Low Volume
Resuscitation in Trauma

Dankook University Hospital
Trauma Center

Ye Rim Chang
Totally different physiology!
History

- Military resuscitation during 1960s used aggressive crystalloid resuscitation with no predefined transfusion ratio of blood component therapy.

- Fluid administration focused on crystalloid use in an effort to balance inputs and outputs.

This approach failed to address **acute traumatic coagulopathy** in the severely injured patients with hemorrhagic shock.
Emergency Department Crystalloid Resuscitation of 1.5 L or More is Associated With Increased Mortality in Elderly and Nonelderly Trauma Patients

Eric J. Ley, MD, Morgan A. Clond, PhD, Marissa K. Srour, BS, Moshe Barnajian, MD, James Mirocha, MS, Dan R. Margulies, MD, and Ali Salim, MD

| TABLE 3. Estimated Odds Ratios for Various Fluid Resuscitation Volumes in the Nonelderly |
|---------------------------------|-----------------|-----------------|
| Volume (L) | Odds Ratio (95% Wald CI) | p   |
| IVF ≥1    | 1.69 (1.00–2.87) | 0.051 |
| IVF ≥1.5  | 2.09 (1.31–3.33) | 0.002 |
| IVF ≥2    | 2.27 (1.41–3.65) | 0.0007 |
| IVF ≥3    | 2.69 (1.53–4.73) | 0.0006 |

IVF, intravenous fluid (L).

| TABLE 5. Odds Ratio for Mortality With Crystalloid Resuscitation in the Elderly |
|---------------------------------|-----------------|-----------------|
| Volume (L) | Odds Ratio (95% Wald CI) | p   |
| IVF ≥1    | 1.10 (0.48–2.49) | 0.82  |
| IVF ≥1.5  | 2.89 (1.13–7.41) | 0.027 |
| IVF ≥2    | 4.57 (1.55–13.53) | 0.006 |
| IVF ≥3    | 8.61 (1.55–47.75) | 0.014 |

IVF, intravenous fluid (L).

| TABLE 2. Multivariate Logistic Regression Model for Nonelderly Patients |
|-----------------------------|-----------------|-----------------|
| Risk Factor | Odds Ratio (95% Wald CI) | p   |
| ISS ≥16      | 17.03 (8.34–34.78) | <0.0001 |
| GCS ≤8       | 16.93 (10.47–27.40) | <0.0001 |
| SBP <90      | 2.51 (1.28–4.94) | 0.0078 |
| IVF ≥1.5     | 2.09 (1.31–3.33) | 0.002  |

| TABLE 4. Multivariate Logistic Regression Model for Elderly Patients |
|-----------------------------|-----------------|-----------------|
| Risk Factor | Odds Ratio (95% Wald CI) | p   |
| ISS ≥16      | 17.15 (5.91–49.79) | <0.0001 |
| GCS ≤8       | 8.06 (3.31–19.63) | <0.0001 |
| Age ≥80      | 3.16 (1.35–19.63) | 0.008  |
| IVF ≥1.5     | 2.89 (1.13–7.41) | 0.027  |
❖ Indication (n = 156)
- Multiple organ injury
- ≥ 6 unit of pRBC in the first 12h
- Shock

❖ Shock resuscitation to achieve oxygen delivery index
- Supranormal: DO$_2$I ≥ 600mL/min
- Normal: DO$_2$I ≥ 500mL/min

Table 2. Outcomes of the Supranormal and Normal Resuscitation Cohorts*

<table>
<thead>
<tr>
<th></th>
<th>Supranormal Resuscitation (n = 85)</th>
<th>Normal Resuscitation (n = 71)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra-abdominal hypertension</td>
<td>42†</td>
<td>20</td>
</tr>
<tr>
<td>Abdominal compartment syndrome</td>
<td>16†</td>
<td>8</td>
</tr>
<tr>
<td>Multiple organ failure</td>
<td>22†</td>
<td>9</td>
</tr>
<tr>
<td>Death</td>
<td>27†</td>
<td>11</td>
</tr>
</tbody>
</table>

*Data are given as percentage of patients.
†P<.05.
Forest plot
Comparison of liberal vs. restricted fluid resuscitation on overall mortality: delaying fluid resuscitation until arrival at hospital, lower-than-normal BP as a guide for fluid resuscitation
High volume resuscitation may be detrimental.

