Optimal Fluid Management...or Doing Harm With Fluid?

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Trauma resuscitation
the beginning, the middle, and the end…

• Response to injury
  (…or why trauma is bad for you)

• Permissive hypotension
  (…or when good fluids turn bad)

• Damage control
  (…or when good doctors turn bad)

• When to stop resuscitating
  (…or when urinating is just not enough)
Why do trauma patients die?

- Overwhelming Injury
- Injury induced bleeding
- Traumatic brain injury
- Non-surgical hemorrhage (coagulopathy)
- Multiple organ failure/ Sepsis
classes of hemorrhagic shock.

Class I
- 750 cc: blood volume loss (BVL) 15%

Class II
- 750 – 1500cc: BVL 15 – 30%

Class III
- 1500 – 2000cc: BVL 30 – 40%

Class IV
- > 2000cc: BVL > 40%
classes of hemorrhagic shock.

Class I: Slightly anxious

Class II: Mildly anxious, HR > 100,
RR 20 - 30, UOP 20 - 30cc/hr

Class III: Confused, anxious, hypotensive
HR > 120, RR 30 - 40,
UOP 5-15cc/ hr

Class IV: Confused, lethargic, hypotensive,
HR > 140, RR > 35, anuric
ACS ATLS classification

Everyone gets 2L of crystalloid.

**Responders** (I, II)
- Fluid 2L LR or .9NS

**Transient Responders**
- (III, ongoing bleeding)
- Blood

**Non-Responders**
- (III, IV, ‘Audible hemorrhage’)
- Lots of Blood
What fluid?

Crystalloid

Minimal in field.

2L in ED

LR or .9NS

LR in general trauma, .9NS in TBI
What fluid? Colloid vs crystalloid

Crystalloid
- Cheap
- Available
- .9 associated with acidosis
- Baxter LR uses L-Lactate (with less inflammation)

Colloid
- Expensive
- Less volume, more volume expansion.
- Less leakage into interstitium?

Bottom line
SAFE trial showed no difference between albumin and saline in patients with trauma without TBI.
Patients with TBI had higher mortality 24.6% vs 15% RR 1.62
All Trauma patients mortality was 13.5% vs 10%
Short of whole blood or HTS, crystalloid used judiciously is best.
Is the ATLS mantra correct?

What is the evidence for giving large amounts of fluid?

Is the physiology of the injured patient more complicated than we think?

Should we change?
Response to trauma

- Injury
- Preservation
- Hemorrhage control
- Resuscitation
- Time
Remember?
A little better
Response to injury - inflammation

Local response:
Complement, kinin, coagulation, fibrinolytic
Phagocytes & endothelial cells

Four major events:

- Vasodilatation
- Increased microvascular permeability
- Cellular activation & adhesion
- Coagulation and Inflammation

Benign as long as it is appropriately regulated
Response to injury - inflammation

Major metabolic response:

Increase in oxygen consumption
A-V oxygen difference maintained if oxygen delivery maintained

Anaerobic metabolism if body fails to meet oxygen deficit - Acidosis
Response to injury - inflammation

Physiological response to stress & injury

- Cardiovascular changes
  HR, contractility, CO
- Neuroendocrine changes
  Catecholamines, cortisol, ADH, GH, glucagon & insulin
- Fluid requirement increases
  increased endothelial permeability – ‘3rd spacing’
Response to injury - inflammation

Activated endothelial cells express multiple factors that make local environment at first anticoagulant and then procoagulant.
Coagulation and fibrinolysis cascades activated & exhausted.
Endothelial cell injury

Excessive microthrombi
Obstruction of local blood flow
Loss of cytoprotectivity

MODS
Response to injury - inflammation

- Insult
- Local response
- Cytokines
  - Macrophages
  - Endothelial cells
- Paracrine/autocrine activation
- Amplification/loss of homeostasis
- SIRS

Stage I
Stage II
Stage III

Endocrine  Haematology  Brain  Liver  Heart  Lung  Gut  Kidney  Metabolic

Multiple organ dysfunction syndrome
Acute Traumatic Coagulopathy: Role of Hypoperfusion and Thrombin Formation

A. PTT (s)

B. PT (s)

C. PTT (s)

D. PT (s)

Prothrombin fragments 1+2

Prothrombin fragments 1+2 (nM)
Acute Traumatic Coagulopathy is Associated with an Increased Mortality

Mortality (%)

Protein C (%)
Acute Traumatic Coagulopathy is Associated with Increased Organ Injury

Odd ratio (95% CI) for Low Protein C

<table>
<thead>
<tr>
<th>Condition</th>
<th>Odd Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator-free days ≤ 26</td>
<td>2.2</td>
</tr>
<tr>
<td>Acute Renal injury</td>
<td>3.6</td>
</tr>
</tbody>
</table>
Activation of Complement is Related to Clinical Outcomes of Patients with Severe Trauma

