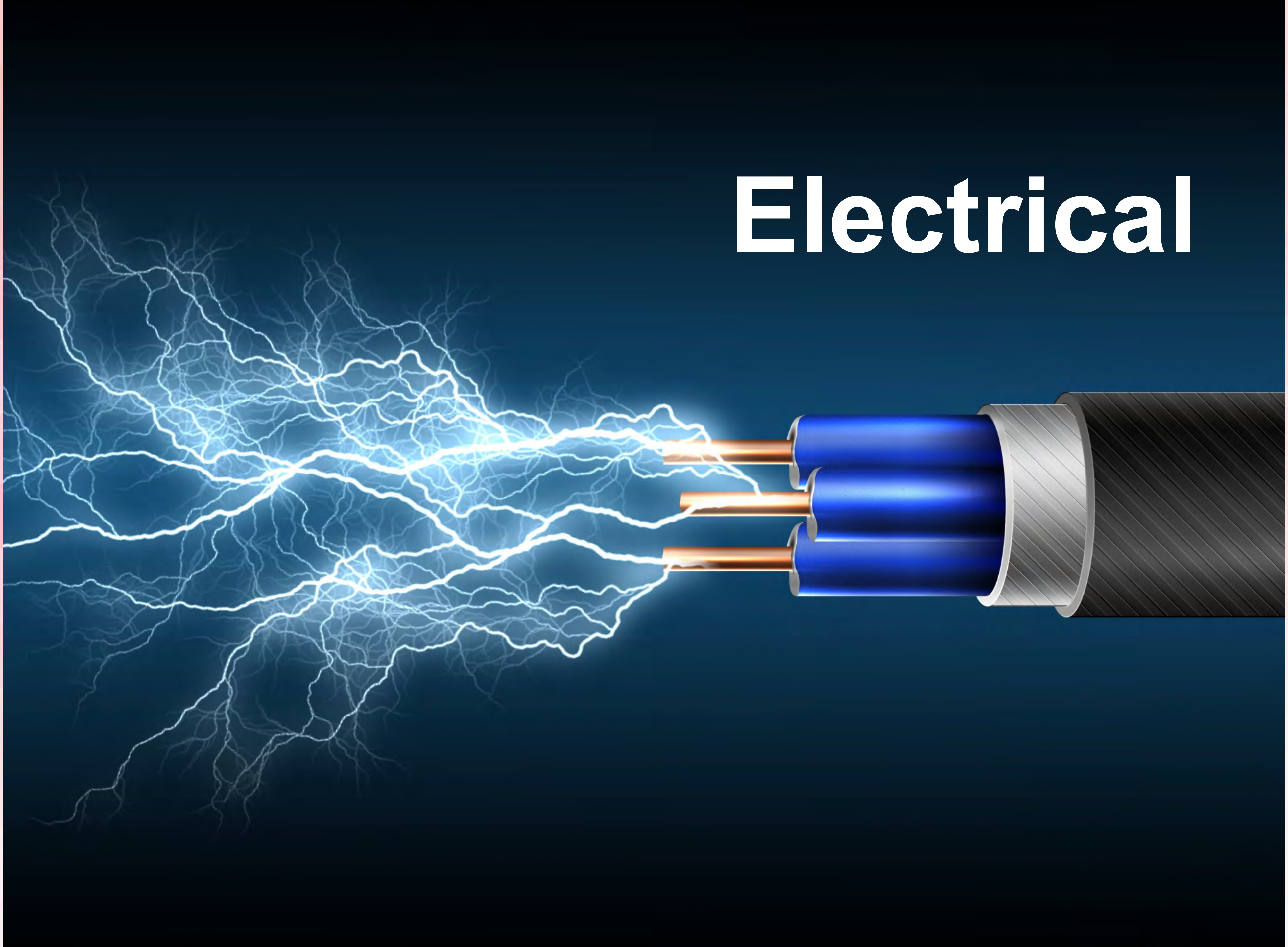
Electrical



Chemical

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Radiological

Understanding Physics

- Newton's First Law of Motion (Law of Inertia)
- Newton's Second Law of Motion
- Newton's Third Law of Motion (Law of Conservation of Energy)
- Kinetic energy

Newton's First Law

- Objects tend to stay at rest or in motion unless acted upon by some force
- Velocity is constant

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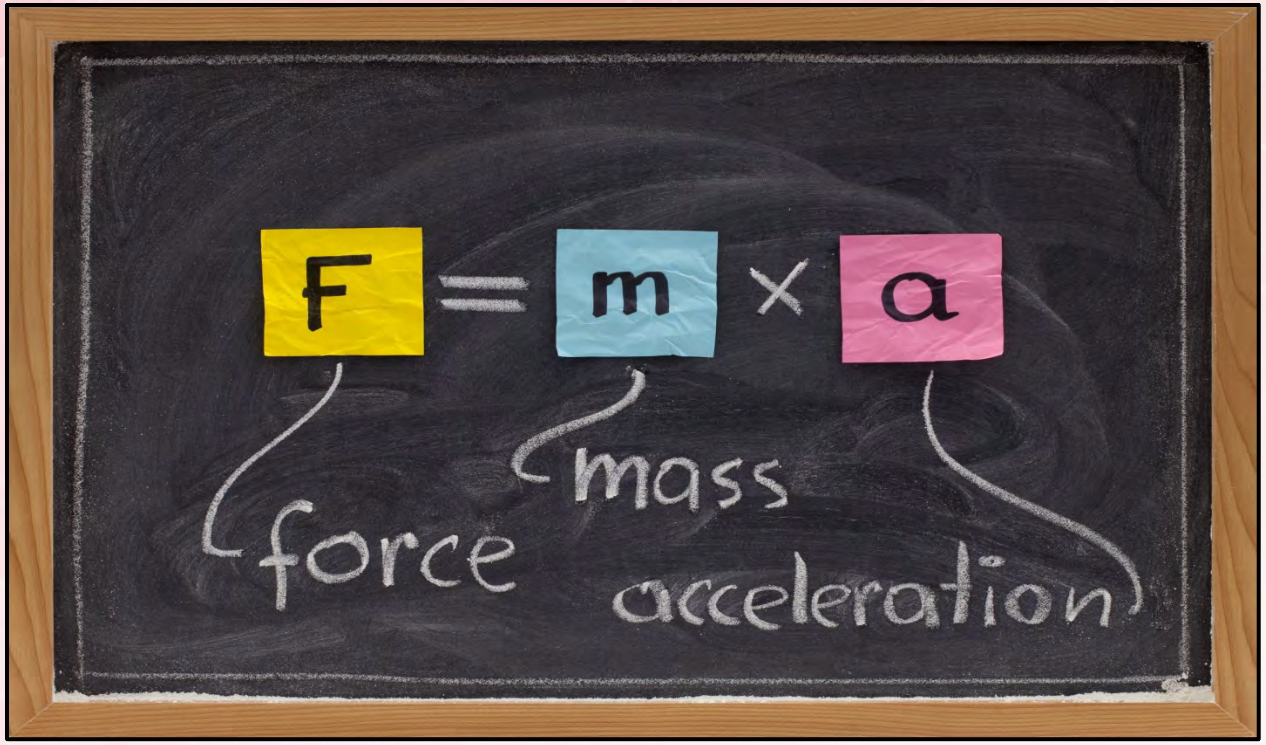
Newton's Second Law

Defines the relationship between acceleration, force, and mass

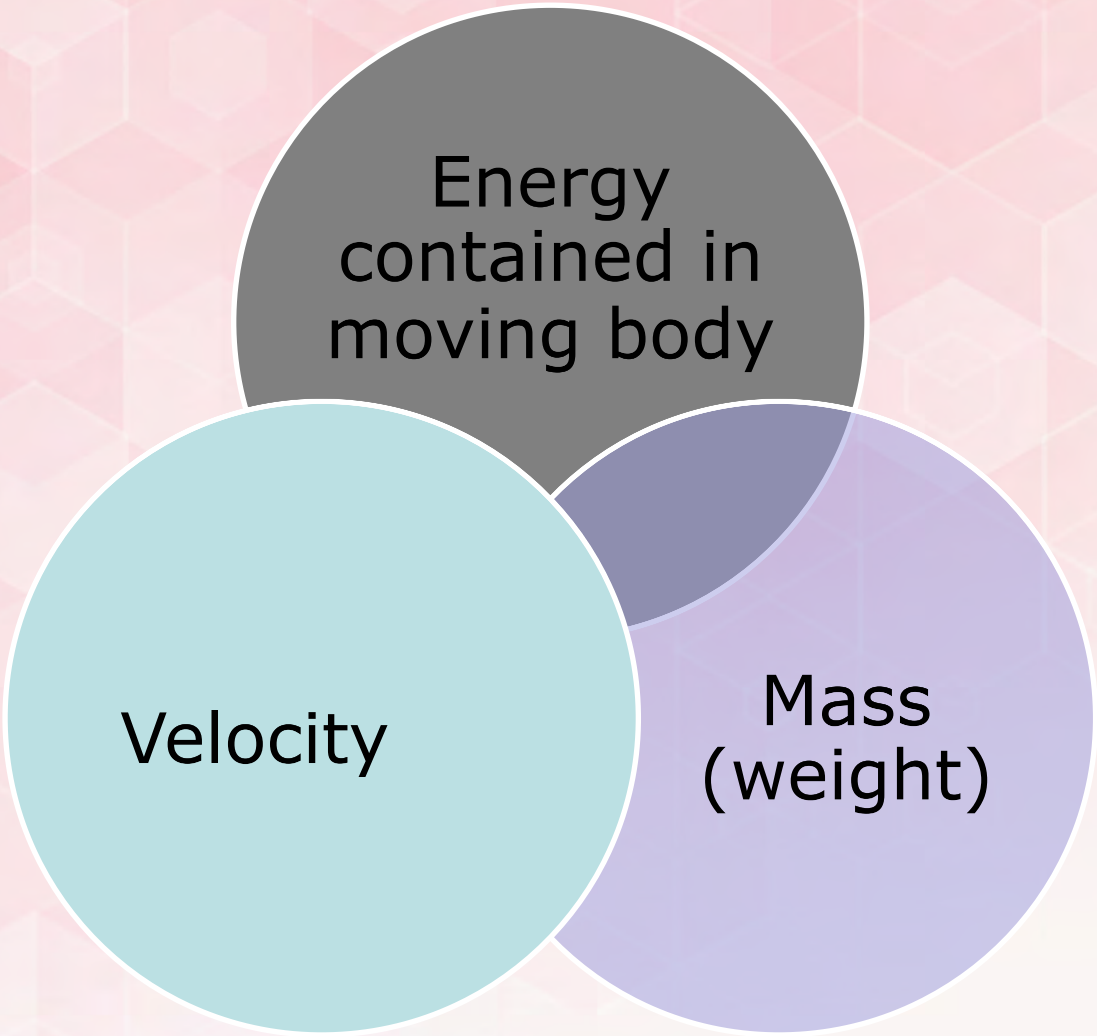


Newton's Third Law

- For every action (force), there is an equal and opposite reaction.
- Energy cannot be created or destroyed
- Energy can only change from one form to another

Kinetic Energy

Kinetic Energy



Example

- Head on collision
- The kinetic energy of two moving bodies that collide are combined.

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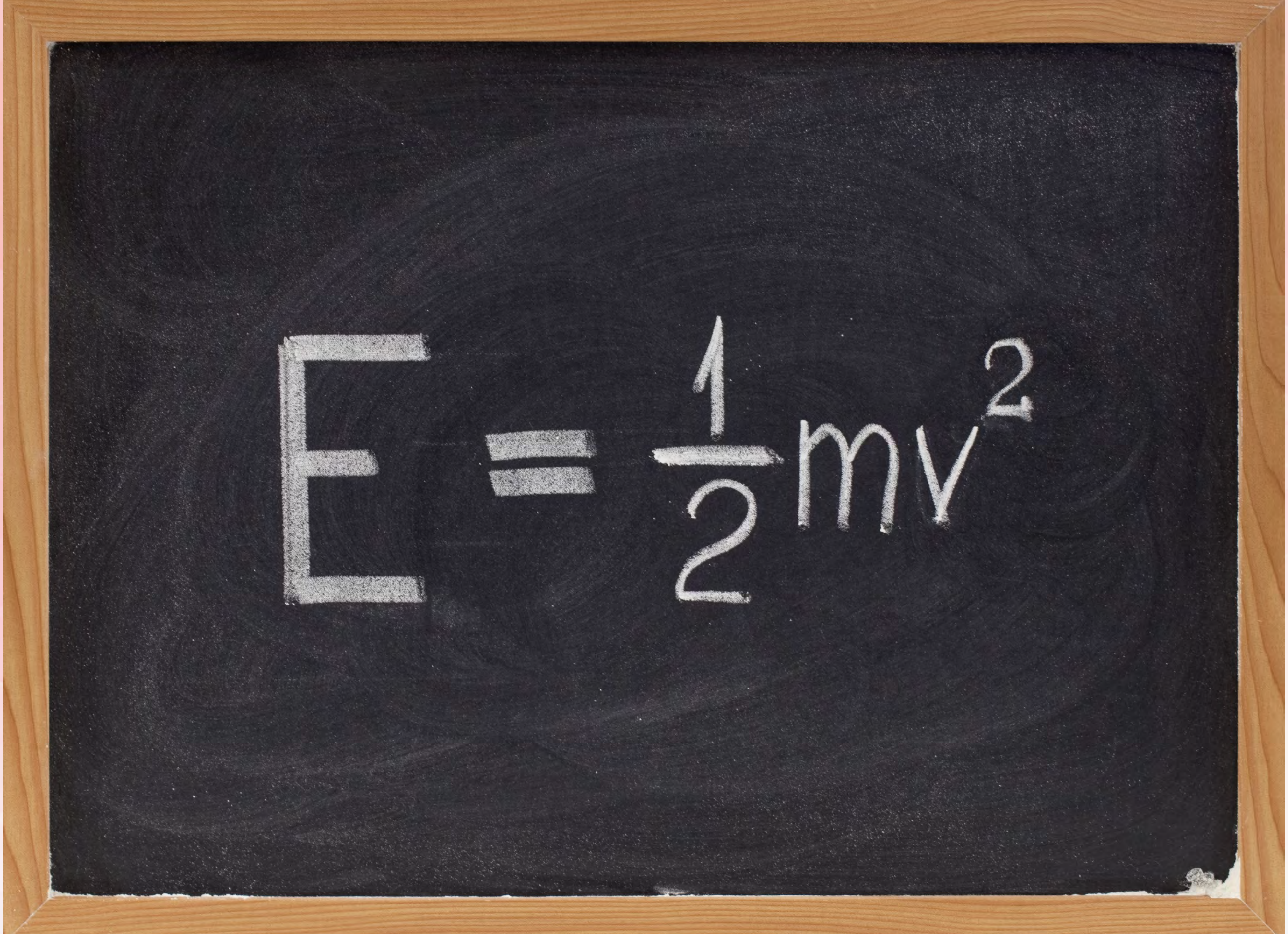
$E = \frac{1}{2}mv^2$

Units of measure: kg, meters /second, and Joules

1 joules = a tennis ball moving at 14 mph
1000 joules = 1 kJ (kilojoule)

EXAMPLE:

180 lbs person moving at 30 mph
80 kg person at 13.41 meters per second

$$KE = \frac{1}{2} m v^2$$

$$KE = 80 (13.41 \times 13.41) / 2$$

$$KE = 7.193 \text{ kJ}$$

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Speed 30 → 42 mph

EXAMPLE:

- 180 lb person moving at 30 mph
- 80 kg person at 13.41 meters per second
- **KE = ½ m v²**
- KE = 80 (13.41 x 13.41) / 2
- KE = 7.193 kJ

EXAMPLE:

- 180 lb person moving at 42 mph
- 80 kg person at 18.774 meters per second
- **KE = ½ m v²**
- KE = 80 (18.774x18.774) / 2
- KE = 14.098kJ

Increase speed from 30 to 42 mph, DOUBLES KE

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Kinematics in Prevention

- Alter host and environment
- Development of devices to reduce injury
- Automotive safety research
- Special population considerations

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Reference.Medscape.com/features/slideshow/fall-in-the-elderly

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BLUNT
PENETRATING

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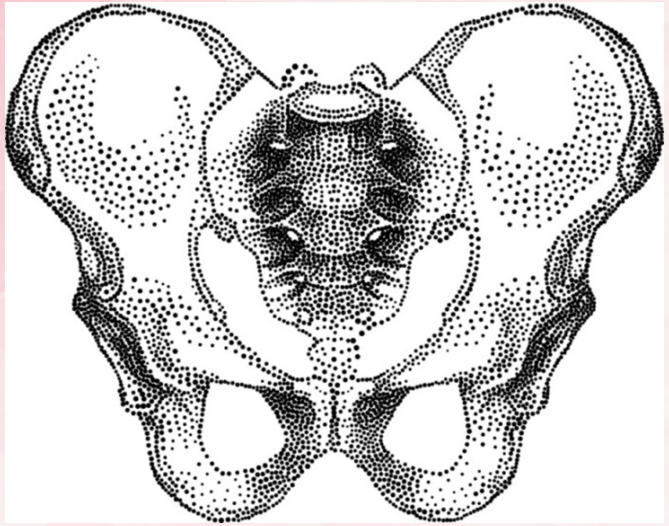
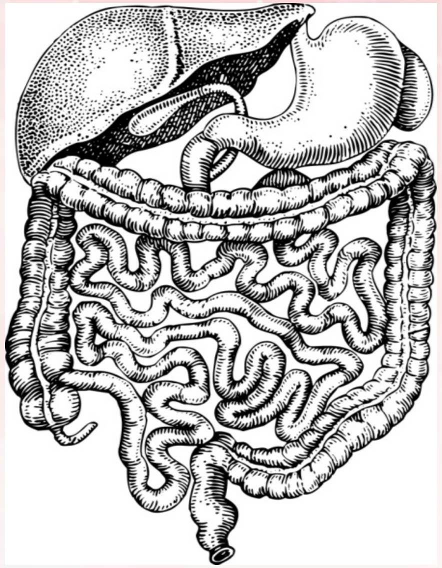
Factors to Consider

- Mass
- Velocity
- Resistance to damage
- Surface characteristics

Resistance to Damage

Preexisting health conditions
Tissue characteristics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Surface area over which force applied

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Acceleration and Deceleration

- Acceleration
  - Rate at which body in motion increases its speed.
- Deceleration
  - Rate at which a body in motion decreases its speed.

Blunt Trauma

- Motor vehicles
- Falls
- Bicycles
- Blunt assault
- Objects
- Machinery

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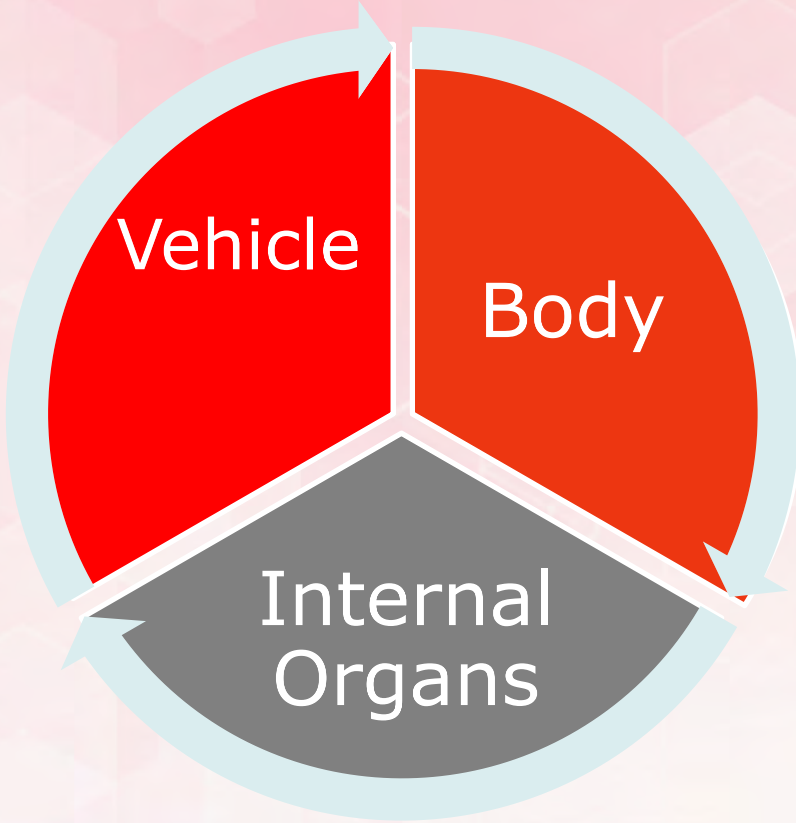
Types of MVC

- Frontal
- Rear-end
- Lateral
- Rotational
- Rollovers

Motor Vehicle Collision

Three Collisions



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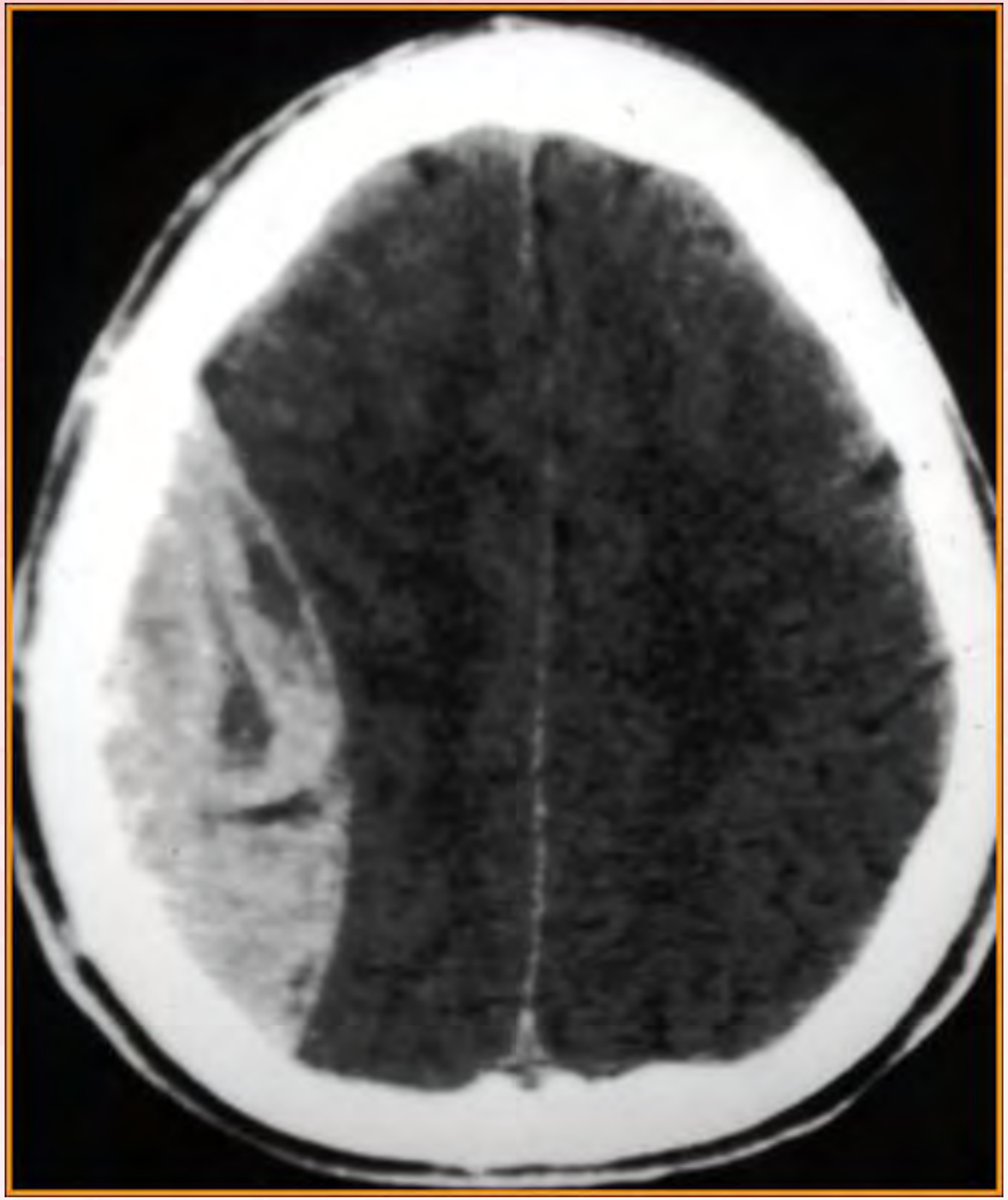

