Damage Control

- Used in the Merchant Marine, maritime industry and navies since the 1950s to describe the emergency control of situations that may hazard the sinking of a ship.
- US Navy defines it as “the capacity of a ship to absorb damage and maintain mission integrity”
Damage Control

USS Cole
12 October 2000
Aden, Yemen
Damage Control
Damage Control in the Surgical Patient

- Control hemorrhage and contamination
- Correct physiologic parameters
- Definitive injury management and closure
Evolution of Damage Control in the Surgical Patient

- 1908 Pringle: compression and hepatic packing for portal venous hemorrhage

Ann Surg 1908; 48:541

NOTES ON THE ARREST OF HEPATIC HEMORRHAGE DUE TO TRAUMA.

BY J. HOGARTH PRINGLE, F.R.C.S.,
OF GLASGOW,

Lecturer on Surgery in Queen Margaret College, Surgeon to the Glasgow Royal Infirmary.

Rupture of the liver is fortunately an accident not often met with, but one which, when it is seen, may be associated with a condition of the patient as serious as any one can meet with in surgical practice. While small lacerations
Evolution of Damage Control in the Surgical Patient

- 1913 Halsted: gutta percha sheets to prevent granulation tissue from growing into gauze packing
Evolution of Damage Control in the Surgical Patient

After WWII through the Viet Nam War era:

- Packing fell into disfavor with reports of necrosis, sepsis and hemorrhage.
- Newer surgical techniques were thought to be better
Evolution of Damage Control in the Surgical Patient

1963: Shaftan, et al: faster and better resuscitation and better treatment of wounds to limit liver mortality

Evolution of Damage Control in the Surgical Patient

1979 Calne, et al: liver hemorrhage temporarily controlled with gauze packing enabling safe transfer and definitive management at a more appropriate institution.

The treatment of major liver trauma by primary packing with transfer of the patient for definitive treatment

R. Y. CALNE, P. MCMASTER AND B. D. PENTLOW*
Evolution of Damage Control in the Surgical Patient

- 1976 Lucas, CE and Ledgerwood, AM
Prospective evaluation of hemostatic techniques for liver injuries *J Trauma* 16:442
Evolution of Damage Control in the Surgical Patient

- 1981 Feliciano DV, Mattox KL, Jordan, GL Jr
- “Intra-abdominal packing for control of hepatic hemorrhage: a reappraisal”
  - *J Trauma. 1981 Apr;21(4):285-90*
- 90% survival rate in 10 patients with perihepatic packing
- “…intra-abdominal packing for control of exsanguinating hepatic hemorrhage appears to be a lifesaving maneuver in highly selected patients in whom coagulopathies, hypothermia, and acidosis make further surgical efforts likely to increase hemorrhage.”
Evolution of Damage Control in the Surgical Patient

- 1983 Stone, et al: coagulopathy contributed to poor outcomes. Proposed truncation of laparotomy, reversal of coagulopathy and then return to the OR for definitive surgical repair

Management of the Major Coagulopathy with Onset during Laparotomy

H. HARLAN STONE, M.D., PRISCILLA R. STROM, M.D., RICHARD J. MULLINS, M.D.

An experience with 31 patients who developed major bleeding diatheses during laparotomy was reviewed. Management of the initial 14 patients was by standard hematologic replacement,

From the Department of Surgery, Emory University School of Medicine, Atlanta, Georgia
Evolution of Damage Control in the Surgical Patient
Evolution of Damage Control in the Surgical Patient

Burch, et al 1992

Abbreviated Laparotomy and Planned Reoperation for Critically Injured Patients


JON M. BURCH, M.D.,* VICTOR B. ORTIZ, B.A.,* ROBERT J. RICHARDSON, M.D.,* R. RUSSELL MARTIN, M.D.,† KENNETH L. MATTOX, M.D.,* and GEORGE L. JORDAN, JR., M.D.*