- Coagulopathy
- Abdominal compartment syndrome
- Multiorgan failure
- Worse survival
Low Volume Resuscitation

Is it correct to give fluid to these trauma patients?
Damage control resuscitation

1. Permissive hypotension
   
   SBP of 80–90 mmHg or MAP of 50 mmHg
   
   : To avoid the adverse effects of early aggressive resuscitation

2. Hemostatic resuscitation (Massive transfusion protocol)
   
   Early use of blood product over isotonic fluid for volume replacement
   
   : Proactive correction of traumatic coagulopathy

3. Rapid control of hemorrhage (Damage control surgery)
1. Permissive hypotension
IMMEDIATE VERSUS DELAYED FLUID RESUSCITATION FOR HYPOTENSIVE PATIENTS WITH PENETRATING TORSO INJURIES

WILLIAM H. BICKELL, M.D., MATTHEW J. WALL, JR., M.D., PAUL E. PEPE, M.D., R. RUSSELL MARTIN, M.D., VICTORIA F. GINGER, M.S.N., MARY K. ALLEN, B.A., AND KENNETH L. MATTOX, M.D.

Immediate group
Fluid administration if SBP ≤ 90mmHg

Delayed group
No fluid until arrival

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/mm³)</td>
<td>274±84</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>

Table 3. Systemic Arterial Blood Pressure, Heart Rate, and Laboratory Findings at the Time of Initial Operative Intervention in Patients with Penetrating Torso Injuries, According to Treatment Group.*

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>IMMEDIATE RESUSCITATION (N = 289)</th>
<th>DELAYED RESUSCITATION (N = 289)</th>
<th>P VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>112±33</td>
<td>113±30</td>
<td>0.98</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>57±22</td>
<td>60±21</td>
<td>0.10</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>102±25</td>
<td>104±23</td>
<td>0.25</td>
</tr>
<tr>
<td>Hemoglobin (g/dl)</td>
<td>10.7±5.8</td>
<td>11.5±2.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Platelet count (×10^3/mm³)</td>
<td>195±97</td>
<td>198±105</td>
<td>0.99</td>
</tr>
<tr>
<td>Systemic arterial pH</td>
<td>7.27±0.16</td>
<td>7.28±0.15</td>
<td>0.75</td>
</tr>
<tr>
<td>Serum bicarbonate concentration (mmol/liter)</td>
<td>21±5</td>
<td>20±4</td>
<td>0.39</td>
</tr>
</tbody>
</table>

*Plus–minus values are means ± SD. To convert values for hemoglobin to millimoles per liter, multiply by 0.62.
IMMEDIATE VERSUS DELAYED FLUID RESUSCITATION FOR HYPOTENSIVE PATIENTS WITH PENETRATING TORSO INJURIES


Immediate group

Fluid administration if SBP ≤ 90mmHg

Delayed group

vs.

No fluid until arrival

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.
Risk of early postoperative death ↓ Coagulopathy ↓ "Restrictive volume replacement under permissive hypotension"

**TABLE 9. Timing of Deaths**

<table>
<thead>
<tr>
<th></th>
<th>MAP = 50 mm Hg (n = 44)</th>
<th>MAP = 65 mm Hg (n = 46)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Died in OR</td>
<td>5</td>
<td>2</td>
<td>0.26</td>
</tr>
<tr>
<td>Died within 24 h of ICU admission</td>
<td>1</td>
<td>8</td>
<td>0.03</td>
</tr>
<tr>
<td>Total deaths &lt;24 h</td>
<td>6</td>
<td>10</td>
<td>0.32</td>
</tr>
<tr>
<td>Died 1-10 d after ICU admission</td>
<td>2</td>
<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td>Died &gt;10 d after ICU admission</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Total deaths &gt;24 h</td>
<td>4</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Overall deaths at 30 d</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 11. Postoperative Complications**