B-pillar

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Child Restraints

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Direct Strike
- Lower arm
- Pelvis
- Abdominal organs
- Hip
- Femur
- Knee

Thrown
- Head
- Face
- Neck
- Skin (road rash)

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Feet-First Falls

- Compression fractures
- Calcaneus fractures
- Fractures of the wrist
- Injury to internal organs
- Injuries to head, back, and pelvis

http://manyfor.com/lucky/a-wooden-ladder-fall-down.html

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Head-First Falls

- Brain injury
- Hyperextension of the head/neck
- Compression of the cervical spine
- Chest, lower spine and pelvic injuries are also common

http://manyfor.com/lucky/a-wooden-ladder-fall-down.html

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Falls - Critical Factors

- Height
- Surface
- Objects struck during fall
- Body part of first impact

Important Heights

20 feet - Adult

2- 3 x height of the child (10 feet)

35 feet: 50 % mortality

(American College of Surgeons, 2017)

Blunt Assault

With weapon, fists, or kicking & stomping

Penetrating Trauma

Ballistics

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$$KE = \frac{1}{2} m v^2$$

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Low energy, 22 caliber,
3-shot pistol on the left

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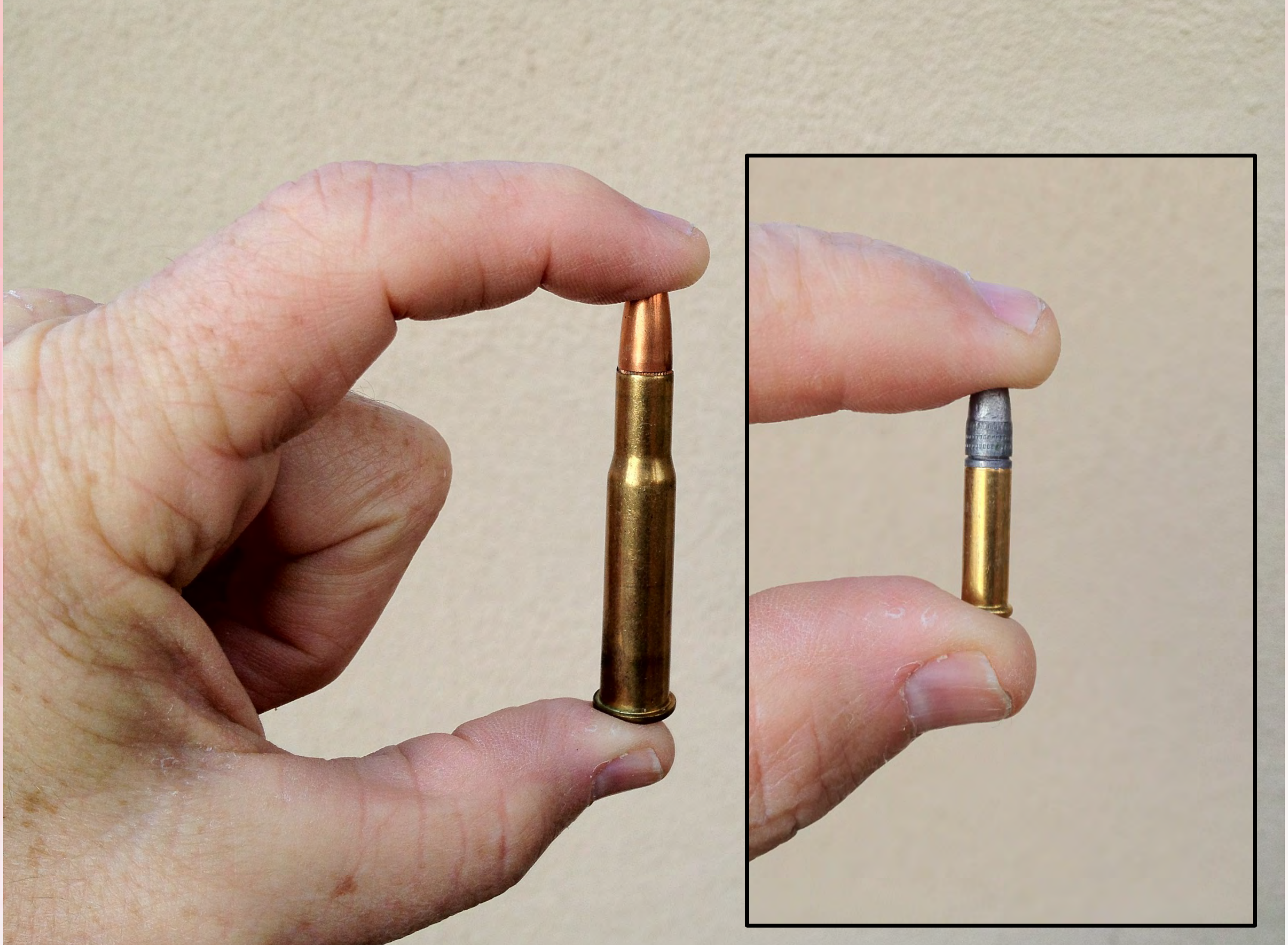

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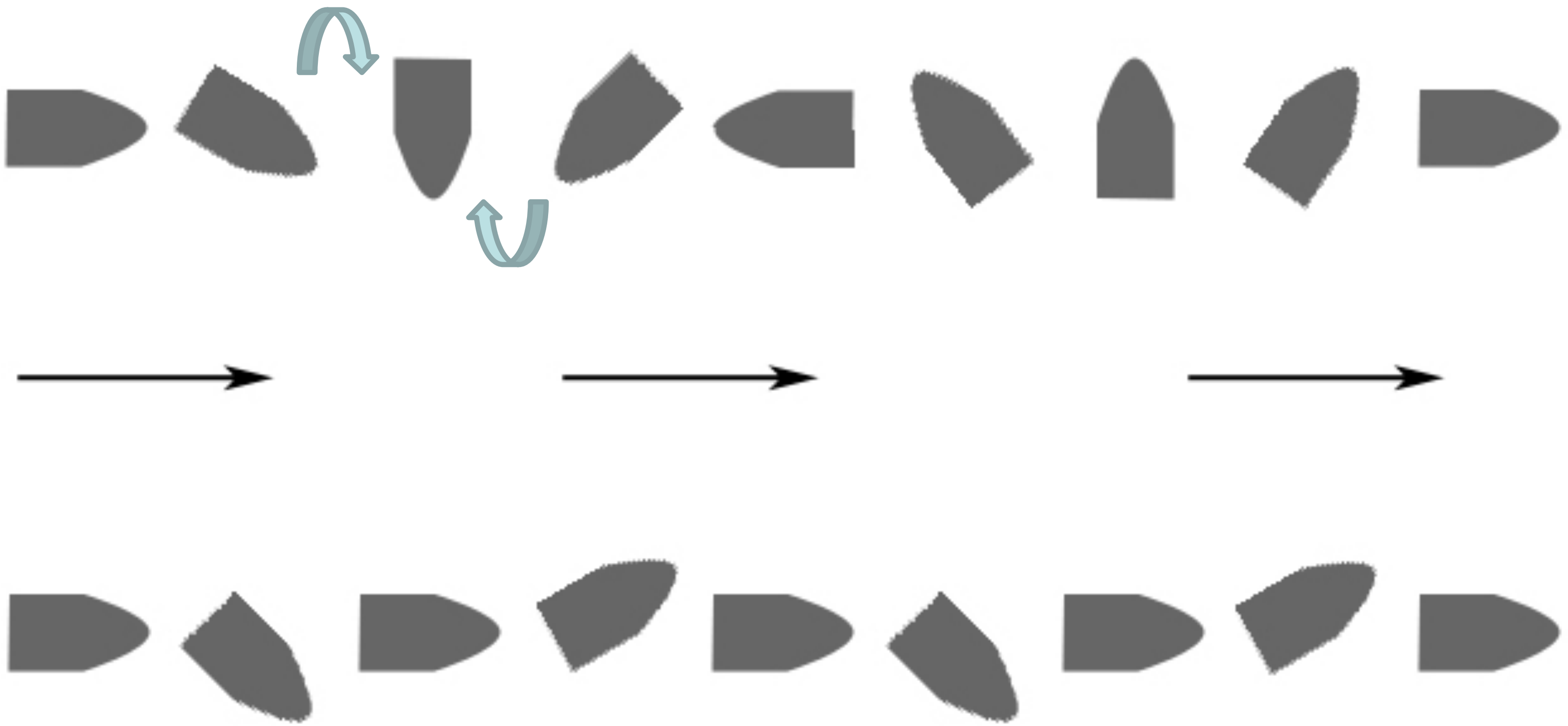
Other Ballistic Characteristics…

- Tumble & Yaw
- Cavitation
- Deformation
- Fragmentation



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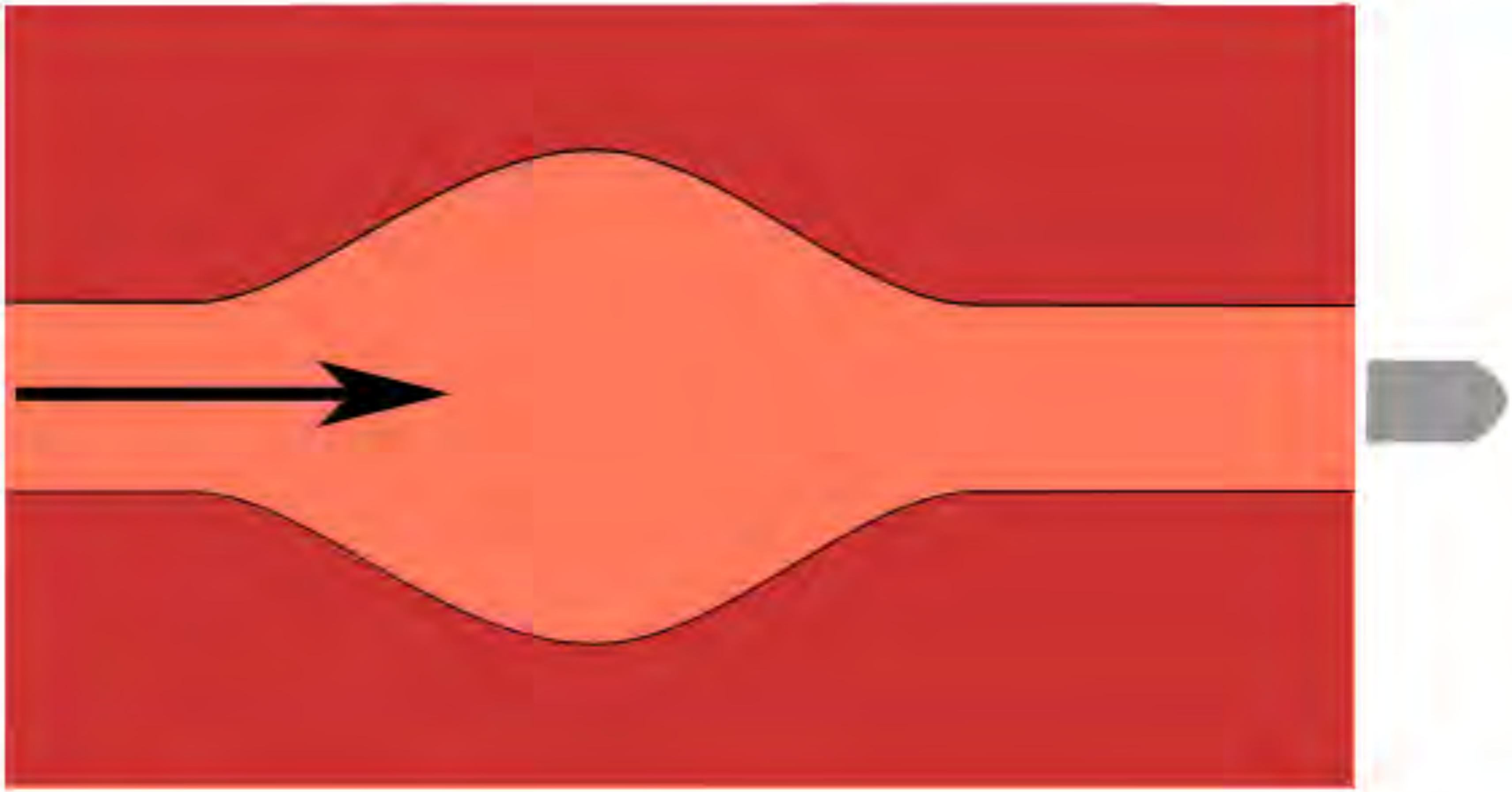

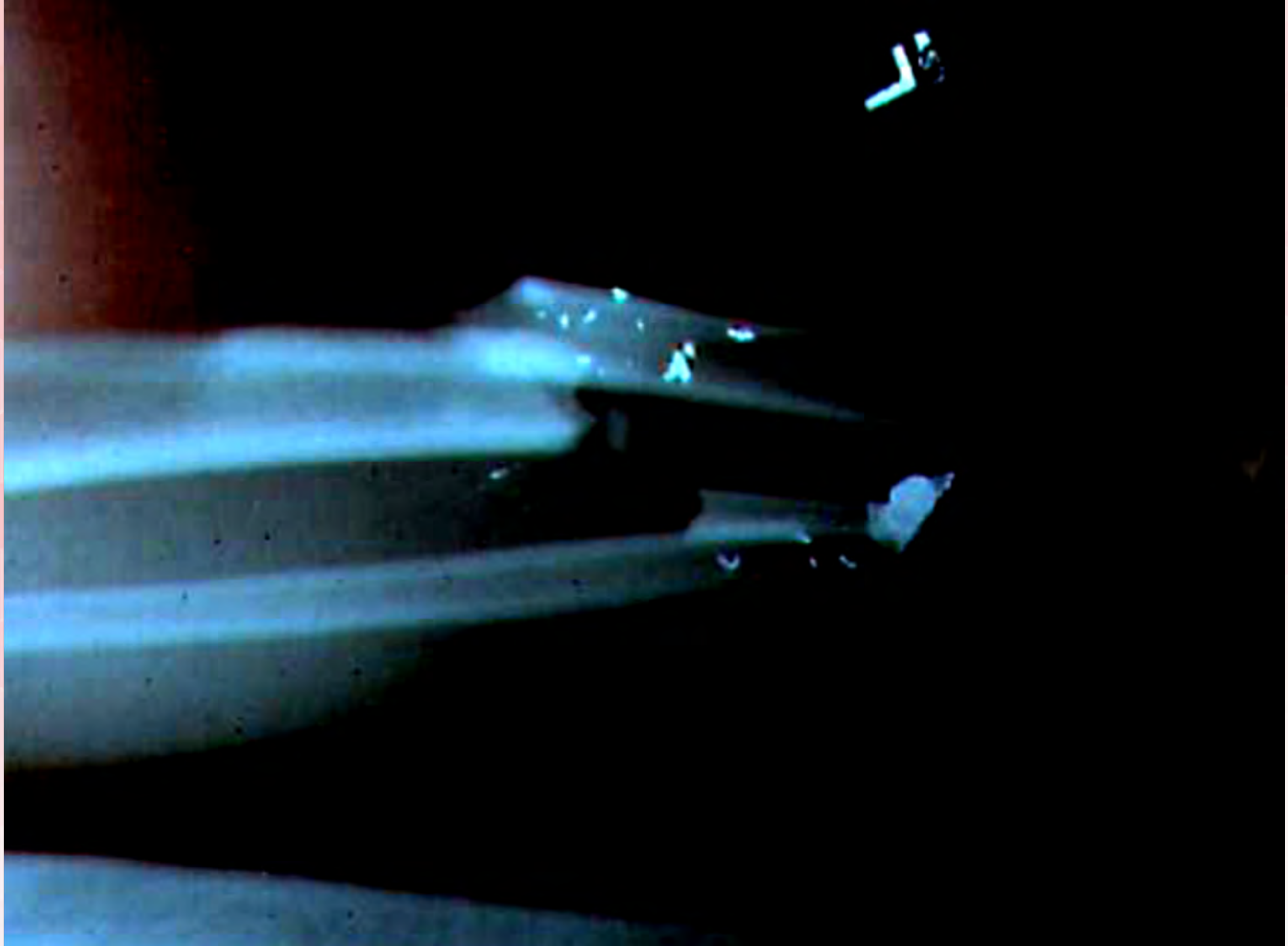

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Hollow-point Bullets a.k.a. hollow-nose

- Contain a hollow in the tip
- Hollow-tip bullets are designed to "mushroom" upon impact - to cause more tissue damage – used for hunting.
- They can be partially jacketed (soft-point) or fully jacketed
- If they are partial jacket, they are called soft-point hollow nose bullets

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2/19,

- High-powered shotgun blast
- Close range

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$$KE = \frac{1}{2} m v^2$$

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Entrance vs. Exit Wounds

- Exit wounds are not always larger
- Avoid labeling wounds entrance or exit
- Include anatomic location, shape, size and any additional finding such as powder burns
- Preserve evidence
  - Cut around not through bullet holes in clothing
  - Handle any bullet carefully
  - Preserve chain of custody

Summary and Conclusions

Injury patterns and severity
are *predictable*,
based on knowledge about
mechanism of injury,
especially mass and velocity

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Hemorrhagic Shock

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Objectives

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

- Understand the definition of hemorrhagic shock
- List the most common causes of hemorrhagic shock
- Recognize hemorrhagic shock signs and symptoms
- Explain the importance of early control of hemorrhage in trauma patients
- Describe the treatment management and ongoing evaluation of hemorrhagic shock

Hemorrhagic Shock

- Feared by all
- Respected by many
- Foreign to none

Shock

- Basic pathophysiology of shock is inadequate blood supply leading to impaired tissue perfusion that causes cellular damage.
- Reduction in tissue perfusion below that necessary to meet metabolic needs
- Clinically manifested by hemodynamic disturbances and organ dysfunction
- Simple Facts:
  - A 70kg individual usually has 5 liters of blood volume/equivalent to 25 units PRBCs
  - The heart as a pump is volume responsive
  - Vitally important to provide hemodynamic support regardless of cause of shock

Inadequate Tissue Perfusion

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Shock

- Loss of normal circulation blood volume
  - Normal blood volume
    - Adult: 7% of the ideal body weight
    - Child: 9% of the ideal body weight
- Classification:
  - Class I-IV designations
  - Not absolute values
  - Useful as a clinical guide
  - Treatment is determined by the patient’s response to interventions

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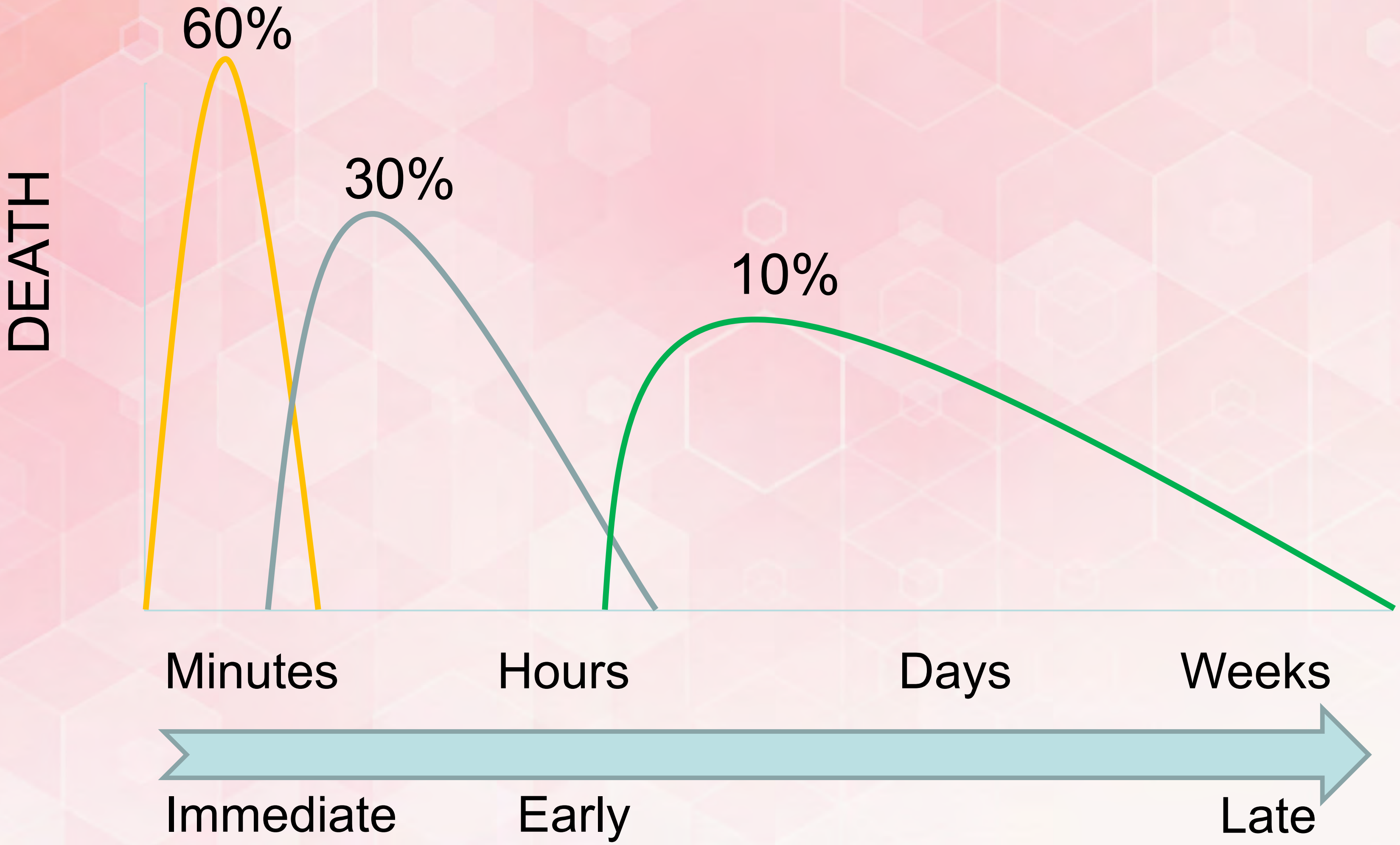
Hemorrhagic Shock

