Damage Control
Resuscitation in Trauma

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I have no financial relationships to disclose.

Really.

Nada.

Zippo.

(you did get me out of taking call for the day........so thanks!)
Objectives

- Discuss the lethal triad
- Highlight some aspects of Damage Control Resuscitation
  - Permissive hypotension
  - Rapid control of surgical bleeding
    - “How I do it.”
  - Use of tranexemic acid (TXA)
  - Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)
- Conclusions
Hypothermia, Acidosis, and Coagulopathy | The Lethal Triad
Hemorrhagic Shock

- Uncontrolled hemorrhage is the second leading cause of death of US trauma patients
  - Massive transfusion patients (>10 units PRBCs/24hrs)
    - 10% of trauma patients
    - 1082 trauma centers:
      - 20 patients per year
      - 100 patients per year at the largest centers!
  - 30% of trauma patients are coagulopathic on admission
Injury and Ischemia

Hypoperfusion
Base deficit > -6

Tissue expresses thrombomodulin (TM)

TM complexes with thrombin

Protein C Pathway activated

Extrinsic Pathway inhibited

Systemic Anticoagulation

Trauma

Induced Coagulopathy

Endothelium releases tPA

Hyperfibrinolysis

Fibrinogen Depletion
Damage Control Resuscitation: Three Components

Damage Control Resuscitation
“stay out of trouble instead of getting out of trouble”

Permissive Hypotension

Hemostatic Resuscitation

Damage Control Surgery
Damage Control Resuscitation: *Guiding Principles*

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**Damage Control Resuscitation Principles**

1. Rapid recognition of high risk for trauma induced coagulopathy
2. Permissive hypotension
3. Rapid/definitive surgical control of bleeding
4. Prevention/treatment of hypothermia, acidosis, and hypocalcemia
5. Avoidance of hemodilution by minimizing use of crystalloids
6. Early transfusion of red blood cell:plasma: platelets in a 1:1:1 unit ratio
7. Use of thawed plasma and fresh whole blood when available
8. Appropriate use of coagulation factor products (rFVIIa) and fibrinogen-containing products

**Optional:** Use of fresh RBCs (storage age < 14 days)

**Optional:** When available thromboelastography to direct blood product and the hemostatic adjunct

**Optional:** Use of tranexamic acid early in resuscitation

**Optional:** Use of Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)

Damage Control Resuscitation: *Guiding Principles*

**Damage Control Resuscitation Principles**

1. Rapid recognition of high risk for trauma induced coagulopathy

2. Permissive hypotension

Damage Control Resuscitation: *Hypotensive Resuscitation*

- Morrison et al. (2011)\(^1\)
  - Ben Taub General Hospital: Level I, Houston, Tx
  - Prospective, randomized trauma trial with two arms
  - Objective: Assessing the effects of a limited transfusion and IV fluid strategy on 30 day morbidity and mortality

\(^1\)Morrison CA et al. Hypotensive Resuscitation Strategy Reduces Transfusion Requirements and Severe Postoperative Coagulopathy in Trauma Patients with Hemorrhagic Shock: Preliminary Results of a Randomized Controlled Trial. *J of Trauma* 2011; 70:652-663
Damage Control Resuscitation: *Hypotensive Resuscitation*

- Morrison et al. (2011)
  - 30 day follow-up
  - Groups well matched for age, mechanism, ISS, RTS, TRISS, SBP, HR, baseline BE, Hct
  - Patients in the LMAP group:
    - significantly less blood products, total IVF
    - significantly lower mortality in early postoperative period and a nonsignificant trend toward lower mortality at 30 days
    - significantly less likely to develop immediate post-op coagulopathy
    - significantly less likely to die from post-op bleeding associated with coagulopathy

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1Morrison CA et al. Hypotensive Resuscitation Strategy Reduces Transfusion Requirements and Severe Postoperative Coagulopathy in Trauma Patients with Hemorrhagic Shock: Preliminary Results of a Randomized Controlled Trial. *J of Trauma* 2011; 70:652-663
Damage Control Resuscitation: Hypotensive Resuscitation

“Hypotensive resuscitation is a safe strategy for use in the trauma population....resuscitating patients with the intent of maintaining a target minimum MAP of 50 mmHg.....significantly decreases postoperative coagulopathy and lowers the risk of early postoperative death and coagulopathy. These preliminary results provide convincing evidence that support the continued investigation and use of hypotensive resuscitation in the trauma setting.”

