Blood Everywhere: How to Stop a Gusher

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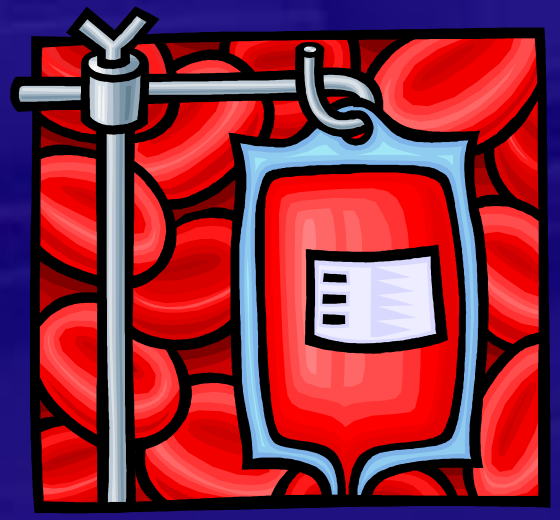

Disclosures

- None
- I don’t know how to play golf or ski

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Power Point version of these slides available at mikemcevoy.com
(click on Open Bar tab)

Outline

- Battlefield medicine and you
- Wound review
- Blood and clots
- Shock
- Stopping a gusher
- Special situations
- Summary

CONTENT WARNING

EMS Bleeding Control

Old

1. Direct Pressure
2. Elevation
3. Addi[illegible]gs
4. [illegible]essure Point
5. Pressure dressing
6. Tourniquet

New

1. Direct Pressure
2. Tourniquet

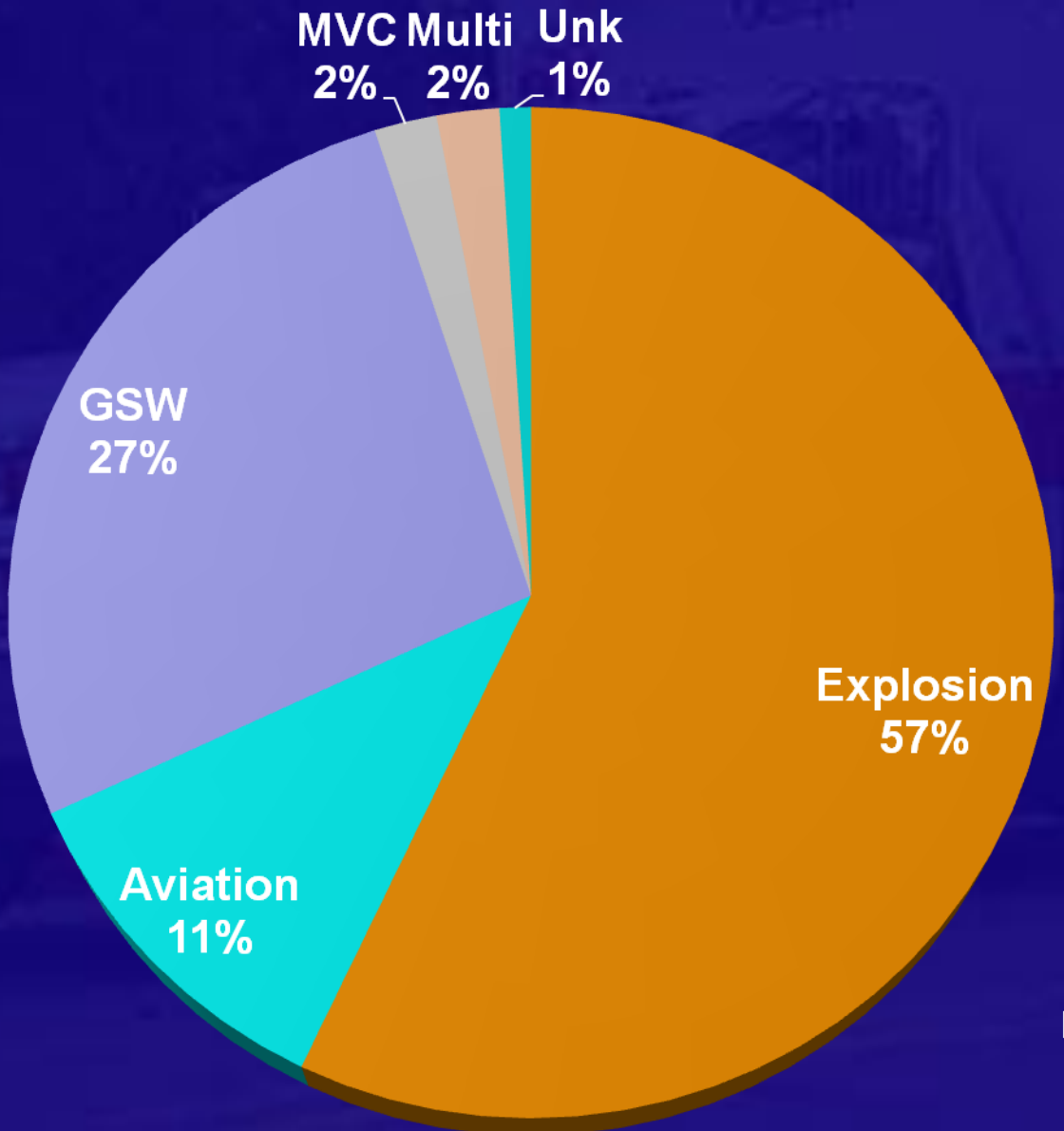
What Happened?

CAUSES OF DEATH ON THE MODERN BATTLEFIELD: 2001-2005

COL John B. Holcomb, MAJ Lisa A. Pearse, CDR Jim Caruso, Mimi Lawnick RN, Charles E. Wade, Howard R. Champion

USAISR, AFMES, USUHS

Battlefield Deaths



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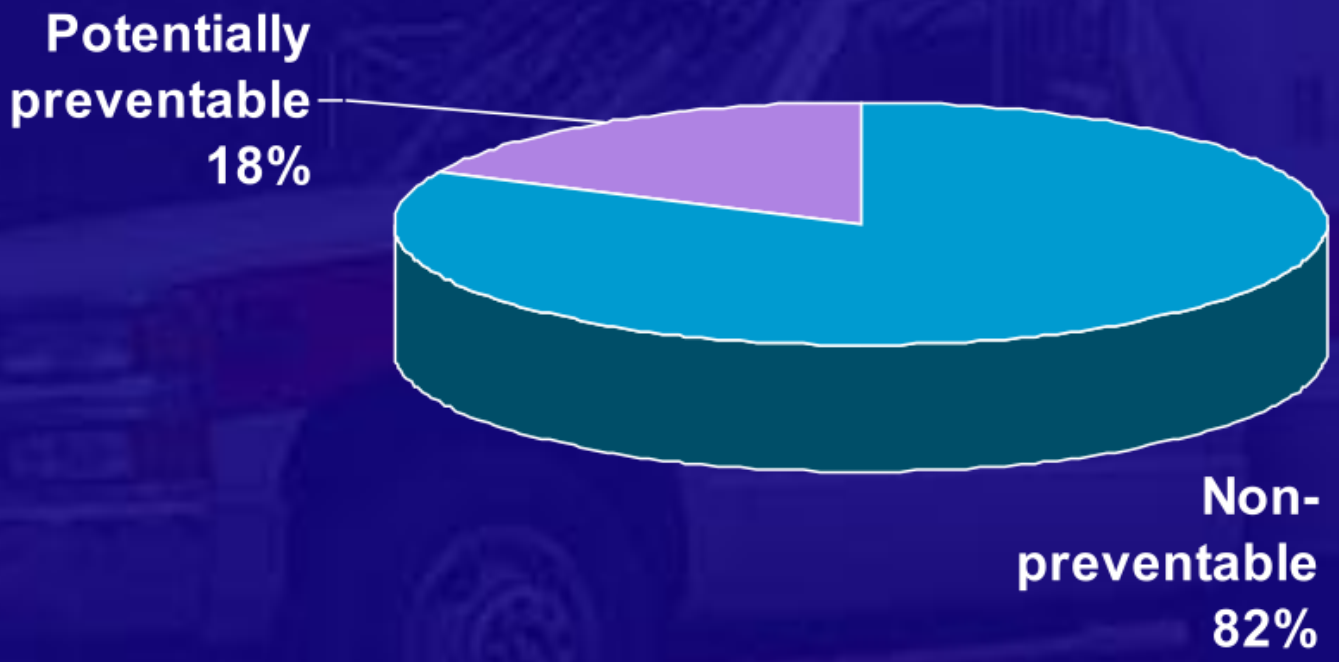
Potentially Preventable Deaths



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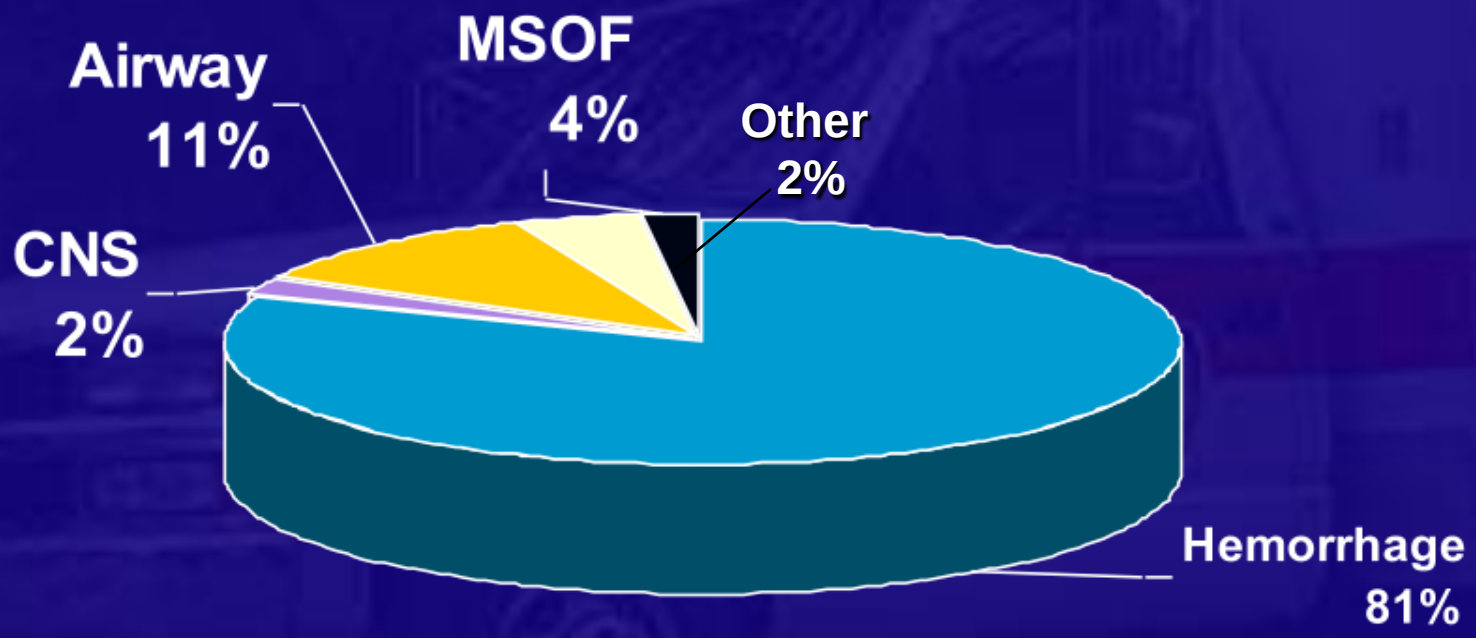
Causes of Preventable Deaths



32% Compressible
68% Non-compressible

Triage Life-Savers

1. Stop bleeding
2. Decompress tension pneumothorax
3. Insert nasopharyngeal airway

MARCH – the combat ABCs

Massive hemorrhage – TQ

Airway – NPA

Respirations – Needle decompression

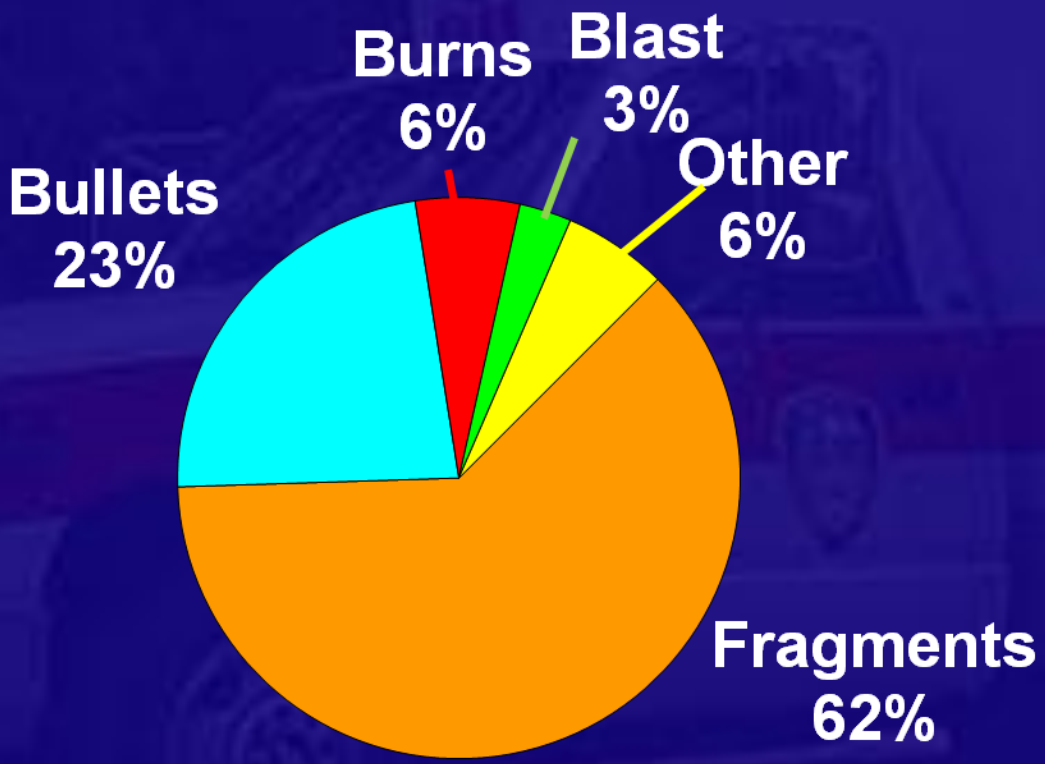
Circulation – IV access, fluids

Hypothermia/Head Injury – warm in air

7 Caveats When Applying Military Literature

- Different weapons
- Less pre-existing dehydration
- Shorter pre-hospital time
- Different surgical intervention
- More resources
- Better monitoring
- Less threatening environment

Causes of Combat Wounds



(WWI, WWII, Korea, Vietnam, Middle East)

WIA WOUNDED AREAS

19 March 2003 – 18 May 2004

HEAD	63
FACE	72
NECK	46
SHOULDERS	61
ARMS	165
WRIST	11
HANDS	96
OTHER	120
LEGS	310
ANKLE	43
FEET	60
EYE	68
EAR	60
CHEST	34
BACK	23
ABDOMEN	24
PELVIS	3
BUTTOCKS	15
GROIN	6

