Initial fluid resuscitation in multiple trauma

ATLS criticized

Armand R.J. Girbes

Netherlands
Advanced Trauma Life Support®
for Doctors

ATLS
American College of Surgeons
Committee on Trauma

Student Course Manual
1997
Initial fluid resuscitation in multiple trauma

• **ATLS – hemorrhage** (Chapter 3, page 93)
  – Class I
    • cf. = condition of blood organ donor
  – Class II
    • Uncomplicated hemorrhage, crystalloids required
  – Class III
    • Complicated hemorrhage, crystalloids and perhaps RBC required
  – Class IV
    • Preterminal event, very aggressive measures necessary
### Table 1
**Estimated Fluid and Blood Losses**
Based on Patient's Initial Presentation

<table>
<thead>
<tr>
<th></th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blood Loss (mL)</strong></td>
<td>Up to 750</td>
<td>750–1500</td>
<td>1500–2000</td>
<td>&gt;2000</td>
</tr>
<tr>
<td><strong>Blood Loss</strong></td>
<td>Up to 15%</td>
<td>15%–30%</td>
<td>30%–40%</td>
<td>&gt;40%</td>
</tr>
<tr>
<td>(% Blood Volume)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pulse Rate</strong></td>
<td>&lt;100</td>
<td>&gt;100</td>
<td>&gt;120</td>
<td>&gt;140</td>
</tr>
<tr>
<td><strong>Blood Pressure</strong></td>
<td>Normal</td>
<td>Normal</td>
<td>Decreased</td>
<td>Decreased</td>
</tr>
<tr>
<td><strong>Pulse Pressure</strong></td>
<td>Normal or increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td>Decreased</td>
</tr>
<tr>
<td>(mm Hg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Respiratory Rate</strong></td>
<td>14–20</td>
<td>20–30</td>
<td>30–40</td>
<td>&gt;35</td>
</tr>
<tr>
<td><strong>Urine Output</strong></td>
<td>&gt;30</td>
<td>20–30</td>
<td>5–15</td>
<td>Negligible</td>
</tr>
<tr>
<td>(mL/hr)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CNS/Mental Status</strong></td>
<td>Slightly anxious</td>
<td>Mildly anxious</td>
<td>Anxious, confused</td>
<td>Confused, lethargic</td>
</tr>
<tr>
<td><strong>Fluid Replacement</strong></td>
<td>Crystalloid</td>
<td>Crystalloid</td>
<td>Crystalloid and blood</td>
<td>Crystalloid and blood</td>
</tr>
<tr>
<td>(3:1 Rule)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 For a 70-kg man.

The guidelines in Table 1 are based on the “3-for-1” rule. This rule derives from the empiric observation that most patients in hemorrhagic shock require as much as 300 mL of electrolyte solution for each 100 mL of blood loss. Applied blindly, these guidelines can result in excessive or inadequate fluid administration. For example, a patient with a crush injury to the extremity may have hypotension out of proportion to his or her blood loss and requires fluids in excess of the 3:1 guidelines. In contrast, a patient whose ongoing blood loss is being replaced by blood transfusion requires less than 3:1. The use of bolus therapy with careful monitoring of the patient’s response can moderate these extremes.
<table>
<thead>
<tr>
<th></th>
<th>Rapid Response</th>
<th>Transient Response</th>
<th>No Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital Signs</td>
<td>Return to normal</td>
<td>Transient improvement; recurrence of ↓BP and ↑HR</td>
<td>Remain abnormal</td>
</tr>
<tr>
<td>Estimated Blood Loss</td>
<td>Minimal (10%-20%)</td>
<td>Moderate and ongoing (20%-40%)</td>
<td>Severe (&gt;40%)</td>
</tr>
<tr>
<td>Need for More Crystalloid</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Need for Blood</td>
<td>Low</td>
<td>Moderate to high</td>
<td>Immediate</td>
</tr>
<tr>
<td>Blood Preparation</td>
<td>Type and crossmatch</td>
<td>Type-specific</td>
<td>Emergency blood release</td>
</tr>
<tr>
<td>Need for Operative Intervention</td>
<td>Possibly</td>
<td>Likely</td>
<td>Highly likely</td>
</tr>
<tr>
<td>Early Presence of Surgeon</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

1 2000 mL Ringer's lactate solution in adults, 20 mL/kg Ringer's lactate bolus in children.
Initial fluid resuscitation in multiple trauma