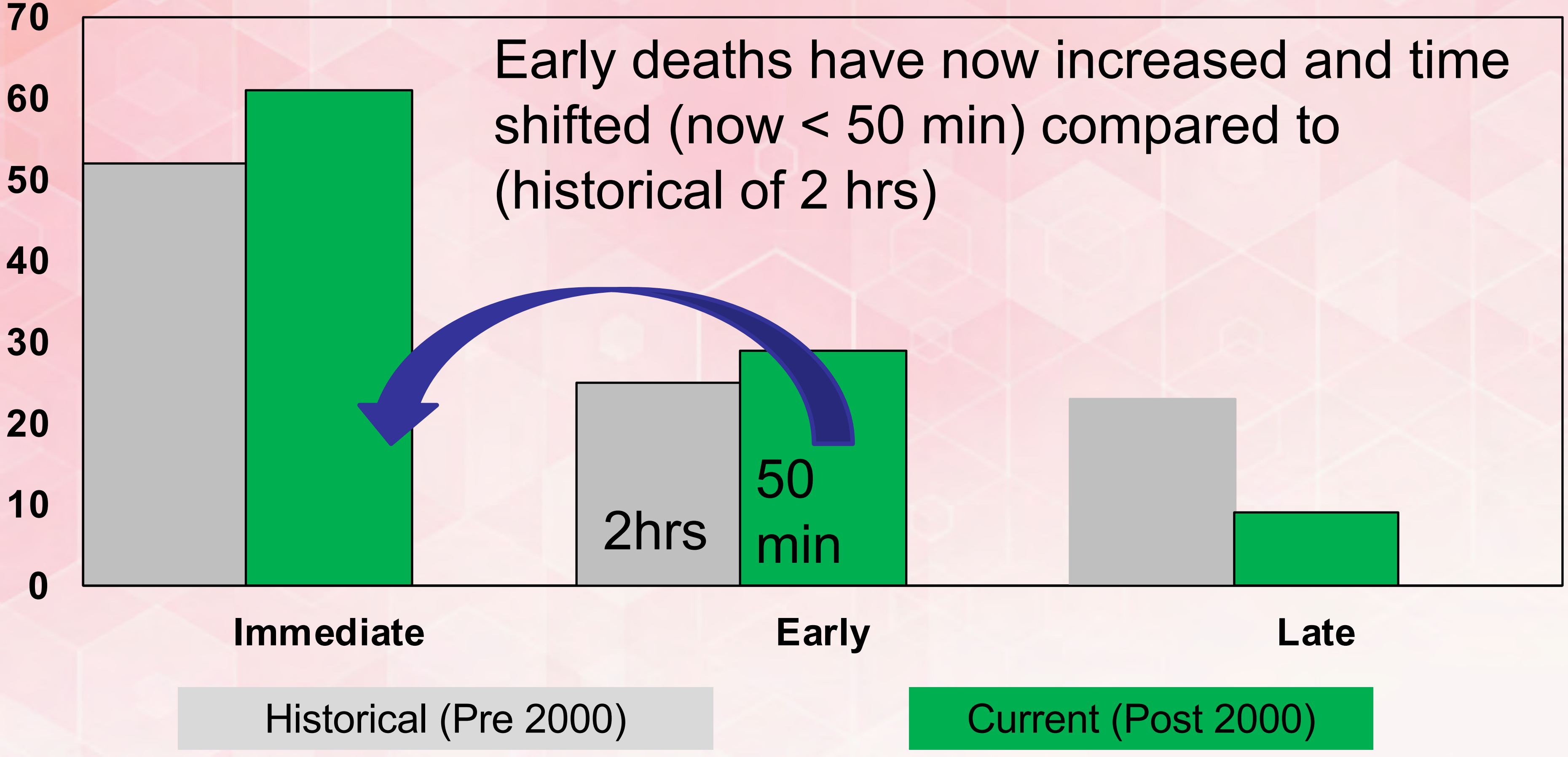
Epidemiology

Historic Trauma
Trimodal Death Distribution



(Sobrino & Shafi, 2013)

Trimodal Moving
Toward Bimodal Death Distribution



(Trunkey, 1983; Gunst, Ghaemmaghami, Gruszecki, Urban, Frankel, & Shafi, 2010)

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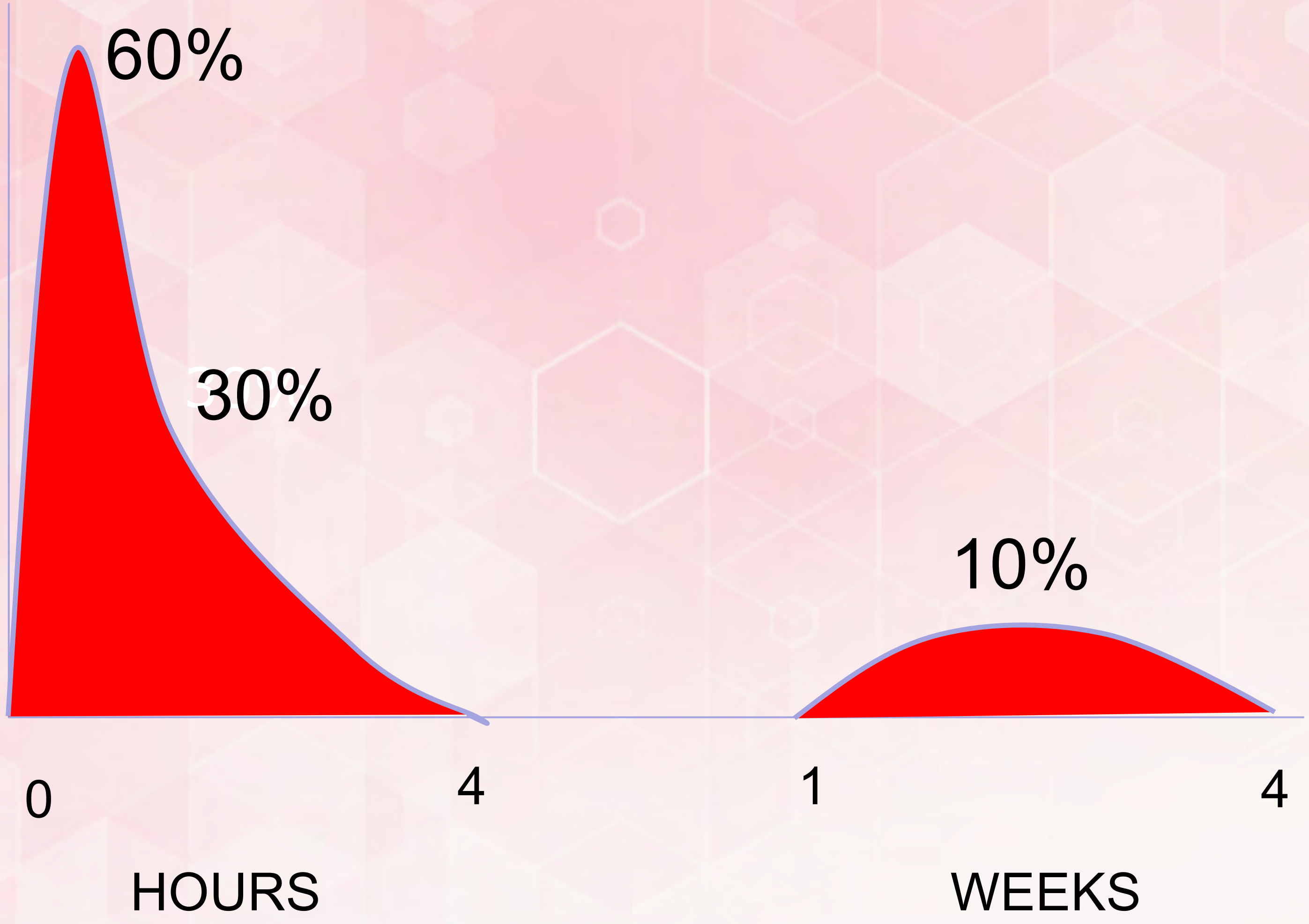
New Bimodal Trauma Death Distribution



(Gunst, Ghaemmaghami, Gruszecki, Urban, Frankel, & Shafi, 2010)

Hemorrhagic Shock

Pathophysiology

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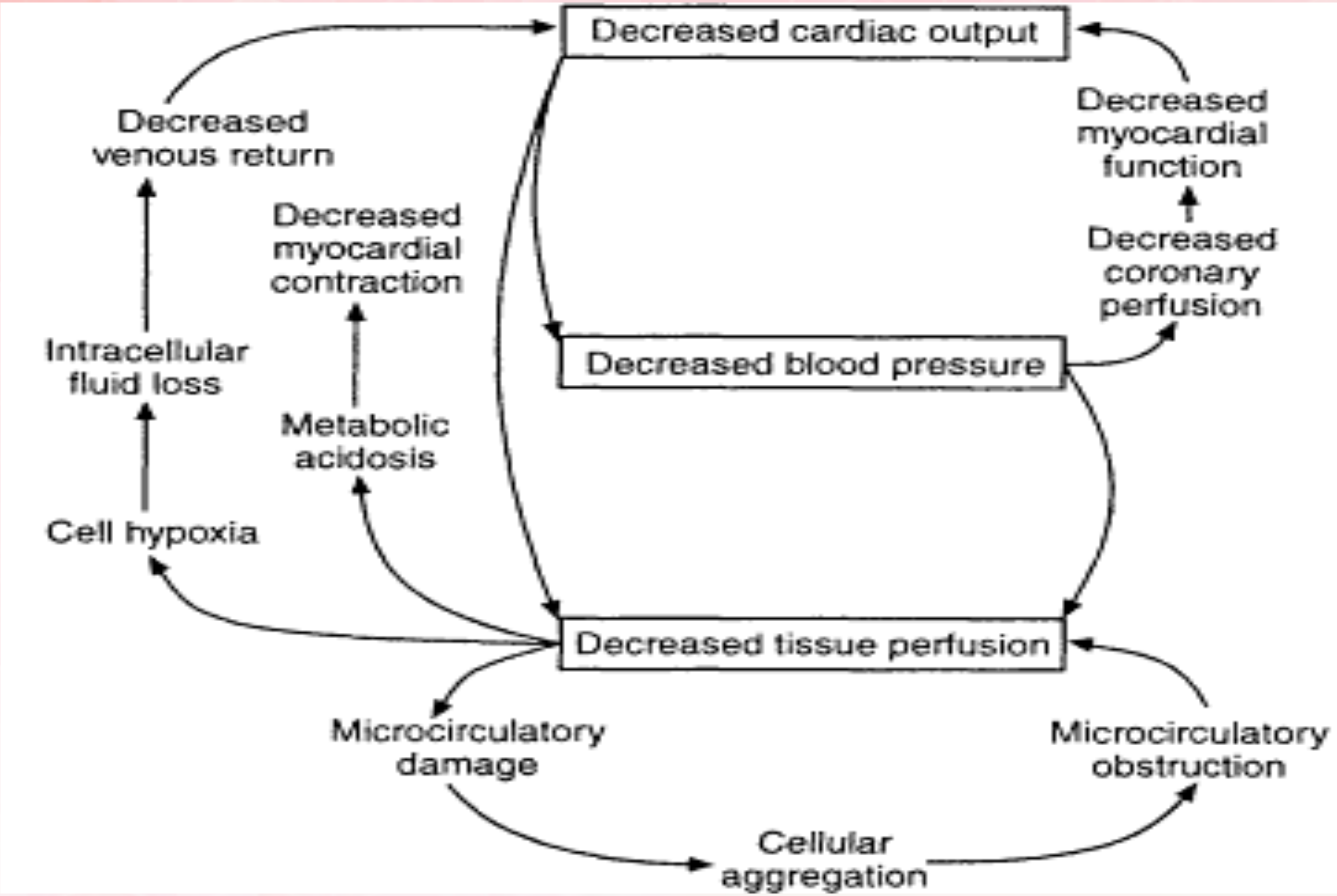
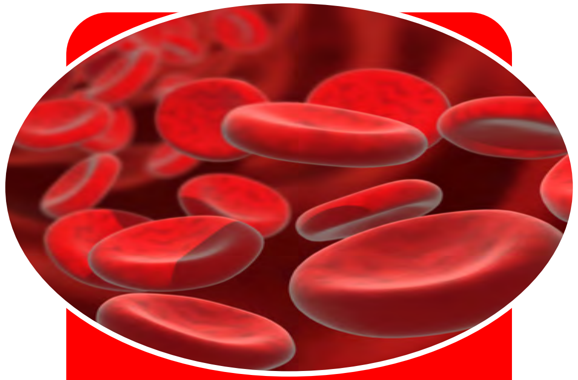
Pathophysiology of Shock



Heart Rate (beats/min) X Stroke Volume (cc/beat) = Cardiac Output (L/min)



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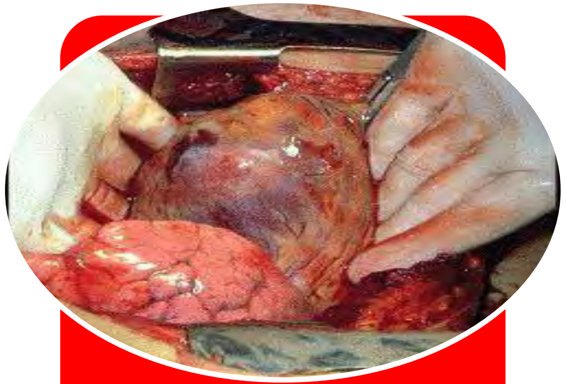

Myocardial Contractility

Afterload

Cardiac Output

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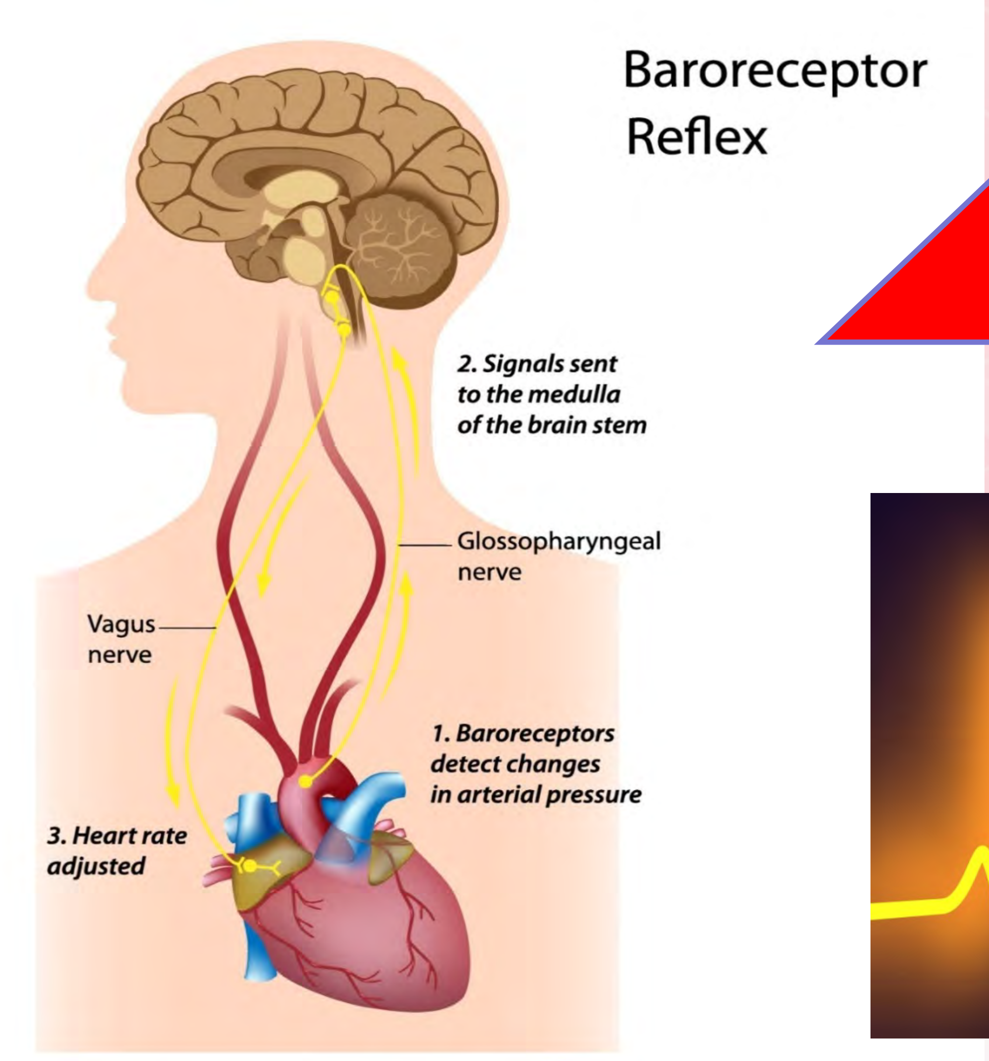
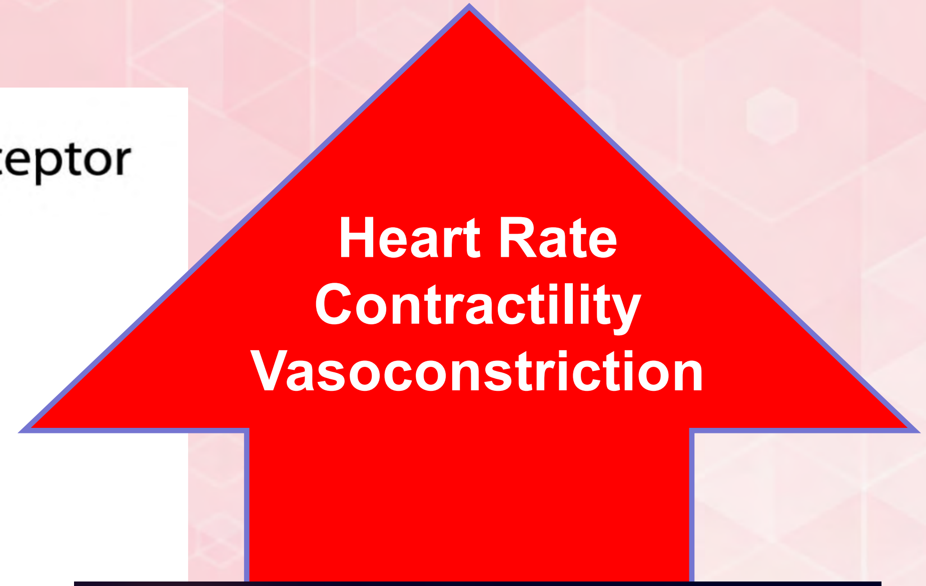
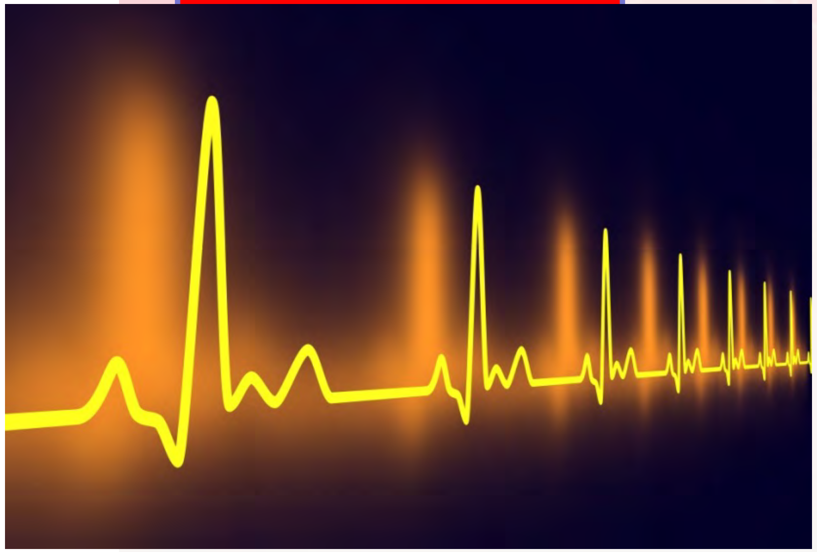
Sympathetic Nervous System



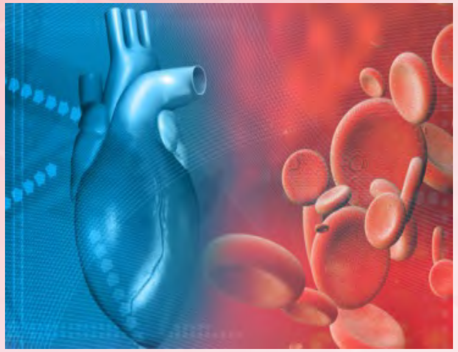


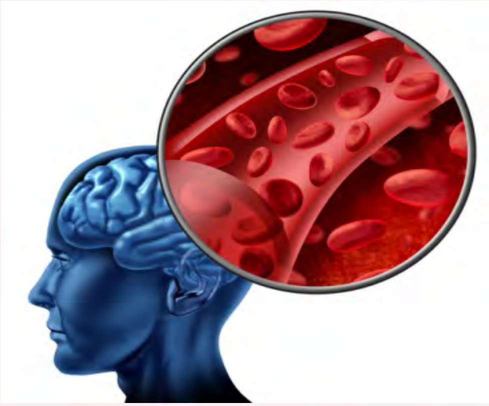


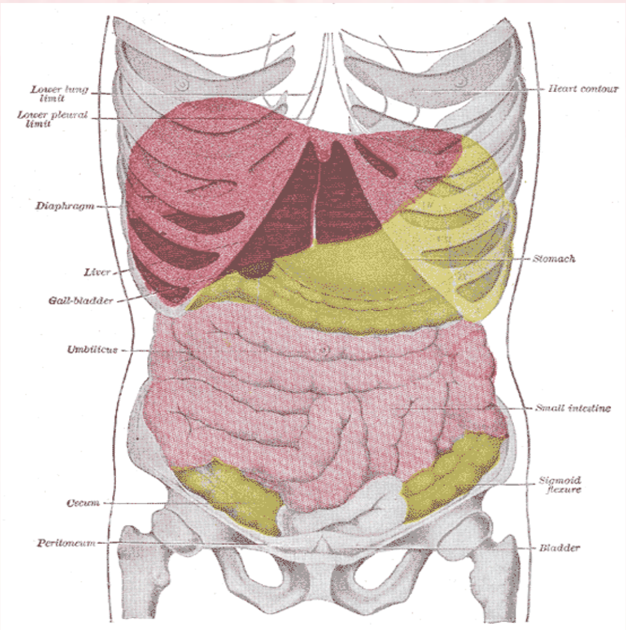
Sympathetic Nervous System

Increased shunting of blood to:

Heart , Brain Skin, Muscle and Visceral Organs



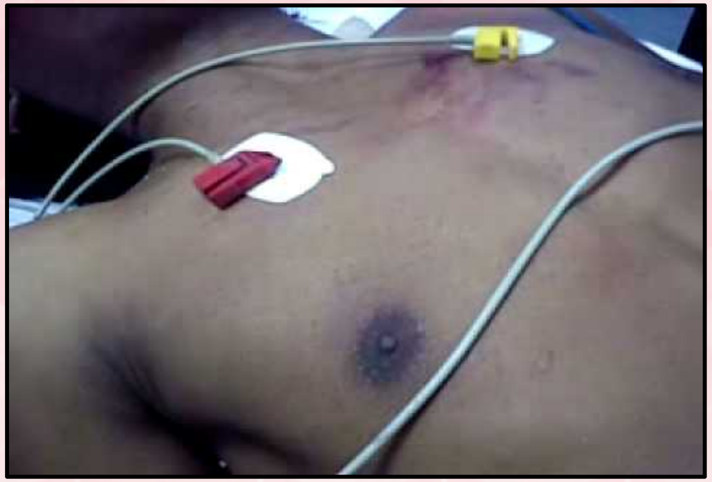




Important Hormones in Shock

Catecholamines: Epinephrine & Norepinephrine

- Increased heart rate & contractility
- Vasoconstriction & narrowed pulse pressure



Renin-Angiotensin Axis: Aldosterone and ADH

- Water & sodium conservation & vasoconstriction
- Increase in blood volume and blood pressure
- Decreased urine output

Cellular Response to Shock

- Acidosis
- Blood Loss
- Inadequate Perfusion
- Cellular Hypoxia
- Aerobic Metabolism
- Anaerobic Metabolism
- Lactic Acid
- Cellular Edema

Stages of Shock

Initial → Compensatory → Progressive → Refractory

Initial Phase

- Due to a decrease in cardiac output:
  - Cool, clammy skin, decreased urine, change in LOC, hypotension
- Reduced perfusion causes a shift from aerobic to ***anaerobic*** metabolism which causes ***lactic acidosis***.