CAUSES

IED-313

Blasts - 185

GSW - 249

Shrapnel – 255

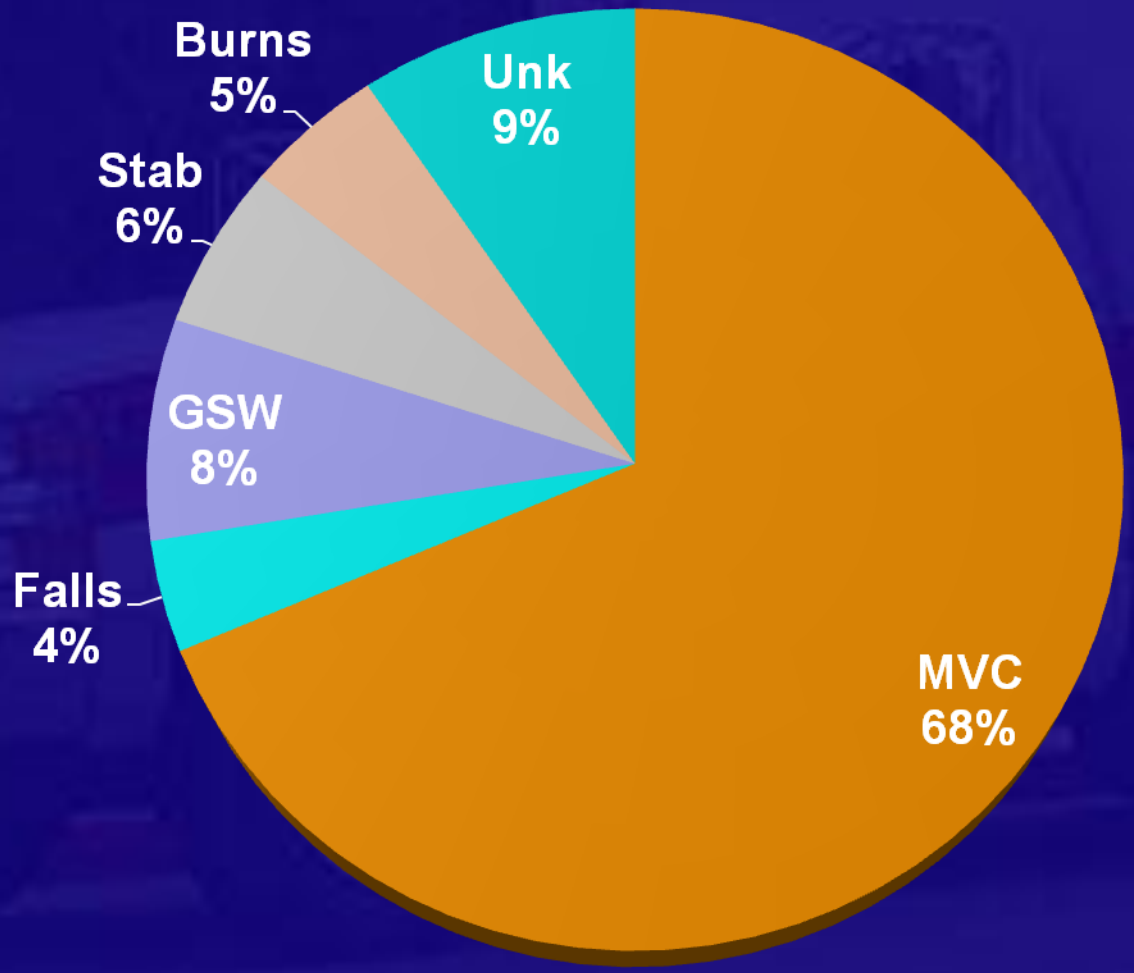
Other - 235

TOTAL WIA 19 Mar 03 – 18 May 04

1237

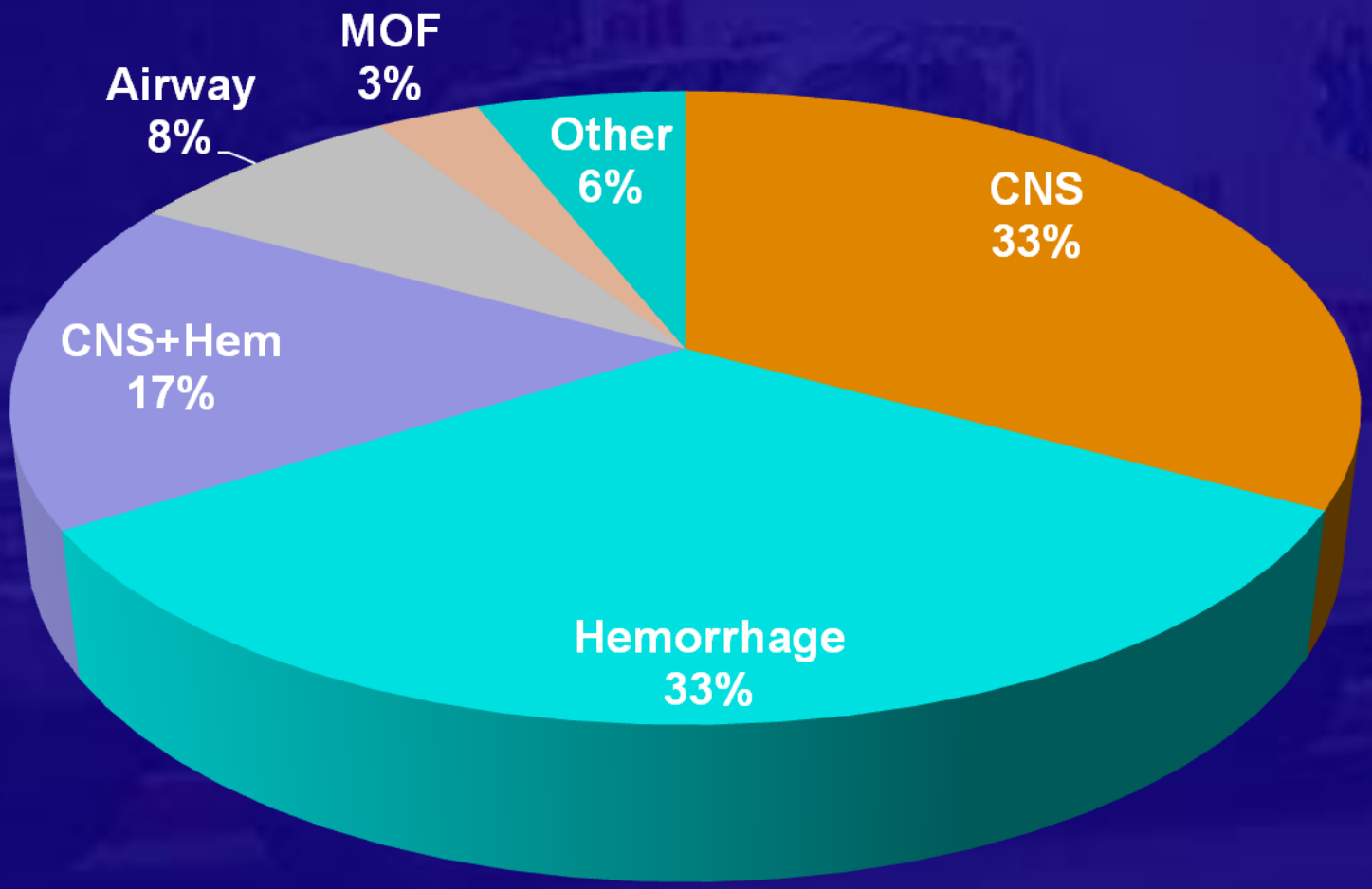
(wounds do not add up to 1237 due to other injuries)

Compare to Civilian Deaths



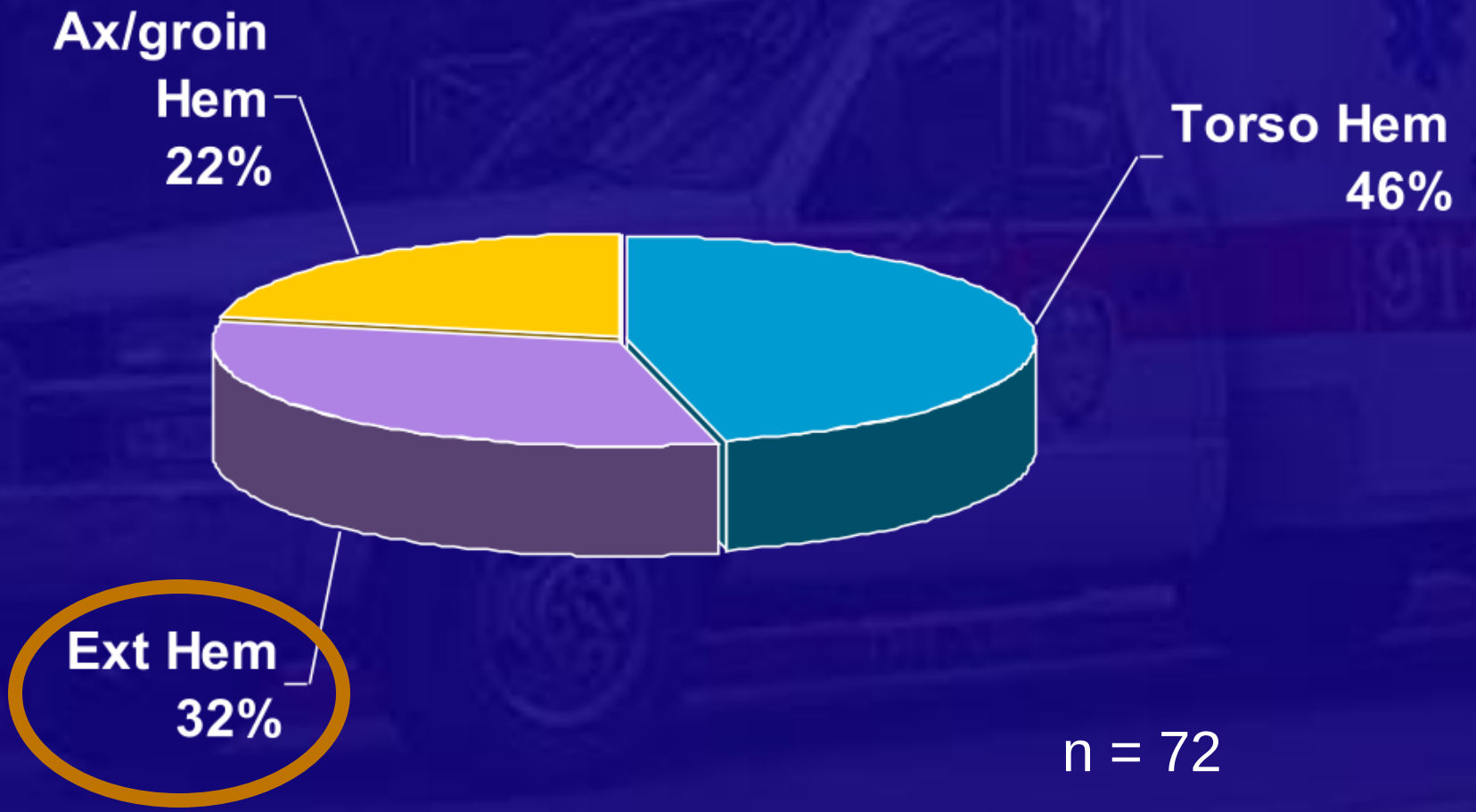
Evans J, et al. Epidemiology of Traumatic Deaths: Comprehensive Population-Based Assessment. *World J Surg*. 2010; 34:158-163

Civilian – All Causes Deaths



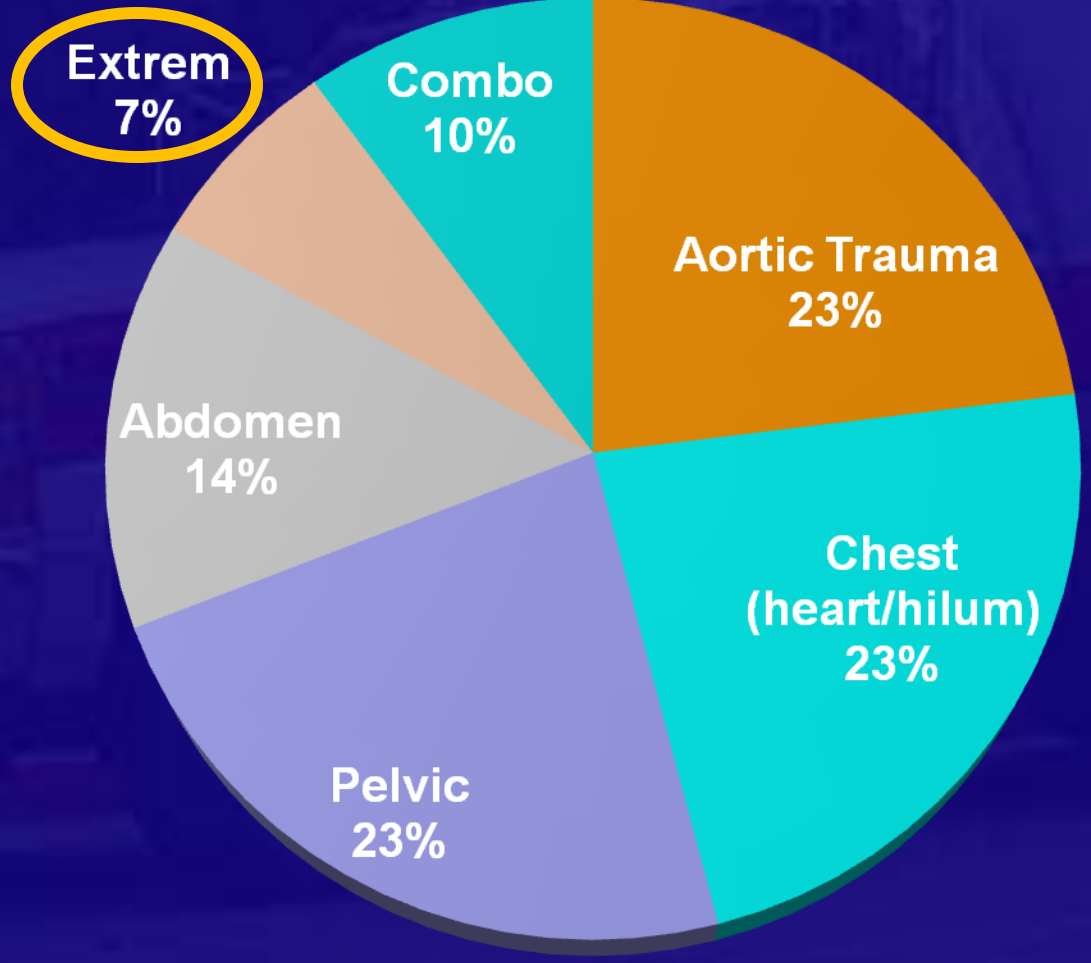
Evans J, et al. Epidemiology of Traumatic Deaths: Comprehensive Population-Based Assessment. *World J Surg*. 2010; 34:158-163