The triad of hypothermia, acidosis, and coagulopathy in critically injured patients is a vicious cycle that, if uninterrupted, is rapidly fatal. During the past 7.5 years, 200 patients were treated with unorthodox techniques to abruptly terminate the laparotomy and

From the Baylor College of Medicine,* The Cora and Webb Mading Department of Surgery, and the Ben Taub General Hospital, Houston, Texas, and the Tripler Army Medical Center,† Hawaii
Evolution of Damage Control in the Surgical Patient

- 1993 Rotondo and the U Penn group coined “damage control laparotomy”

20 year review: mortality 52%, morbidity 40%
Damage Control
in the Surgical Patient

- Trauma, general surgery, vascular surgery, ortho
- Evolved to combat lethal triad and abort the ‘bloody, vicious cycle’
The Lethal Triad

HYPOTHERMIA

ACIDOSIS  COAGULOPATHY
“THE BLOODY VICIOUS CYCLE”

Kashuk J L, Moore EE, Millikan J S, Moore J B
J Trauma 1982; 22:672-279
Damage Control
in the Surgical Patient

- Communication essential between resuscitation team and ED, IR, OR, ICU, blood bank, laboratory and pharmacy
- Damage control patient is at or near the point of physiologic exhaustion
Damage Control
in the Surgical Patient

Recognition of who needs it

- Shock
- Coagulopathy
- Hypothermia (temperature $\leq 35^\circ C$)
- Massive transfusion or resuscitation
  - $\geq 10$ units of PRBCs
- Acidosis (pH $< 7.3$ or worsening base deficit)
- Definitive repair would require prolonged operative time or extensive surgical procedures ($> 90$ minutes)
- Surgeon ‘gestalt’
  - High-energy blunt torso trauma, multiple visceral injuries, multiple torso penetrating injuries, multiregional injury
Damage Control
in the Surgical Patient

Make the decision early!
Damage Control
in the Surgical Patient

Components

1. Abbreviated surgery for rapid control of hemorrhage and contamination
2. Resuscitation in the ICU with correction of physiologic abnormalities
3. Subsequent definitive repair and abdominal wall closure
Damage Control in the Surgical Patient

Abbreviated resuscitative surgery

- Do only necessary procedures
- Control bleeding
  - Ligation
  - Shunting
  - Packing
- Excision/stapling of bowel to prevent further contamination
- Limit heat loss
- Chest/abdomen/extremity all potential candidates
Damage Control in the Surgical Patient

- Temporary closure of the open abdominal defect
  - Towel clip closure
  - Zipper closure
  - Bogota bag
  - Velcro Closure
  - Vacuum pack
Temporary Closures

- **Vacuum Pack dressing**
  - Inexpensive
  - Perforated plastic sheet overlying bowel
  - Covered with towels, drains and adhesive drape
  - Drains placed to suction to control drainage
ICU Resuscitation

- Warm the patient
- Correct the acidosis
- Correct the coagulopathy
Hypothermia

-4.6°C per hour even with warm IV fluid, gases and air convection blankets

Mortality from 40% to 100% with core temp from 34°C to < 32°C
  - Jurkovich et al. *J Trauma* 1987; 27:1019
Hypothermia

- Cardiac dysrhythmias
- Reduces cardiac output
- Shifts the hemoglobin saturation curve to the left
- Affects clotting cascade
  - Platelet dysfunction, endothelial abnormalities and alterations in the fibrinolytic system
  - Coagulation assays inaccurate for hypothermic patient
  - $< 35^\circ\text{C} \rightarrow$ PT and PTT prolonged
Rewarming in the ICU

- Warm up the room
- Keep the patient dry
  - Remove wet linen/clothing
- Cover the head (foil, plastic)
- Warm the ventilator circuit
- Air-convection blanket
- All lines should have warming device
Rewarming in the ICU

If the temperature doesn’t respond

- Warm pleural lavage with NS via chest tubes
- Continuous AV warming
- Gel pads simulate water immersion connected to a control module
Resuscitation