Any patient who is cool & tachycardic is in shock until proven otherwise (ATLS)

(American College of Surgeons, 2012)

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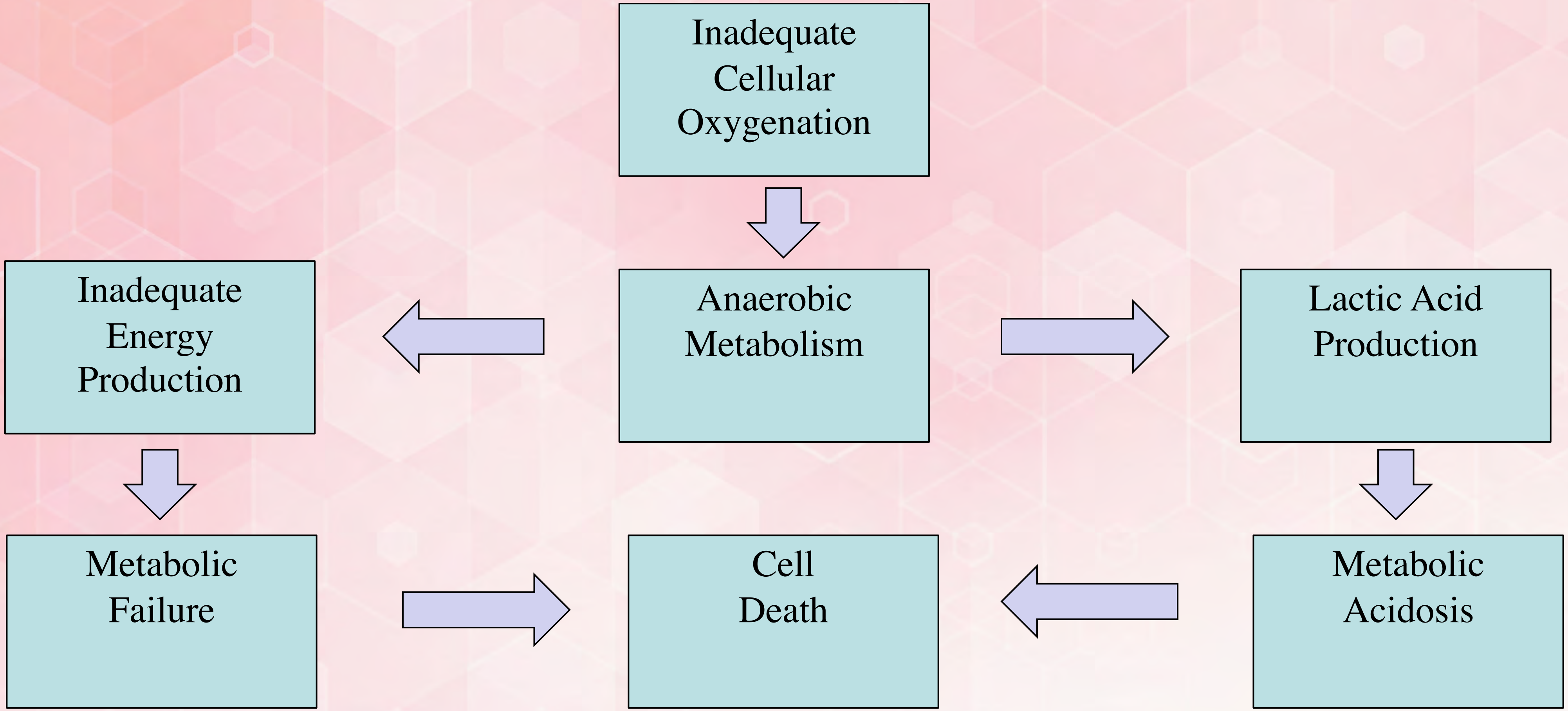
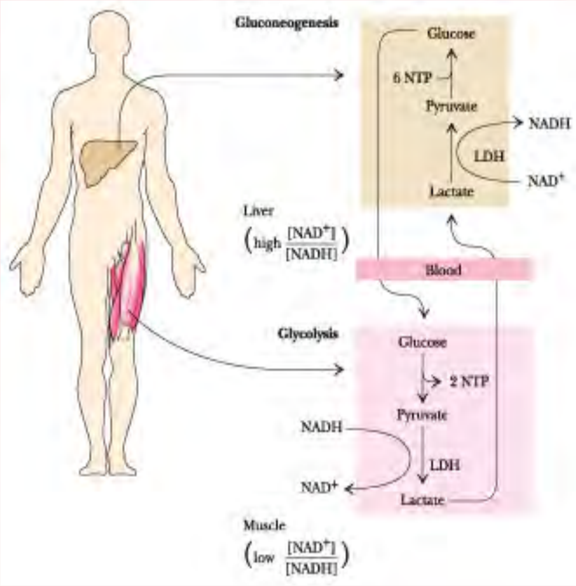
Anaerobic Metabolic Phase



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
- Lactate is produced in cells when Pyruvate can not enter the TCA (Krebs) Cycle because of low oxygen tension (anaerobic metabolism)
  - Pyruvate is generated through glucolysis

<u>Lactate Clearance</u>
•Liver 60%
•Kidney 30%
•Heart ≈5%
•Skeletal Muscle ≈5%



Lactic Acidosis

- Results from inadequate oxygen:
  - Delivery (DO2) to the bodies' tissues
  - Consumption (VO2) by the bodies tissue
  - Anaerobic metabolism
- Pyruvate Dehydrogenase is inhibited at low oxygen tensions
  - Pyruvate can not enter the Krebs Cycle
  - Pyruvate becomes a substrate for Lactate Dehydrogenase
  - Lactate accumulates in cells/tissue
- Lactate levels correlate with the degree of tissue hypo-perfusion and poor DO2

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Compensatory Phase

Pale Skin

- As a result of vasoconstriction of the peripheral vessels: the skin is the least priority tissue for blood flow

Cold and Clammy Skin

- Shock decreases the skin surface temperature as a result of vasodilatation,   which will increase the internal body temperature. Because the skin plays a major role in controlling body temperature, as it will help in exchanging heat with the external environment.

Increased heart rate

- Shock will decrease the volume of blood pumped from the heart an the blood flow to the brain. That will activate the baroreceptors in the carotid bodies to increase HR trying to supply enough blood to the vital organs

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Progressive Phase

- Metabolic acidosis worsens
  - Poor perfusion
  - Low cardiac output
  - Poor oxygenation
  - Increases cellular damage.
- Hypoperfusion of organs leading to multiple organ dysfunction.
- Acids and waste products cause vasodilation, acidosis and hypoxia
- Microthrombi form due to decreased venous return
- Cardiopulmonary failure begins heading to dysrhythmias, ischemia and pulmonary edema.

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Refractory Phase

- No longer responding to therapy
- Severe and continuous hypotension despite fluid, blood and blood product resuscitation and vasopressors
- Hypoxia despite oxygen therapy
- Decreased body temperature
- Multiple emboli, severe coagulopathy
- MODS (multiple organ dysfunction syndrome)

Hemorrhagic Shock

Injuries Prone to Hemorrhage

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Injuries Prone to Hemorrhage

Vascular	Solid Organ	Bones
Aorta Vena Cava	Spleen Liver	Pelvis Femur

Quickly Rule Out Blood Loss

Chest – CXR / FAST

Abdomen - FAST

Pelvis – Exam / Xray

Femur – Exam / Xray

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Fracture Associated Blood Loss

• Humerus	750 ml
• Tibia	750 ml
• Femur	1500 ml
• Pelvis	> 3 L

<u>Associated Soft Tissue Trauma</u>

Release of Cytokines

- Increased permeability
- Magnify fluid loss

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Confounding Factors In Response To Hemorrhage

- Patients age
- Pre-existing disease / meds
- Severity of injury
- Access to care
- Duration of shock
- Amount prehospital fluid
- Presence of hypothermia

Hemorrhagic Shock

Assessment

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

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The Four Classes of Hemorrhagic Shock

	CLASS I	CLASS II	CLASS III	CLASS IV
BloodLoss (ml) %	<750 15%	750-1500 15%-30%	1500-2000 30-40%	>2000 >40%
HR	<100	>100	>120	>140
BP	normal	normal	decrease	decrease
PP	normal	decrease	decrease	decrease
RR	14-20	20-30	30-40	>35
UOP	>30	20-30	5-15	negligible
CNS	slightly anxious	mildly anxious	anxious confused	confused lethargic

(American College of Surgeons, 2008)

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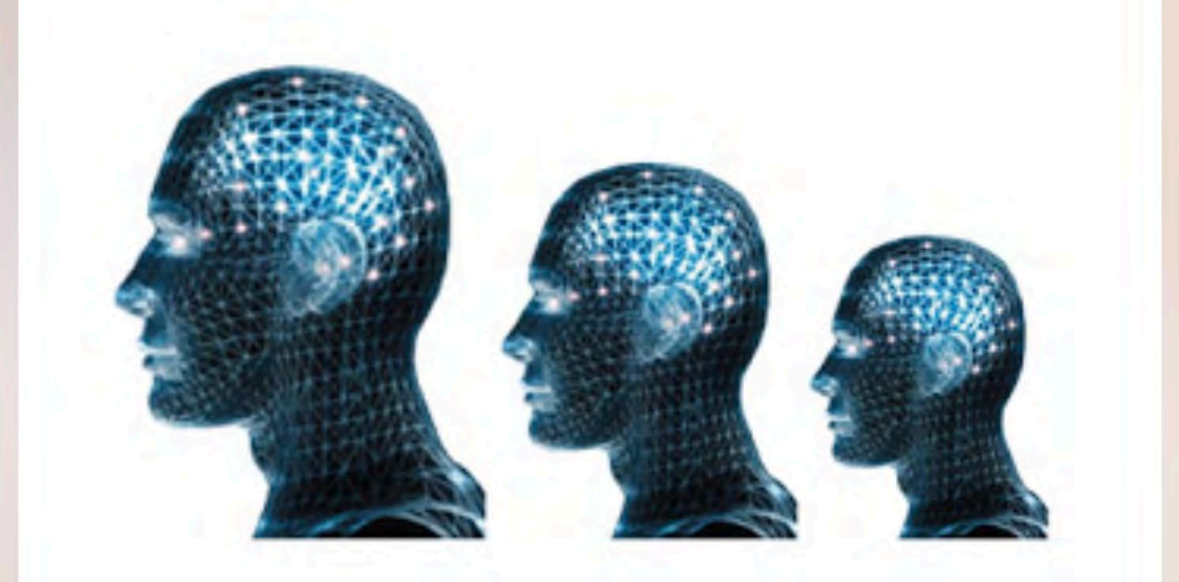
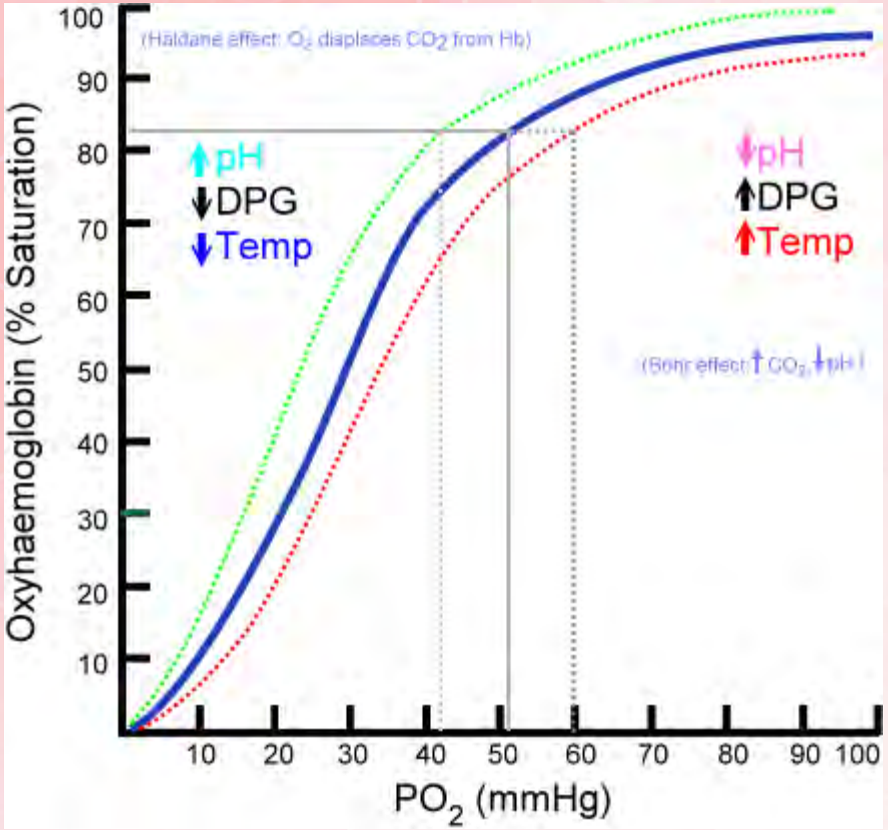
Changing Mentation

- One of the first signs of shock
- Indicator of perfusion or lack of
- Could be affected by drugs & alcohol



Hypoxia/Head Injury Until proven otherwise

Ox-Hemoglobin Dissociation Curve



The curve: Relating SaO2 to PaO2

The oxyhemoglobin dissociation curve graphically represents the affinity between oxygen and hemoglobin—specifically, how the oxygen saturation of hemoglobin (SaO2) relates to the partial pressure of arterial oxygen (PaO2). The curve's position and overall shape depend on various factors, including the partial pressure of carbon dioxide (PaCO2), body temperature, and blood pH.

(Hooley, 2015)

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Ox-Hemoglobin Dissociation Curve

Control factors	Change	Shift of curve
Temperature	↑	→
	↓	←
2,3-BPG	↑	→
	↓	←
pCO_2	↑	→
	↓	←
Acidity $[H^+]$	↑	→
	↓	←

Shift to the Left

- Higher saturation of oxygen bound to Hgb
- RBCs hold onto oxygen at the tissues
  - Alkalosis
  - ⇩ CO2
  - ⇩ Temperature
  - Banked Blood

Shift to the Right

- Lower saturation of oxygen to Hgb
- RBCs release oxygen at tissues
  - Acidosis
  - ⇧ CO2
  - ⇧ Temperature
  - COPD
  - Polycythemia

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Normal Vital Signs do not r/o possible hypovolemic shock or hypo-perfusion

Value of Manual Vital Signs

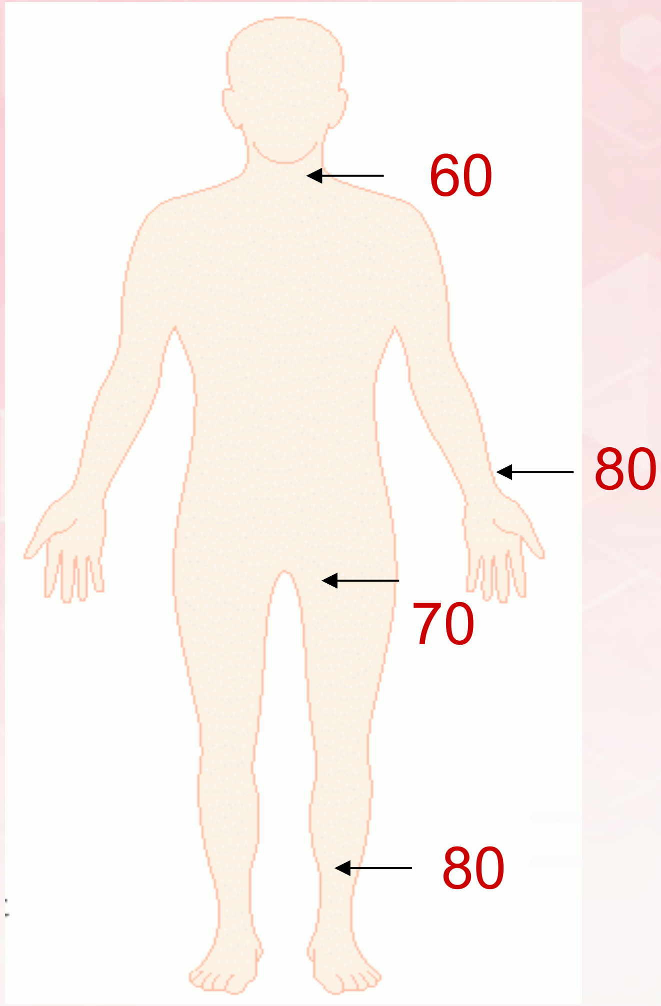
Pulse
Character

GCS
Motor
Verbal

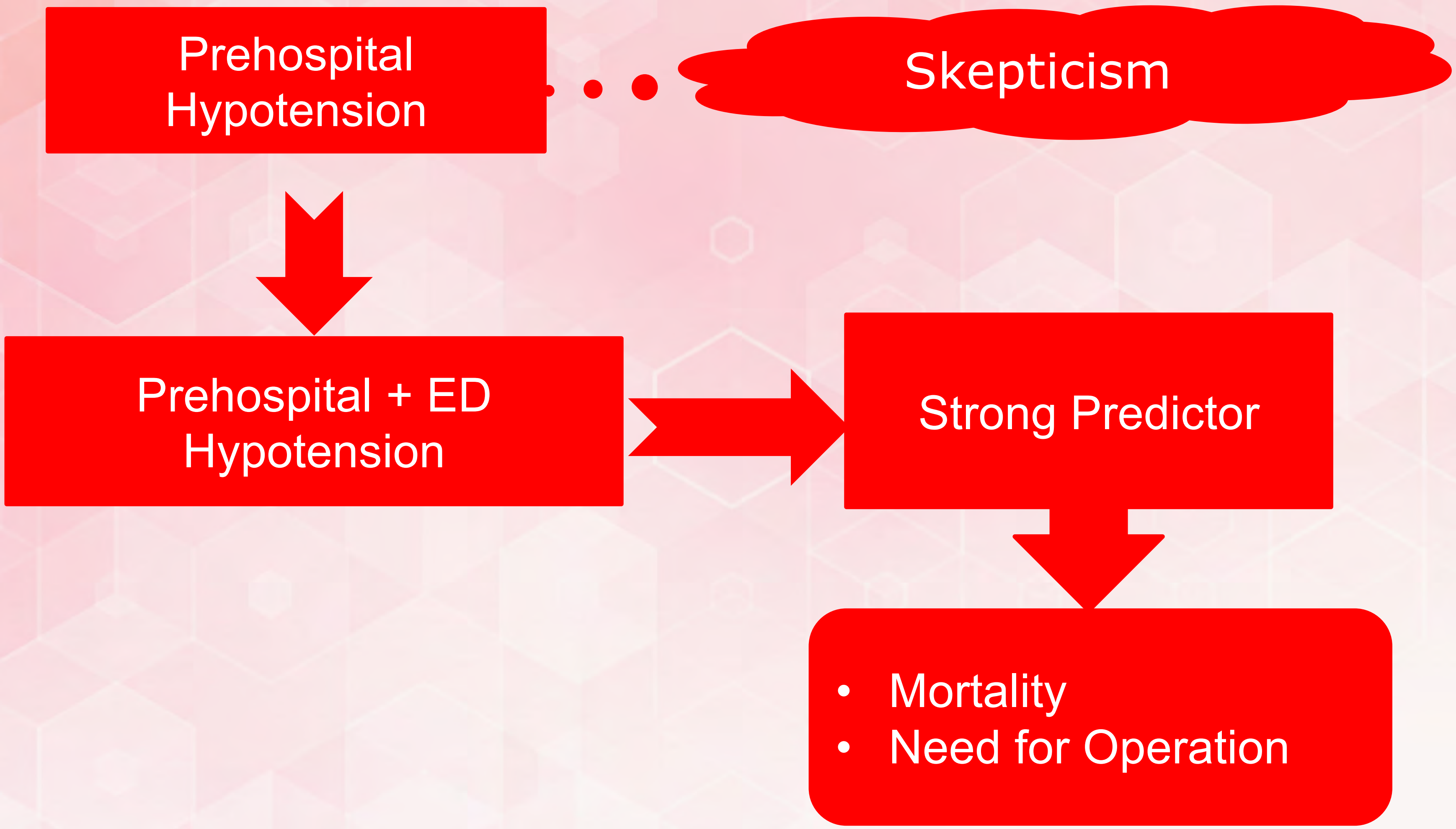
Most Predictive for Need of Life Saving Interventions

Rough BP Estimation from Pulse

- If you can palpate this pulse, you know the SBP is roughly this number



Beware Dismissal of Prehospital BP



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Blood Pressure

- **Systolic BP drop a late sign and responds to volume loss**
  - Decrease based upon total volume loss
  - Non-linear due to compensatory mechanisms
  - Insensitive sign of early shock
- **Systolic BP does not fall until:**
  - Adults ~30% blood loss
  - Pediatrics ~40-45% blood loss
- **SBP $\leq$ 90 mm Hg: mortality approaches 65%**
- **Infrequently & or inadequately monitored**
  - First BP should always be manual
  - Automated BP overestimated by 10 mm Hg

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Hypotension Redefined?