Potentially Preventable Military Hemorrhagic Deaths



n = 72

Civilian Hemorrhage Deaths



Beyond Statistics

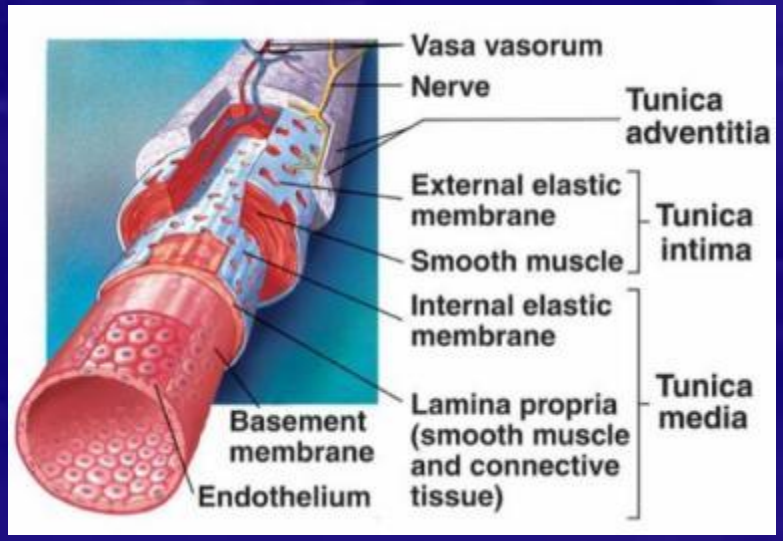
Combat Application Tourniquet

Military Experience

Tourniquets Save Lives

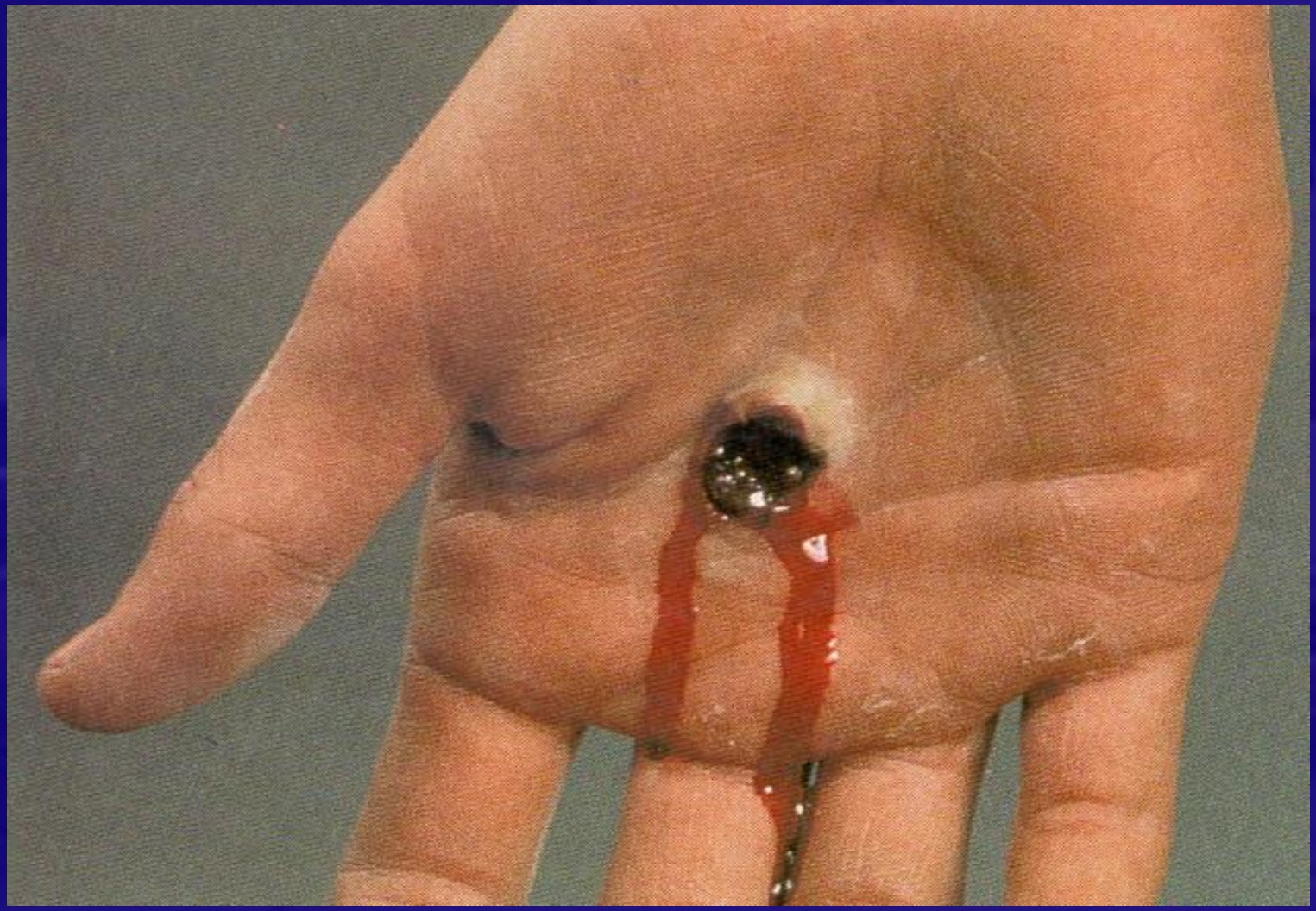
Hemorrhage

- "Open circuit"
  - blood vessel
- Types:
  - Internal vs. External
  - Art, Venous, Capillary



Laceration (“Lac”)

Puncture Wound



Abrasion

Incision

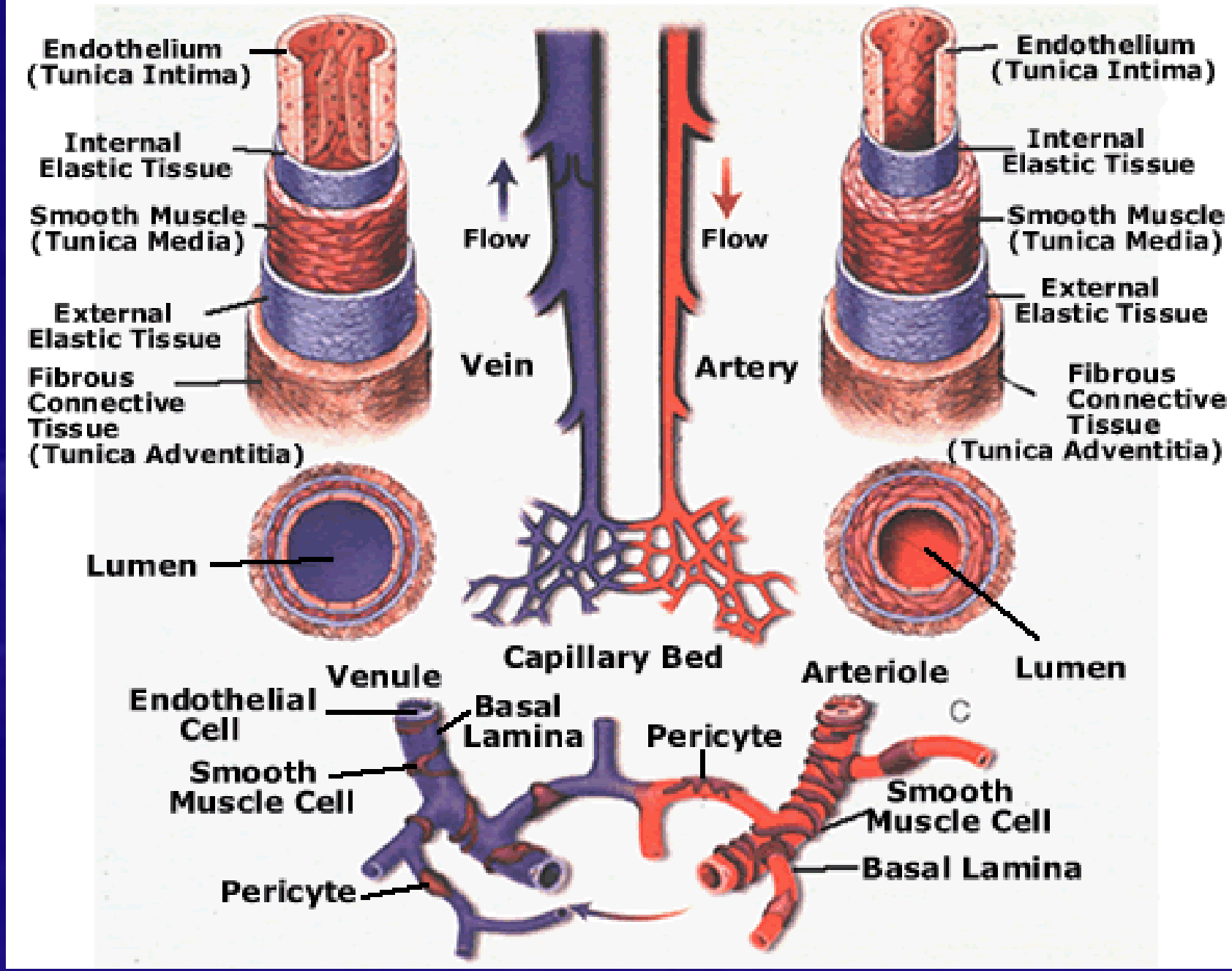
Degloving Injury

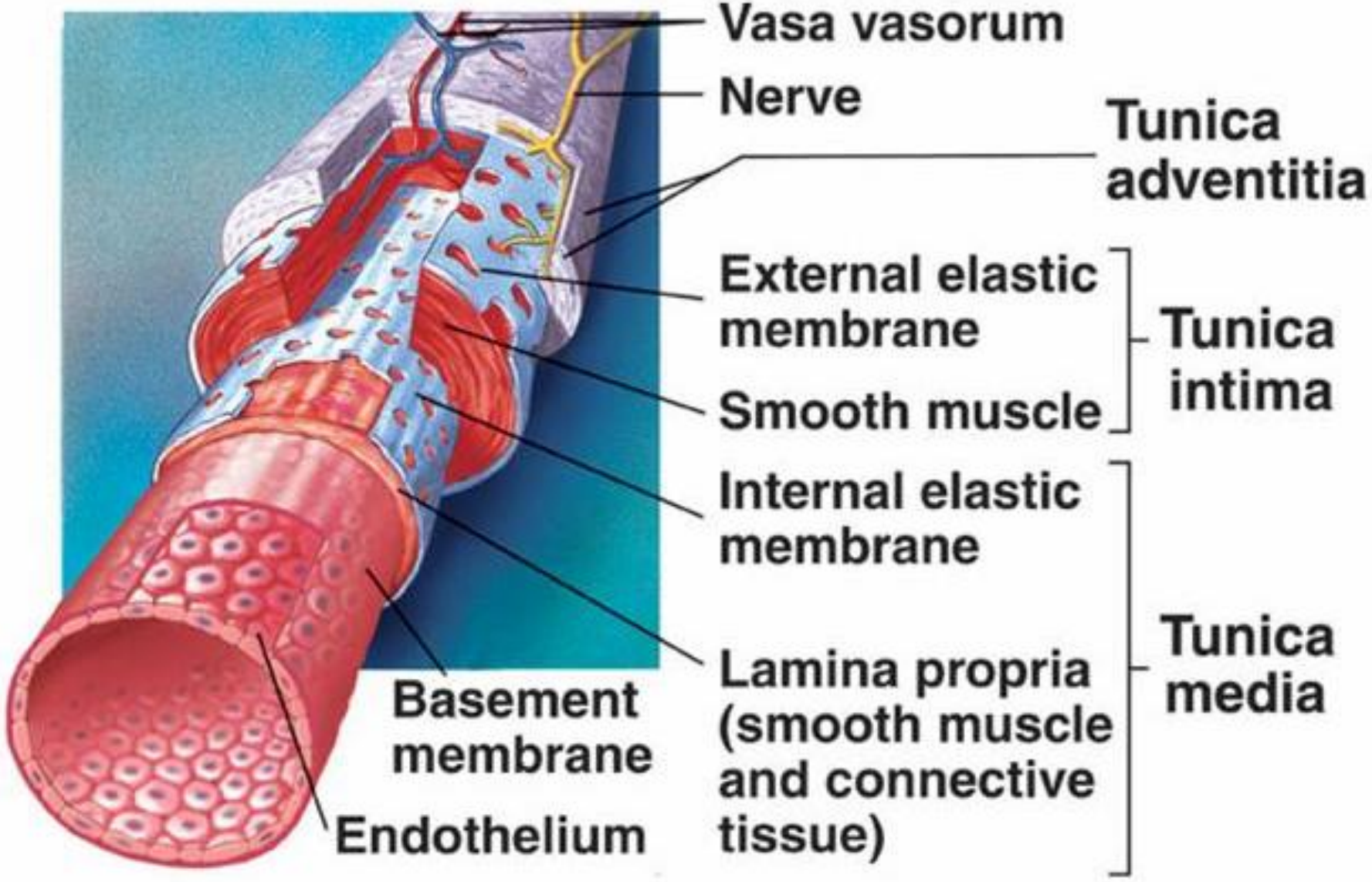
Dorsal

Plantar

Internal Bleeding

Internal


Endothelium
(Tunica Intima)
Internal
Elastic Tissue
Smooth Muscle
(Tunica Media)
External
Elastic Tissue
Fibrous
Connective
Tissue
(Tunica Adventitia)
Lumen
Flow
Flow
Vein
Artery
Capillary Bed
Endothelium
(Tunica Intima)
Internal
Elastic Tissue
Smooth Muscle
(Tunica Media)
External
Elastic Tissue
Fibrous
Connective
Tissue
(Tunica Adventitia)
Lumen
Venule
Endothelial
Cell
Basal
Lamina
Smooth
Muscle Cell
Pericyte
Arteriole
Pericyte
Smooth
Muscle Cell
Basal Lamina


Vasa vasorum
Nerve
Tunica adventitia
External elastic membrane
Smooth muscle
Tunica intima
Internal elastic membrane
Lamina propria (smooth muscle and connective tissue)
Tunica media
Basement membrane
Endothelium

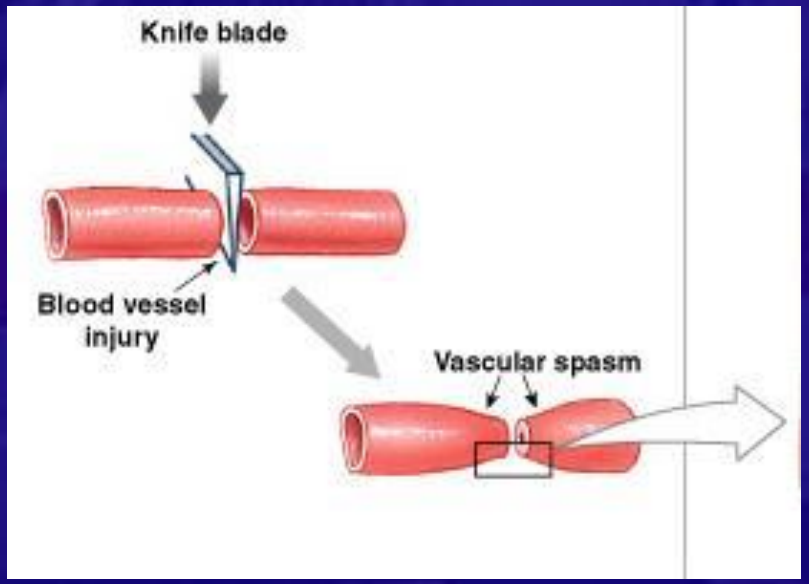
Hemostasis: Blood Stoppage

- Blood flow unimpeded thru intact endothelial blood vessel walls
- If a wall is damaged: fast, localized, controlled response plugs the hole
- **Three phases of hemostasis:**
    1. Vascular spasm
    2. Platelet plug formation
    3. Coagulation

1. Vascular Spasm

Stimuli cause vasospasm:

1. Direct injury to smooth muscle
2. Chemicals released by endothelial cells & platelets
3. Reflexes initiated by local pain receptors

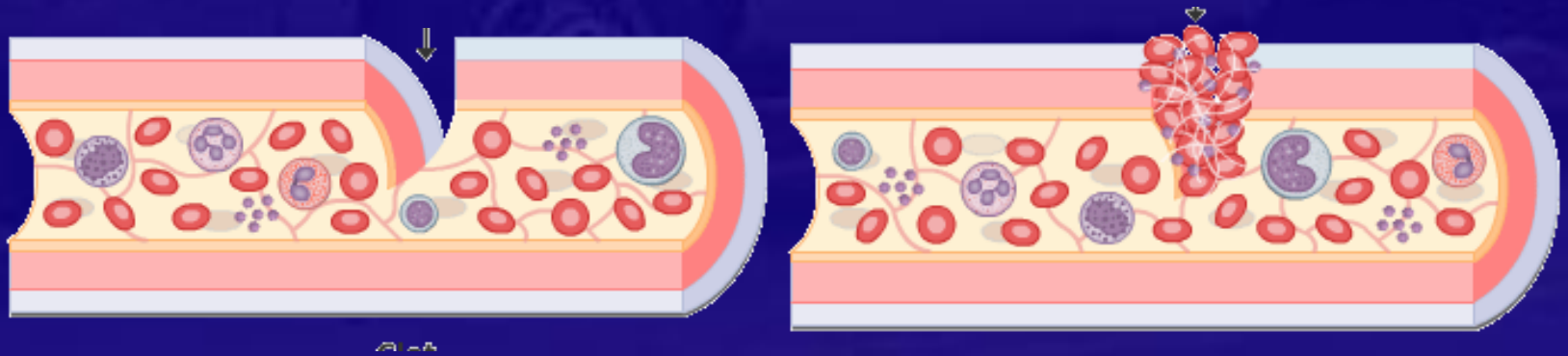


Spasm becomes more efficient with increased tissue damage.