- **Access:**
  - At least 2 large bore IVs
  - Central access
    - Introducer sheath—make sure large enough to float PA catheter if needed
    - Poiseuille’s Law
  - Lines placed in ED or OR usually considered “dirty”, may keep for 24 hours

\[
\text{Volume Flowrate} = \frac{\text{Pressure difference} \times \text{radius}^4}{\frac{8}{\pi} \text{viscosity} \times \text{length}}
\]
# Resuscitation

<table>
<thead>
<tr>
<th>Size</th>
<th>IV tubing</th>
<th>Blood Tubing</th>
<th>Trauma Tubing</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 g</td>
<td>125 ml/min</td>
<td>193 ml/min</td>
<td>247 ml/min</td>
</tr>
<tr>
<td>8.5 Fr</td>
<td>160 ml/min</td>
<td>310 ml/min</td>
<td>&gt;800 ml/min</td>
</tr>
</tbody>
</table>

- Dutky et al. Factors affecting rapid fluid resuscitation with large bore introducer catheters. *J Trauma* 1989; 29:856
Resuscitation

- A-line
- Urinary bladder pressure
- Baseline fluid rate 125 cc/hr with boluses as necessary
- PA catheter
  - Older patients
  - Large volume resuscitation
  - Base deficit/lactic acidosis not improving
- May need to consider inotropes---but only after tank is full
- H/H, Chem profile including Ca++, Phos, Mg++, lactic acid, INR, fibrinogen, platelet q 4 hours
Resuscitation

Endpoints of Resuscitation

- Re-establish end-organ perfusion
- Adequate urinary output
- Hematocrit > 20% (value depends upon age/sx)
  Keep > 30 if still bleeding!
- Restoration of vital signs
  - Normal mixed venous oxygenation
  - Normal or high cardiac output
- Clearance of lactic acidosis/base deficit
- Normalize pH---preferably without NaHCO₃ or THAM
Resuscitation

- Standardized resuscitation
  - Computerized (although started as a paper protocol)
  - Helped streamline resuscitations
  - Less dependence on junior residents knowing when to call

Standardized Trauma Resuscitation

*Female Hearts Respond Better*

*Bruce A. McKinley, PhD; Rosemary A. Kozar, MD, PhD; Christine S. Cocanour, MD; Alicia Valdivia, RN; R. Matthew Sailors, PhD; Drue N. Ware, MD; Frederick A. Moore, MD*
DO2I goal

1) Hb (PRBC; Hb > 10)
2) volume (LR; PCWP > 15)
3) Optimize CI - PCWP (Starling curve)
4) low dose Inotropes
5) vasopressor

Met inclusion criteria

On ICU admission:
at, PA, NG tonometer catheters
baseline ABG, Hb, lactate

DO2I goal

Monitor:
lactate, BD, PrCO2
bladder pressure
Q 4h (reassess sooner if abnormal)

24 hours?

Yes
Stop resuscitation
standard ICU care

No

1) Hb (PRBC; Hb > 10)
2) volume (LR; PCWP > 15)

3) Optimize CI - PCWP (Starling curve)

4) low dose Inotropes
5) vasopressor

Echocardiography
Resuscitation

- Intravascular volume restoration best accomplished using FFP in a 1:1 ratio with PRBCs
- Crystalloid use is more limited
Massive Transfusion
Massive Transfusion

- Massive transfusion
  - $\geq$ 10 units in first 24 hrs
  - More than one blood volume in first 12 hrs
- Traditional transfusion regimen: 6 units of PRBCs, then start FFP
- Hirshberg et al: computer model suggested that FFP:PRBC is 2:3
- FFP:PRBC of 1:1 is associated with decreased mortality and decreased transfusion requirements
Resuscitation

- **Blood Products**
  - Fresh whole blood
  - PRBCs + FFP
    - 1:1 or 1:2 ratio
  - Platelets
    - > 70,000
    - > 100,000 if intracerebral injury or eye injury
  - Cryoprecipitate
    - < 100 mg/dL
  - Recombinant factor VIIa (rFVIIa)
    - Diffuse coagulopathy
Massive Transfusion Protocol