1Morrison CA et al. Hypotensive Resuscitation Strategy Reduces Transfusion Requirements and Severe Postoperative Coagulopathy in Trauma Patients with Hemorrhagic Shock: Preliminary Results of a Randomized Controlled Trial. J of Trauma 2011; 70:652-663
Damage Control Resuscitation: *Guiding Principles*

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**Damage Control Resuscitation Principles**

1. Rapid recognition of high risk for trauma induced coagulopathy
2. Permissive hypotension
3. **Rapid/definitive surgical control of bleeding**

Damage Control Surgery: *Three Components*

**Part I**
- OR: Part I

**Part II**
- ICU

**Part III**
- OR: Part II

### Abbreviated Resuscitative Surgery
Rapid control of contamination and hemorrhage
Obtain as quickly as possible:
- Control hemorrhage
- Restore flow where needed
- Control or contain contamination
- Intra-abdominal packing and temporary abdominal closure

### Resuscitation, Diagnosis, and the “Deep Breath”
Over 24 to 48 hours:
- Core re-warming
- Correction of coagulopathy
- Fluid resuscitation and optimization of hemodynamic status
- Re-examination and diagnosis of all injuries
- Get your “ducks in a row”

### Definitive Management
With restoration of normal physiology:
- Definitive management of abdominal injuries
- Abdominal wall closure
When should I consider “Damage Control Surgery” pre-operatively?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massive blood loss</td>
<td>10 - 15 units of packed red blood cells</td>
</tr>
<tr>
<td>Severe Injury</td>
<td>ISS &gt; 35</td>
</tr>
<tr>
<td>Hypotension</td>
<td>Shock &gt; 70 minutes</td>
</tr>
<tr>
<td>Hypothermia</td>
<td>Temperature &lt; 34° C</td>
</tr>
<tr>
<td>Coagulopathy</td>
<td>Partial Thromboplastin Time &gt; 60 sec</td>
</tr>
<tr>
<td>Acidosis</td>
<td>pH &lt; 7.2</td>
</tr>
</tbody>
</table>

“With these caveats, the need for packing as a planned therapeutic approach can often be anticipated preoperatively.”

1 Shapiro MB et al. Damage Control: Collective Review. *J of Trauma* 2000; 49: 969 - 978
When should I consider “Damage Control Surgery” during an operation?

• Decision to truncate the procedure
  • Made when, in the judgement of the surgeon, definitive repair is either
    • likely to exceed the patient’s physiologic reserve
    • technically impossible

Indications for a “Damage Control” Approach*

1. Inability to achieve hemostasis due to coagulopathy
2. Inaccessible major venous injury
3. Time-consuming procedure in a patient with suboptimal response to resuscitation
4. Management of extra-abdominal life-threatening injury
5. Reassessment of intra-abdominal contents
6. Inability to re-approximate fascia due to visceral edema

Primary Operation and Hemorrhage Control

- Initial Damage Control Laparotomy (Part I)
  - Five Components
    - Control of hemorrhage
    - Exploration
    - Control of contamination
    - Definitive packing
    - Rapid abdominal closure
Damage Control Resuscitation: *Surgical Control*

- **Incision of choice**
  - midline, one motion, xiphoid to symphysis pubis
  - pelvic fracture: limit incision initially to above the umbilicus
  - Previous midline incision?
    - bilateral subcostal approach
    - facilitates dissection of bowel from undersurface of the midline scar

- **Now....rapid and orderly!**
  - blood and clot are quickly removed
  - wide lateral retraction of the abdominal wall with handheld retractors
  - four quadrant, multiple laparotomy pad “resuscitative” packing

- Warm the room
- Blood available
- Prep: “Crotch to notch”

- Incision of choice
- Remove blood and clot

- Lateral handheld retraction of abdominal wall

- 4 quadrant resuscitative packing
Damage Control Resuscitation: *Surgical Control*

- Gather information about sites of bleeding
- Place large mechanical retractor
- Control hemorrhage?
  - Yes - clamps or hands
  - No - vascular injury!
- Deep breath and take control!
- Anesthesia catch-up

Deep breath! Take control of the room. Let anesthesia know your parameters! Allow anesthesia to catch up.

Site of bleeding?

- Retroperitoneal vascular injury!
  - Look for retroperitoneal hematoma
  - Eviscerate small bowel
  - Bring aorta, IVC, and branches into the surgical field
- Hemorrhage Controlled?