Active Bleeding?

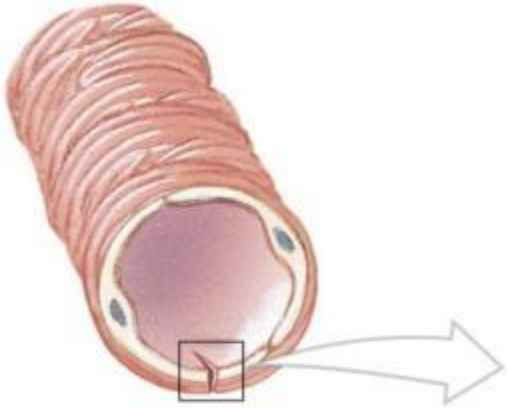
2. Platelet Plug Formation

- Platelets normally inactive
- When exposed to damaged endothelium and underlying exposed ***collagen,*** swell & form spikes, become sticky and adhere to collagen
- Plates release serotonin (enhances vascular spasm), ADP (attracts more platelets) etc.
- Platelet plug limited to immediate area of injury by prostacyclin (released by endothelial cells)

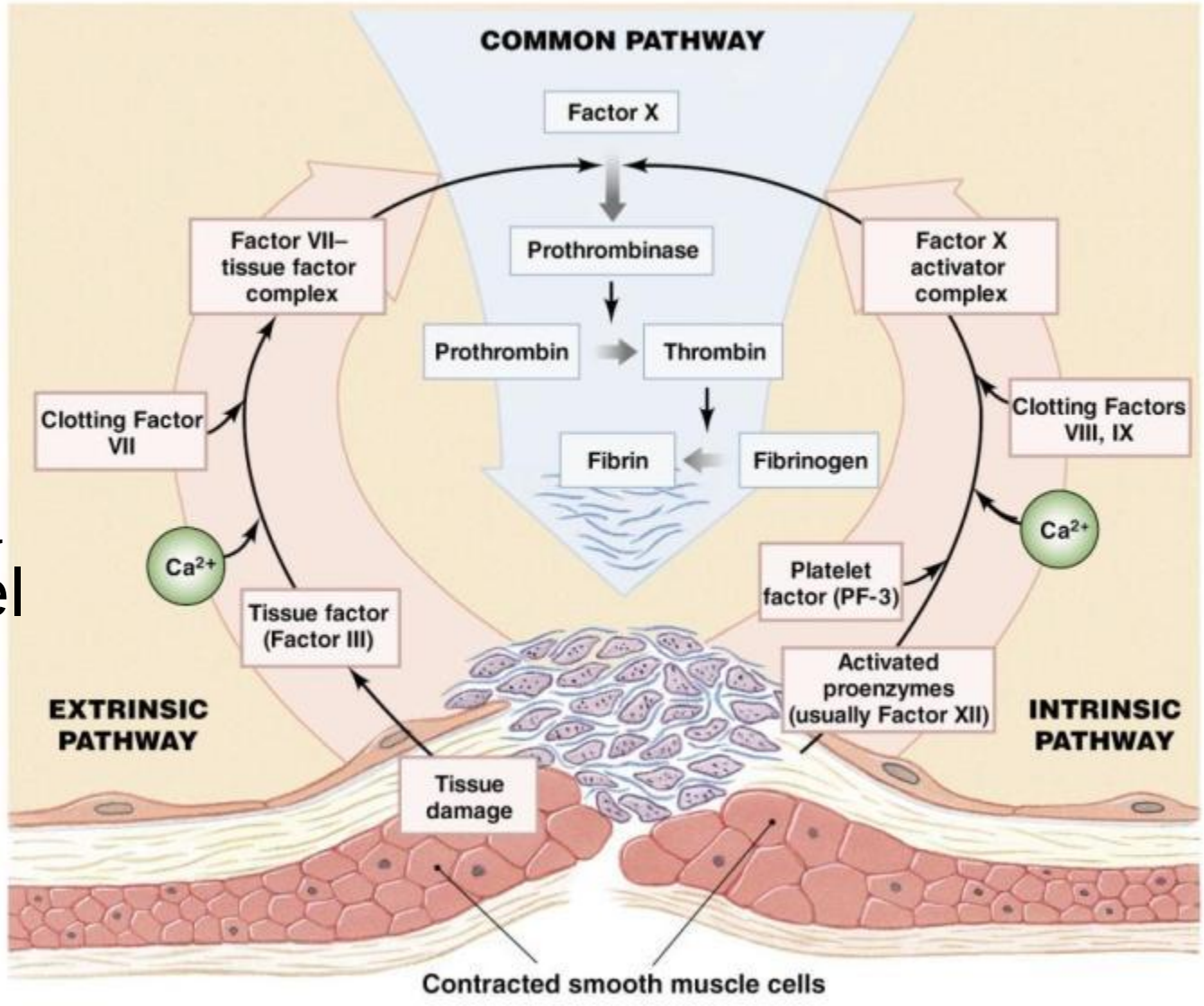


15 seconds

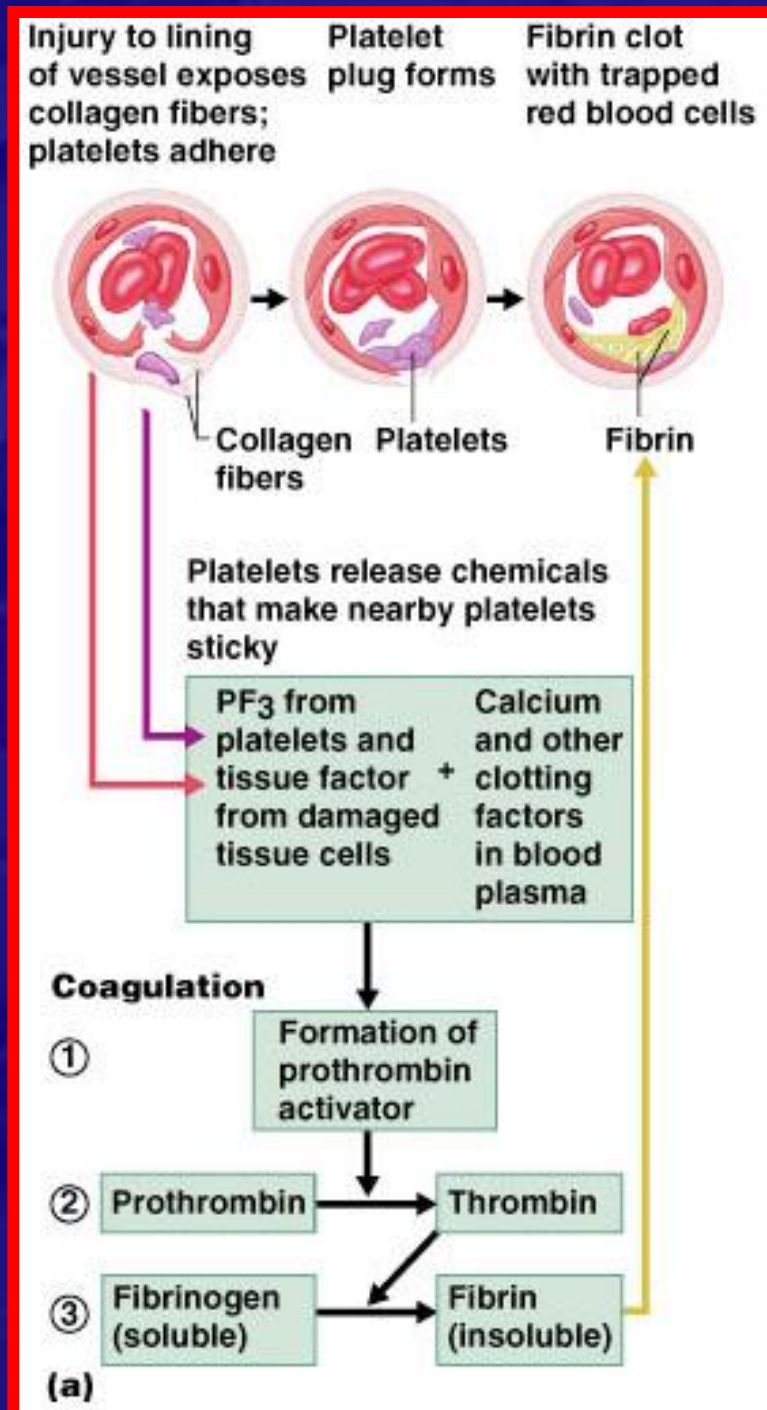
3. Coagulation



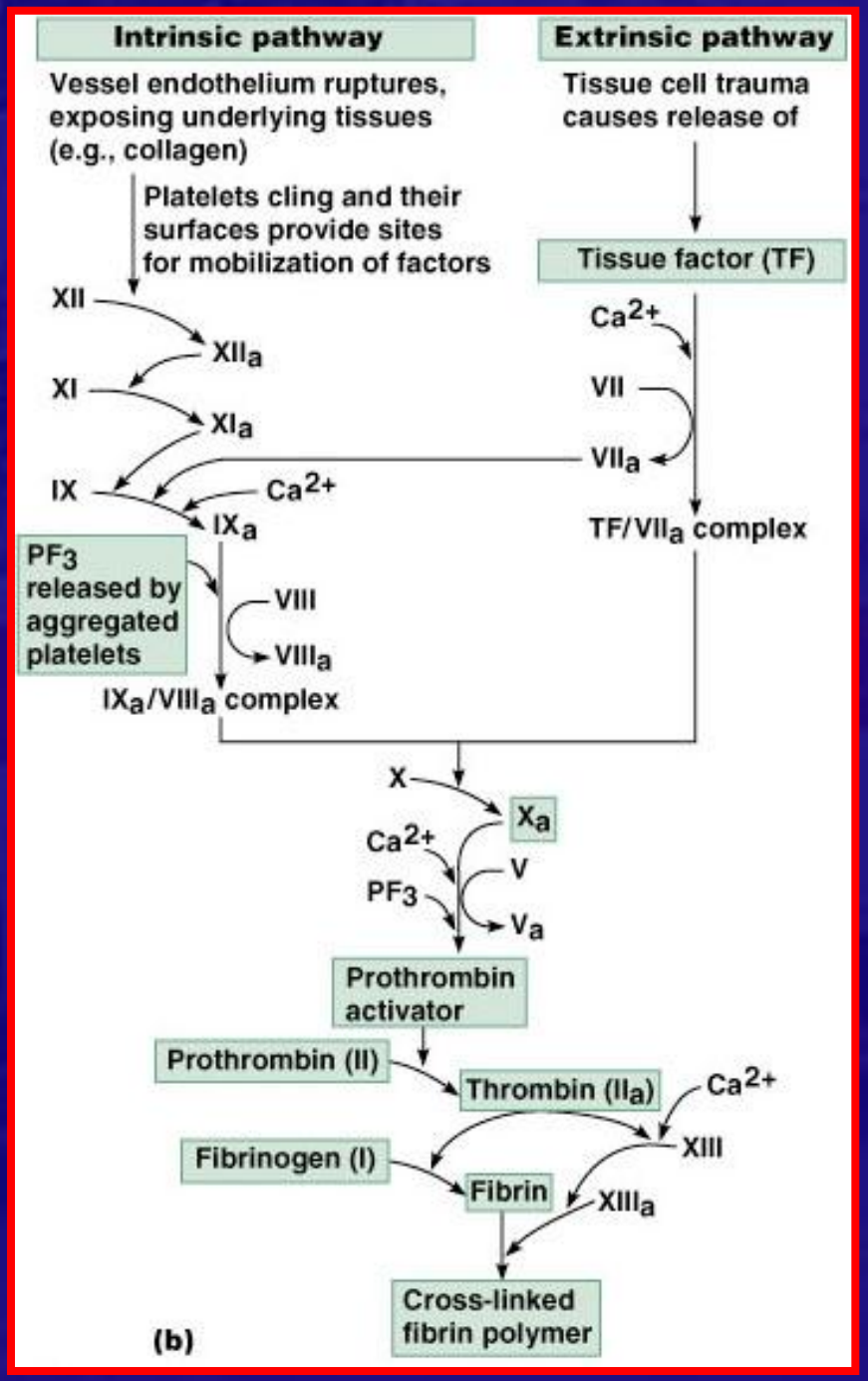
- Transforms blood from a liquid to a gel
- Begins in 30 seconds



Coagulation: 3 Steps



Detailed Events of Coagulation



Coagulation: Clotting Factors

Factor	Structure	Name	Source	Concentration in Plasma (μg/ml)	Pathway
I	Protein	Fibrinogen	Liver	2500–3500	Common
II	Protein	Prothrombin	Liver, requires vitamin K	100	Common
III	Lipoprotein	Tissue factor (TF)	Damaged tissue, activated platelets	0	Extrinsic
IV	Ion	Calcium ions	Bone, diet, platelets	100	Entire process
V	Protein	Proaccelerin	Liver, platelets	10	Extrinsic and intrinsic
VI	(No longer used)				
VII	Protein	Proconvertin	Liver, requires vitamin K	0.5	Extrinsic
VIII	Protein factor (AHF)	Antihemophilic	Platelets, endothelial cells	15	Intrinsic
IX	Protein factor	Plasma thromboplastin	Liver, requires vitamin K	3	Intrinsic
X	Protein	Stuart–Prower factor	Liver, requires vitamin K	10	Extrinsic and intrinsic
XI	Protein antecedent (PTA)	Plasma thromboplastin	Liver	< 5	Intrinsic
XII	Protein	Hageman factor	Liver	< 5	Intrinsic; also activates plasmin
XIII	Protein factor (FSF)	Fibrin-stabilizing	Liver, platelets	20	Stabilizes fibrin, slows fibrinolysis

Factors limiting clot growth

1. Swift removal of clotting factors
2. Inhibition of activated clotting factors:
   - ***Fibrin acts as anticoagulant*** by binding thrombin and ***preventing***:
     - Positive feedback effects of coagulation
     - Accelerated production of prothrombin activator
     - Acceleration of intrinsic pathway by activating platelets
   - ***Heparin*** – a natural anticoagulant found in granules of basophils & mast cells (and produced by endothelial cells) inhibits thrombin
     - Secreted in small amounts into plasma

Clot Retraction & Repair

- Clot retraction starts in 30-60 minutes
- Platelets contract (due to actin & myosin)
  - Platelets pull on surrounding fibrin strand & squeeze serum out of the mass
  - Serum = plasma minus clotting proteins
- Presence of clot causes endothelial cells to release *tissue plasminogen activator* (TPA)
- Fibrinolysis begins in 2 days and continues until clot totally dissolved (several days)

Shock: 3 Kinds

Despite what you might read or hear, there are ONLY three shock states:

1. Hypovolemic
2. Distributive
3. Cardiogenic

Normal Adult Blood Volume
5 Liters

ACS Classification of Acute Hemorrhage

Class	% Blood Loss	Clinical Signs
I	Up to 750 ml (15%)	Slight increase in HR; no change in BP or respirations
II	750-1500 ml (15-30%)	Increased HR and respirations; restlessness (anxiety, fright or hostility); [increased diastolic BP]
III	1500-2000 ml (30-40%)	Increased HR and respirations; falling systolic BP; significant AMS
IV	>2000 (>40%)	Severe tachycardia; severe ↓ BP; cold, pale skin; decreased LOC

500 ml Blood Loss

4.5 Liters Blood Volume

500 ml Blood Loss

- Mental State: Alert
- Radial Pulse: Full
- Heart Rate: Normal or slightly increased
- Systolic Blood pressure: Normal
- Respiratory Rate: Normal
- Is the patient going to die from this?