**Factor VIIa**

- No FDA indication for traumatic shock
- Should only be considered on a compassionate use basis after surgical bleeding controlled, aggressive coagulation factor and platelet replacement has occurred and acidosis corrected
- Thrombotic events in this patient population not well characterized
- Use remains controversial
- More use of 1:1 PRBC to FFP, decreased use of Factor VIIa
Metabolic Acidosis

- Hypoperfusion
  - Shift from aerobic to anaerobic metabolism at the cellular level, i.e., cellular hypoxia

- Lactic acidosis
  - Able to clear lactate within 24 hours = 100% survival
Metabolic Acidosis

- Usually corrects on its own once patient is warm and volume resuscitated.
- $O_2$ debt repaid.
- Anaerobic $\rightarrow$ aerobic metabolism.
- Need for NaHCO$_3$ rare but...
  - If cardiotonic agents needed, keep pH > 7.2.
  - Avoid use of bicarb and THAM as this eliminates the use of base deficit for monitoring resuscitation.
Ventilation

- At risk for Acute Lung Injury (ALI)
  - Direct parenchymal lung injury
  - Shock
  - Massive resuscitation volumes
    - Chest wall compliance compromised
    - Pulmonary edema

- Abdominal packing/Abdominal hypertension
  - Elevate diaphragm
  - Increased thoracic pressure
  - Decreased compliance
Pitfalls

- Continued hemorrhage
  - Expect H/H to decrease
    - Equilibration
    - Continued non surgical losses especially if coagulopathy and hypothermia are not yet corrected
  - > 2 units PRBC/hour x 3 hours
    - Especially in a warm, non coagulopathic patient
Pitfalls

- Continued hemorrhage
  - Expect H/H to decrease
    - Equilibration
    - Continued non surgical losses especially if coagulopathy and hypothermia are not yet corrected
  - > 2 units PRBC/hour x 2 hours
    - Especially in a warm, non coagulopathic patient

Vessels that were constricted and NOT ligated at time of Op may begin bleeding as patient is warmed and resuscitated

RETURN TO THE OR (or IR)
Pitfalls

- Continued shock
  - Missed injury
  - Failed repair with leakage
  - Insufficient replacement of fluid from open abdomen
Urgent Reoperation

- OR is best place to be
- Vent requirements too much for the OR
  - Use bedside vent in the OR (if you can transport on vent)
  - Bring the OR to the ICU bedside
    - Not optimal if bleeding expected
Primary Abdominal Compartment Syndrome (ACS)

- Complication of damage control laparotomy
  - Abdominal packs
  - Ongoing bleeding
  - Progressive bowel edema
- Failure of non operative management of solid organ injuries
Secondary ACS

- No abdominal injuries
- Severe shock requiring massive resuscitation
- Pelvic fractures
- Bowel edema and ascites
Definitive Repair

- When to return to the OR?
  - When patients are warm, acidosis and coagulopathy corrected
  - 36-72 hours had reduced risk of rebleeding for patients with perihepatic packing
  - Coincides with fluid mobilization
    - ? Use of diuretics
Definitive Repair

Bowel injuries:

Colostomy or anastomosis?

- Delayed anastomoses were as safe as colostomy

Stapled vs hand-sewn anastomosis?

- Controversial as to which is best
- Surgeon comfort with technique
- Presence of bowel edema?
  - Edematous bowel more prone to leak
  - Wait for edema to resolve to do anastomosis
Closure

Velcro Patch
Vacuum Closure

- 92% of patients closed in mean of 9.9 ± 1.9 days

Closure

When the abdomen can’t be closed
- Bowel becomes “stuck”
- Multiple solutions
  - Permanent mesh
  - Absorbable mesh
  - Prosthetic patches
  - Bioprosthetic patches
  - STSG directly on granulated bowel
  - Component separation
SURVIVED – DISCHARGED TO HOME PID # 37
“The art of medicine consists in amusing the patient while nature cures the disease”

Voltaire