The New Hypotension: SBP $\leq$ 110

- Slope of the mortality curve increased such that mortality was 4.8% greater for every 10-mm Hg decrement in SBP.
- Clinically relevant definition of hypotension and hypoperfusion than is 90 mm Hg.
- Research demonstrates that optimal SBP for improved mortality in hemorrhagic shock increases with age

(Eastbridge et al. 2007)

New SBP for Early Diagnosis of Shock?

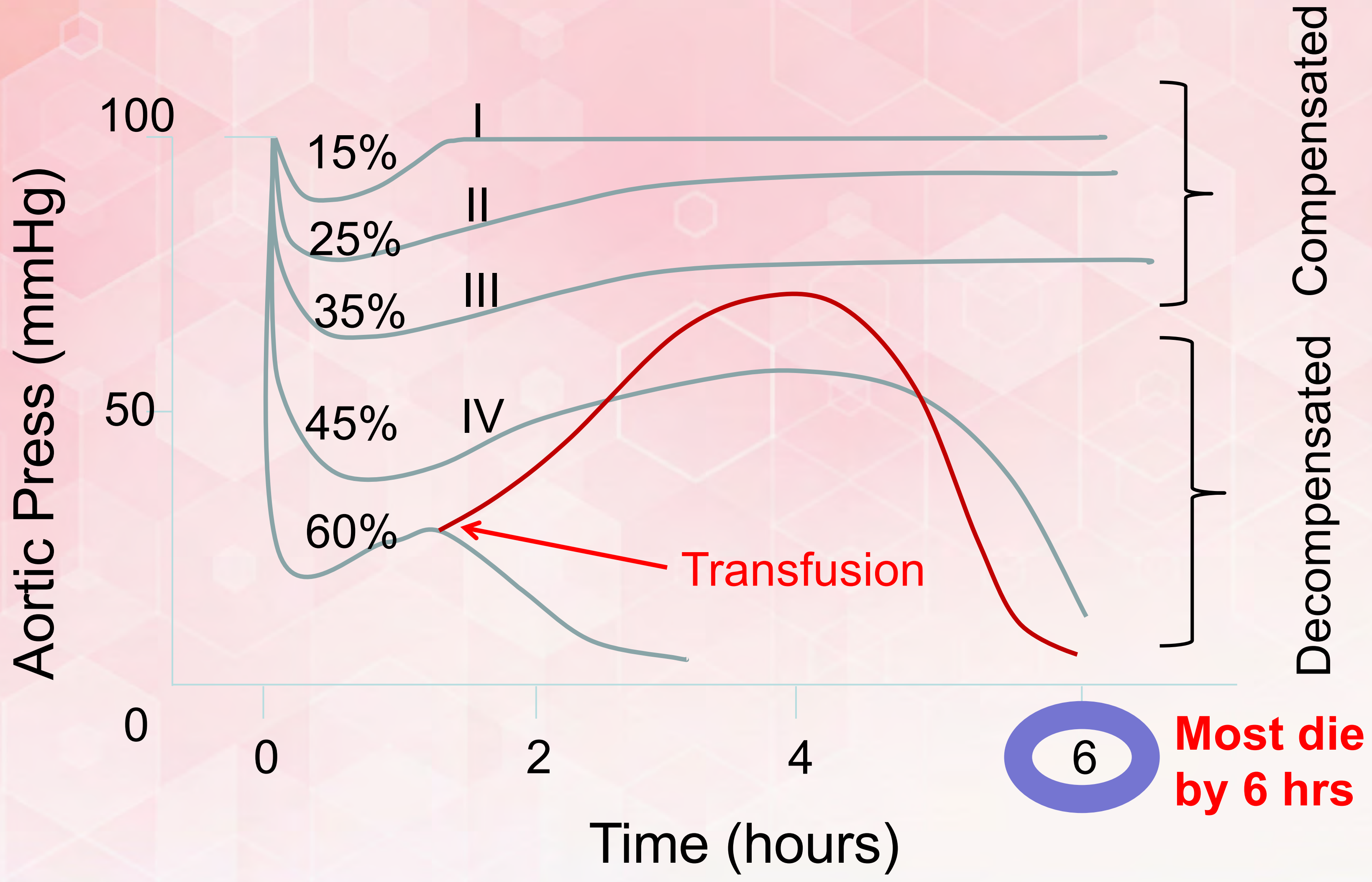
Adult Trauma

60 70 80 90 100 **[110]** 120 130

Geriatric Trauma

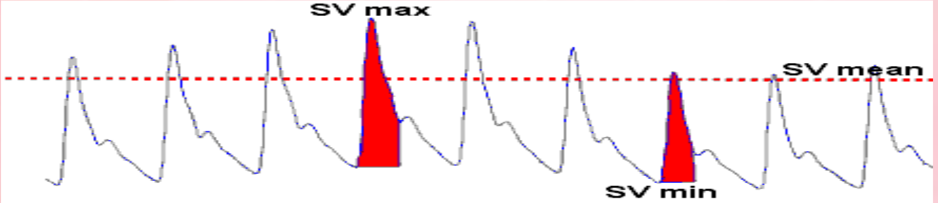
90 100 110 120 130 **[140]** 150 160

Effects of Blood Volume Loss on Mean Arterial Pressure in Classes of Shock



Arterial Pressure Waveform Systems

- Measures pulse pressure & stroke volume *variation*



- Reliable predictors of volume responsiveness
- Determines where the patient lies on their own individual Starling curve

Examples of systems:
PiCCO (Phillips)
pulseCO (LiDCO,Ltd.)
FloTrac/Vigileo (Edwards)

Pulse Pressure

- Narrowed pulse pressure suggests significant blood loss
- Result of increasing diastolic pressure from compensatory catecholamine release

100/66 100/74 100/77 100/84

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Pulse

- Lacks specificity alone
- Age dependent
- Affected by:
  - Emotion
  - Fever
  - Pain
  - Drugs
- Pulse **&** character together more reliable

- Trended over time *may?* have sensitivity
- When to be concerned?

  80 90 100 110 >120

Any patient who is cool & tachycardic is in shock until proven otherwise (ATLS)

(American College of Surgeons, 2012)

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Relative Bradycardia (Paradoxical Bradycardia)

- Defined as Pulse < 90 with SBP < 90
- Occurs in up to 45% of all hypotensive trauma
- Cause remains unclear:
  - Sign of rapid & severe internal bleeding?
  - Increased vagal tone from blood in abdominal cavity?
  - Protective reflex designed to increase diastolic filing in the presence of severe hypovolemia?

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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

(Montoya, Charry, Calle-Toro, Nunez, & Poveda, 2015)

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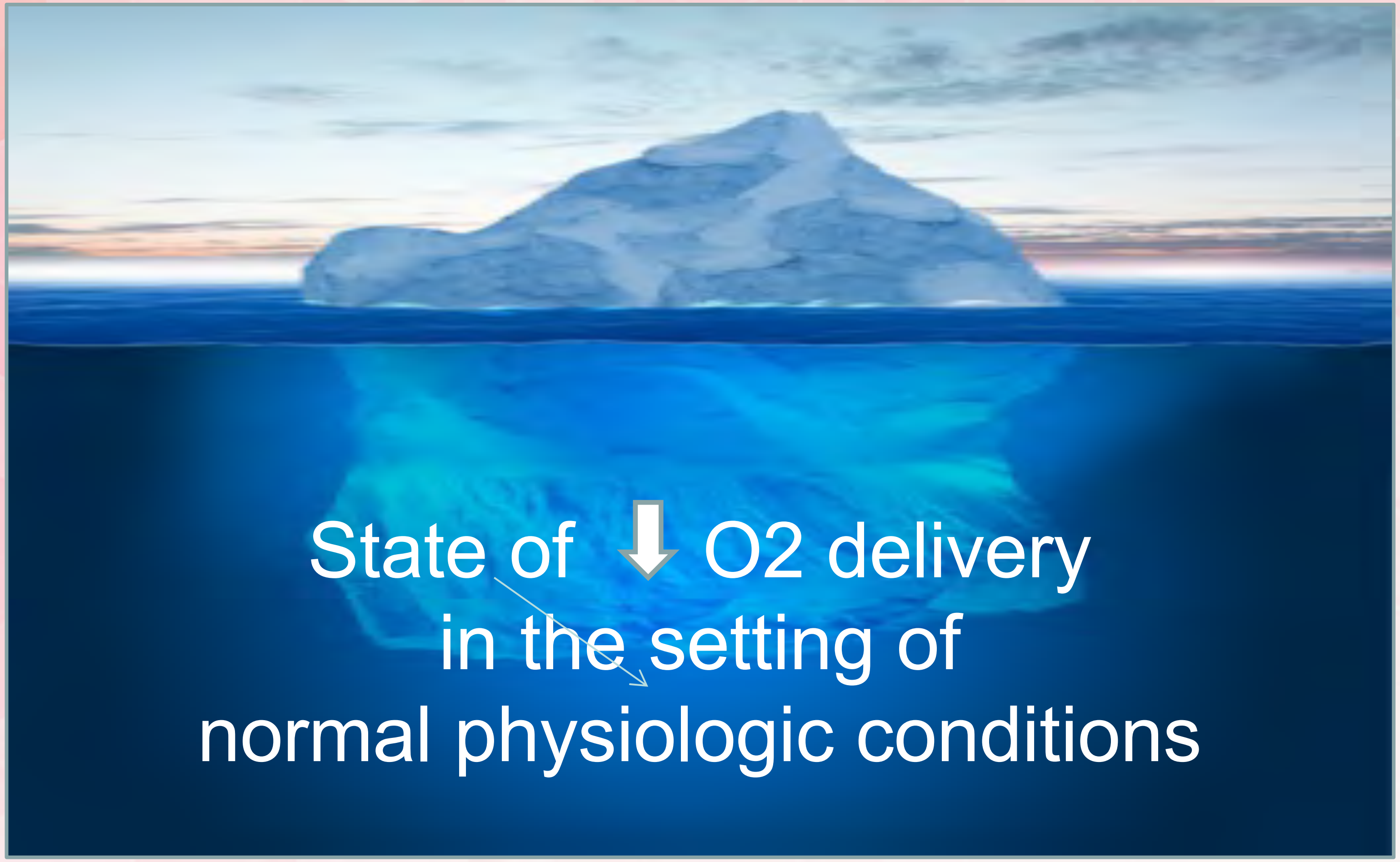
Occult Hypoperfusion



Patients don't suddenly deteriorate,
rather we suddenly notice…

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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
- Echocardiography
- Arterial Wave Analsyis
- StO2 (NIRS)

Skin Perfusion

- **Pale, cool, mottled**
  - Vasoconstriction
- **Most sensitive in pediatrics**
  - Starts distal extremities
  - Ascends towards trunk
- **Capillary Refill**
  - Normal < 2 seconds
  - Unreliable to measure

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Urine Output

Adult	0.5 ml / kg / hour
Child	1.0 ml / kg / hour
Toddler	1.5 ml / kg / hour
Infant	2.0 ml / kg / hour

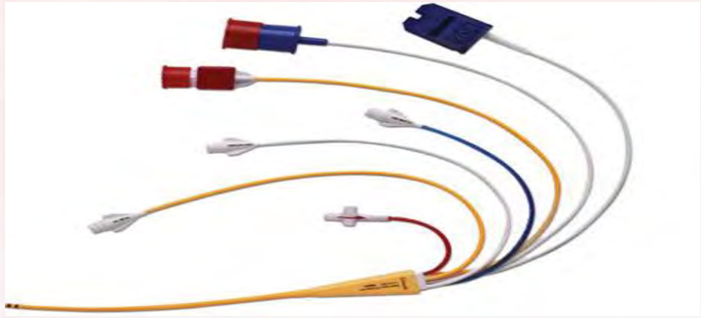
Hemodynamic Monitoring

Central Venous Pressure

- Not advocated for hemorrhagic shock
- Poor relationship between CVP and blood volume
- Unreliable for assessing response to fluid
- Use:
  - Acute air embolus
  - Acute PE
  - Rt Ventricular infarction
  - Acute lung injury

Pulmonary Artery Catheter

- Not advocated for hemorrhagic shock
- Dynamic response of the systems too slow to guide therapy
- Use:
  - May benefit geriatric trauma
  - Sepsis goal directed therapy



(Hu et al., 2013)

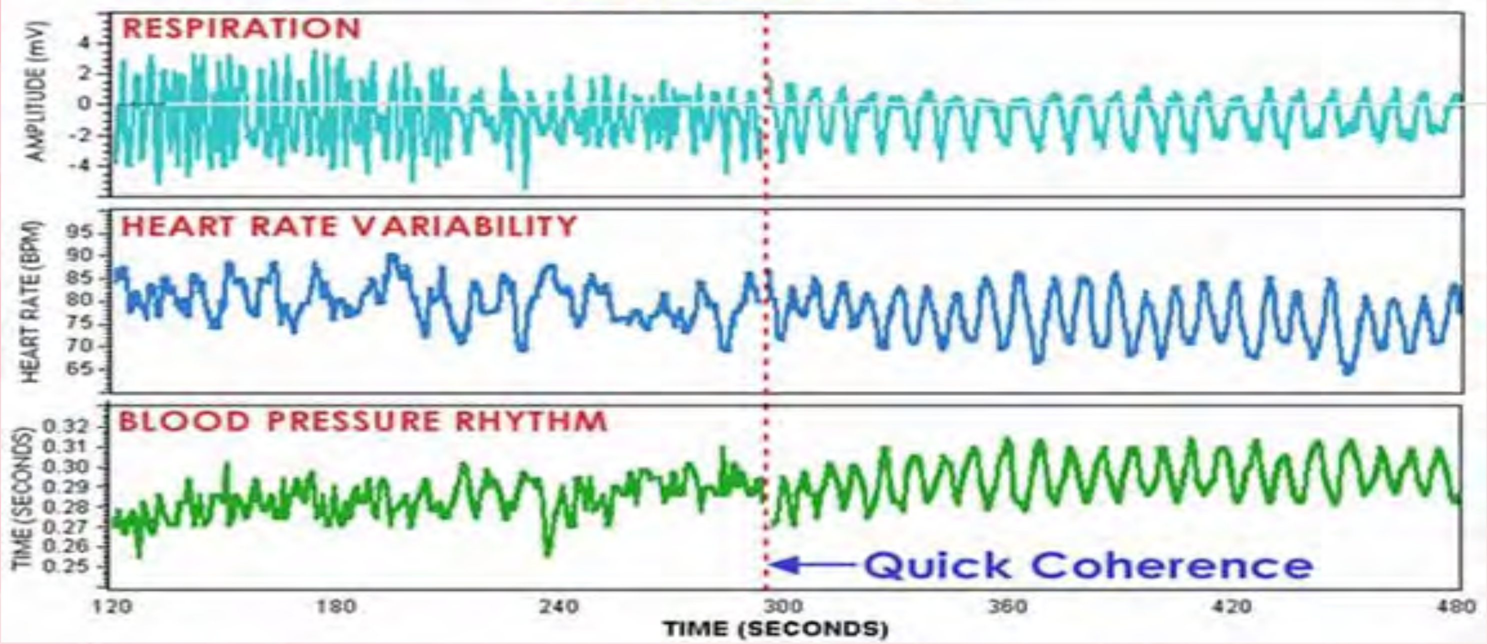
Doppler Echocardiography (Transthoracic or Transesophageal)

- Allows for physician bedside assessment:
  - Ventricular function
  - Volume status
  - Stroke volume
  - Cardiac output

- Dependent on:
  - Technology investment
  - Technical expertise
  - Intra-observer variability
- Excellent diagnostic tool
- Poor monitoring device

Physiologic Variability as Predictors

- Subtle patterns of variation produced by healthy biological systems is normal



- Loss of this variability is seen in critical illness
- Early loss of HR variability predicts mortality in trauma

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

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Hemorrhagic Shock

Lab Values

Hemoglobin / Hematocrit

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

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Arterial pH

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

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Lactate

- Indirect measure of oxygen debt
- Normal value = 1.0 mEq/L
- Values > 1.0 correlate to magnitude of shock
- Lactate Levels > 5 = ↑ mortality
- Ability to clear lactate within 24 hours:
  - Predictive of survival
- Inability to clear lactate within 12 hours:
  - Predictive of multisystem organ failure

Base Deficit

- Sensitive measure of inadequate perfusion
- Normal range -3 to +3
- Run on blood gases
- Admission BD correlates to blood loss
- Worsening BD:
  - Ongoing bleeding
  - Inadequate volume replacement

Base Deficit Classification

Category	Base Deficit	Mortality
Mild	< 5	11%
Moderate	6-9	23
Severe	10-15	44%
	16-20	53%
	>20	70%

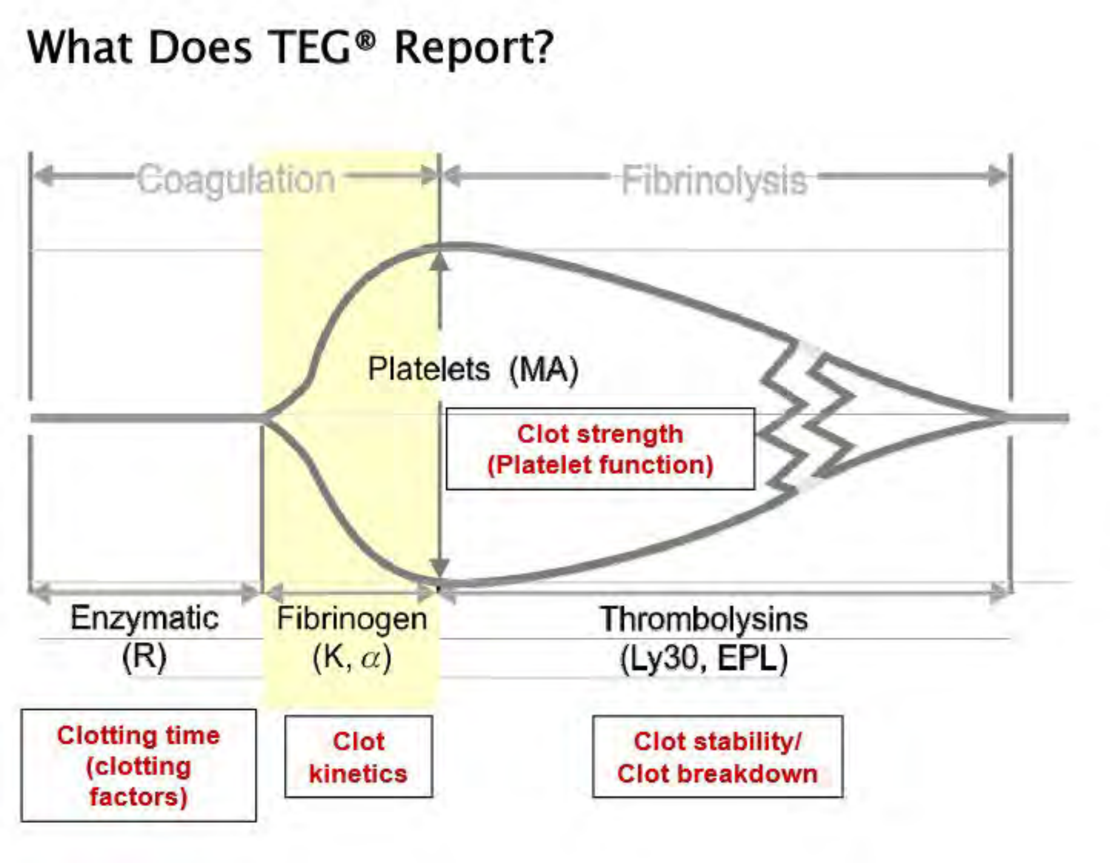
International Normalized Ratio (INR)

- 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

Thromboelastography (TEG)

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



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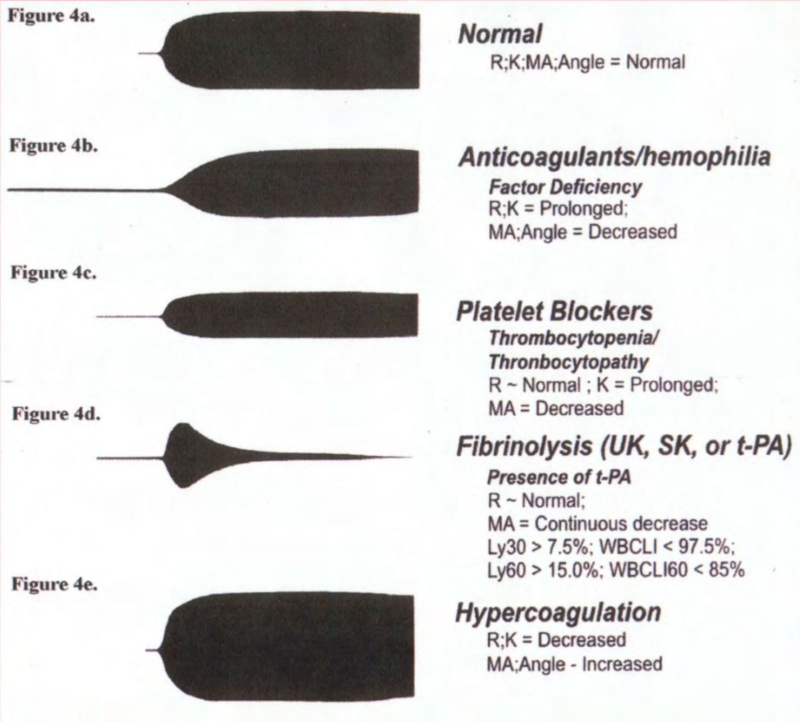
Thromboelastogram (TEG)