• We – human beings (including doctors) – like certainty
• Certainty $\rightarrow$ feeling of safety
• We need safety
Feel safe

• My personal career

  – < 6 years
    • my parents know everything
  – 6-12 years
    • my school teacher knows everything
  – 12-18 years
    • My high-school teachers went to university: they know everything
  – 18-24 years
    • Doctors who finished their study know everything
  – 24-28 years
    • The consultant / medical specialist knows everything
  – 28-30 years
    • My professor / head of department knows everything
  – > 30 years
    • Disappointment …
  – > 40
    • More disappointment …
ATLS and Religion

Hemorrhagic shock
Initial fluid resuscitation in multiple trauma

• **Warning**

  – Initial part is provocative
  – Presentation will increase, rather than eliminate, doubts
Initial fluid resuscitation in multiple trauma

- Show the data
  - Not opinions
Hemorrhagic shock

• **Therapy**
  – Early and aggressive fluid resuscitation (as ATLS)
  – Data
    • Experimental work
    • Hemorrhage model – irreversible shock
    • “Wiggers preparation”
Hemorrhagic shock

• **Observations from Wiggers preparation**
  – Irreversible shock induction requires:
    • 45 minutes of severe hypotension (MAP < 30-40 mm Hg)
    • Several hours of hypotension
  – Prolonged hemorrhagic shock \( \Rightarrow \) ECF deficit
    • ECF deficit correction requires 3x estimated blood loss
      – \( \Rightarrow \) 3:1 rule
Hemorrhagic shock

Fluid Therapy in Hemorrhagic Shock

TOM SHIRES, MD; DALE COLN, MD; JAMES CARRICO, MD; AND STANLEY LIGHTFOOT, MD, DALLAS

ARCHIVES OF SURGERY
Vol 88, April, 1964
Hemorrhagic shock

- Mongrel dogs n=30 (previous splenectomy)
- Hemorrhagic shock model
  - Bleeding 50 ml/min till MAP 50 mm Hg (via side arm of arterial catheter)
  - MAP 50 mm Hg during 90 minutes (by additional bleeding)
  - MAP 30 mm Hg during 45 minutes (id)
  - Administration of shed blood plus RL or Plasma or nothing
    - RL - 5% of body weight
    - Plasma - 10 cc/kg
- In cage and observation

Shires et al. 1964
Hemorrhagic shock

Shires et al. 1964
Hemorrhagic shock

• **Conclusions**
  – Importance of ECF
  – Reduction of standard Wiggers model 80% mortality to 30%
Hemorrhagic shock

• In this (controlled hemorrhagic) model:
  – Rapid restoration of circulating volume and ECF 有益
  – 3:1 rule
  – crystalloids important!!
  – 3:1 rule
Hemorrhagic shock

• Wiggers model
  – Is this reality?
  – Is it similar to reality?
Hemorrhagic shock

• **Is this reality?**
  
  – Maybe, after surgical control (if applicable)
  
  – No, if bleeding is not controlled
Hemorrhagic shock

The detrimental effects of intravenous crystalloid after aortotomy in swine*

William H. Bickell, MD, Stephen P. Bruttig, PhD, Gregory A. Millnamow, MA,
John O’Benar, PhD, and Charles E. Wade, PhD, San Francisco, Calif., and Tulsa, Okla.

From these data we conclude that, in this model of uncontrolled arterial hemorrhage resulting from abdominal aortotomy, rapidly administering lactated Ringer’s solution intravenously significantly increases hemorrhage and death.
(Surgery 1991;110:529-36.)
Hemorrhagic shock

• Bickell
  – Questions the validity of the Wiggers model
  – Questions the current guidelines
  – Model with uncontrolled bleeding
Hemorrhagic shock
Hemorrhagic shock
Crystalloid resuscitation

• **Swine n=16**
  – Splenectomy
  – Aortotomy wire – 0.5 cm
  – Close abdomen

  – Spontaneous breathing
  – Pulling the wire \(\rightarrow\) 0.5 cm tear in aorta
Crystalloid resuscitation

• **Protocol**
  – 2 treatment groups
    • No treatment
    • Crystalloid treatment according to 3:1 rule (3x26 ml/kg)

• **Endpoints**
  – Survival
  – Blood loss
Crystalloid resuscitation

• Survival

Bickell et al. 1991
Crystalloid resuscitation

• Hemorrhage

- Control group  783 ± 85 ml
- Crystalloid group  2142 ± 178 ml

Bickell et al. 1991
Crystalloid resuscitation

• Hemodynamics

Bickell et al. 1991
Crystalloid resuscitation

• Conclusions

– Crystalloids kill

Bickell et al. 1991
Crystalloid resuscitation

• Reinvention of old knowledge!!!