- Yes
- No
Damage Control Resuscitation: *Surgical Control*

• After you’ve “caught up…..”
  • Further exploration
    • Pack removal, starting away from the site of injury
      • Increases working room
      • Improves exposure
    • Control bleeding first
      • Ligation of non-critical vessels
      • Temporary shunting of critical vessels
        • simple plastic tubes
        • intravascular stents
      • Aortic occlusion: preferably at diaphragmatic hiatus
      • Aquamantis for solid organ injuries
• Bleeding controlled?
  • Yes
  • Remove packs
  • No
  • 3 options:
    • Ligate vessels
    • Temporary Shunt
    • Aortic occlusion
• Caught up?
  • Yes
  • Hold your ground
  • No
  • Big breath! Biggest immediate problem has been dealt with!

Hold your ground

Big breath! Biggest immediate problem has been dealt with!

On to control of contamination!
Damage Control Resuscitation: Surgical Control

- Control Contamination
  - Hollow viscus injury - limit soilage
    - staples, clamps, suture
    - resection without anastamosis
- Proceed?
  - Decision in concert with anesthesia team
    - hypothermia?
    - acidosis?
    - prolonged shock?
    - coagulopathy?
    - presence and status of extra-abdominal injuries?

“Paradoxically, the more injured patient with more severe pathophysiology requires less to be done at this initial stage.”

Contamination? Yes

Damage Control mode?
- hypothermia?
- acidosis?
- prolonged shock?
- coagulopathy?
- other injuries?

No

Time to get out!
Proceed to therapeutic packing and temporary closure

Yes

Multiple options:
- Clamps
- Suture
- Staple

No anastamosis!

Damage Control mode?
- hypothermia?
- acidosis?
- prolonged shock?
- coagulopathy?
- other injuries?

No

OK to proceed to definitive repair, but be certain to revisit bailout criteria!
Damage Control Resuscitation: *Surgical Control*

- Pack and get out!
  - Therapeutic packing: 3 principles
    1. Pressure stops bleeding
    2. Pressure vectors should recreate tissue planes
    3. Tissue viability should be preserved
  - Coagulants are your friends!
    - Fibrin glue
    - RDH bandage
      - Microalgia derived polysaccharide
      - Hemostatic mechanism unknown
      - Effective in coagulopathic states
      - No donated products required
      - No premixing
      - Stable shelf-life
      - Evarrest Patch (Ethicon)

This is not defeat! Keep the patient alive at any cost, utilizing unconventional approaches and abbreviated surgical technique!
Damage Control Resuscitation: *Guiding Principles*

**Damage Control Resuscitation Principles***

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**Optional:** Use of fresh RBCs (storage age < 14 days)

**Optional:** When available thromboelastography to direct blood product and the hemostatic adjunct

**Optional:** Use of tranexamic acid early in resuscitation

**Optional:** Use of Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)

Damage Control Resuscitation: TXA

- Tranexamic Acid (TXA)
  - A synthetic derivative of the lysine that inhibits fibrinolysis by blocking the lysine binding sites on plasminogen.¹
  - Systematic review of the randomized trials of tranexamic acid in patients undergoing elective surgery identified 53 studies including 3836 participants:²
    - Tranexamic acid reduced the need for blood transfusion by a third (relative risk [RR] 0·61, 95% CI 0·54–0·70)
    - no significant reduction in mortality (0·61, 0·32–1·12).

Because the hemostatic responses to surgery and trauma are similar, tranexamic acid might reduce mortality due to bleeding in trauma patients.

Injury and Ischemia

Hypopertusion
Base deficit > -6

Endothelium releases tPA

Hyperfibrinolysis

Fibrinogen Depletion

Trauma

Induced Coagulopathy

TXA
Damage Control Resuscitation: CRASH-2

- Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant hemorrhage (CRASH-2): a randomized, placebo-controlled trial
  - Randomized, double blinded, controlled trial in 274 hospitals in 40 countries
  - 20,211 adult trauma patients with, or at risk of, significant bleeding randomly assigned within 8 h of injury to either:
    - tranexamic acid (loading dose 1 g over 10 min then infusion of 1 g over 8 h)
  - Primary outcome was death in hospital within 4 weeks of injury, and was described with the following categories: bleeding, vascular occlusion (myocardial infarction, stroke and pulmonary embolism), multi-organ failure, head injury, and other.
**Damage Control Resuscitation: CRASH-2**

<table>
<thead>
<tr>
<th></th>
<th>TXA (%) (n = 10096)</th>
<th>Placebo (%) (n = 10115)</th>
<th>Relative Risk</th>
<th>CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Cause mortality</td>
<td>1463 (14.5%)</td>
<td>1613 (16.0%)</td>
<td>0.91</td>
<td>0.85 - 0.97</td>
<td>0.0035</td>
</tr>
<tr>
<td>Risk of Death Due to Bleeding</td>
<td>489 (4.9%)</td>
<td>574 (5.7%)</td>
<td>0.85</td>
<td>0.76 - 0.96</td>
<td>0.0077</td>
</tr>
</tbody>
</table>

Tranexamic acid safely reduced the risk of death in bleeding trauma patients in this study. On the basis of these results, tranexamic acid should be considered for use in bleeding trauma patients.

