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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(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. Additional dressings
4. Pressure 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

- Explosion: 57%
- GSW: 27%
- Aviation: 11%
- MVC Multi: 2% (twice)
- Unk: 1%

n=413
Potentially Preventable Deaths

- Potentially preventable: 18%
- Non-preventable: 82%

n = 413
Causes of Preventable Deaths

- Hemorrhage: 81%
- Compressible: 32%
- Non-compressible: 68%

- Airway: 11%
- MSOF: 4%
- Other: 2%
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

- Bullets: 23%
- Burns: 6%
- Blast: 3%
- Other: 6%
- Fragments: 62%

(WWI, WWII, Korea, Vietnam, Middle East)
Compare to Civilian Deaths

Civilian – All Causes Deaths

- Hemorrhage: 33%
- CNS: 33%
- CNS+Hem: 17%
- Other: 6%
- MOF: 3%
- Airway: 8%

Potentially Preventable Military Hemorrhagic Deaths

- Ax/groin Hem: 22%
- Torso Hem: 46%
- Ext Hem: 32%

n = 72
Beyond Statistics
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
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.
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)
3. Coagulation

- Transforms blood from a liquid to a gel
- Begins in 30 seconds
Coagulation: 3 Steps

Injury to lining of vessel exposes collagen fibers; platelets adhere

Collagen fibers
Platelets
Fibrin

Platelets release chemicals that make nearby platelets sticky

PF₃ from platelets and tissue factor from damaged tissue cells
Calcium and other clotting factors in blood plasma

Coagulation

1. Formation of prothrombin activator
2. Prothrombin → Thrombin
3. Fibrinogen (soluble) → Fibrin (insoluble)
Detailed Events of Coagulation
# Coagulation: Clotting Factors

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

5 Liters Blood Volume

1 liter by volume

1 liter by volume

1 liter by volume

1 liter by volume

1 liter by volume
## ACS Classification of Acute Hemorrhage

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

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

Military studies: Army (USAISR) & Navy (NMRC)
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
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 ($\leq 8$)
- 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

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

Mobic 15mg
Tylenol ER 650mg, 2 caplets
Moxifloxacin 400mg

In the event of open combat wound swalllow all four pills with water.

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

• How do you manage pain?

[Diagram of WHO Analgesic Ladder]

- Aspirin & NSAIDs (if pain unrelieved)
- Add local anaesthetic & weak opioids (if pain unrelieved)
- Add strong opioids
Step 5 – Resuscitate

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

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

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 $\Rightarrow$ 500 ml IVF (may repeat X 1)
3. Bleeding uncontrolled = no IVF

Ideal permissive hypotension < 90 min.
Severe damage when > 120 min.

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

Step 5 – Resuscitate: REBOA

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

Self-expanding Foam

- Swine study, splenic rupture
Noncompressible Area?

- Direct pressure to a deep wound
- Expanding pellets…XStat™
Sucking Chest Wound (Open Pneumothorax)

(Requires a hole in the chest the size of a nickle or bigger)
Sucking Chest Wound (Treated)

Change: Cover completely 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

New: AED Pad

(No longer recommended)
Sucking Chest Wound

Even Better: Halo Chest Seal

PMI (Progressive Medical International)
GSW

Entrance wound
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

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

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