<table>
<thead>
<tr>
<th></th>
<th>MAP = 50 mm Hg (n = 38)</th>
<th>MAP = 65 mm Hg (n = 36)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulopathy</td>
<td>23 (60.5%)</td>
<td>22 (61.1%)</td>
<td>0.93</td>
</tr>
<tr>
<td>Thrombocytopenia</td>
<td>15 (39.5%)</td>
<td>8 (22.2%)</td>
<td>0.09</td>
</tr>
<tr>
<td>Anemia</td>
<td>16 (42.1%)</td>
<td>17 (47.2%)</td>
<td>0.97</td>
</tr>
</tbody>
</table>
A controlled resuscitation strategy is feasible and safe in hypotensive trauma patients: Results of a prospective randomized pilot trial

**Controlled resuscitation (CR) group**
- 250 mL if no radial pulse or SBP < 70 mmHg
- Additional 250 mL boluses to maintain a radial pulse or an SBP ≥ 70 mmHg

**Standard resuscitation (SR) group**
- 2 L initially & additional fluid to maintain an SBP ≥ 110 mmHg

24h-mortality in blunt trauma subpopulation: CR group (3.2%) vs. SR group (17.7%)

→ **Controlled resuscitation may offer an early survival advantage in blunt trauma**
Principles of Damage Control Resuscitation

- Avoid/reverse hypothermia
- Minimize blood loss with early hemorrhage control measures during initial evaluation
- Delay resuscitation/target low-normal blood pressure before definitive hemostasis
- Minimize crystalloid administration
- Use MT protocol to ensure sufficient blood products are available in a prespecified ratio
- Avoid delays in surgical or angiographic hemostasis
- Transfuse blood components that optimize hemostasis
- Obtain functional laboratory measures of coagulation (e.g., TEG or TEM) to guide ongoing
- Give pharmacologic adjuncts to safely promote hemostasis
Recommendation 13. **Tissue oxygenation**

We recommend a target systolic blood pressure of 80–90 mmHg until major bleeding has been stopped in the initial phase following trauma without brain injury. (**Grade 1C**)

Recommendation 14. **Restricted volume replacement**

We recommend use of a restricted volume replacement strategy to achieve target blood pressure until bleeding can be controlled. (**Grade 1B**)

2. Hemostatic resuscitation
Tissue hypoperfusion algorithm
**Tissue hypoperfusion algorithm**

**Traumatic shock**
- Combination of several insults after injury
  - eg. small volume of hemorrhage + significant tissue injury, hypovolemic + neurogenic + obstructive + cardiogenic
**Estimated blood loss**

<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>Blood loss (mL)</td>
<td>Up to 750</td>
<td>750–1500</td>
<td>1500–2000</td>
<td>&gt;2000</td>
</tr>
<tr>
<td>Blood loss (% blood volume)</td>
<td>Up to 15%</td>
<td>15%–30%</td>
<td>30%–40%</td>
<td>&gt;40%</td>
</tr>
<tr>
<td>Pulse rate (BPM)</td>
<td>&lt;100</td>
<td>100–120</td>
<td>120–140</td>
<td>&gt;140</td>
</tr>
<tr>
<td>Systolic b pressure</td>
<td>Normal</td>
<td>Normal</td>
<td>Decreased</td>
<td>Decreased</td>
</tr>
<tr>
<td>Pulse pressure (mm Hg)</td>
<td>Normal or increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td>Decreased</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>14–20</td>
<td>20–30</td>
<td>30–40</td>
<td>&gt;35</td>
</tr>
<tr>
<td>Urine output (mL/hr)</td>
<td>&gt;30</td>
<td>20–30</td>
<td>5–15</td>
<td>Negligible</td>
</tr>
<tr>
<td>CNS/mental status</td>
<td>Slightly anxious</td>
<td>Mildly anxious</td>
<td>Anxious, confused</td>
<td>Confused, lethargic</td>
</tr>
<tr>
<td>Initial fluid replacement</td>
<td>Crystalloid</td>
<td>Crystalloid</td>
<td>Crystalloid and blood</td>
<td>Crystalloid and blood</td>
</tr>
</tbody>
</table>
### TABLE 3.2 Responses to Initial Fluid Resuscitation