Review of the Literature: **CRASH-2**

- **Cost:**
  - From CRASH-2, cost per life year saved:
    - Tanzania: $48
    - India: $66
    - UK: $64
  - At MUSC:
    - $239 a gram
    - $478 for the CRASH-2 protocol (2 grams)
      - tranexamic acid (loading dose 1 g over 10 min then infusion of 1 g over 8 h)
Damage Control Resuscitation: *Guiding Principles*

**Damage Control Resuscitation Principles**

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**Optional:** Use of Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)

What is REBOA?

- Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)
  - Balloon Catheter placed in Femoral Artery
  - Occlusion to stop infra-diaphragmatic bleeding
  - Technically easier than aortic cross clamping
  - Can be done prior to loss of pulse
What is REBOA?

- **TEMPORARY** bridge to hemorrhage control
  - Surgical Control
  - Endovascular Control
- Two occlusion locations based on expected source of hemorrhage
  - Zone I
  - Zone III
- Animal models suggest merit with up to 90 min of occlusion
- Balloon should be taken down ASAP
  - Ideally within 30 - 60 min
What is REBOA? **Technique**

1. Arterial Access and positioning of the sheath
2. Selection and positioning of the balloon
3. Inflation of the balloon
4. Operative / procedural control of bleeding
5. Deflation of the balloon
6. Sheath removal
What is REBOA? **Technique**

1. Arterial Access and positioning of the sheath
   - Obtain Common Femoral Artery Access
     - 2 cm below inguinal ligament
     - At least 18G if placing an a-line
   - Place Wire
   - Place 7F Sheath
   - Attach a-line transduction tubing
   - Confirm with X-Ray
   - Inflate balloon until pressure increases
   - Secure in place
What is REBOA?

**Technique**

2. Selection of Zone of Occlusion and positioning of the balloon
   - Two occlusion locations based on expected source of hemorrhage
     - Zone I
       - Sternal notch
     - Zone III
       - Xyphoid process
What is REBOA? *Technique*

3. Inflation of the balloon:
   - Monitor Arterial Waveform Feedback
     - Zone I: 8 cc
     - Zone III: 2 cc
   - Look for increase in BP above the Balloon
   - Feel for loss of contralateral pulse
   - Note the time of inflation

“Start 2, Start 8, don’t over-inflate!”
What is REBOA? *Technique*

4. Operative / procedural control of bleeding
   - Rapid control of hemorrhage after placement
   - Packing and clamps
   - Most suturing, ligating, solid organ removal, and vascular shunting can be done after balloon deflated
   - Pitfall:
     - Failure to work with heightened **URGENCY** after REBOA placed
     - Leaving balloon inflated too long
       - Zone 1: 30 – 60 min occlusion time
       - Zone 3: over 60 min may be tolerated
       - Longer time increases spinal cord, intestinal, extremity, and solid organ ischemia
     - Failure to secure the catheter
       - Migration can occur due to increased aortic distention by improved BP
What is REBOA? Technique

5. Deflation of the balloon
   • Pitfall:
     • Deflating the balloon too quickly before the treatment team is ready
   • Volume load prior to deflating balloon
   • Prepare for “wash-out”
   • 5 minutes for deflating the balloon
   • Committing multiple resources to a futile resuscitation
6. Sheath Removal

- May be used as arterial line
- Remove after coagulopathy is reversed.
- Arterial injury
  - Serial vascular exams to evaluate for compartment syndrome or evidenced of impaired flow from dissection or clot
  - Open placement requires open removal and repair
- REBOA Catheter removed ASAP
  - Sheath remains until coagulopathy reversed
  - Sheath removed and pressure held for 30 min
  - Pt on strict bed rest without moving leg for 6 hours
  - Q1 Hour Neurovascular checks of access leg
  - U/S to eval for femoral injury 1-3 days later

Pitfalls:

- Arterial thrombosis
- Inability to remove catheter
- Removal of sheath too soon

What is REBOA? Technique
What do I do when my patient is hemorrhaging?