Injection of a fluid that will increase blood pressure has dangers in itself. Hemorrhage in a case of shock may not have occurred to a marked degree because pressure has been too low and the flow too scant to overcome the obstacle offered by a clot. 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.

WB Cannon, 1918

Cannon WB, Fraser J.
JAMA 1918, 70:618-621
Initial fluid resuscitation in multiple trauma

- **Current belief**
  - Hypotensive injury victims
    - Good outcome propter large fluid resuscitation
  - Hypotensive injury victims who die
    - Despite FR or too late FR and/or already “irreversible” shock

Solomonov et al. CCM 2000
Fluid resuscitation

- The proof of the (human) pudding is in the eating
Delayed fluid resuscitation

- **Patients n=598**
  - Penetrating torso injury
  - Prehospital RRsys ≤ 90 mm Hg
  - **Exclusion**
    - Fatal gunshot wound to the head

Bickell, NEJM 1993
Delayed fluid resuscitation

• **Protocol**
  – Randomization
    • Even days   - immediate resuscitation
      – 14 G needle + rapid infusion en route
    • Odd days   - delayed resuscitation

Bickell, NEJM 1993
Table 1. Characteristics of 598 Patients with Penetrating Torso Injuries Who Received Immediate or Delayed Fluid Resuscitation.*

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>IMMEDIATE RESUSCITATION (N = 309)</th>
<th>DELAYED RESUSCITATION (N = 289)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>31±11</td>
<td>31±10</td>
</tr>
<tr>
<td>Male sex (% of patients)</td>
<td>88</td>
<td>91</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>58±35</td>
<td>59±34</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>26±14</td>
<td>26±14</td>
</tr>
<tr>
<td>Revised Trauma Score</td>
<td>5.4±2.1</td>
<td>5.6±2.1</td>
</tr>
<tr>
<td>Probability of survival</td>
<td>69</td>
<td>72</td>
</tr>
<tr>
<td>Mechanism of injury (% of patients)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gunshot wound</td>
<td>65</td>
<td>67</td>
</tr>
<tr>
<td>Stab wound</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>Shotgun-blast wound</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Primary site of surface injury (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Chest</td>
<td>33</td>
<td>35</td>
</tr>
<tr>
<td>Abdomen</td>
<td>63</td>
<td>62</td>
</tr>
<tr>
<td>Patient care times (min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response interval</td>
<td>8±5</td>
<td>8±6</td>
</tr>
<tr>
<td>Scene interval</td>
<td>9±8</td>
<td>7±6</td>
</tr>
<tr>
<td>Transport interval</td>
<td>13±6</td>
<td>12±6</td>
</tr>
<tr>
<td>Trauma-center interval</td>
<td>44±65</td>
<td>52±99</td>
</tr>
<tr>
<td>Intraoperative interval</td>
<td>114±105</td>
<td>134±101</td>
</tr>
</tbody>
</table>

*Plus-minus values are means ±SD.

†P = 0.028 for the comparison between groups.
Table 2. Systemic Arterial Blood Pressure and Laboratory Findings on Arrival at the Trauma Center in Patients with Penetrating Torso Injuries, According to Treatment Group.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Immediate Resuscitation (N = 309)</th>
<th>Delayed Resuscitation (N = 289)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>79±46</td>
<td>72±43</td>
<td>0.02</td>
</tr>
<tr>
<td>Hemoglobin (g/dl)</td>
<td>11.2±2.6</td>
<td>12.9±2.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Platelet count (×10^3/mm^3)</td>
<td>274±184</td>
<td>297±88</td>
<td>0.004</td>
</tr>
<tr>
<td>Prothrombin time (sec)</td>
<td>14.1±16</td>
<td>11.4±1.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Partial-thromboplastin time (sec)</td>
<td>31.8±19.3</td>
<td>27.5±12</td>
<td>0.007</td>
</tr>
<tr>
<td>Systemic arterial pH</td>
<td>7.29±0.17</td>
<td>7.28±0.15</td>
<td>0.46</td>
</tr>
<tr>
<td>Serum bicarbonate concentration (mmol/liter)</td>
<td>20±10</td>
<td>20±11</td>
<td>0.82</td>
</tr>
</tbody>
</table>