**Diagram A**

- **Mortality**
  - Bars represent different mortality rates across different Bb concentrations (μg/ml):
    - <.49
    - .49-.60
    - .61-.81
    - >.81

**Diagram B**

- **Mortality**
  - Bars represent different mortality rates across different sC5b-9 concentrations (ng/ml):
    - <145
    - 145-202
    - 203-305
    - >305

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**Diagram C**

- **Bb [μg/ml]**
  - Categories: No ALI/ARDS, ALI/ARDS, VFD > 26, VFD 26, No ARF, ARF, Transfusion 2, Transfusion > 2
  - Bars represent different levels of Bb concentrations with asterisks indicating significance.

**Diagram D**

- **sC5b-9 [ng/ml]**
  - Categories: No ALI/ARDS, ALI/ARDS, VFD > 26, VFD 26, No ARF, ARF, Transfusion 2, Transfusion > 2
  - Bars represent different levels of sC5b-9 concentrations with asterisks indicating significance.
Response to injury - our fluids contribute

permeability

neutrophil rolling
Response to injury - our fluids contribute to permeability
Resuscitation - what’s wrong? why change?

1. The clinical trajectory of patients is set during the first few hours of resuscitation

2. Continuous fluid resuscitation in the face of on-going hemorrhage leads to physiological exhaustion

3. Induced tissue edema leads to multiple organ failure

4. Shock activates and our therapy amplifies the inflammatory response
# Fluid resuscitation - a history

<table>
<thead>
<tr>
<th>Era</th>
<th>Focus</th>
<th>Resuscitation</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>World War I</td>
<td>Wound toxins</td>
<td>None</td>
<td>Early death</td>
</tr>
<tr>
<td>World War II, Korean war</td>
<td>Intravascular repletion</td>
<td>Colloids, blood</td>
<td>↑ Early survival</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ARF → death</td>
</tr>
<tr>
<td>Vietnam war</td>
<td>Intravascular and extracellular fluid repletion</td>
<td>Crystalloids, banked blood</td>
<td>↑ Early survival</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>↓ ARF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ARDS → death</td>
</tr>
<tr>
<td>1970s–80s</td>
<td>ICUs, organ failure, metabolic support</td>
<td>PA catheters, endpoints of resuscitation</td>
<td>↓ ARF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ARDS ? MOF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>↑ MOF deaths</td>
</tr>
<tr>
<td>Mid-1980s to present</td>
<td>Trauma centres, trauma systems</td>
<td>Rapid triage, damage control, shock and trauma ICUs</td>
<td>↑ Early survival</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>↑ ARDS/MOF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>↓ ARDS/MOF deaths</td>
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ARF=acute renal failure. ARDS=adult respiratory distress syndrome. MOF=multiple organ failure.
Permissive Hypotension

“if the pressure is raised before the surgeon is ready to check any bleeding that may take place, blood that is sorely needed may be lost.”

Permissive hypotension (rediscovery)

Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries

Bickell WH, Wall MH, Pepe PE, Martin RR, Ginger VF, Allen MK, Mattox KL, Department of Emergency Services, Saint Francis Hospital, Tulsa, Oklahoma, USA


- Prospective, randomized pre-hospital trial
- 598 patients with penetrating torso trauma and systolic BP < 90
- Initial BP averaged 72 mmHg in ‘limited’ resusc, 78mm in ‘standard’
- Standard resuscitation vs Limited resuscitation (until surgical intervention)
- 2480 mls vs 375 mls IV fluids
- Limited resuscitation : 30% mortality and 23% complication rate
- Standard Resuscitation : 38% mortality (p=0.04) and 30% complication rate
Permissive hypotension - evidence

Early versus late fluid resuscitation: lack of effect in porcine hemorrhagic shock.

Chudnofsky CR, Dronen SC, Syverud SA, Hedges JR, Zink BJ.
Department of Emergency Medicine, University of Cincinnati, Ohio 45267-0769.

- Porcine model simulating early vs late resuscitation
- 28 animals bled at 1.25 ml/kg/min
- Early: 1 mL/kg/min beginning 20 minutes after initiation of hemorrhage
- Late: 3 mL/kg/min beginning 35 minutes after hemorrhage
- Both groups received blood and saline at 3 mL/kg/min 45 minutes after hemorrhage began
- Both groups had hemorrhage controlled 25 minutes after simulated hospital arrival.
- Survival 57% in both groups.
Permissive hypotension - evidence

The detrimental effects of intravenous crystalloid after aortotomy in swine.