<table>
<thead>
<tr>
<th></th>
<th>RAPID RESPONSE</th>
<th>TRANSIENT RESPONSE</th>
<th>MINIMAL OR NO RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital signs</td>
<td>Return to normal</td>
<td>Transient improvement, recurrence of decreased blood pressure and increased heart rate</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>Low to moderate</td>
<td>Moderate as a bridge to transfusion</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>

¹Isotonic crystalloid solution, 2000 mL in adults; 20 mL/kg in children.
Predicting massive transfusion

ABC Score

- Penetrating mechanism (0 = no, 1 = yes)
- ED SBP of 90 mm Hg or less (0 = no, 1 = yes)
- ED HR of 120 bpm or greater (0 = no, 1 = yes)
- Positive FAST (0 = no, 1 = yes)

→ ABC score of 2 or greater was 75% sensitive and 86% specific for predicting massive transfusion.
Severely injured patients who met criteria for highest-level trauma activation (n= 680)

- Time from patient arrival to MT protocol activation: 9 minutes (median)
- Time from MT activation call to delivery of first cooler: 8 minutes (median)

### TABLE 2. Multivariate Regression Predicting 24-h Mortality

<table>
<thead>
<tr>
<th></th>
<th>OR</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to receipt of first cooler, min</td>
<td>1.05</td>
<td>1.01–1.10</td>
<td>0.035</td>
</tr>
<tr>
<td>Anatomic injury severity (ISS)</td>
<td>1.03</td>
<td>1.02–1.05</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Disturbed arrival physiology (w-RTS)</td>
<td>0.69</td>
<td>0.60–0.81</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Randomization arrival physiology group (1:1:2)</td>
<td>1.69</td>
<td>1.01–2.86</td>
<td>0.047</td>
</tr>
<tr>
<td>RI, units</td>
<td>1.12</td>
<td>0.60–2.05</td>
<td>0.719</td>
</tr>
</tbody>
</table>

### TABLE 3. Multivariate Regression Predicting 30-d Mortality

<table>
<thead>
<tr>
<th></th>
<th>OR</th>
<th>95% CI</th>
<th>p</th>
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<td>RI, units</td>
<td>1.12</td>
<td>0.60–2.05</td>
<td>0.719</td>
</tr>
</tbody>
</table>

Resuscitation intensity
Higher plasma and platelet ratios early in resuscitation were associated with decreased mortality in patients who received transfusions of at least 3 units of blood products during the first 24 hours after admission.
Transfusion of Plasma, Platelets, and Red Blood Cells in a 1:1:1 vs a 1:1:2 Ratio and Mortality in Patients With Severe Trauma

The PROPRR Randomized Clinical Trial

John B. Holcomb, MD; Barbara C. Tilley, PhD; Sarah Baraniuk, PhD; Erin E. Fox, PhD; Charles E. Wade, PhD; Jeanette M. Podbielski, RN; Deborah J. del Junco, PhD; Karen J. Brasil, MD, MPH; Eileen M. Bulger, MD; Rachael A. Callcut, MD, MSPH; Mitchell Jay Cohen, MD; Bryan A. Cotton, MD, MPH; Timothy C. Fabian, MD; Kenji Inaba, MD; Jeffrey D. Kerby, MD, PhD; Peter Muskat, MD; Terence O’Keefe, MBChB, MSPH; Sandro Ricci, MD, PhD; Bryce R. H. Robinson, MD; Thomas M. Scalea, MD; Martin A. Schweiber, MD; Deborah M. Stein, MD; Jordan A. Weinberg, MD; Jeannie L. Callum, MD; John R. Hess, MD, MPH; Nena Martijevic, PhD; Christopher N. Miller, MD; Jean-Francois Pittet, MD; David B. Hoyt, MD; Gail D. Pearson, MD, ScD; Brian Leroux, PhD; Gerald van Belle, PhD, for the PROPRR Study Group