*Plus–minus values are means ±SD. To convert values for hemoglobin to millimoles per liter, multiply by 0.62.
<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>IMMEDIATE RESUSCITATION (N = 309)</th>
<th>DELAYED RESUSCITATION (N = 289)</th>
<th>P VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before arrival at the hospital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ringer’s acetate (ml)</td>
<td>870±667</td>
<td>92±309</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Trauma center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ringer’s acetate (ml)</td>
<td>1608±1201</td>
<td>283±722</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Packed red cells (ml)</td>
<td>133±393</td>
<td>11±88</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Operating room†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ringer’s acetate (ml)</td>
<td>6772±4688</td>
<td>6529±4863</td>
<td>0.31</td>
</tr>
<tr>
<td>Packed red cells (ml)</td>
<td>1942±2322</td>
<td>1713±2313</td>
<td>0.07</td>
</tr>
<tr>
<td>Fresh-frozen plasma or platelet packs (ml)</td>
<td>357±1002</td>
<td>307±704</td>
<td>0.45</td>
</tr>
<tr>
<td>Autologous-transfusion volume (ml)</td>
<td>95±486</td>
<td>111±690</td>
<td>0.76</td>
</tr>
<tr>
<td>Hetastarch (ml)</td>
<td>499±717</td>
<td>542±696</td>
<td>0.41</td>
</tr>
<tr>
<td>Rate of intraoperative fluid administration (ml/min)</td>
<td>117±126</td>
<td>91±88</td>
<td>0.008</td>
</tr>
</tbody>
</table>

*Plus-minus values are means ± SD.
†For these analyses there were 268 patients in the immediate-resuscitation group and 260 patients in the delayed-resuscitation group.
Table 5. Outcome of Patients with Penetrating Torso Injuries, According to Treatment Group.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>IMMEDIATE RESUSCITATION</th>
<th>DELAYED RESUSCITATION</th>
<th>P VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival to discharge — no. of patients/total patients (%)</td>
<td>193/309 (62)*</td>
<td>203/289 (70)†</td>
<td>0.04</td>
</tr>
<tr>
<td>Estimated intraoperative blood loss — ml‡</td>
<td>3127±4937</td>
<td>2555±3546</td>
<td>0.11</td>
</tr>
<tr>
<td>Length of hospital stay — days§</td>
<td>14±24</td>
<td>11±19</td>
<td>0.006</td>
</tr>
<tr>
<td>Length of ICU stay — days§</td>
<td>8±16</td>
<td>7±11</td>
<td>0.30</td>
</tr>
</tbody>
</table>
• Delay of aggressive fluid resuscitation IMPROVES outcome in penetrating torso injury

Bickell, NEJM 1993
Fluid resuscitation

- Delayed fluid resuscitation better in subset of patients - penetrating torso injury
  - Blood pressure restoration maintains bleeding and flushes clot
  - Dilution of clotting factors
  - Rheology

- Is this true for other hypotensive trauma patients?
Fluid resuscitation

The effect of vigorous fluid resuscitation in uncontrolled hemorrhagic shock after massive splenic injury

Solonov et al.
CCM 2000;28:749-754
Fluid resuscitation
Splenic injury

- Standard splenic injury
- 4 groups rats
  - Sham operation
  - Untreated after splenic injury (SI)
  - Saline infusion 41.5 ml/kg after SI
  - Hypertonic saline (7.5%) 5 ml/kg after SI

Solomonov et al. CCM 2000
Fluid resuscitation

Splenic injury

Survival

Solomonov et al. CCM 2000
Fluid resuscitation

Splenic injury

- Vigorous infusion of saline
  - increases abdominal bleeding
  - Decreases survival time

Solomonov et al. CCM 2000
Impact of Fluid Resuscitation on survival
Animal studies


- Sheep model, lacerated pulmonary vessels
- No fluid resuscitation vs RL 30 ml/kg
- Increased rate, volume and duration of hemorrhage with resuscitation.
Impact of Fluid Resuscitation on survival

Animal studies

Stern SA et al.