Bickell, WH, Brutting SP, Millnamow GA, O'Benar J, Wade CE
Division of Military Trauma Research, Letterman Army Institute of Research,
Presidio of San Francisco

- 16 swine. Splenectomy & aortotomy
- Treatment group: 80 ml/kg Ringer’s
- No treatment: 0 ml/kg
- Mortality higher in treatment group (8 of 8 vs 0 of 8)
- Volume of hemorrhage higher in treatment group
  2142 +/- 178 ml versus 783 +/- 85 ml
Permissive hypotension - evidence

Hypotensive resuscitation during active hemorrhage: Impact on in-hospital mortality

Dutton RP, MacKenzie CF, Scalea TM, R Adams Cowley Shock Trauma Center, and the Departments of Anesthesiology and Surgery, University of Maryland School of Medicine, Baltimore, Maryland.

J Trauma 2002 June;52(6):1141-1146

- Patients in hemorrhagic shock randomized to target BP of 70mmHg or 100mmHg
- Fluid administered to this endpoint until hemorrhage control
- 114 mm Hg vs. 100 mm Hg, p < 0.001
- No difference in mortality
Improved Survival with Early Fluid Resuscitation Following Hemorrhagic Shock

Alberto S. Santibanez-Gallerani, M.D., Annabel E. Barber, M.D., Shelley J. Williams, M.S., Yan Zhao, B.S., G. Tom Shires, M.D.
Department of Surgery, University of Nevada School of Medicine, Las Vegas, Nevada,

- 80 rats
- Systemic heparin
- Hemorrhage to 35% of blood volume
- Randomised to early (15mins), delayed (60mins) or no fluid resuscitation
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World J. Surg. 25, 592-597, 2001
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Permissive hypotension - evidence

Over 44 further animal studies in the literature

None supporting early or aggressive fluid resuscitation

Includes evidence to support the use in concomitant traumatic brain injury

Much smaller number of clinical studies
Ineffectiveness of On-Site Intravenous Lines: Is prehospital time the culprit?


- 217 patients on-site intravenous fluid replacement (IV group) with patients for whom this intervention was not performed (no-IV group).
- The mortality rates for the IV and no-IV groups were 23 and 6% (p < 0.001)
- Use of on-site intravenous fluid replacement was associated with a significant increase in the risk of mortality (adjusted odds ratio = 2.3; p = 0.04)
Permissive hypotension - evidence

Timing and volume of fluid administration for patients with bleeding following trauma.

Kwan I, Bunn F, Roberts I, WHO Pre-Hospital Trauma Care Steering Committee.
Department of Paediatric Epidemiology and Biostatistics,

Cochrane Database of Systematic Reviews. Last updated 2000 Sep 25.
Repeated in the Cochrane Library, Issue 3, 2002

‘meta-analysis’ of 3 studies
RR mortality:

A (n=598) : RR 1.26
B (n=50) : RR 5.4
C (n=1309) : RR 1.03

CONCLUSIONS: We found no evidence from randomised controlled trials to support early or larger volume of intravenous fluid administration in uncontrolled hemorrhage.
Coagulopathy

**Causes:**

- **Tissue Injury**
  - Tissue factor release
  - Long bone
  - Brain
- **Inflammation**
- **Hypothermia**
- **Hemodilution**
Hypothermia

**Causes:**

- Shock
- Cold intravenous fluids
- Cool environment
- Open body cavities
- Cold ventilation
Acidosis

**Causes:**
- Shock
- Hypothermia

**Effects:**
- Coagulopathy
- Myocardial depression
Severe Trauma

Bleeding – Consumption

Fluid Replacement  RBC Transfusion

Dilution  Hypothermia

Coagulopathy

Classical Teaching...
Physiological exhaustion

HYPOTHERMIA

COAGULOPATHY      ACIDOSIS

Diagram showing the relationship between hypothermia, coagulopathy, and acidosis.
‘The modern operation is safe for the patient –

The modern surgeon must make the patient safe for the modern operation’

- Lord Moynihan

1890
Damage Control

Multiple trauma patients are more likely to die from their intra-operative metabolic failure than from a failure to complete operative repairs.
Damage Control

Arrest hemorrhage
Prevent sepsis
Protect from further injury
NOTHING ELSE
Damage Control

**Surgical techniques**

Liver packing
Splenectomy
Vascular shunts
Bowel stapling
Pulmonary tractotomy
Lung twist
Damage control orthopedics
Damage Control

More than just a surgical technique

Prehospital care
Emergency department conduct
Operating room
ICU care

Change in Mindset
Trauma resuscitation

- Preservation
  - Haemorrhage control
- Resuscitation
  - Time

Injury