“Damage Control”
Damage Control Resuscitation: *Guiding Principles*

**Damage Control Resuscitation Principles***

1. Rapid recognition of high risk for trauma induced coagulopathy
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Damage Control Resuscitation: Conclusions

• Remember:
  • There is no Level I or 2 evidence that this algorithm works!
  • There has never been a randomized trial of damage control surgery
  • Many of the underlying techniques have come from the military experience
    • applicability to urban trauma is questionable
    • applicability to rural trauma is questionable

“Damage Control Resuscitation continues to evolve…….”

Damage Control Resuscitation: Conclusions

“Damage Control Resuscitation continues to evolve…….”

- “Damage Control Protocol Boosts Survival in Trauma Patients by 250%”\(^1\)
  - “To truly achieve the outcomes expected with damage control resuscitation, you need to apply all three tenets, not just the principle of higher plasma and platelet ratios.”
- Retrospective study, 390 patients
  - 282 treated with damage control laparotomy alone
  - 108 treated with three part damage control resuscitation strategy (DCR)
  - Never been studied in a civilian population
Damage Control Resuscitation: Conclusions

“Damage Control Protocol Boosts Survival in Trauma Patients by 250%”

- DCR group had:
  - Improved 24 hour survival (97% vs. 88%, $P = 0.006$)
  - Improved 30 day survival (86% vs. 76%, $P = 0.03$)
  - Less evidence of the lethal triad on arrival to the ICU (46% vs. 88% $P < 0.001$)
  - Less IVF (5 vs. 14 L), less PRBCs (7 vs. 13 units), less plasma (8 vs. 11 units) and less platelets (no units vs. six units) in the first 24 hours

“After controlling for age, arrival base deficit, INR, and blood pressure, DCR was independently associated with a 2.5 increased odds of 30-day survival (95% CI 1.10 - 5.58; $P = 0.028$). DCR was the only factor that predicted 30-day survival.”

“Needless to say, DCR was a very meaningful adjunct to DCL management......their results will be very hard to ignore.”

Donald Trunkey, MD
Official Discussant
Professor of Surgery
Oregon Health & Science University
Thank you for your kind attention.
New Innovation: *Hype Curve*

VALUE

- Peak of Irrational Exuberance
- Real Company, Real Value
- Slope of Reality
- Trough of Diis disillusionment
- The Valley of Death
- An Idea

TIME
The ER-REBOA™ Catheter Quick Reference Guide
6 REBOA Steps: ME-FIIS (Pronounced ‘Me-Fiz’)

1. Measure
   - Sternal Notch
   - Xiphoid Process
   - Placement depth:
     - Zone 1: ~46 cm
     - Zone 3: ~28 cm
   - Deflate balloon
     - Ensure balloon is fully deflated
     - Hold vacuum for 5 seconds and close stopcock

2. Empty
   - Advance & twist peel-away to cover P-tip
     - Corkscrew twist to wrap balloon tightly
     - Ensure the balloon and P-tip are captured

3. Flush
   - Attach & flush arterial line
     - Use standard techniques
     - Ensure all air is purged

4. Insert
   - Insert peel-away into valve
     - Approximately 5 mm
   - Advance catheter to desired depth
     - Hold orange peel-away
     - Advance blue Catheter
     - Pull peel-away back after balloon passes valve

5. Position catheter
   - IF available, use x-ray or fluoroscopy to confirm position using radiopaque markers

Get Early CFA Access
- Obtain access using standard techniques
5. **Inflate**

### Inflation Volume

- **Zone 1**: Start with 8 cc
- **Zone 3**: Start with 2 cc

“Start 2, Start 8, Don’t Overinflrate.”
Start small, then check

![Inflation chart](image)

**Deflate**

- Deflate slowly
- Prepare team for potential rebound hypotension

![Deflation image](image)

**Remove**

- Fully deflate balloon
- Hold vacuum for 5 seconds and close stopcock
- Corkscrew twist the catheter to facilitate removal
- If necessary, remove catheter and introducer sheath as a unit

![Removal image](image)

**Caution**

- Check for full and equal pulse in each leg using your standard technique

- Monitor arterial waveform feedback
  - Look for increase in blood pressure above balloon
  - Feel for loss of contralateral pulse
  - Mark time of inflation

- Secure Catheter close to the introducer sheath

- Provide definitive hemorrhage control
  - The clock is ticking!
  - Move quickly to definitive control

![Catheter and Stopcock](image)

### Provide Definitive Treatment

![Stopcock and Catheter](image)

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**The REBOA Company**

www.prytimemedical.com

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This instruction is not a replacement for the instruction for use (IFU). The EIR-REBOA™ Catheter 3FU should be read in its entirety before using the device.

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