- The figure defines the treatment

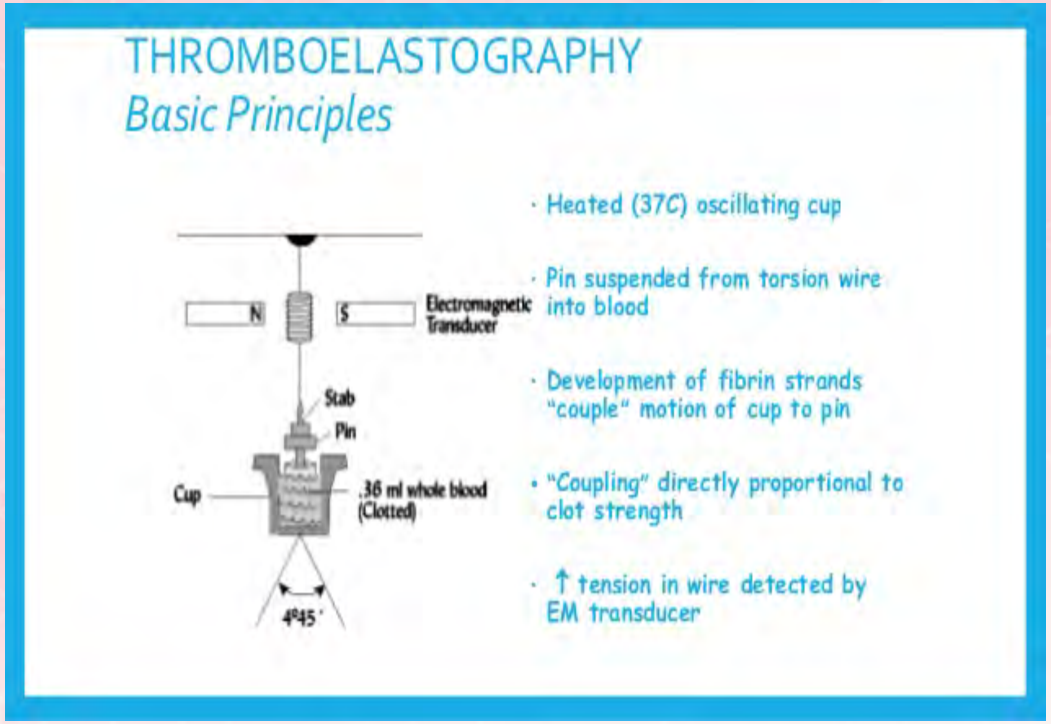


TEG

- Rapid, clinician operated, point of care test
- Allows for individualized quick monitoring
- Where used:
    - ED, OR, Angio, ICU
    - Flat screen monitors
    - Project results in all areas
- Large volume of research coming that will establish TEG protocols in trauma resuscitation

TEG Uses

- Predicts need for transfusion
- Targets use of blood components
- Identify hyperfibrinolytic patients
- Assess LMWH monitoring in high risk ICU pts
- Assess impact of platelet inhibitors (aspirin and Plavix) with Platelet Mapping
- Possibly the only method for detecting degree of anticoagulation by Dabigatran (Pradaxa)



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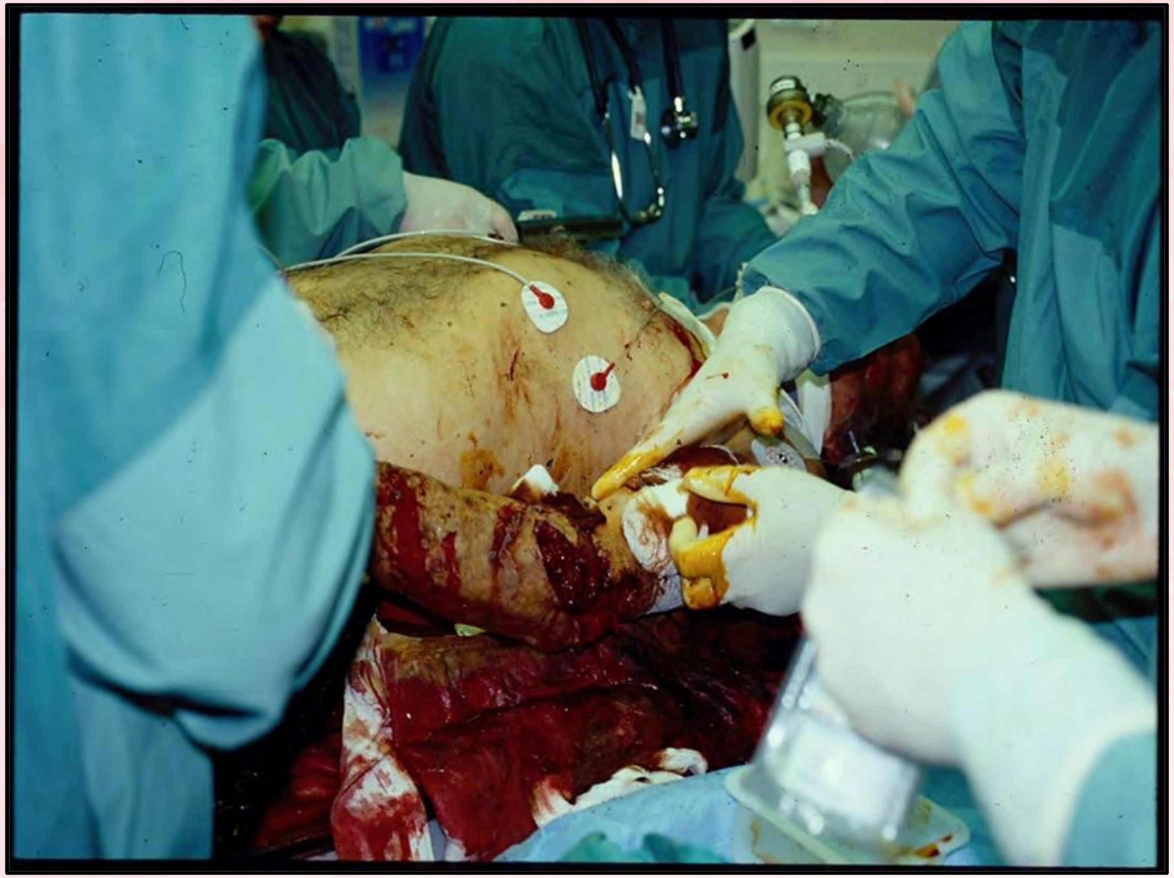
Hemorrhagic Shock

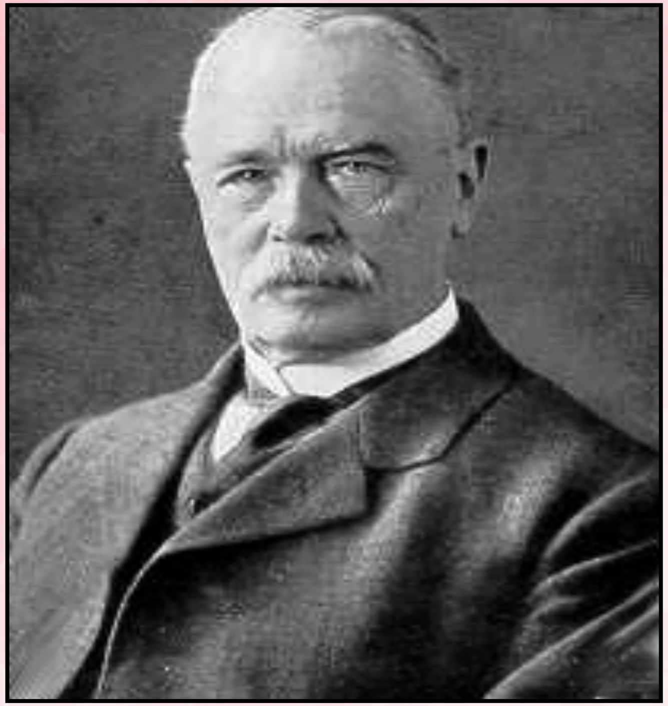
Treatment

airway… breathing… circulation…



Is There a Shock Position?

- Dr. Friedrich Trendelenburg 1800's
- To improve surgical exposure - pelvic organs



No Benefit in Shock

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Mechanical Means of Stopping Hemorrhage

Pelvic Binders or a Sheet

- Reduce pelvis volume
- Tamponade effect

Tourniquets

- Studied extensively in war
- Used more readily today
- Good outcomes
- Safe and effective

Mechanical Means of Stopping Hemorrhage

Hemostatic Dressings

- Research advancing quickly
  - Made from Kaolin
  - Actions:
    - Direct compression
    - Activation of clotting Factor VII
    - Adhesion
  - Utility
    - Speed of application (under fire)
    - Pliable, Z Fold conformation

https://www.bleedingcontrol.org/

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IV Access Principles in Shock

- Fastest, simplest route best (antecubital)
- Large bore, 14-16 gauge, 2 inch length
- Flow limited by IV gauge & length ***not size of vein***

Optimally

- Two people attempting simultaneously
- Two different sites (above & below diaphragm)
- Two to three sites required per major trauma
- Progression [PIV → Femoral → Subclavian]
- Consider Intraosseous (IO) ***early*** as rescue device

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Avoid IV Access

- Injured limb
- Distal to possible vascular wound
- Femoral access with injury below diaphragm

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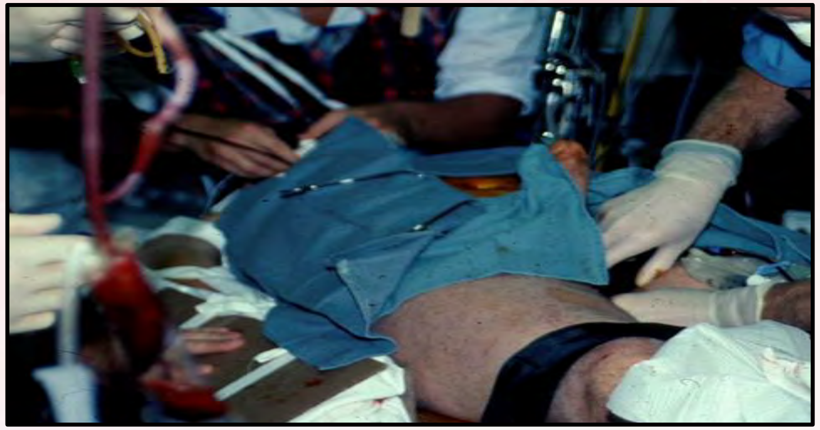
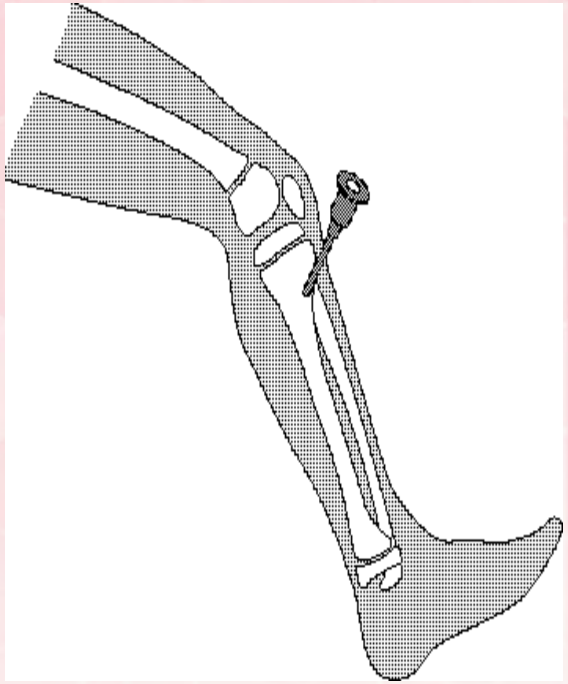
IV Access in Shock

- **Femoral Vein**
  - 8.5/9.0 French Introducer
  - Side port removed ↑ flow rate
  - Out of the way of intubation or chest procedures
- **Subclavian/Internal Jugular**
  - Higher risk (pneumothorax)
  - Lower success rate
  - In chest injuries, place on side of injury



Intraosseous Devices

- Temporary access
- Children & adults
- Insert within 1 minute
- Manual or power drill
- Prox tibia/humerus/sternum
- Avoid fracture /injury sites
- Good for fluid/blood/meds
- Flow rates up to 125 mL/min w pressure bag
- Risk: extravasation → compartment syndrome



(Day, 2011)

Pre Hospital IV Placement in Trauma? EAST 2009 Guideline

- **No evidence to support IV placement at <u>scene</u>**
- Enroute OK
- Limit 2 attempts → I.O.
- Saline lock/Keep open
- Avoid continuous IV
- Use small boluses (250cc)
- Titrate to palpable radial

(Cotton et al., 2009)

Fluid Resuscitation

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)

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What Fluid to Use?

- Crystalloids are inexpensive and readily available
  - Normal Saline
  - Lactated Ringer's-
    - Closest to ECF by electrolytes.
    - Metabolized by liver and kidneys to generate bicarb
- Only 20-33% of crystalloid solution will stay in the vascular space.
- 60% will move to interstitial space within 30 minutes.
  - ¾ of these fluids infused will move to the interstitial space causing 3rd spaced edema
- Hypotonic fluids shift everywhere, only give for maintenance or dehydration

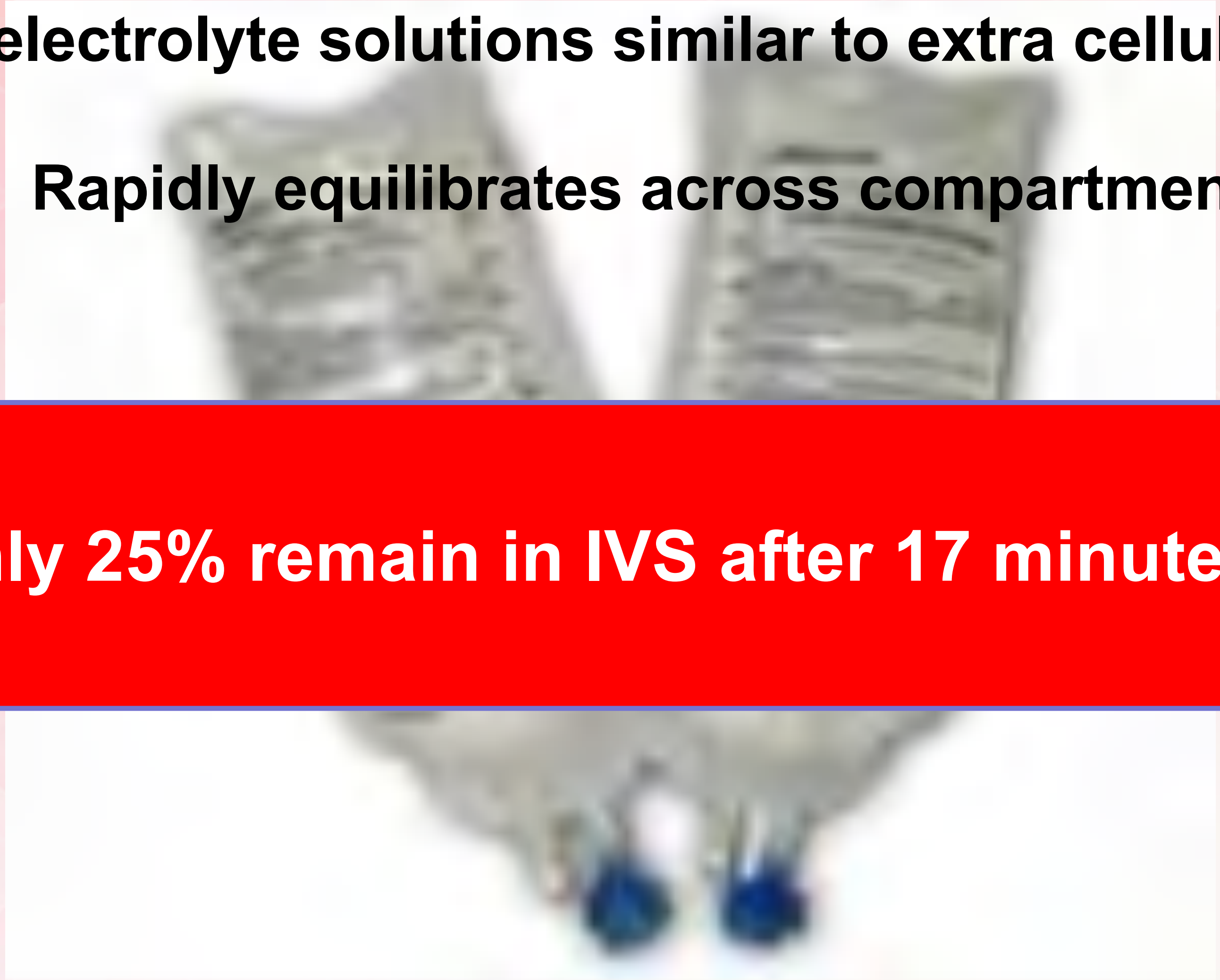
What choice of resuscitation fluids do we have..?

- Crystalloids
  - Hypotonic (5% Dextrose, 0.45% Saline) – do not remain intravascular
  - Isotonic Fluids (LR, 0.9% Saline) – backbone of crystalloid resuscitation
  - Hypertonic (3%, 6%, 23% Saline) – being used more frequently
- Colloids
  - Protein (5%, 25% Albumin or gelatin solutions)
  - Non-protein (starches and dextrans)
- Blood Products
  - Traditional (PRBC, FFP and Platelets)
  - Hemoglobin-based oxygen carrying solutions

Crystalloids (Isotonic Solutions)

Balanced electrolyte solutions similar to extra cellular fluid (ECF)

Rapidly equilibrates across compartments



Only 25% remain 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

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Small Volume Resuscitation Paradigm Shift

- Using hypertonic/hyperosmotic fluid
- Remains in vascular space longer
- Restores vascular volume
- Without flooding patient
- Started by military → civilian trauma

Examples:

- Hetastarch (Hespan/Hextend)
- Hypertonic Saline (3% to 7.5%)

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Small Volume Resuscitation: Hetastarch/Hespan/Hextend

- Plasma volume expander
- 500cc hetastarch expands blood volume 800cc

500ml Hetastarch ⟷ Equivalent ⟷ 2-3 L LR

- Safe and effective at 500cc bolus
- Cons:
  - May cause coagulopathy in large doses (>2L dose)
  - Renal tubular dysfunction concern

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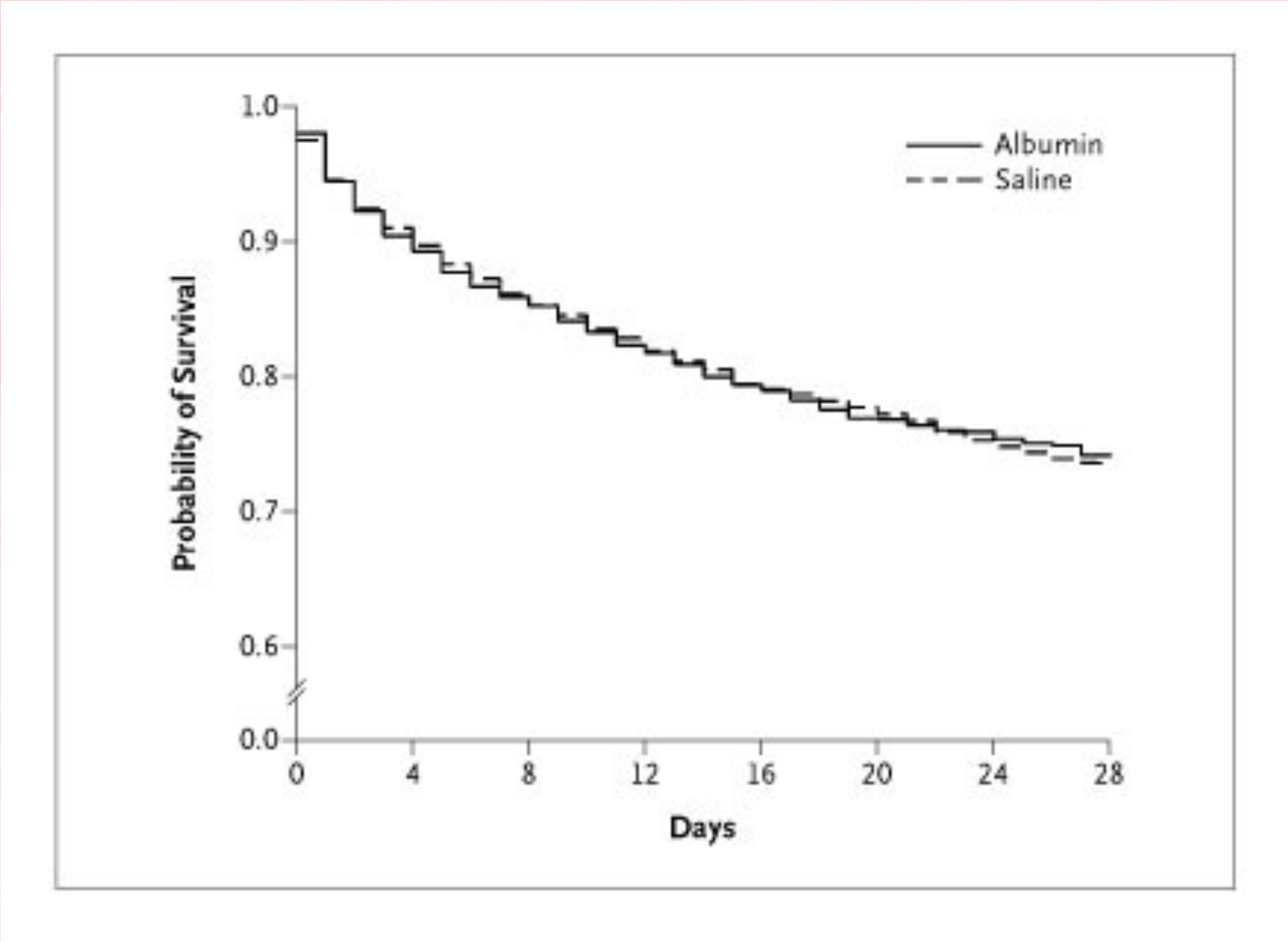
Albumin and Saline Fluid Resuscitation

- SAFE Study Investigators (Saline versus Albumin Fluid Evaluation)
- Multicenter randomized double-blind trial in Australia and New Zealand
- N=6997 – November 2001 to June 2003
    - Saline group N=3500
    - Albumin group N=3497
- Either 0.9% saline or 4% albumin for intravascular fluid resuscitation x 28 days

(Finfer et al., 2004)

Kaplan-Meier Estimates of the Probability of Survival

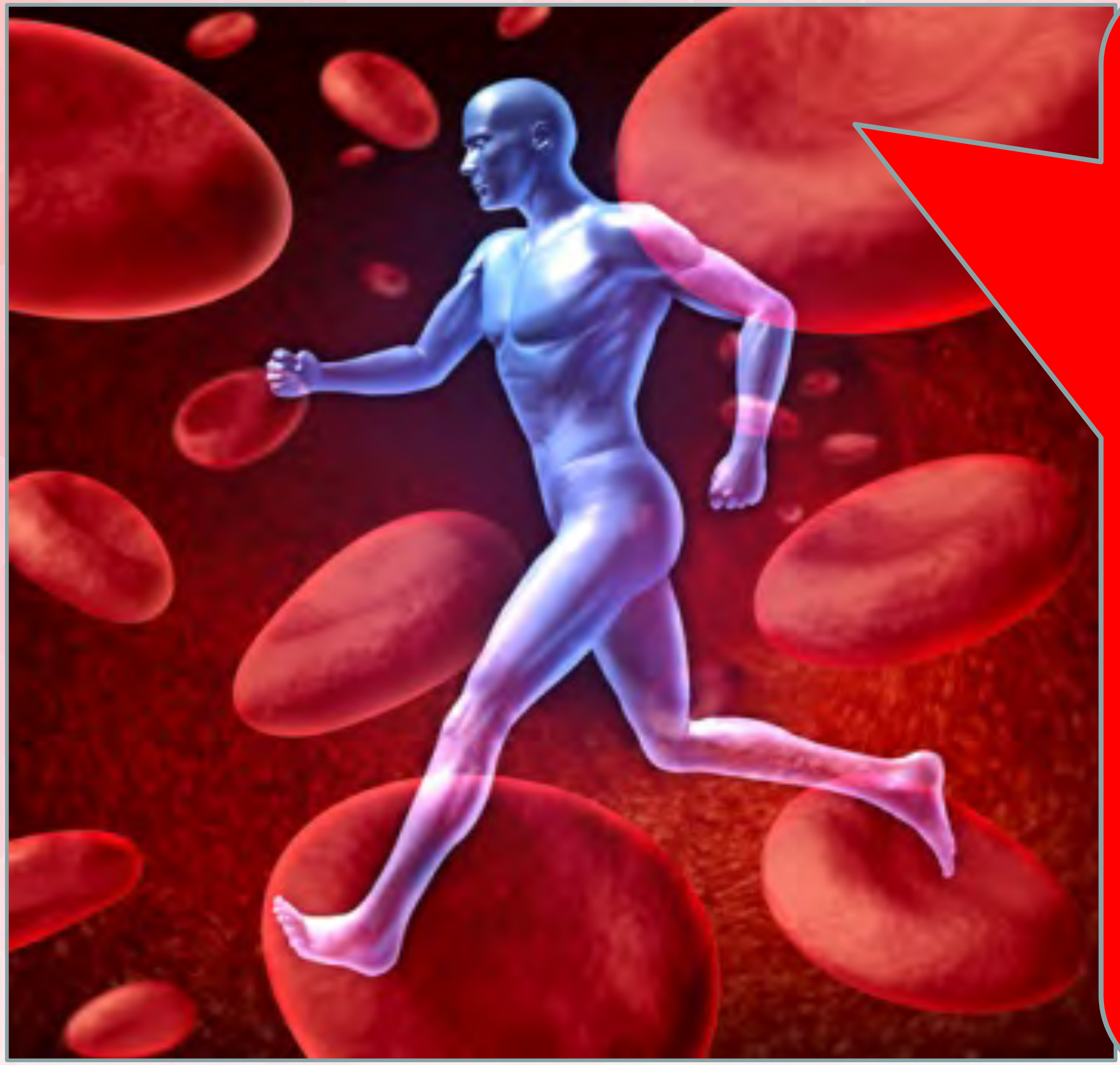


(Finfer et al., 2004)

Response Fluid Resuscitation

EVAL	Rapid Response	Transient Response	No Response
Vital Signs	Return to normal	Transient improvemen	Remain abnormal
Estimated Blood Loss	Minimal (10-20%)	Moderate and ongoing (20-40%)	Severe (>40%)
Need for more IV fluid	Low	High	High
Need for Blood	Low T&C	Moderate Type Spec Specific	Immediate O Pos/Neg
OR	Possibly	Likely	High

(Shere-Wolfe & Fouche, 2012)



If it doesn't carry oxygen or it doesn't clot!