680 Randomized

338 Randomized to 1:1:1 group

24-h Mortality
3 Withdraw consent
0 Lost to follow-up
338 Included in mortality analysis

30-d Mortality
18 Withdraw consent
3 Lost to follow-up
338 Included in mortality analysis

342 Randomized to 1:1:2 group

24-h Mortality
2 Withdraw consent
0 Lost to follow-up
342 Included in mortality analysis

30-d Mortality
17 Withdraw consent
1 Lost to follow-up
342 Included in mortality analysis

Table 2. Trial Outcomes by Treatment Group

|                        | 1:1:1 Group (n = 338) | 1:1:2 Group (n = 342) | Difference (95% CI), % | Adjusted RR (95% CI) | P Value
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>24-h Mortality, No. (%)</td>
<td>43 (12.7)</td>
<td>58 (17.0)</td>
<td>-4.2 (-9.6 to 1.1)</td>
<td>0.75 (0.52 to 1.08)</td>
<td>.12</td>
</tr>
<tr>
<td>30-d Mortality, No. (%)</td>
<td>75 (22.4)</td>
<td>89 (26.1)</td>
<td>-3.7 (-10.2 to 2.7)</td>
<td>0.86 (0.65 to 1.12)</td>
<td>.26</td>
</tr>
<tr>
<td>Achieved hemostasis</td>
<td>291 (86.1)</td>
<td>267 (78.1)</td>
<td></td>
<td></td>
<td>.006</td>
</tr>
</tbody>
</table>
Table 3. Adjudicated Cause of Death by Treatment Group and Period From Randomization

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>1:1:1 Group (n = 338)</th>
<th>1:1:2 Group (n = 342)</th>
<th>Difference (95% CI),%a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total No. of deaths</td>
<td>43</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>Cause of death</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exsanguination</td>
<td>31 (9.2)</td>
<td>50 (14.6)</td>
<td>-5.4 (-10.4 to -0.5)</td>
</tr>
<tr>
<td>Traumatic brain injury</td>
<td>11 (3.3)</td>
<td>12 (3.5)</td>
<td>-0.3 (-3.2 to 2.7)</td>
</tr>
<tr>
<td>Respiratory, pulmonary contusion, or</td>
<td>3 (0.9)</td>
<td>1 (0.3)</td>
<td>0.6 (-0.9 to 2.4)</td>
</tr>
<tr>
<td>tension pneumothorax</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sepsis</td>
<td>0</td>
<td>0</td>
<td>0 (-1.1 to 1.1)</td>
</tr>
<tr>
<td>Multiple organ failure</td>
<td>0</td>
<td>0</td>
<td>0 (-1.1 to 1.1)</td>
</tr>
<tr>
<td>Type of cardiovascular event</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td>0</td>
<td>1 (0.3)</td>
<td>-0.3 (-1.7 to 0.9)</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>1 (0.3)</td>
<td>1 (0.3)</td>
<td>0 (-1.4 to 1.4)</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>0</td>
<td>1 (0.3)</td>
<td>-0.3 (-1.7 to 0.9)</td>
</tr>
<tr>
<td>Transfusion-related fatality</td>
<td>0</td>
<td>0</td>
<td>0 (-1.1 to 1.1)</td>
</tr>
</tbody>
</table>

a Calculated using exact unconditional methods based on the Farrington-Manning score statistic.

b A patient may have had more than 1 cause of death.
Warm fresh whole blood

World War II
Plasma transfusion

Original Article

Fresh whole blood use by forward surgical teams in Afghanistan is associated with improved survival compared to component therapy without platelets


The Use of Fresh Whole Blood in Massive Transfusion

Thomas B. Repine, MD, Jeremy G. Perkins, MD, David S. Kauvar, MD, and Lorne Blockborne, MD
Fluids

• Which type of fluids?
• How much?
• How fast?
• Monitoring
1. Which type of fluids?