No

1000 ml Blood Loss

4.0 Liters Blood Volume

1000 ml Blood Loss

- Mental State: Alert
- Radial Pulse: Full
- Heart Rate: 100 +
- Systolic Blood pressure: Normal lying down
- Respiratory Rate: May be normal
- Is the patient going to die from this?

No

1500 ml Blood Loss

3.5 Liters Blood Volume

1500 ml Blood Loss

- Mental State: Alert but anxious
- Radial Pulse: May be weak
- Heart Rate: 100+
- Systolic Blood pressure: May be decreased
- Respiratory Rate: 30
- Is the patient going to die from this?

Probably not

2000 ml Blood Loss

3.0 Liters Blood Volume

2000 ml Blood Loss

- Mental State: Confused/lethargic
- Radial Pulse: Weak
- Heart Rate: 120 +
- Systolic Blood pressure: Decreased
- Respiratory Rate: >35
- Is the patient going to die from this?

Maybe

2500 ml Blood Loss

2.5 Liters Blood Volume

2500 ml Blood Loss

- Mental State: Unconscious
- Radial Pulse: Absent
- Heart Rate: 140+
- Systolic Blood pressure: Markedly decreased
- Respiratory Rate: Over 35
- Is the patient going to die from this?

Probably

So What's the Problem?

- Military
  - 9% fatal bleeds are preventable
- Civilian
  - 10 million ED visits annually in US for external hemorrhage
- Definite advances have been made/are being made in hemorrhage control (both external and internal)

Step 1 – Find the Leak!

- You cannot control what you cannot see
- Use a gloved hand to locate the bleeder
- May need to irrigate the area with saline
- Blot dry, remove debris with sterile 4x4

Can You Find the Bleeder(s)?

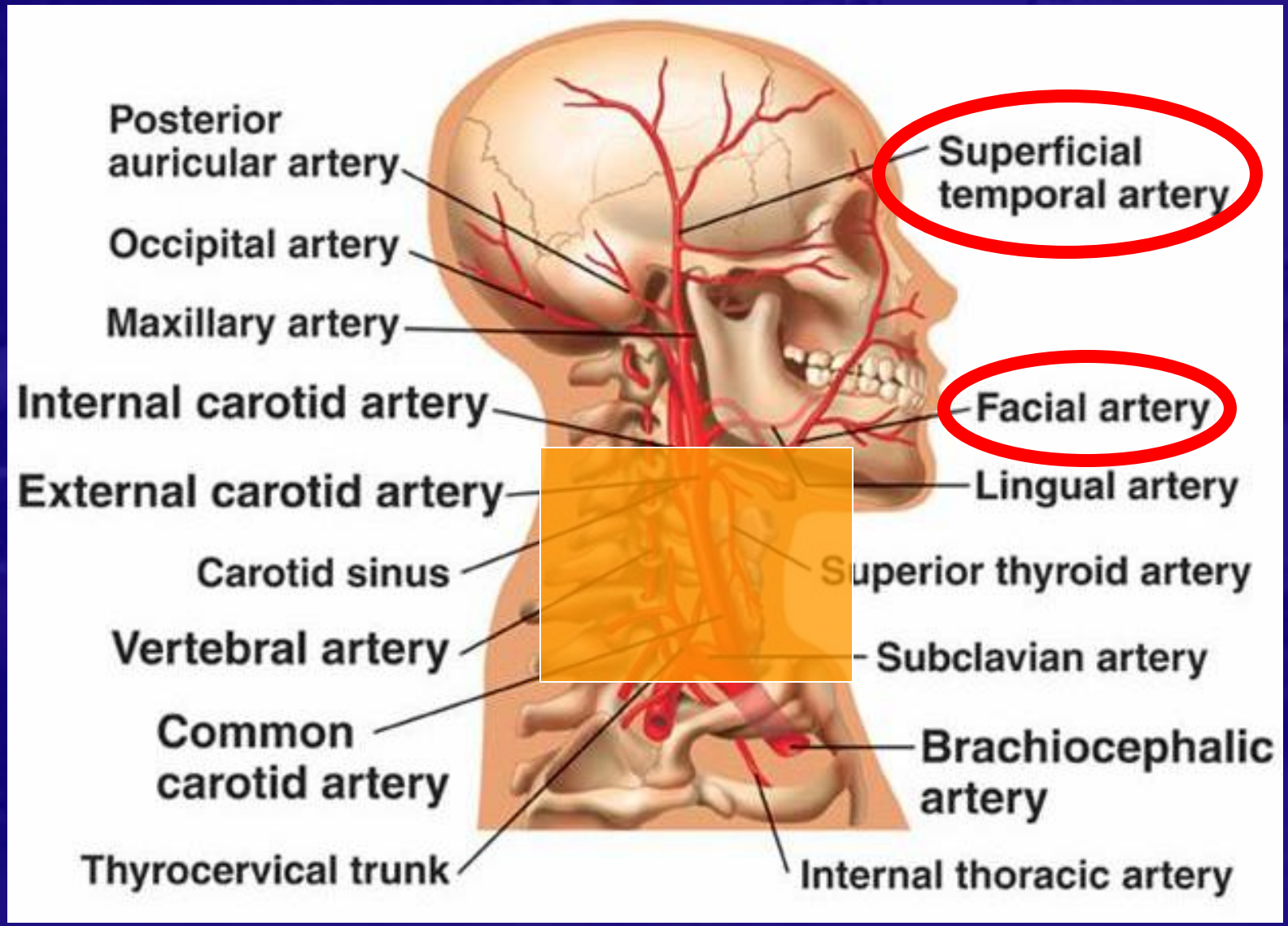
Can You Find the Bleeder?

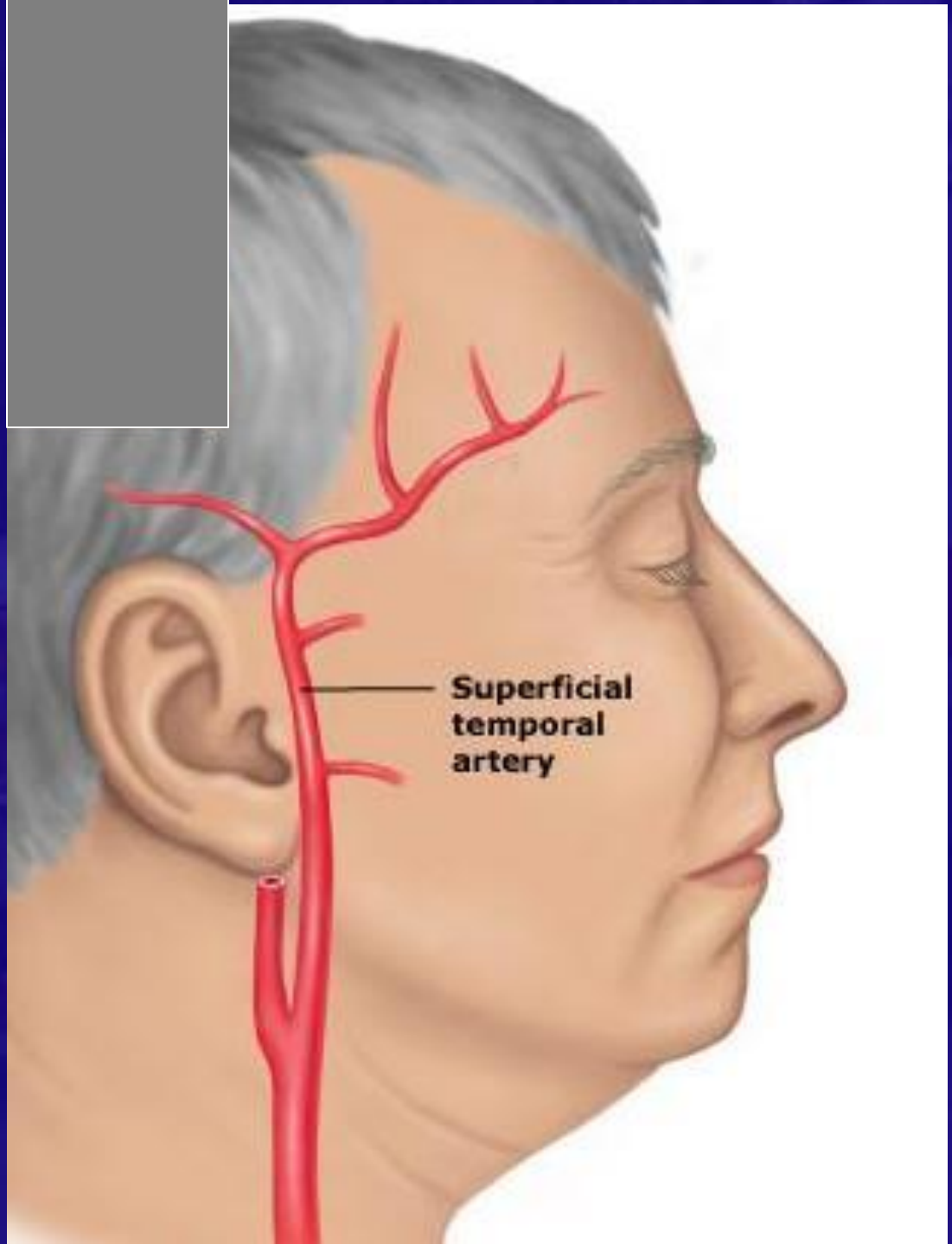
Can You Find the Bleeder?

Can You Find the Bleeder?

Can You Find the Bleeder?

Know Your Anatomy




Superficial
temporal
artery

Step 2 - Compression

- Once bleeding source identified, apply direct pressure to tamponade flow
- Place a dressing on the wound when available (initially, use your gloved hand)
- Add dressings until bleeding stops ~~(removing dressings disrupts clots)~~
- Continue direct pressure until bleeding stops (at least 3 min, may need 10 min)

Step 2 - Compression

- Once bleeding source identified, apply direct pressure to tamponade flow
- Place a dressing on the wound when available (initially, use your gloved hand)
- Change soaked dressings
- Continue direct pressure until bleeding stops (at least 3 min, may need 10 min)

Step 3 – Hemostatic Dressing

- Elevation helpful
- Pressure points technically near impossible to properly apply
- Pressure dressings beneficial
- Hemostatic dressings **VERY helpful**

Hemostatic Agents/Dressings

- The latest & greatest surgical advance
- Continually evolving
- Included in PHTLS, ATLS, EMR, EMT
- Available OTC

Military Experience

QuikClot®

- Early versions very exothermic – up to 147°F (discontinued in 2008)
- Difficult to debride
- New Advanced Clotting Sponge (ACS)
  - Gauze sack – easily removed from wound
  - Prehydrated (reduces exothermic reaction)
- Controls bleeding in 3 – 5 minutes
- Can remain in place for up to 24 hours

Hemostatic Agents/Dsgs Compared

	QC ACS	*HemCon*	*Celox*	WoundStat	*Combat Gauze*
Hemostatic efficacy	+	+	+++	++++	++++
Side effect	None	None	---	---	None
Ready to use	√	√	√	√	√
Training requirement	+	+	+	+++	++
Lightweight and durable	++	+++	+++	++	+++
2 yrs Shelf life	√	√	√	√	√
Stable in extreme condition	√	√	√	√	√
FDA approved	√	√	√	√	√
Biodegradable	No	No	Yes	No	No
Cost ($)	~30	~75	~ 25	30- 35	~25

Military studies: Army (USAISR) & Navy (NMRC)

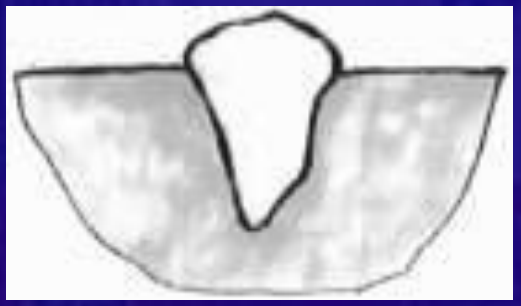
Combat Gauze™

3-inch x 4-yard roll of sterile gauze impregnated with kaolin. Activates clotting factors and platelets, absorbs water (increasing concentration of platelets and clotting factors at bleeding site)