Don't give it to me!

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	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 Progression: Emerg Uncrossmatched (immediate) Type Specific (20 min) Cross Matched (60 min)	Non Trauma Center • Frozen • thaw time • 2 u in 30 minutes Trauma Center • Room Temp • Good for 5 days • Monitor wastage	Room temp Agitated

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

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Massive Transfusion Definition

Old Definition

10 units of PRBC within **24** hours

New Definition

10 units of PRBC within **6** hours

(Zink, Sambasivan, Holcomb, Chisholm, & Schreiber, 2009)

Component Therapy vs. Whole Blood

1 u PRBC
335ml, Hct 55%

1u Plasma
275ml, 80% Coags

1 u Platelets
50ml, $5.5X10^{10}$

Total: 650 ml
Hct 29%
Platelest 80,000
Coag Factors 65%

Whole Blood 500 ml
Hct 38-50%
PLTs 150-400,000
Coag Factors 100%

(Armand & Hess, 2003)

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Blood Progression in Hemorrhage

Immediate

Emergency Uncrossmatched

O+ Males
O- Females/ Peds

10 minutes

Type Specific

ABO & Rh Compatible

35-45 minutes

Crossmatched

ABO & Rh Type Antibodies

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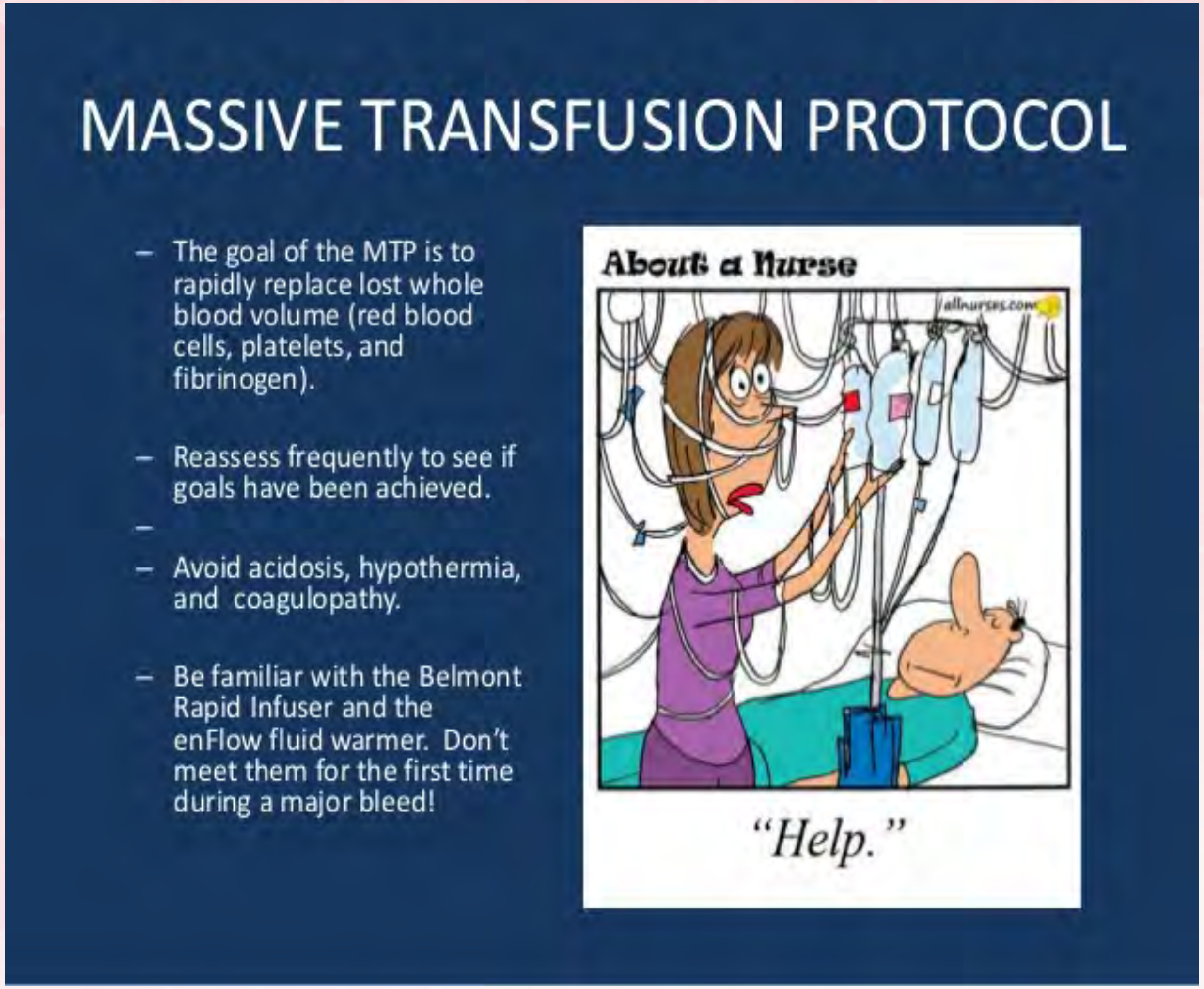
Massive Transfusion Protocol



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Question	Recommendation
PICO 1	In adult patients with severe trauma, we *recommend* the use of a massive transfusion/damage control resuscitation protocol in comparison to no protocol to reduce mortality.
PICO 2	In adult patients with severe trauma, we *recommend* targeting a high ratio of plasma and platelets to red blood cells as compared to a low ratio to reduce mortality. This is best achieved by transfusing equal amounts of RBC, PLAS, and PLT during the early empiric phase of resuscitation.
PICO 3	In adult patients with severe trauma, we cannot recommend for or against the use of rVIIa as a hemostatic adjunct in comparison to no rVIIa.
PICO 4	In adult patients with severe trauma, we *conditionally recommend* the use of TXA as an in-hospital hemostatic adjunct in comparison to no TXA.

(Cannon et al., 2017)

Principle	References
Avoid/reverse hypothermia	Gentilello,[1] Shafi[2]
Minimize blood loss with early hemorrhage control measures during transport and initial evaluation	Kragh,[3] Schroll,[4] Inaba,[5] Leonard,[6] Yong,[7] Dubose[8]
Delay resuscitation/target low-normal blood pressure before definitive hemostasis	Bickell,[9] Dutton[10]
Minimize crystalloid administration	Duchesne,[11] Schreiber[12]
Use MT protocol to ensure sufficient blood products are available in a prespecified ratio	O'Keeffe,[13] Cotton[14]
Avoid delays in surgical or angiographic hemostasis	Meizoso,[15] Schwartz,[16] Tesoriero[17]
Transfuse blood components that optimize hemostasis	Borgman,[18] Holcomb,[19] Holcomb[20]
Obtain functional laboratory measures of coagulation (e.g., TEG or TEM) to guide ongoing resuscitation	Gonzalez,[21] Tapia[22]
Give pharmacologic adjuncts to safely promote hemostasis	CRASH-2,[23] Morrison,[24] Hauser[25]

TEG, thromboelastography; TEM, thromboelastometry.

(Cannon et al., 2017)

Hurley Medical Center
Flint, Michigan
Trauma Service

Massive Transfusion Tracking Sheet

Numerical Order of Transfusions

Suggested Use: Follow the numbers, cross off units as you give them & doc time given next to each #

	Chest Shipment	RBC's	Thawed Plasma	PLT's 1 pooled Apheresis unit 1 pooled unit = 6-8 single units	CRYO 2 pooled units 1 pooled unit = 5 single units	rFVIIa Dose 6 mg dose for > 100 kg 5mg dose for 65-100 kg (Pediatric dosing per physician)
Class I Activation	Chest 1	1 3 5	2 4* → 6	1 Gm Bolus Tranexamic Acid (TXA) Followed by 1Gm drip over 8 hours		
	Chest 2	7 9 11	8 10 12			
Massive Transfusion	Chest 3	14 16 18	15 17 19	13		
	Chest 4	23 25 27	24 26 28		20, 21	22 Consider
	Chest 5	30 32 34	31 33 35	29		
	Chest 6	39 41 43	40 42 44		36, 37	38 Consider
	Chest 7	46 48 50	47 49 51	45		
	Chest 8	55 57 59	56 58 60		52, 53	54 Consider
	Chest 9	62 64 66	63 65 67	61		
	Chest 10	71 73 75	72 74 76		68, 69	70 Consider
Continue as necessary						

- Remember to deactivate the massive transfusion guideline over the trauma radio when finished

Judy Mikhail 2010

ADHB Paediatric Massive Transfusion Protocol (MTP)

Team Leader Responsibilities

- Notify Coag Lab and send Coag requests on the Labplus Urgent form (orange border)
- Activate protocol by ringing Blood Bank (ext 24015) and say "I am activating the Paediatric Massive Transfusion Protocol Alpha, Bravo or Charlie"
- Call for each box as required
- Make a decision to cease MTP and contact Blood Bank

Blood Bank Responsibilities

- Ensure X-match sample processed ASAP after O neg release
- Notify NZBS Medical Officer after issuing MTP Box One
- Thaw next box in advance and await request
- Ensure supply of platelets
- If no neonatal rbc, ffp or plt, issue adult unit labelled with volume to transfuse
- Provide fresh blood for Alpha channel as per fresh blood policy

Contacts

- Blood Bank - Ext 24015
- Coagulation Lab - Ext 7572
- SSH Anaesthetic Co-ordinator – 021 334 344
- rVIIa gate keeper – on call Liver transplant anaesthetist

rVIIa Requirements

- Ongoing haemorrhage after box 3
- pH > 7.2
- Platelets > 50
- Fibrinogen > 1 g/L
- Dose: 90 microg/kg rounded to vial

Additional treatment thresholds

- Ongoing haemorrhage after box 3 - if PR > 1.5 or APTT > 40 consider additional 20mL/kg FFP
- If fibrinogen < 1g/L consider additional 5mL/kg Cryoprecipitate
- If platelets < 75 consider additional 10mL/kg platelets
- If ionized Ca++ < 1mmol/L give 0.1mL/kg 10% Calcium gluconate

Massive bleeding with either shock or abnormal coagulopathy

Ensure delivery of X-match specimen to Blood Bank

ALPHA	BRAVO	CHARLIE
5-10kg	11-20kg	21-45kg
Give 1 Units O-neg Neonatal RBC	Give 2 Units O-neg Neonatal RBC	Give 2 Units O-neg or type specific RBC

Ring Blood Bank to Activate Paediatric Massive Transfusion Protocol

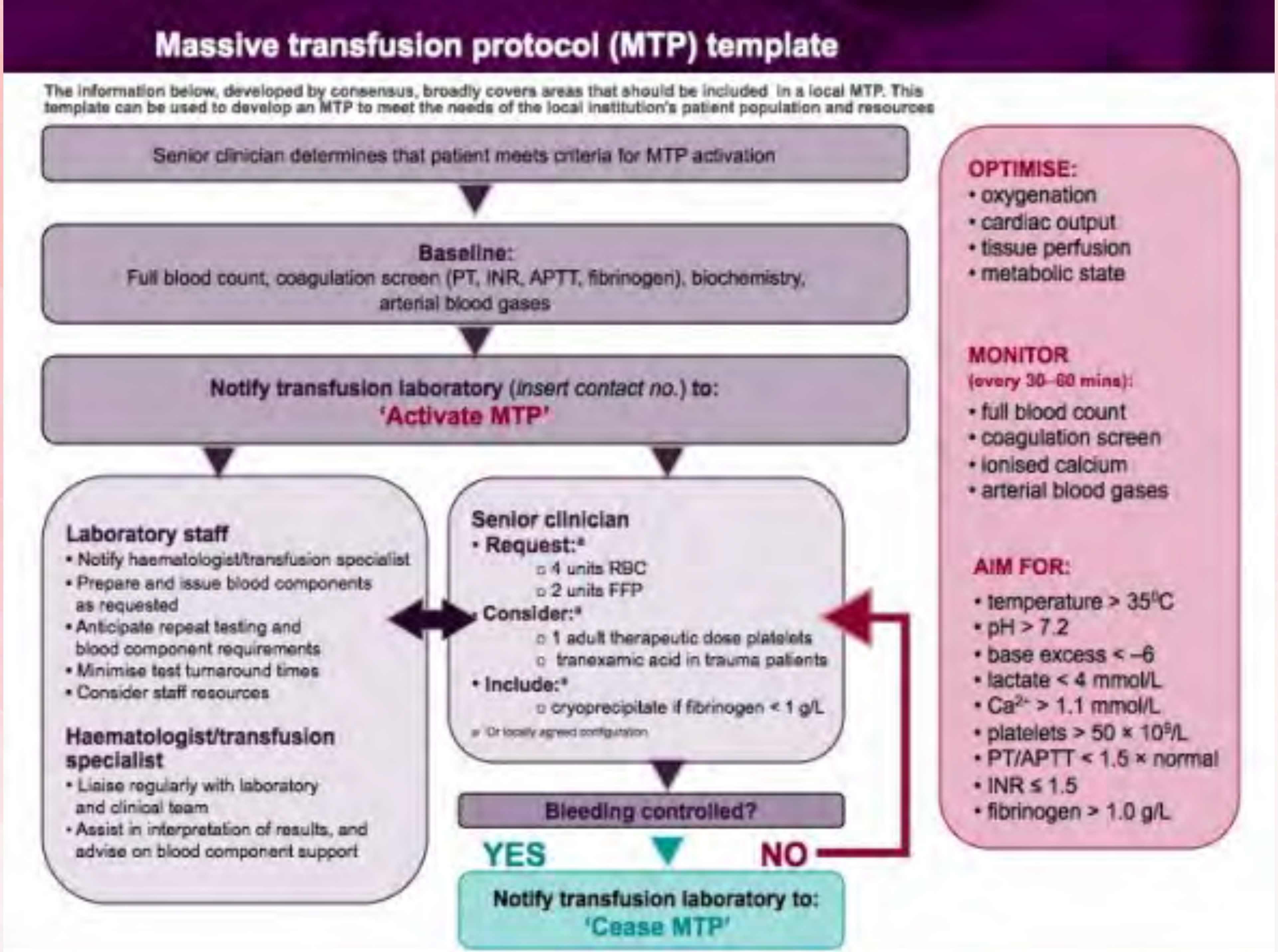
REQUEST, DELIVER AND TRANSFUSE AS BELOW:

ALPHA	BRAVO	CHARLIE	
MTP BOX ONE 1 Neo RBC 2 Neo FFP	MTP BOX ONE 1 Whole Blood or 1 adult RBC and 1 adult FFP	MTP BOX ONE 2 Whole Blood or 2 adult RBC and 2 adult FFP	Check • Coags • FBC • ABGs • Ca^{++}
MTP BOX TWO 2 Neo RBC 2 Neo FFP 1 Neo Platelets	MTP BOX TWO 1 adult RBC 1 adult FFP 150mL Platelets	MTP BOX TWO 2 adult RBC 2 adult FFP 1 adult Platelets	
MTP BOX THREE 2 Neo RBC 1 Neo FFP 50mL Cryoprecipitate	MTP BOX THREE 1 adult RBC 1 adult FFP 1 Cryoprecipitate	MTP BOX THREE 2 adult RBC 2 adult FFP 2 Cryoprecipitate	Check • Coags • FBC • ABGs • Ca^{++}
MTP BOX FOUR 2 Neo RBC 2 Neo FFP 1 Neo Platelets	MTP BOX FOUR 1 adult RBC 1 adult FFP 150mL Platelets	MTP BOX FOUR 2 adult RBC 2 adult FFP 1 adult Platelets	rVIIa if indicated
and alternate boxes 3 & 4...	and alternate boxes 3 & 4...	and alternate boxes 3 & 4...	Check • Coags • FBC • ABGs • Ca^{++} Repeat every 30 min

Typical component volumes

- Red cells: neonatal: 75 mL adult: 300
- FFP: neonatal: 55 mL adult: 245
- Platelets: neonatal: 50 mL adult: 270
- Cryoprecipitate: 100mL

Paediatric MTP – 8 March 2011



SOCIETY OF TRAUMA NURSES

Hemorrhagic Shock

Drugs: Is there a role?

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Recombinant Factor VIIa
NovoSeven

- Refractory bleeding in trauma
- Activates Extrinsic coagulation cascade
- Off label use in trauma and expensive
- Research Results in Trauma:
  - Numerous anecdotal reports
  - 1 RCT published trauma:
    - ↓ blood use
    - ↓ MSOF ↓ ARDS
    - Trend toward ↓ mortality
    - No ↑ thrombotic events

<u>Correct before use</u>:

- Hypofibrinogenemia
  - Give Cryoprecipitate
- Thrombocytopenia
  - Give Platelets
- Hypothermia
  - Correct Temperature
- Acidosis
  - Consider Bicarbonate

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Recombinant Factor VIIa
NovoSeven

- Include in Massive Transfusion Protocol:
  - Do not use to 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

Tranexamic acid (TXA)

- Derivative of AA Lysine - **inhibits fibrinolysis**
- Inexpensive ($80/dose) and proven safety profile
- CRASH2 trial (Williams-Johnson, McDonald, Strachan, & Williams, 2010) Prospective RCT, > 20,000 pts
  - Stat sig 1.5% reduction in mortality (overall)
  - Subgroup analysis (Severe bleeding & early admin)
    - Reduced bleeding by 30% **IF** given within 1 hour
- MATTERs trial (Morrison, Dubose, Rasmussen & Midwinter, 2012) Camp Bastion in Afghanistan
  - Marked improvement in survival in most severely injured compared to those who did not receive it
- Roberts, et.al (2013) Multi Center randomized control, > 20,000 patients
  - All cause mortality from bleeding were reduced
  - Most beneficial with early administration (< 3 hours)

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Tranexamic Acid (TXA)
Example Protocols

Military Protocol

- Give within 1-3 hours of injury
- 1 unit of blood
- 1 Gm of Bolus of TXA
- 1 Gm Infusion over 8 hrs

Oregon Health & Science University Protocol

- MTP activated
- Pt has received > 4 units within 2 hours
- Give 1 Gm bolus
- Start 1 Gm drip over 8 hrs

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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

(Boeck, 2016)

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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

(Boeck, 2016)