- Trauma 8th ed. 2017
- ATLS 9th ed. 2012
- KTAT (Korean Trauma Assessment and Treatment) 2nd ed.
- European guidelines on management of bleeding following major trauma 2016

**balanced**

: *Isotonic crystalloids*

**Warmed fluids**

0.9 % sodium chloride

- Aggravation of metabolic acidosis
- Relevant dilution of blood components
  → Aggravation of coagulopathy / hypothermia

*Lethal triad*
1) Balanced solution

Severely injured patients
- GCS < 9 or deteriorating;
- SBP < 90 mmHg; pulseless;
- Need for intubation
1) Balanced solution

- 0.9% NaCl (n=33) vs. Plasma-Lyte A (n=32)

**Improved acid-base status**
**Less hyperchloremia at 24 hours post-injury**
2) Colloids in trauma

A Comparison of Albumin and Saline for Fluid Resuscitation in the Intensive Care Unit

The SAFE Study Investigators*

2004

Albumin (n = 3497) vs. saline (n = 3500)
Trauma patients 17%

Mortality in TBI patients:
Albumin (24.5 %) vs. saline (15.1 %) (RR 1.62; \( p=0.009 \))
Saline or Albumin for Fluid Resuscitation in Patients with Traumatic Brain Injury

The SAFE Study Investigators*

515 Patients were eligible
- 492 from SAFE study
- 23 from additional screening from SAFE database

255 Were randomly assigned to albumin
- 24 withdrew
  - 1 withdrew consent
  - 5 were clinically misclassified with TBI
  - 8 were radiologically misclassified
  - 10 were misclassified according to the GCS

231 Patients were assessable
- 17 were lost to follow-up

Primary outcomes were obtained in 214 patients

260 Were randomly assigned to saline
- 31 withdrew
  - 1 withdrew consent
  - 9 were clinically misclassified with TBI
  - 11 were radiologically misclassified
  - 10 were misclassified according to the GCS

229 Patients were assessable
- 23 were lost to follow-up

Primary outcomes were obtained in 206 patients
Fluid resuscitation with *albumin* was associated with *higher mortality* rates than was resuscitation with saline in critically ill patients with traumatic brain injury.
Hydroxyethyl Starch or Saline for Fluid Resuscitation in Intensive Care

John A. Myburgh, M.D., Ph.D., Simon Finfer, M.D., Rinaldo Bellomo, M.D.,
Laurent Billot, M.Sc., Alan Cass, M.D., Ph.D., David Gattas, M.D.,
Parisa Glass, Ph.D., Jeffrey Lipman, M.D., Bette Liu, Ph.D., Colin McArthur, M.D.,
Shay McGuinness, M.D., Dorrilyn Rajbhandari, R.N., Colman B. Taylor, M.N.D.,
and Steven A.R. Webb, M.D., Ph.D., for the CHEST Investigators
and the Australian and New Zealand Intensive Care Society Clinical Trials Group*

6% HES (n = 3358) vs. 0.9% saline (n = 3384)

No difference in 90-day mortality in trauma subgroup.
Resuscitation with hydroxyethyl starch improves renal function and lactate clearance in penetrating trauma in a randomized controlled study: the FIRST trial (Fluids in Resuscitation of Severe Trauma)

M. F. M. James, W. L. Michell, I. A. Joubert, A. J. Nicol, P. H. Navsaria, and R. S. Gillespie

1 Department of Anaesthesia and 2 Department of Surgery, Groote Schuur Hospital and Faculty of Health Sciences, University of Cape Town, Anzio Road, Observatory, Cape Town, Western Cape 7925, South Africa

Trauma patients (penetrating, n=67; blunt, n=42)
HES (130/0.4) provided significantly **better lactate clearance** and **less renal injury** than saline.