REQUIRES TRAINING

Combat Gauze Directions
Pack Wound Completely

RIGHT



WRONG

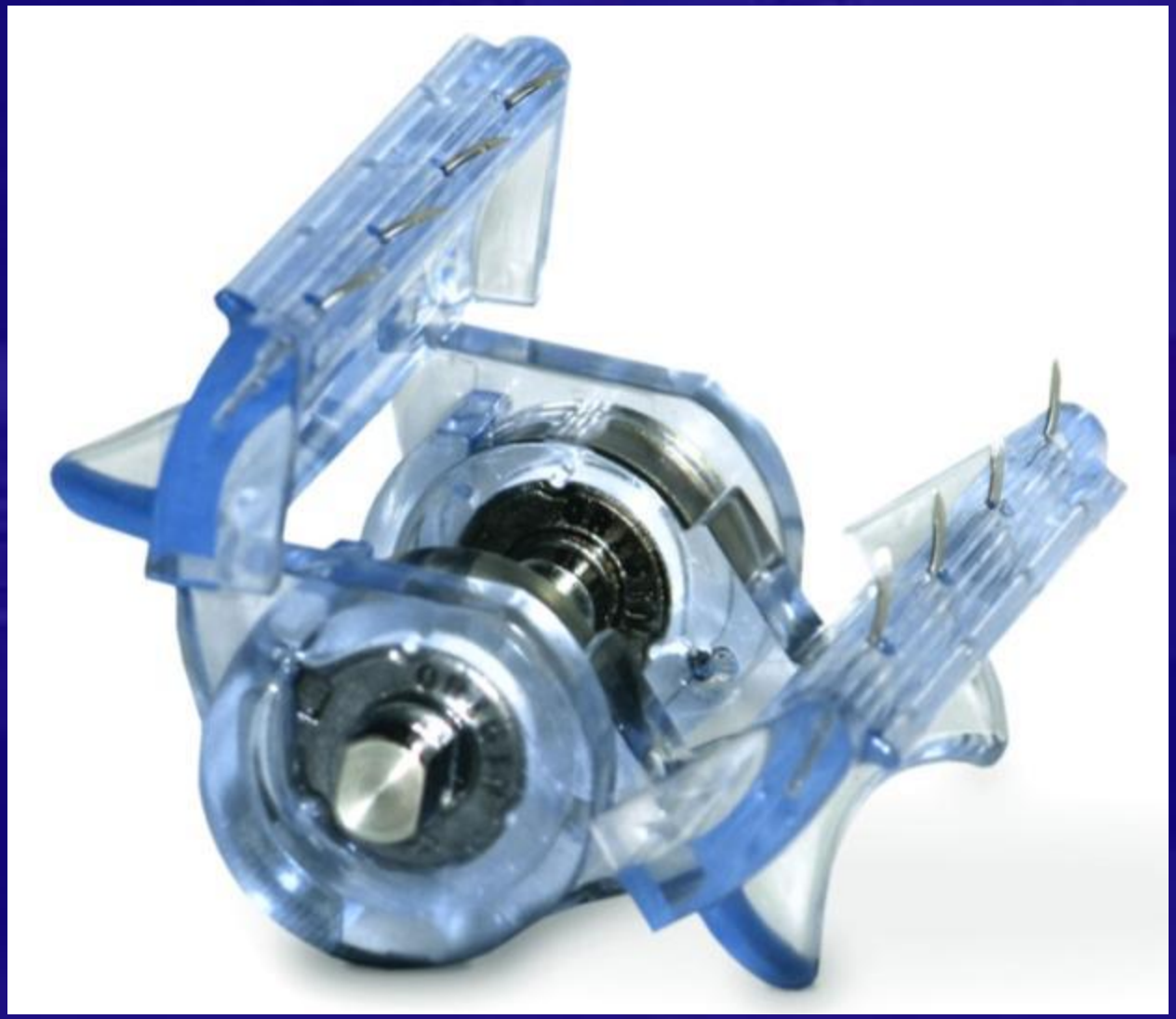
Combat Gauze Directions
Apply Direct Pressure

- Apply pressure until bleeding stops
- Hold pressure for 3 minutes
- Reassess to ensure bleeding is controlled.
- Combat Gauze may be repacked or a second gauze used if initial application fails to provide hemostasis.
- If gauze saturates, **replace** it!

“I don’t have time to hold it”

- Direct pressure requires time to achieve hemostasis
- Complicating factors:
  - Anticoagulation
  - Other priorities
  - Personnel pool…

iTClamp™



Chainsaw Trauma

Chainsaw – Post Repair

79 yo rollover MVC - scalp

Large Subgaleal Hematoma

- Removed
- Packed with Combat Gauze
- Reapplied

Step 4 – Tourniquet

- May be placed immediately:
  - Short handed or alone
  - Adverse conditions (hostile fire…)
  - Multiple priorities (airway, breathing)
- Apply before s/s shock ensue
  - "first resort," not "last resort"
- 2 – 3" above wound, avoid joints

TCCC – GSW or IED? Apply to proximal extremity

Tourniquets

- Safely used in surgery for hours (≤ 8)
- Disappeared in 1960's due to:
  - Inappropriate civilian use
  - Tissue and nerve damage

If at first you don't succeed…

- Combat study 428 TQ to 309 limbs
- 82% effective first TQ
- 92% effective second TQ

Kragh JF, Walters TJ, Baer DG, Fox CJ, Wade CE, Salinas J, Holcomb JB. Practical Use of Emergency Tourniquets to Stop Bleeding in Major Limb Trauma. J Trauma. 2008;64:S38 –S50.

Tourniquets

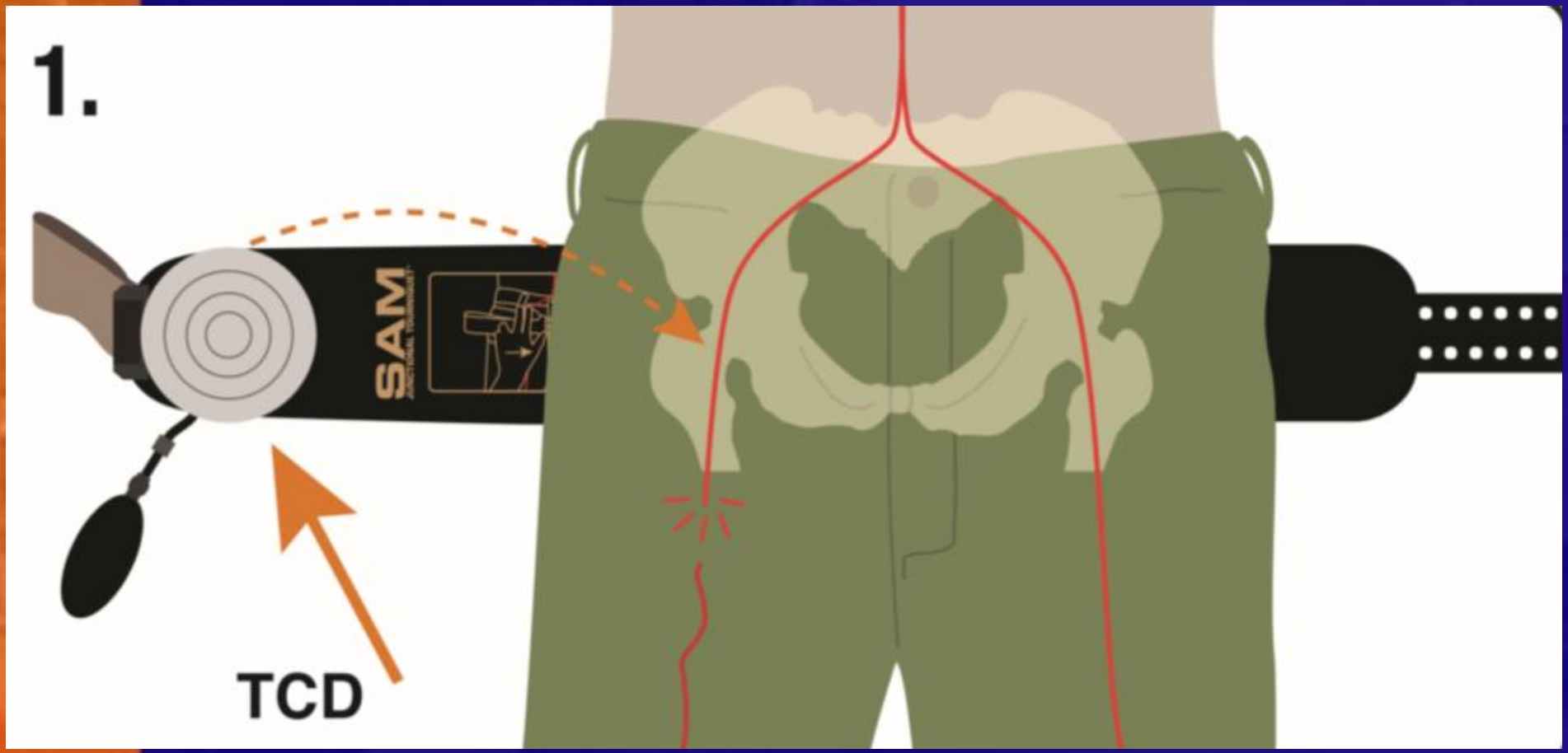
- Best TQ: wide & pressure measurable:

Apply proximal to wound or extremity, inflate to just above SBP

Junctional Tourniquet

- “Pressure Point” concept
- Well validated in military settings
- ? Civilian
- Femoral
- Axillary
- Abdominal

Junctional Tourniquet



Step 4a – Pain Control

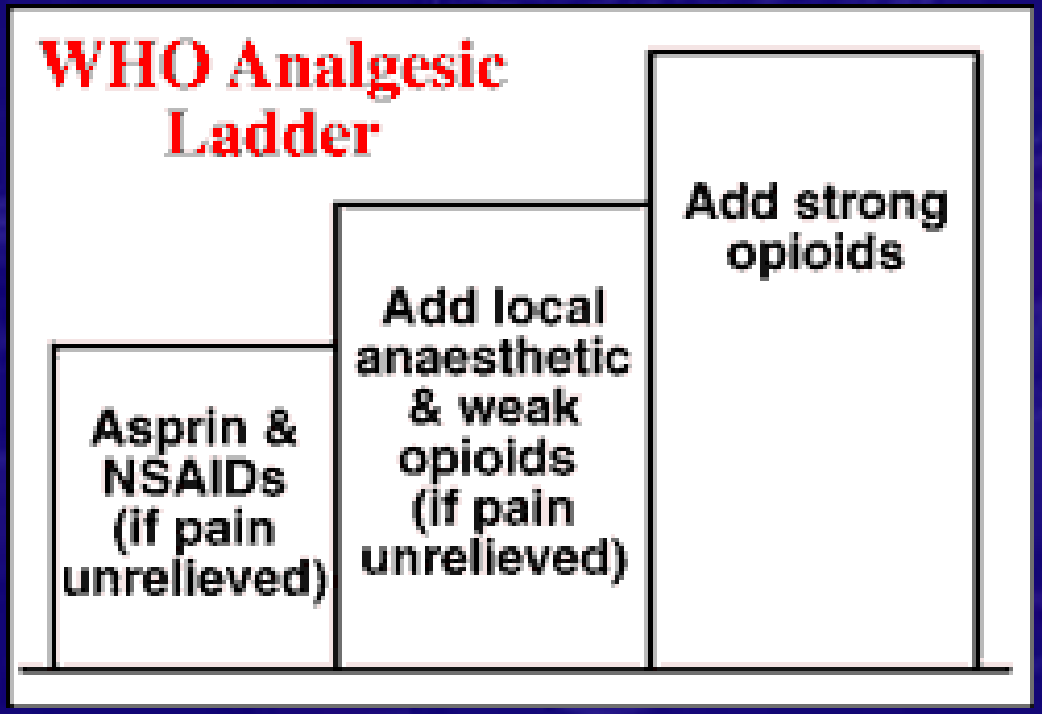
- Tourniquets HURT!
- Pain management essential

Combat Pill Pack

Pain Management and Infection Control
For Combat Casualties
"Just Got Easier To Swallow"

Pain Management

- How do you manage pain?



Step 5 – Resuscitate

- Is time important?
- "Golden Hour" conceived by Maryland Shock Trauma Center
- No evidence basis in repeated studies

Newgard CD, et al. Emergency Medical Services Intervals and Survival in Trauma: Assessment of the "Golden Hour" in a North American Prospective Cohort. *Ann Emer Med.* 2010; 55(3): 235-260

Step 5 - Resuscitate

- Are there time critical trauma patients?
- First rule of hemorrhage control =

  Find the leak (you cannot control what you cannot see)
- Shock without evident bleeding requires

  “Cold hard steel”

Step 5 - Resuscitate

IV fluids in hypovolemic shock:

- No ↑ survival, some ↑ mortality

Theories on IVF in trauma:

1. ↑ BP dislodges clots
2. ↑ BP = ↑ bleeding
3. IVF hemodilutes clotting factors

EMS/ED: Permissive Hypotension

Duchesne JC et al. Damage Control Resuscitation: From Emergency Department to the Operating Room. *The Amer Surgeon.* 2011; 77: 201-206.

Step 5 - Resuscitate

Permissive hypotension – allow SBP 80 or to palpate a radial pulse (MAP 50 – 60):

1. Bleeding controlled, no shock = no IVF
2. Bleeding controlled, shock ➔ 500 ml IVF (may repeat X 1)
3. Bleeding uncontrolled = no IVF

Ideal permissive hypotension < 90 min.

Severe damage when > 120 min.

Li T, et al. Ideal Permissive Hypotension to Resuscitate Uncontrolled Hemorrhagic Shock and the Tolerance Time in Rats. *Anesthesiology.* 2011; 114 (1): 111-119.

Permissive Hypotension Exceptions:

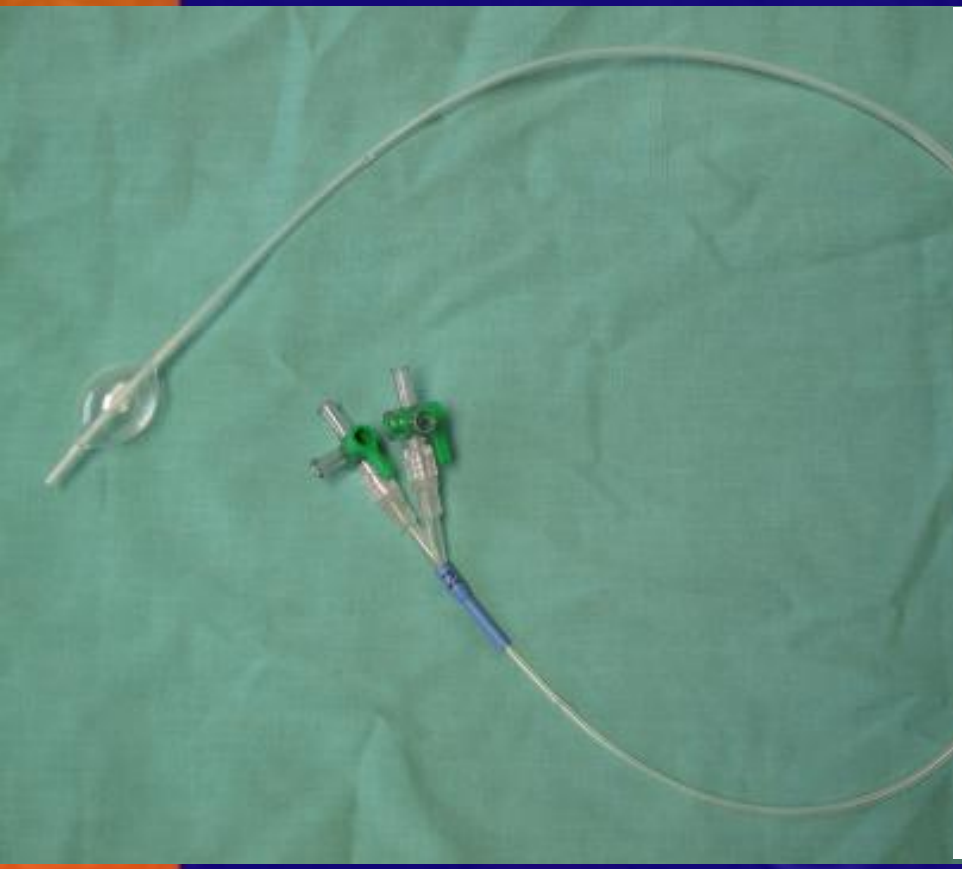
- TBI (Traumatic Brain Injury)
  - A single SBP < 90 = worse outcomes
- Elderly?
  - Most have baseline hypertension
  - SBP of 100-110 probably inadequate