• Swine model of aortotomy
• None vs. Resusc. to MAP 40, 60 or 80 mm Hg

• Increased hemorrhage/higher mortality with MAP 80
Impact of Fluid Resuscitation on survival
Animal studies
Bolus versus continuous fluid resuscitation and splenectomy for treatment of uncontrolled hemorrhagic shock after massive splenic injury

Krausz & Hirsch
J Trauma, 2003
Impact of Fluid Resuscitation on survival

Animal studies

• Results
  – Continuous infusion RL less bleeding than bolus RL
  – Continuous HTS less bleeding than bolus HTS
  – Best survival in continuous HTS group
Impact of Fluid Resuscitation on survival
Clinical studies

Dutton RP et al.
Hypotensive Resuscitation During Active Hemorrhage:
Impact on in-Hospital Mortality.

• 110 patients, hemorrhagic shock, SBP 90 or less
• Target SBP >100 mm Hg vs. 70 mm Hg until homeostasis
• Mix of blunt and penetrating injuries
• No difference in survival or duration of hemorrhage
Initial fluid resuscitation
Role of timing

Effects of Delaying Fluid Resuscitation on an Injury to the Systemic Arterial Vasculature

JAMES F. HOLMES, MD, JOHN C. SAKLES, MD, GREG LEWIS, MD, DAVID H. WISNER, MD
Initial fluid resuscitation
Role of timing

• **Adult sheep n=21**
  – LIMA transsection
  – Chest drain
  – Three groups
    • NR no resuscitation
    • SR standard resuscitation (start after 15')
    • DR delayed resuscitation (start after 30')
  – Observation time 1 hour ➔ all animals survived
Initial fluid resuscitation
Role of timing

- Relation MAP ( ) and rate of hemorrhage (•)
## Initial fluid resuscitation
### Role of timing

<table>
<thead>
<tr>
<th>Table 3: Hematocrit, Cardiac Index, and Oxygen Delivery Measurements in the Three Resuscitation Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Hematocrit (%)</strong></td>
</tr>
<tr>
<td>No resuscitation</td>
</tr>
<tr>
<td>Standard resuscitation</td>
</tr>
<tr>
<td>Delayed resuscitation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Cardiac index (mL/kg/min)</strong></th>
<th>0 Min</th>
<th>15 Min</th>
<th>30 Min</th>
<th>45 Min</th>
<th>60 Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>No resuscitation</td>
<td>69 ± 15</td>
<td>22 ± 5</td>
<td>33 ± 4</td>
<td>38 ± 6</td>
<td>39 ± 8</td>
</tr>
<tr>
<td>Standard resuscitation</td>
<td>73 ± 8</td>
<td>30 ± 22</td>
<td>99 ± 42*</td>
<td>70 ± 25</td>
<td>52 ± 21</td>
</tr>
<tr>
<td>Delayed resuscitation</td>
<td>78 ± 12</td>
<td>25 ± 10</td>
<td>33 ± 8</td>
<td>133 ± 33*</td>
<td>124 ± 23*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Oxygen delivery (mL O₂/kg/min)</strong></th>
<th>0 Min</th>
<th>15 Min</th>
<th>30 Min</th>
<th>45 Min</th>
<th>60 Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>No resuscitation</td>
<td>72 ± 13</td>
<td>20 ± 6</td>
<td>30 ± 9</td>
<td>34 ± 10</td>
<td>35 ± 9</td>
</tr>
<tr>
<td>Standard resuscitation</td>
<td>86 ± 19</td>
<td>30 ± 18</td>
<td>53 ± 20*</td>
<td>37 ± 14</td>
<td>28 ± 10</td>
</tr>
<tr>
<td>Delayed resuscitation</td>
<td>93 ± 18</td>
<td>27 ± 11</td>
<td>37 ± 11</td>
<td>101 ± 34*</td>
<td>87 ± 26*</td>
</tr>
</tbody>
</table>

*p < 0.05. Values are expressed as mean ± standard deviation.
Initial fluid resuscitation in multiple trauma

• Cochrane library, issue 3
  – Timing and volume of fluid administration for patients with bleeding
    Kwan I et al. 2003

• No evidence from RCT for or against early fluid resuscitation
• Continuing uncertainty about FR
• RCT needed
Initial fluid resuscitation in multiple trauma

• And now? What do I do? CONCLUSIONS
  – Permissive hypotension – not too aggressive EARLY resuscitation
    • Target of SBP 100 mm Hg may be too high
    • BP may be imprecise parameter
  – In case of concomitant TBI
    • Different!!
    • Other presentation; hypertonic saline?