**European guideline 2016**

We suggest that the use of colloids be **restricted** due to the adverse effects on hemostasis. (Grade 2C)
3) Hypertonic saline

**PROS**
- Redistribution of extracellular & intracellular water into the intravascular space
  → Volume effect exceeding the amount of infused volume
- Limited edema formation
- Marked reduction of baggage load for rescue forces
- Anti-inflammatory* and immunomodulatory effects†

**CONS**
- Capillary pressure ↑ → blood loss↑ or reactivate bleeding

**RCT**, 209 Blunt trauma patients‡
- 250 ml 7.5 % hypertonic saline vs. 6 % dextran 70
- no significant difference in organ failure and in ARDS-free survival

*Ann Surg 2007; 245:635  
†Ann Surg 2006;243:47  
‡Arch Surg. 2008;143(2):139
Hypertonic saline for traumatic brain injury

- Medical therapies for brain injury
  - Temporary hyperventilation, mannitol, hypertonic saline, barbiturates, and anticonvulsants.

- RCT, 2005
  - 9 patients
  - Hypertonic saline vs. dextran + 20% mannitol

: Hypertonic saline was more effective in reducing ICP

Hypertonic saline for traumatic brain injury

- RCT, 2004
  - Prehospital setting
  - 250mL hypertonic solution (HTS) vs. Ringer’s lactate
  - No difference in neurological function at 6 months

- RCT, 2010
  - Prehospital setting, 1282 patients
  - 250 mL HTS / HTS + dextran vs. 0.9% saline

- RCT, 2011
  - Prehospital setting, 853 patients
  - 250 mL HTS vs. HTS + dextran vs. 0.9% saline

No survival difference

JAMA. 2010;304(13):1455
Hypertonic saline for traumatic brain injury

- RCT, 2015
  - Prehospital setting
  - n = 34
  - 250 mL HTS vs. HTS + dextran vs. 0.9% saline
  - Hypertonic saline *interfere coagulation*

European guideline 2016

The evidence suggests that hypertonic saline solutions will neither improve survival nor improve neurological outcome after TBI.

*Shock. 2015;44(1):25*
2. How fast?

Current guidelines for resuscitation of shock

- **Rapid normalization of blood pressure** may be the general consensus when the bleeding is controlled or ongoing blood loss is absent.
- **No specific guideline for the speed of reperfusion**


*J Trauma Acute Care Surg.* 2014;76(3):771
3. Monitoring

• Lactate
  – produced by anaerobic glycolysis
  – Indirect marker of oxygen debt, tissue hypoperfusion, and the severity of hemorrhagic shock
  – Diagnostic & prognostic marker since 1960s

• Base deficit
  – Classification
    - **Mild**: -3 to -5 mEq/L
    - **Moderate**: -6 to -9 mEq/L
    - **Severe**: < -10 mEq/L