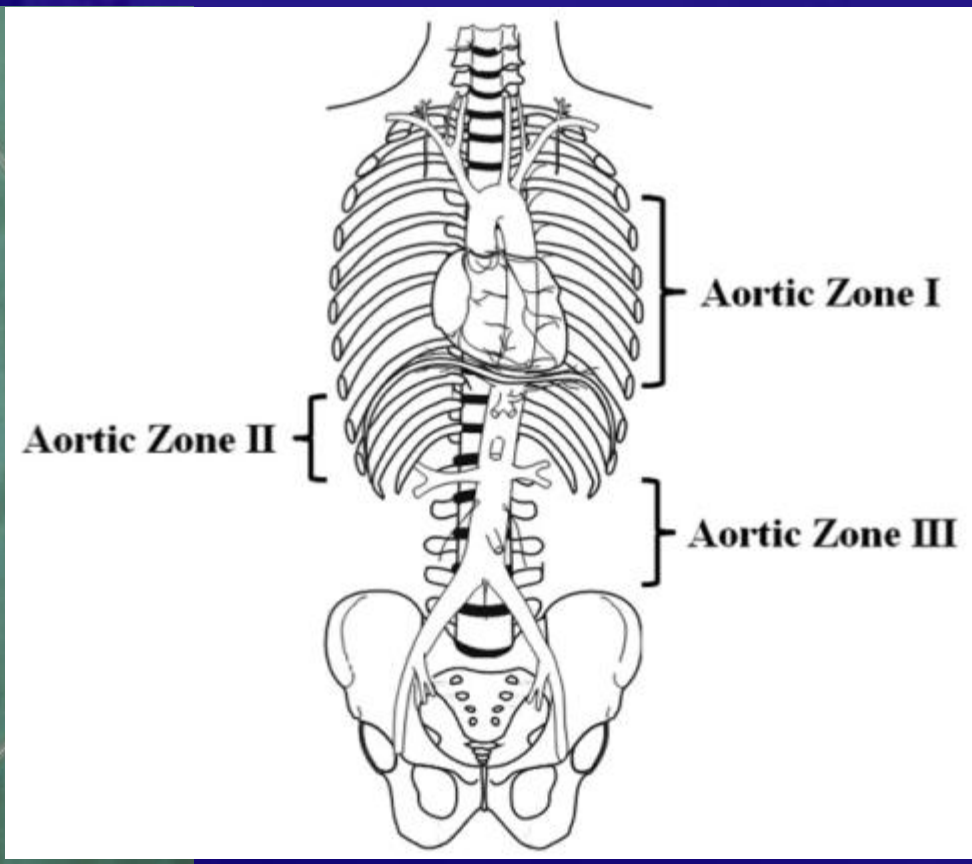
Step 5 – Resuscitate: OPTIONS

- No OR? No Surgeon?
- REBOA (Resuscitative Balloon Occlusion of the Aorta)
- First reported 1954, EMS use 1970's
- "Non-surgical aortic cross-clamp"
- Femoral arterial access – endovascular balloon occlusion

Stannard A et al. J Trauma. 2011;71:1869-72.
Brenner ML et al. J Trauma Acute Care Surg. 2013;75:506-11.

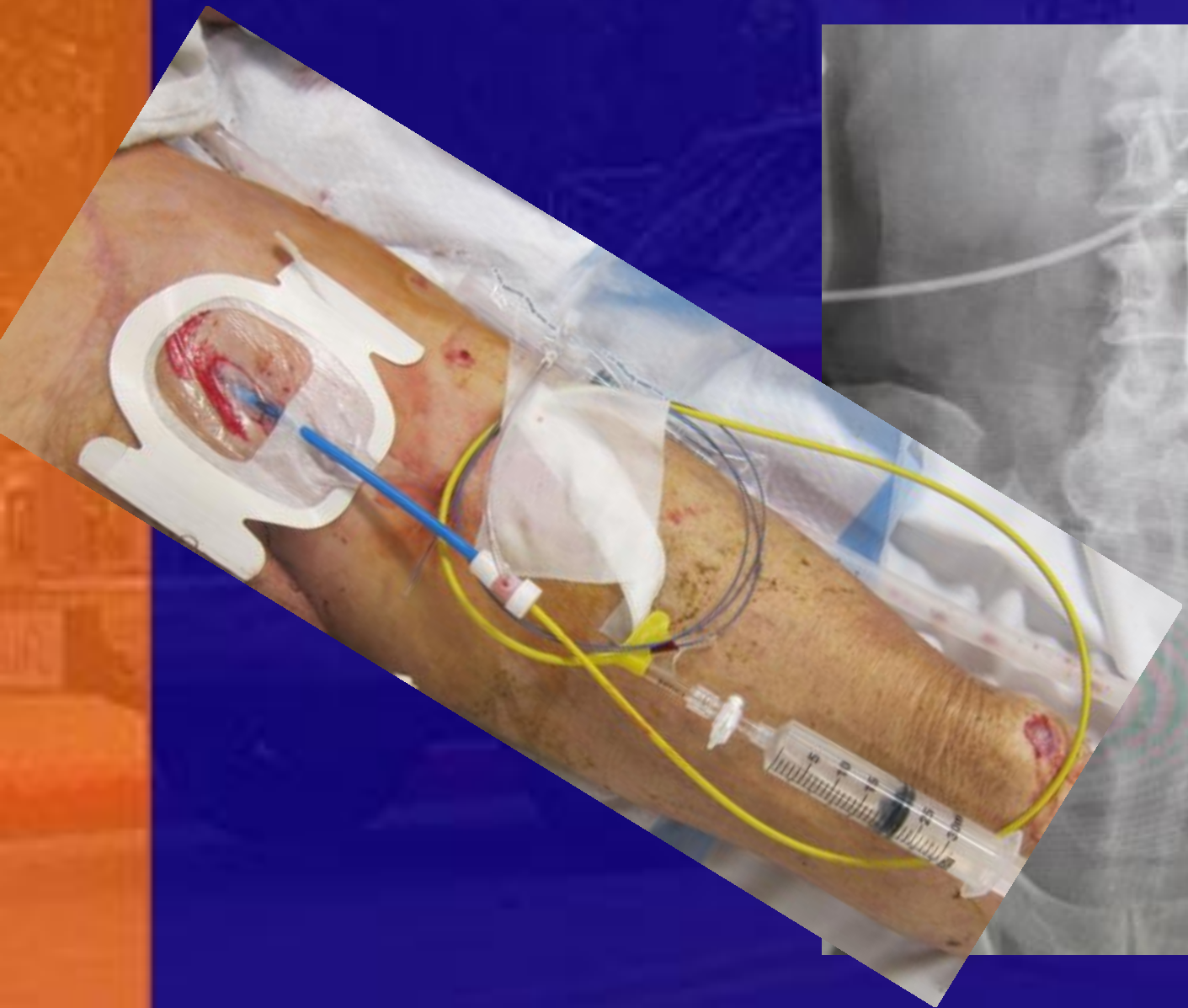
Step 5 – Resuscitate: REBOA





Stannard A et al. J Trauma. 2011;71:1869-72.
Brenner ML et al. J Trauma Acute Care Surg. 2013;75:506-11.

Step 5 – Resuscitate: REBOA



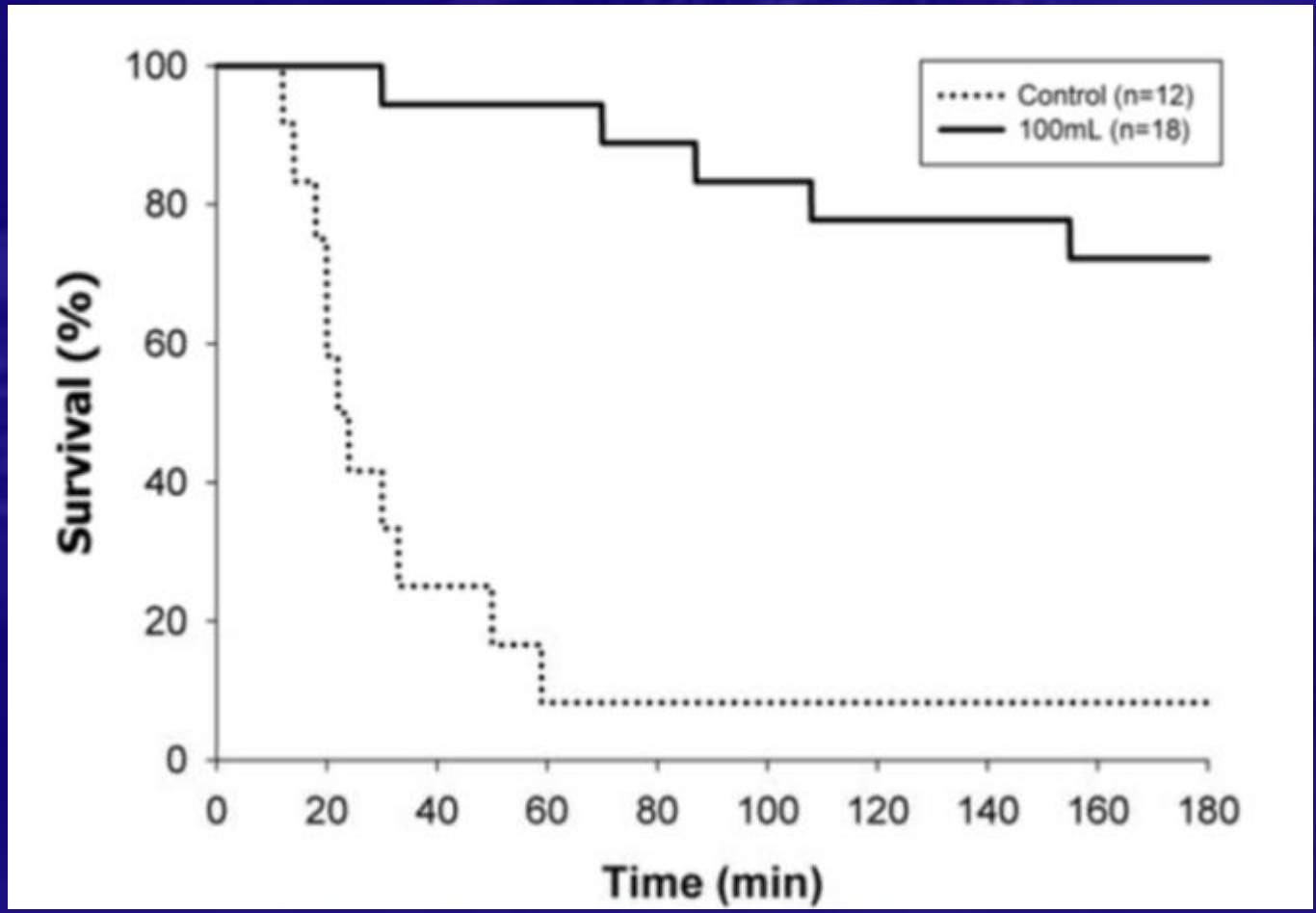
Step 5 – Resuscitate: OPTIONS

- No OR? No Surgeon?
- “Belly Foam” – injected polyurethane polymer, mixes 2 liquids to create a self-expanding (30X) solid foam
- Tamponade the bleeding site(s)
- Promising animal studies

Peev MP et al J Trauma Acute Care Surg. 2014:76:619-23.
Rago A et al. Self-expanding foam for prehospital treatment of intra-abdominal hemorrhage: 28-day survival and chronic safety. J Trauma (submitted)

Self-expanding Foam

- Swine study, splenic rupture

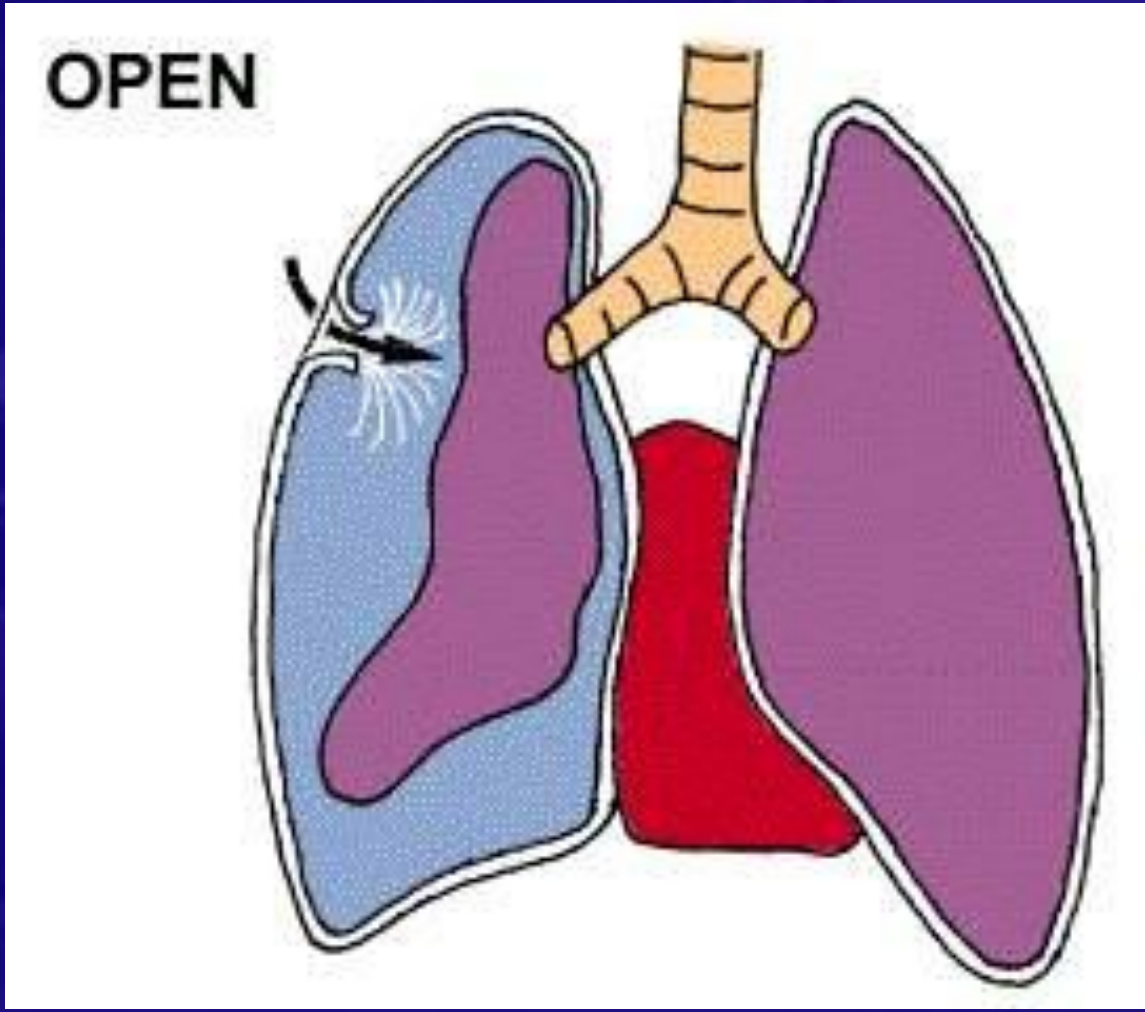


Noncompressible Area?