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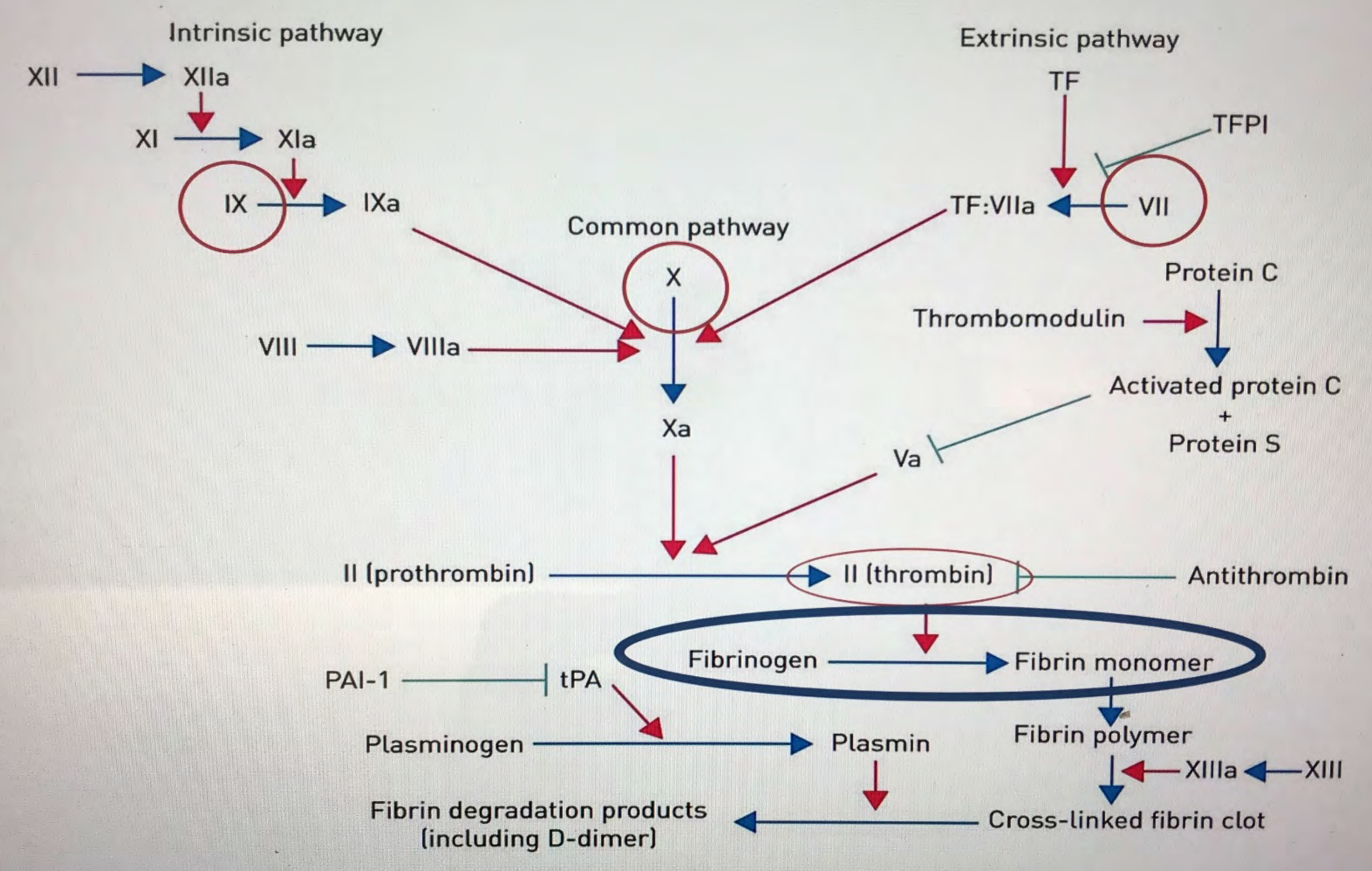

Figure 7. PCC action on fibrinogen

(Boeck, 2016)

Hemorrhagic Shock

Evolving Treatment Concepts

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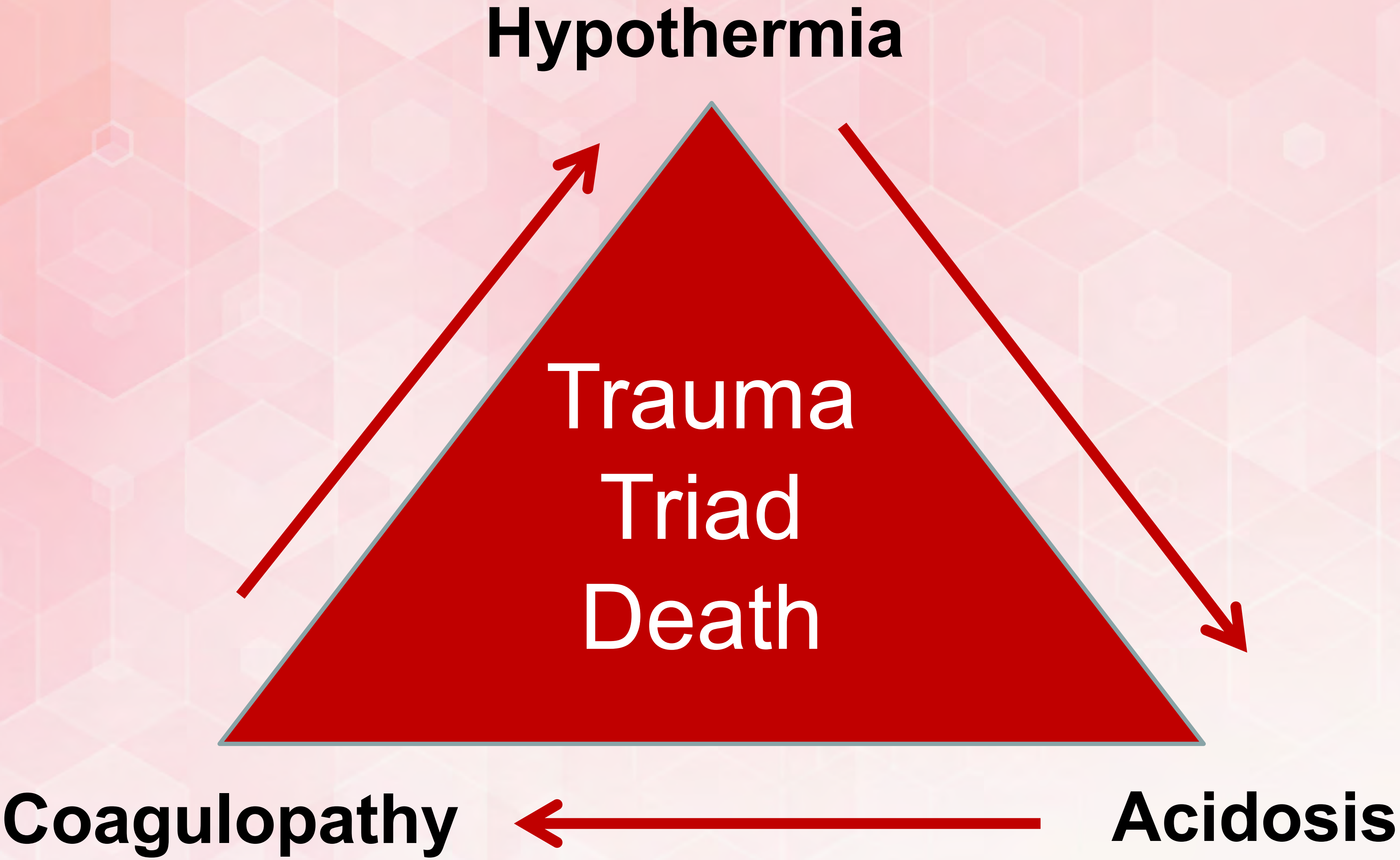

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Hypothermia

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

Moderate to Severe Hypo-thermia Occurs In <10% of Trauma

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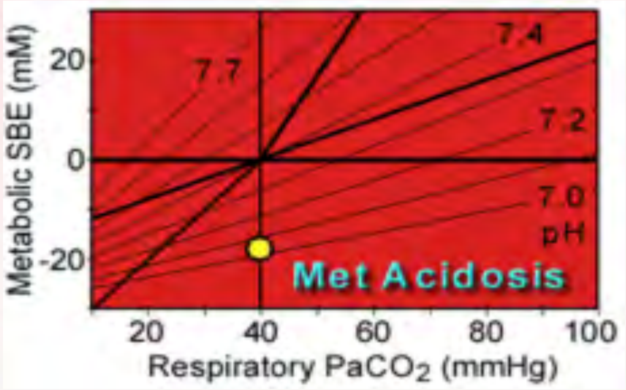
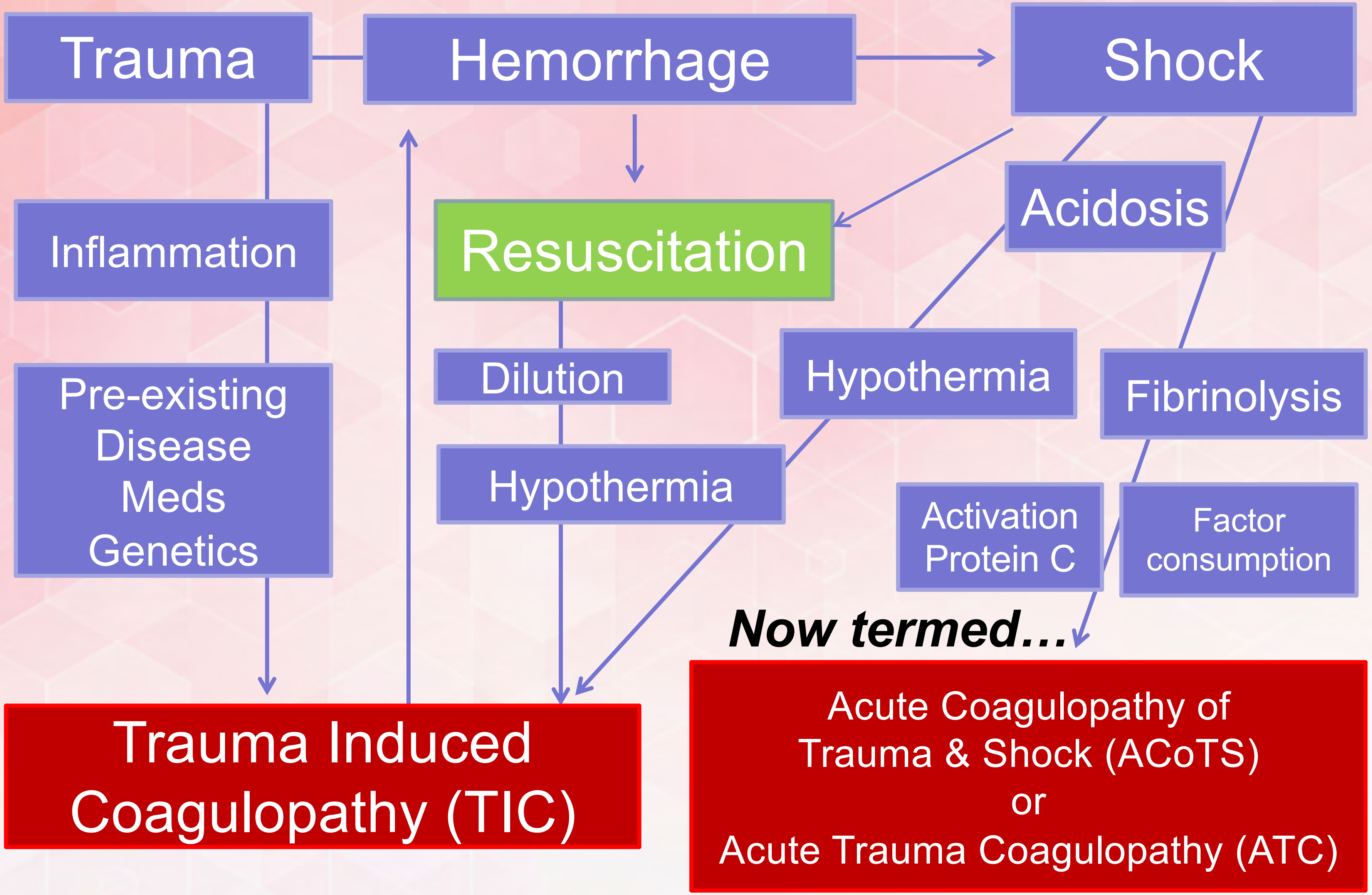
Acidosis

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

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



Trauma Coagulopathy Theory



Changing Paradigm

Traditional

ED | OR Death

Damage Control

ED | OR | ICU | OR | ICU

Damage Control Surgery (1990's)

Stage I
Initial Control of Hemorrhage

↓

Stage II
Stabilization

↓

Stage III
Definitive Treatment

Damage Control Resuscitation

Permissive Hypotension

Hemostatic Resuscitation

Damage Control Surgery

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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)

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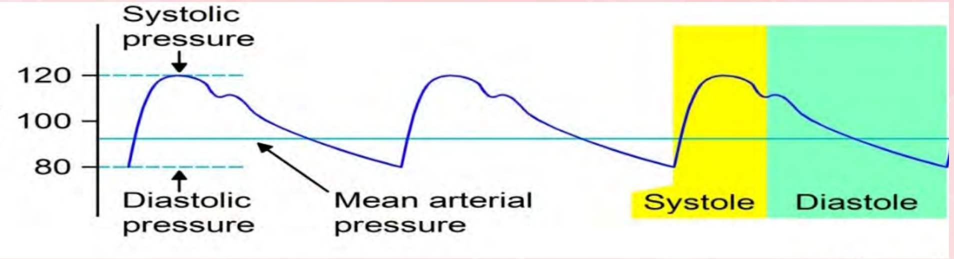
Mean Arterial Pressure (MAP)



Fatal Hypoperfusion

Disrupt Thrombus

MAP	40	50	60	70	80

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Human RCT Studies: Permissive Hypotension

Bickell, 1994

- Randomized trial (n=598)
- Penetrating hypotensive
- EMS study

EMS Fluid → 62% Survival

EMS No Fluid → 70% Survival

Dutton, 2002

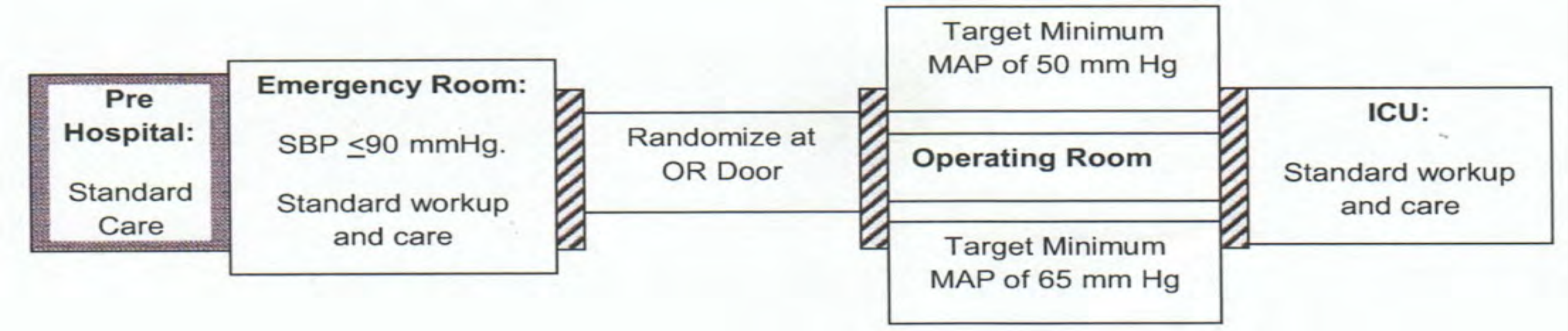
- Randomized trial (n=110)
- Blunt + Penetrating hypotensive
- Emergency Department study

ED SBP 80 → 92% Survival

ED SBP 100 → 92% Survival

Permissive Hypotension
RCT Intraoperative

- N=90
- Blunt & Penetrating Injury
- Hypotensive, To OR for chest or abdomen injuries
- Maintaining target minimum MAP 50 vs. 65
- Results: Hypotensive resuscitation is safe
  Decreased Coagulopathy and early death



(Morrison et al., 2011)

Review Article for Hypotensive Resuscitation

- Recommend a target systolic blood pressure of 80 to 90 mmHg until major bleeding has been stopped in the initial phase following trauma without brain injury." (Grade 1C)
- Recommend that a mean arterial pressure ≥80 mmHg be maintained in patients with combined hemorrhagic shock and severe TBI (GCS ≤ 8)." (Grade 1C)

(Carrick, Leonard, Slone, Mains, & Bar-Or, 2016; Spahn et al, 2013)

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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**

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Geriatric Patients?

Traumatic Brain Injury?

(Jin et al., 2012)

Hemostatic Resuscitation

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

Blood Loss

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

(American College of Surgeons, 2012)

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New Treatment Paradigm

Component Therapy vs. Whole Blood

1 u PRBC
335ml, Hct 55%

1u Plasma
275ml, 80% Coags

1 u Platelets
50ml, $5.5X10^{10}$

Total: 650 ml
Hct 29%
Platelest 88,000
Coag Factors 65%

Whole Blood 500 ml
Hct 38-50%,
PLTs 150-400,000
Coag Factors 100%

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Hemorrhagic Shock

Putting it all together!

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Summary

- Assess for coagulopathy early
- LR is fluid of choice in trauma
- Utilize Massive Transfusion Protocol
- Small volume resuscitation techniques
- Consider Tranexamic acid (TXA), PCC and Factor VIIa
- Correct acidosis, coagulopathy and hypothermia
- STOP THE BLEEDING

Chapter 3 - Mechanism of Injury: Understanding the Kinematics of Trauma Test Questions

1. Using the physics formula KE = ½ m v^2, which factor emerges as the most important for predicting severity of injury?

    a. m = momentum
    b. injury severity is inversely proportional to the combined mass of the colliding objects
    c. velocity
    d. kinetic energy is directly related to injury severity, and is predicted by ½ inertia times $(\text{mass and velocity})^2$

2. Select injuries you would anticipate for an injured car driver that was struck on his driver's side by another car running a red light in an intersection ("T-bone" crash), with both cars going at 40 mph.

    a. Neck hyper-flexion with T-8 compression fracture, open tib-fib fracture, and ruptured small bowel
    b. Multiple left rib fractures with pneumothorax, lung contusion, pelvis fracture, epidural hematoma
    c. Bilateral hip fracture-dislocations, anterior-posterior pelvis fracture, liver laceration
    d. Neck hyper-extension with cervical fracture and possible cord injury, bilateral patella fractures, bilateral lung contusions

3. Trauma can be defined as the application of excessive energy to the human body above it tolerance, resulting in damage. Some forms that this energy may take include…

    a. Kinetic, thermal, electrical, chemical, and radiological
    b. Gravity, blast, and quantum-physical
    c. Nano-kinetic, friction-traction, and hypoxic
    d. Crush, acceleration/deceleration, and inertial

4. Injuries due to explosions may be severe and difficult to treat, because…

    a. Of the effects of the blast wave itself on solid organs
    b. The effects of radiation may have a delayed presentation
    c. Of the difficulty in making the diagnosis of bowel perforation
    d. The injuries may be due to the blast-wave itself, combined with blunt injury, penetrating injury from flying debris, and burns

5. “Delta V” (ΔV) refers to…

   a. The combined velocities of two moving objects which collide
   b. The fact that the total force resulting in injury is diminished due to the “ride-down” time produced by the “wrinkle zone” of the car
   c. The vector or direction of forces involved in a collision
   d. Change in vector

6. A certain amount of kinetic energy is produced when a 180-pound person is driving a car which strikes a solid bridge abutment at 30 mph. If the car’s speed in this example were increased to 42 miles per hour, this would…

   a. Result in damage that would increase by about 25% because 30 mph represents about 25% less velocity than 42 miles per hour
   b. Result in a “delta V” of 72 miles per hour
   c. Approximately double the kinetic energy, and thus the predicted severity of injury to the driver
   d. Produce some increased severity of injury, but not as much as when the driver weighs 225 pounds, since the mass is squared

7. Tissue damage may increase in gunshot wounds due to the dynamics of the projectile. Examples of these types of dynamics include:

   a. Bullet size
   b. Tumble, yaw, fragmentation, cavitation, and deformation
   c. Tattooing of the skin by gunpowder in close-range gunshots
   d. Fragmentation, deformation, pigmentation, and shotgun pellet spread

8. Bumper height from the pavement may be 24-36” in SUV’s and larger pick-ups, while bumper height may be as low as 16-18” in some smaller cars. You are informed that the two trauma patients due to arrive shortly are a mother and small child who were struck by a SUV in a crosswalk. You could predict that…

   a. The speed they were struck is a good predictor of the severity of injuries
   b. The mother would be likely to have severe tib-fib fractures, while the child is more likely to have femur/hip/pelvis fractures
   c. If much speed was involved, both are likely to have a lot of road rash from sliding along the pavement after they are accelerated up to the speed the SUV was traveling
   d. All of the above

9. The withholding of essential energy can also produce injury, such as:

    a. Traumatic asphyxia, cerebral hypoxia from hanging, and frostbite
    b. Injuries produced by "negative pressures" within the blast zone
    c. Hemorrhagic and neurogenic shock
    d. None of the above

10. The most important practical concept to take away from a study of the kinematics of injury, useful for the practical prediction of injury severity, is that…

    a. Thermal, radiological, and blast-type injuries combined cause more severe injuries than blunt-type kinetic injuries, since most blunt injuries seen at trauma centers are actually from low-velocity events
    b. Mass squared means that injury severity increases exponentially as the combined mass of the moving objects increases
    c. "up and over", "down and under" and crumple-zone "ride-down" time are the most important predictors
    d. The mass of the moving object is related to the injury severity, and as the combined velocities of the moving objects increase, the resulting severity of injury exponentially increases

Chapter 3 - Mechanism of Injury: Understanding the Kinematics of Trauma Answer Key

1. c
2. b
3. a
4. d
5. a
6. c
7. b
8. d
9. a
10. d

Chapter 4 - Hemorrhagic Shock Test Questions

1. An early sign of occult hemorrhagic shock is:

    a. Widened pulse pressure
    b. Elevated shock index
    c. Hypothermia
    d. Apnea

2. During the primary survey the initial management of a bleeding patient is:

    a. Provide O2 and ventilation
    b. Prevent heat loss
    c. Direct pressure to external signs of hemorrhage
    d. Initiate IV access

3. Causes of lethal major blood loss and ongoing hemorrhage can be concealed. Which injury has the greatest potential to sequester blood?

    a. Pneumothorax
    b. Head laceration
    c. Pelvic fracture
    d. Amputation

4. Isotonic crystalloids:

    a. Remain in the vascular space
    b. Enhance immune system function
    c. Include Hetastarch and Albumin
    d. Rapidly equilibrate across compartments

5. Urinary output is a clinical measure of a patient in shock since it reflects:

   a. Fluid overload
   b. Catecholamine levels
   c. Serum sodium
   d. Organ perfusion

6. Lab values which are indicators of acidosis include:

   a. pH, Base deficit, Lactate levels
   b. Potassium, sodium, calcium
   c. BUN, Creatinine
   d. Hemoglobin, hematocrit

7. A reliable tool for measuring tissue perfusion when there is metabolic acidosis and ongoing hemorrhage is:

   a. Pulse oximetry
   b. Base deficit/excess
   c. Creatinine
   d. Lactate levels

8. The goal of fluid resuscitation is:

   a. Only achieved with central venous access
   b. Restore adequate tissue perfusion
   c. To provide an initial infusion of 2 liters of crystalloids for all patients
   d. To only administer colloids

9. The most accurate definition of the shock state is:

   a. The level of carbon dioxide in the blood exceeds 50mmHg
   b. Inadequate perfusion to meet end organ oxygenation requirements
   c. Metabolic needs increase and there is a concurrent decrease in body temperature
   d. Cell permeability loss, and oxygen and nutrients cannot be transported to the cell

10. Which would be the first choice for intravenous line placement during initial resuscitation?
    a. External jugular
    b. Subclavian vein
    c. Antecubital vein
    d. Saphenous vein

11. Class III shock results from __________% of acute blood loss.
    a. Greater than 40%
    b. 30-40%
    c. 15-20%
    d. Less than 15%

Chapter 4 - Hemorrhagic Shock Answer Key

1. b
2. a
3. c
4. d
5. d
6. a
7. b
8. b
9. b
10. c
11. b