  – Better prognostic marker than pH †

*J Trauma. 1996;41(5):769
† J Trauma. 1998;44(1):114
### 3. Monitoring

- **Base deficit**
  - Better prognostic marker than pH

#### Base deficit and pH clearance

<table>
<thead>
<tr>
<th>Group</th>
<th>Admission</th>
<th>2 hours</th>
<th>4 hours</th>
<th>8 hours</th>
<th>16 hours</th>
<th>24 hours</th>
<th>48 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD_survive</td>
<td>-7.0 ± 0.1</td>
<td>-6.3 ± 0.4</td>
<td>-5.4 ± 0.3</td>
<td>-4.2 ± 0.4</td>
<td>-1.2 ± 0.3</td>
<td>0.6 ± 0.3</td>
<td>2.6 ± 0.2</td>
</tr>
<tr>
<td>BD_died</td>
<td>-7.3 ± 0.1</td>
<td>-9.8 ± 0.9</td>
<td>-7.7 ± 0.9</td>
<td>-6.2 ± 0.8</td>
<td>-3.5 ± 0.9</td>
<td>-1.9 ± 0.9</td>
<td>-0.3 ± 0.9</td>
</tr>
<tr>
<td><strong>p value</strong></td>
<td>0.02</td>
<td>0.001</td>
<td>0.004</td>
<td>0.011</td>
<td>0.002</td>
<td>0.001</td>
<td>0.001</td>
</tr>
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<tbody>
<tr>
<td>BD_survive</td>
<td>-14.1 ± 0.4</td>
<td>-8.7 ± 0.6</td>
<td>-7.5 ± 0.6</td>
<td>-4.9 ± 0.5</td>
<td>-1.7 ± 0.4</td>
<td>0.4 ± 0.5</td>
<td>2.6 ± 0.4</td>
</tr>
<tr>
<td>BD_died</td>
<td>-15.9 ± 0.5</td>
<td>-13.6 ± 1.0</td>
<td>-10.0 ± 1.1</td>
<td>-7.1 ± 1.1</td>
<td>-5.4 ± 1.2</td>
<td>-3.4 ± 1.2</td>
<td>-1.1 ± 0.8</td>
</tr>
<tr>
<td><strong>p value</strong></td>
<td>0.002</td>
<td>0.001</td>
<td>0.026</td>
<td>0.032</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>

NS, not significant.

*J Trauma. 1998;44(1):114*
3. Monitoring

Fluid overload, de-resuscitation, and outcomes in critically ill or injured patients: a systematic review with suggestions for clinical practice

Manu L.N.G. Malbrain, Paul E. Marik, Ine Witters, Colin Cordemans, Andrew W. Kirkpatrick, Derek J. Roberts, and Niels Van Regemortel

Analogy between the four D’s of antibiotics and fluid therapy

- Drug
- Dosing
- Duration
- De-escalation

- Resuscitation
- Optimization
- Stabilization
- Evacuation
**Arterial Pressure Waveform Analysis**

- PiCCO$_2$ (Pulsion Medical Systems)
- LiDCOplus/LiDCOrapid (LiDCO limited)
- FloTrac Vigileo (Edwards Life Sciences)

**TransPulmonary ThermoDilution methods**

- PiCCO (Pulsion Medical Systems)
- Volume View (Edwards Life Sciences)

**Lithium Dilution Technique**

- LiDCO (LiDCO limited)

**Ultrasound Indicator Dilution**

- COstatus (Transonic Systems, Inc.)
Summary of recommendations

In surgical patients being evaluated or treated for shock, we conditionally recommend a protocol that includes *Focused ultrasound* be utilized versus a standard protocol to predict fluid responsiveness, to reduce complications and organ failures and to reduce mortality.

In surgical patients being evaluated or treated for shock, we conditionally recommend a protocol that includes *arterial waveform analysis derived variables* be utilized versus a standard protocol to predict fluid responsiveness, to reduce complications and organ failures and to reduce mortality.
Injured patients from an academic level-1 trauma center meeting criteria for MTP activation

- Viscoelastic assay thrombelastography (TEG = 56)
- Conventional coagulation assays (CCA = 55)

Utilization of a **goal-directed, TEG-guided MTP** to resuscitate severely injured patients improves **survival** compared with an MTP guided by CCA.
In hemorrhagic shock,
- Restrictive volume replacement under permissive hypotension
- Early use of blood product with balanced ratio
- Followed by rapid control of bleeding

Balanced

- Warmed isotonic crystalloids
- Restricted use of colloids
- Hypertonic saline has no benefit.

High volume resuscitation may be detrimental!

- Focused USG & arterial waveform analysis derived variables can be utilized for monitoring.