- Direct pressure to a deep wound
- Expanding pellets…XStat™

Xstat – RevMedX.com

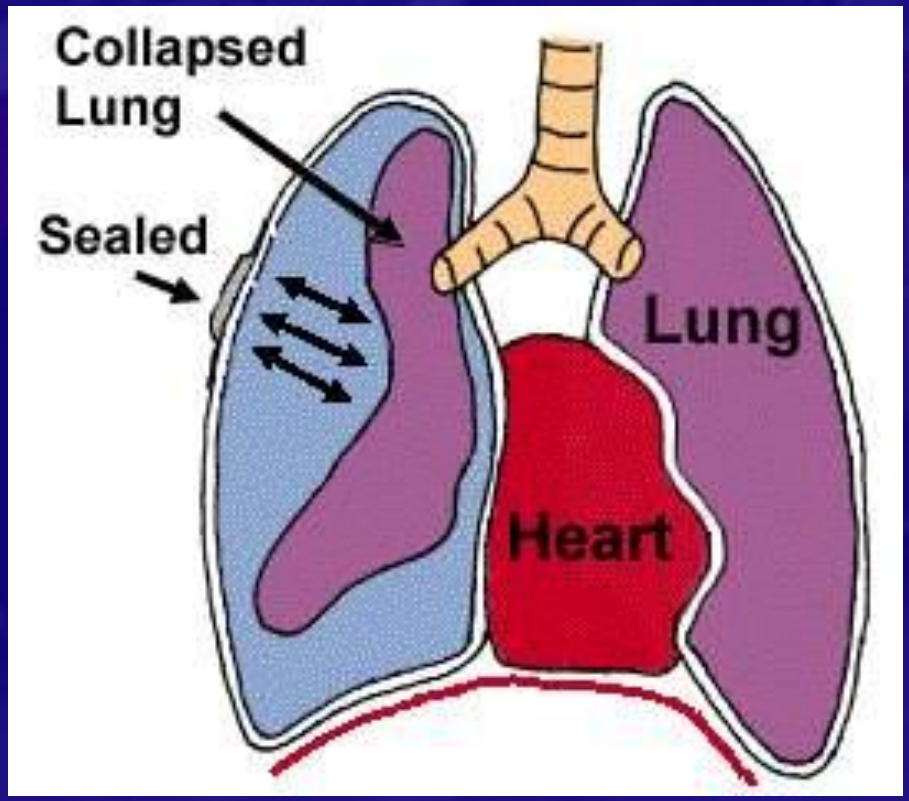
Sucking Chest Wound (Open Pneumothorax)



(Requires a hole in the chest the size of a nickle or bigger)

Sucking Chest Wound (Treated)

Change: Cover <u>completely</u> with occlusive dsg; if signs of tension pneumothorax develop – REMOVE to allow decompression (have pt cough, if able)



Sucking Chest Wound

Old: Asherman's Seal

(No longer recommended)

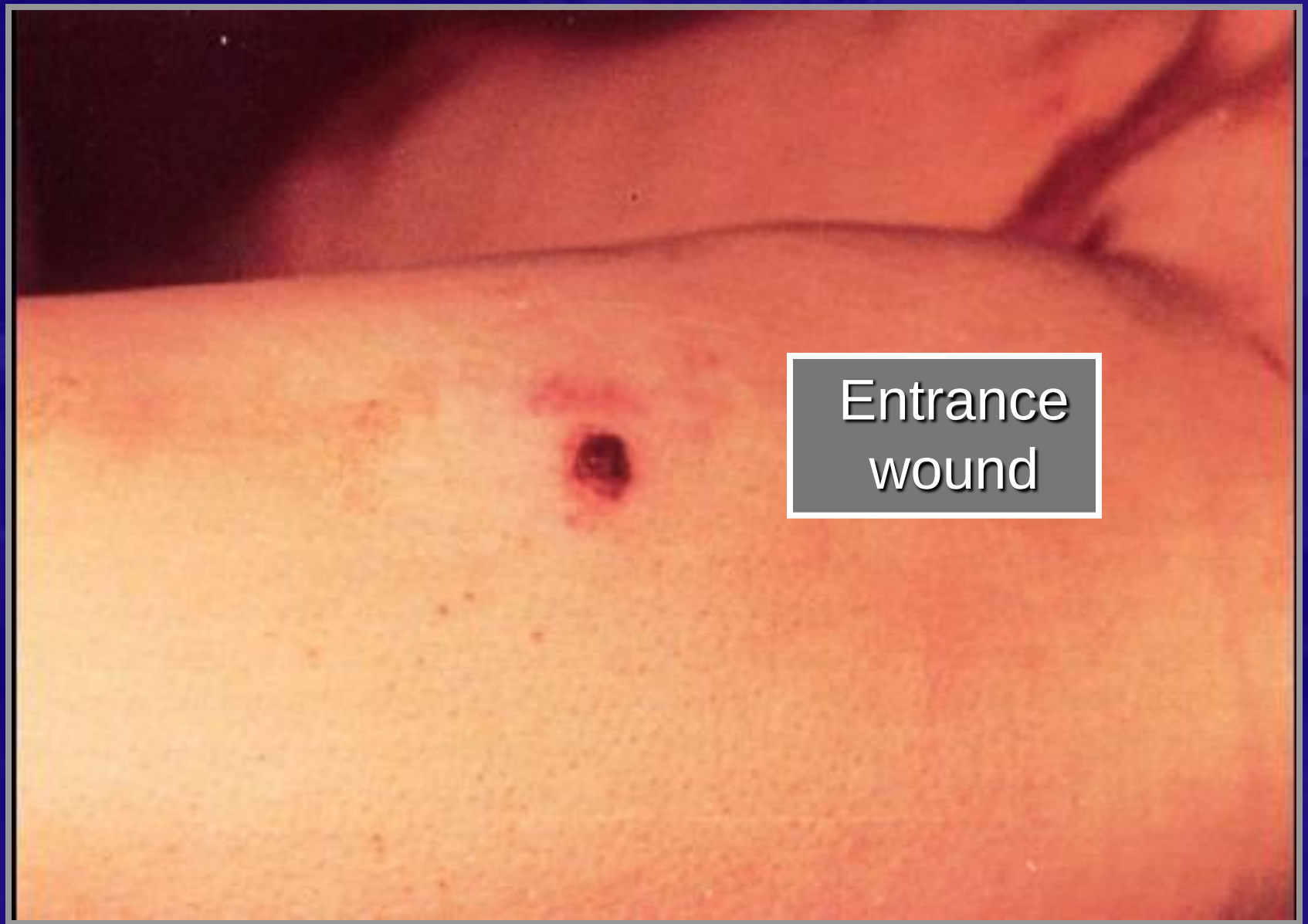
New: AED Pad

Sucking Chest Wound

Even Better: Halo Chest Seal

PMI (Progressive Medical International)

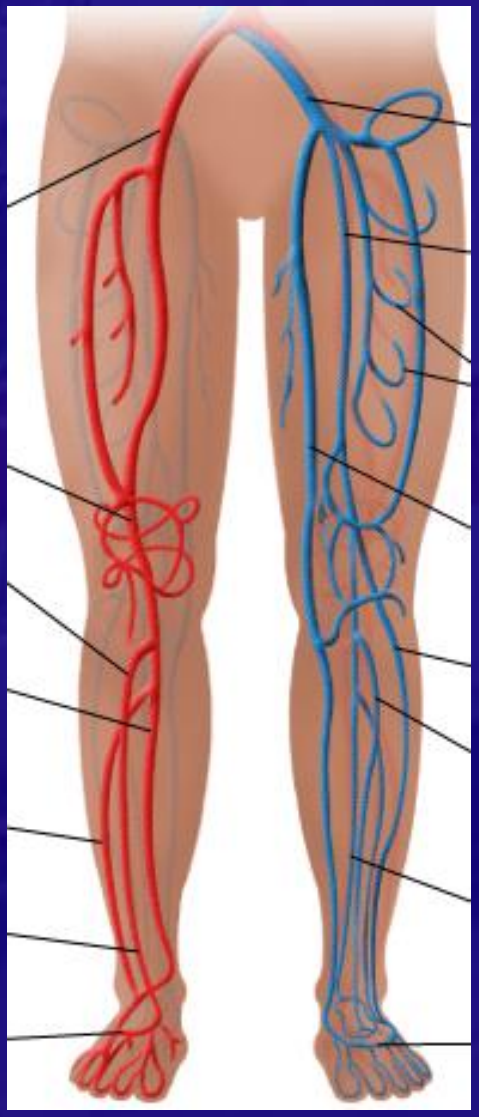
GSW



GSW

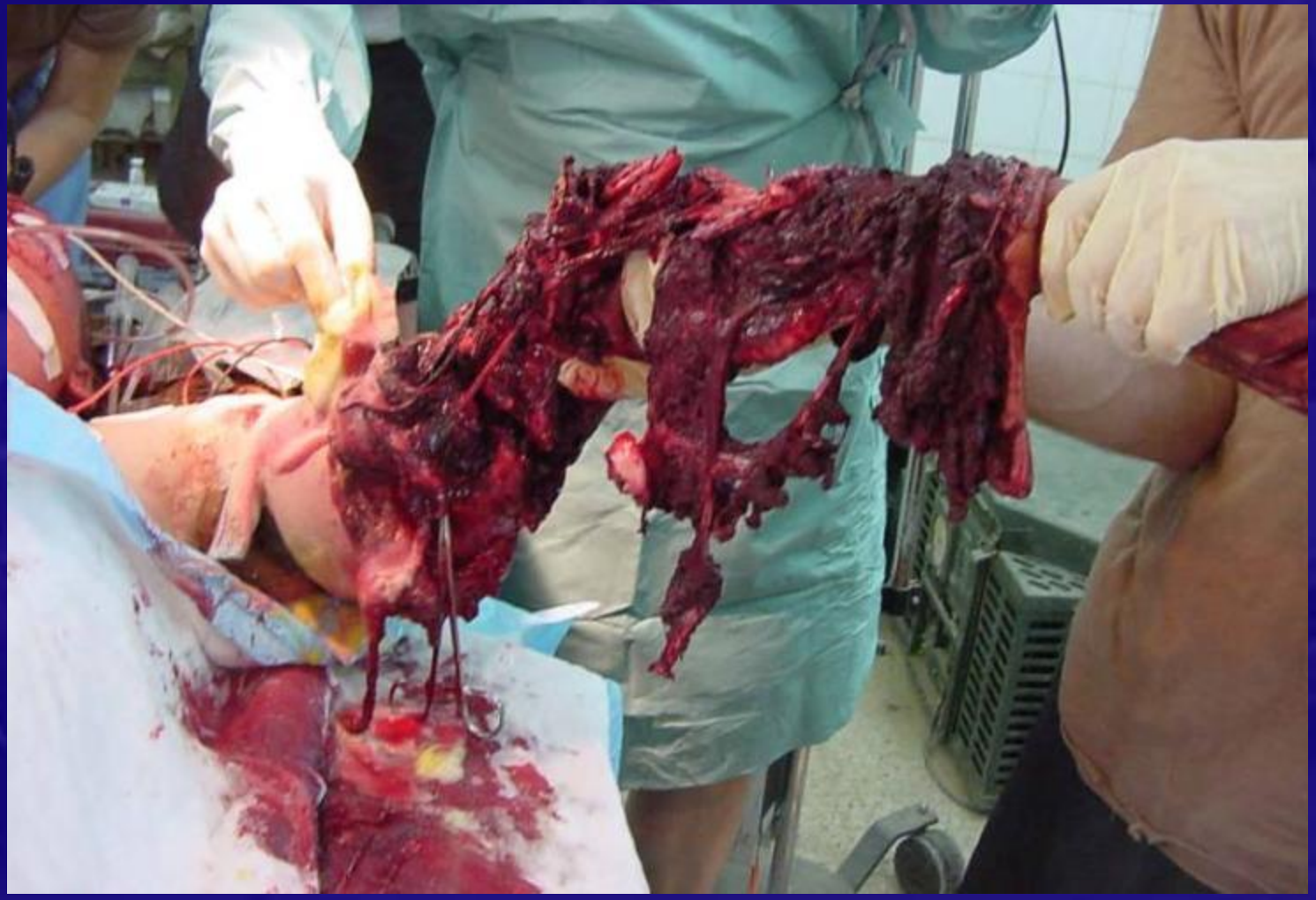
Exit wound

Possible Underlying Injuries



Why no bleeding? (Explosion)

Why no bleeding? Need TQ?



Type of Wound? Concerns?

Patient “fell into a window”

Head CT

Treatment?

Chin Wound – Treatment?

Treatment?

Knee Wound – Treatment?

The Future: TXA?

- Tranexamic acid
  - Prevents activation of plasmin (enzyme)
  - In turn prevents fibrin breakdown (protein)
- Bottom line: allows more effective clot formation

The Future: TXA?

- Several clinical trials (military & civilian)
- Mixed and controversial results
- Appears recently that TXA use may be associated with ↑ DVT & PE (9 &12 X)

MATTERs (Military Trial):
- True benefit (NNT 1:7)
- Relative mortality ↓ 6.7%
- ↑ risk thrombotic events

CRASH-2 (Prehospital Trial):
- True benefit (NNT 1:6.7)
- No significant mortality ↓
- No ↑ thrombotic events

PATCH (Prehospital Trial):
- Selects out hypotensive trauma patients who are likely to need blood products.

CRASH-2 Issues

- Only approximately 5% of patients had bleeding as a cause of death.
- The CRASH-2 approach to randomization. The CRASH-2 wording is: “Doctor is reasonably certain that antifibrinolytic agents are indicated or contraindicated – Do not randomize”.
- Concern regarding selection bias.
- No data regarding injury severity of the patient cohort.
- No data regarding shock in the patient cohort (i.e. lactate and base deficit) and there was the inability to determine if the cohorts were similar.
- Small sample size of hypotensive (SBP < 90 mm Hg) (31.5%) and tachycardic (HR>107) (48%) patients which were the target populations.
- No data regarding fibrinolysis on admission and no coagulation testing. The rate of fibrinolysis at admission in North American trauma centers is approximately 5%.
- The most common cause of death was traumatic brain injury (TBI).
- TXA did not reduce blood transfusions. Only 50% of study cohort received blood transfusions.
- No adverse events were regarded as serious, unexpected, or suspected to be related to the study treatment.
- Concern about possible inadequate reporting.
- Patient follow-up reported as 100% which is difficult to believe.
- Effect size was small. This effect was statistically significant but not a clinically meaningful finding. The study determined a 0.8% absolute reduction in “death caused by bleeding”.

Napalitano, et al. J Trauma July 2013

Why Not Blood Products?

- Some air medical services carry blood
- FFP study underway in EMS systems:

COMBAT (Control Of Major Bleeding After Trauma)

COMBAT Study - Denver

- Control Of Major Bleeding After Trauma
- Study effects on TIC (Trauma Induced Coagulopathy); randomizes into:
  1. Standard crystalloid resuscitation
  2. 2 units thawed plasma (type AB, FP 24)
- Equip ambulances with storage/thawing devices
- Use ROC criteria (SBP < 70 or SBP 71-90 with HR > 108)

COMBAT Study - Denver

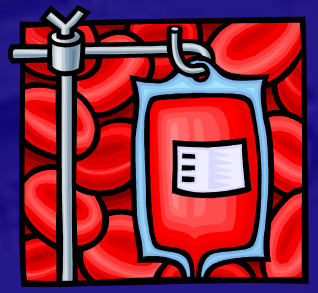
Ambulance Equipment ($13,600 each):

- Shore power ($1500)
- Inverter/charger ($1200)
- Lithium battery w/ controller ($3000)
- Plasmatherm Dry Water Bath ($7000)
  - Can run 36 hours on battery power
- Charging system control panel ($300)
- FFP Storage cooler ($600)

Return of the MAST?

- Post athletic event muscle recovery…

Summary



- Use hemostatic dsgs & TQs
- You have 5 L blood. Lose ½ and die.
- Step # 1 = find the leak (may need OR)
- Know your anatomy
- Tx BP after STOP bleed; or keep SBP ≤ 80
- Seal 4 sides sucking chest wound (AED)
- Don’t panic: all bleeding stops eventually

Thanks for your attention!

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