"BLOOD FAR FORWARD"

1. Donor Performance and reinfusion - Donor safety research

2. Blood efficacy and safety - Blood Research

3. Training and educational requirements
ACKNOWLEDGEMENTS

Prof. Kevin Ward MD
  – Department of Emergency Medicine, University of Michigan

CDR Geir Strandenes MD
  – Norwegian Navy Special Operations Command
  – Blood Far Forward / Helse-Bergen

LTC Andrew P. Cap, MD, PhD, FACP
  – Chief, Coagulation and Blood Research program
  – US Army Institute of Surgical Research

Dr. Theodor Fosse
  – Blood far forward / Helse-Bergen

Dr. Håkon Eliassen
  – Blood far forward
DISCLAIMER

The opinions or assertions contained herein are the private views of the author and are not to be construed as official or as reflecting the views of the Norwegian armed forces medical services or Helse-Bergen.
OUTLINE

Brief summary of history of DCR

Patophysiology of hemorrhagic shock and oxygen debt - implications on coagulopathy of trauma (blood failure) and outcome.

RDCR principles

Permissive hypotension in the presurgical and surgical phase – implications for oxygen debt and the management in the ICU

Strategies to improve oxygen delivery during field care/delayed evacuation
GOAL OF PREHOSPITAL CARE

REDUCE MORTALITY    REDUCE MORBIDITY

From the time the enemy’s missile strikes until the surgeon begins to repair the damage it has caused, every effort is directed toward a single aim, that of presenting to the surgeon a patient who will be as favorable an operative risk as possible. Several principles that are basic...
GORDON WATSON 1918:

Gordon Watson (1918), in a note attached to one of Robertson's papers (20), stated that there was no comparison between the results of transfusion, which were instantaneous and permanent, and those secured by infusions of saline, which were "a flash in the pan" and followed by more serious collapse.
EXPERIMENT 1918

(a) Systolic blood pressure (mmHg)

- 1 litre 0.9% NaCl
- Death

(b) Systolic blood pressure (mmHg)

- Infusion during operation

Day after operation:
- 1
- 2
- 3
- 4
- 5
- 6
Crystalloid solutions:

“These agents are primarily useful for the correction of dehydration. As "blood substitutes" they are not very effective, and are dangerous.”
“Curiously enough, a fact that is often not adequately appreciated is that plasma, lacking hemoglobin, is not, a satisfactory substitute for blood in the wounded man who is seriously bled-out. Plasma gives more time to get whole blood into the patient.”
CLINICAL EXPERIENCES IN THE EARLY MANAGEMENT OF THE MOST SEVERELY INJURED BATTLE CASUALTIES*

CURTIS P. ARTZ, LIEUTENANT COLONEL, M.C., JOHN M. HOWARD, CAPTAIN, M.C., YOSHIO SAKO, CAPTAIN, M.C., ALVIN W. BRONWELL, CAPTAIN, M.C. AND THEODORE PRENTICE, CAPTAIN, M.C.

FT. SAM HOUSTON, TEXAS

FROM THE SURGICAL RESEARCH TEAM IN KOREA, ARMY MEDICAL SERVICE GRADUATE SCHOOL, WALTER REED ARMY MEDICAL CENTER WASHINGTON, D.C.
TABLE VII. **Most Severely Wounded—Admitted in Severe Shock; 33 Patients, 7 Deaths.**
(Case Fatality Rate, 21 Per Cent)

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of Wound</th>
<th>Evac. Time (min.)</th>
<th>Admin. Blood Pressure</th>
<th>Preop. Blood (ml)</th>
<th>Blood Total 1st 24 hrs. (ml)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Extrem.</td>
<td>110</td>
<td>70/30</td>
<td>2,000</td>
<td>2,500</td>
<td>Recovered</td>
</tr>
<tr>
<td>2</td>
<td>Extrem.</td>
<td>105</td>
<td>80/40</td>
<td>2,000</td>
<td>3,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>3</td>
<td>Abdomen</td>
<td>180</td>
<td>70/40</td>
<td>2,500</td>
<td>3,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>4</td>
<td>Extrem.</td>
<td>120</td>
<td>40/0</td>
<td>—</td>
<td>3,500</td>
<td>Recovered</td>
</tr>
<tr>
<td>5</td>
<td>Abdomen</td>
<td>60</td>
<td>60/0</td>
<td>2,000</td>
<td>3,500</td>
<td>Recovered</td>
</tr>
<tr>
<td>6</td>
<td>Extrem.</td>
<td>270</td>
<td>80/40</td>
<td>2,000</td>
<td>4,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>7</td>
<td>Abdomen</td>
<td>185</td>
<td>60/30</td>
<td>2,500</td>
<td>4,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>8</td>
<td>Extrem.</td>
<td>270</td>
<td>70/40</td>
<td>3,750</td>
<td>4,750</td>
<td>Recovered</td>
</tr>
<tr>
<td>9</td>
<td>Chest</td>
<td>—</td>
<td>60/0</td>
<td>2,500</td>
<td>3,500</td>
<td>Recovered</td>
</tr>
<tr>
<td>10</td>
<td>Abdomen</td>
<td>—</td>
<td>40/0</td>
<td>3,000</td>
<td>5,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>11</td>
<td>Thor-abd.</td>
<td>150</td>
<td>80/40</td>
<td>3,000</td>
<td>5,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>12</td>
<td>Abdomen</td>
<td>—</td>
<td>70/40</td>
<td>4,000</td>
<td>5,500</td>
<td>Recovered</td>
</tr>
<tr>
<td>13</td>
<td>Extrem.</td>
<td>120</td>
<td>70/40</td>
<td>3,500</td>
<td>6,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>14</td>
<td>Extrem.</td>
<td>195</td>
<td>80/40</td>
<td>5,500</td>
<td>6,500</td>
<td>Recovered</td>
</tr>
<tr>
<td>15</td>
<td>Extrem.</td>
<td>45</td>
<td>70/30</td>
<td>3,000</td>
<td>7,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>16</td>
<td>Extrem.</td>
<td>170</td>
<td>70/40</td>
<td>2,500</td>
<td>7,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>17</td>
<td>Abdomen</td>
<td>130</td>
<td>70/40</td>
<td>4,000</td>
<td>9,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>18</td>
<td>Abdomen</td>
<td>90</td>
<td>70/40</td>
<td>5,000</td>
<td>10,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>19</td>
<td>Abdomen</td>
<td>90</td>
<td>74/52</td>
<td>3,500</td>
<td>11,500</td>
<td>Recovered</td>
</tr>
<tr>
<td>20</td>
<td>Extrem.</td>
<td>103</td>
<td>0/0</td>
<td>5,500</td>
<td>5,500</td>
<td>Recovered</td>
</tr>
<tr>
<td>21</td>
<td>Abdomen</td>
<td>180</td>
<td>0/0</td>
<td>4,000</td>
<td>6,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>22</td>
<td>Extrem.</td>
<td>120</td>
<td>0/0</td>
<td>6,000</td>
<td>6,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>23</td>
<td>Chest</td>
<td>190</td>
<td>0/0</td>
<td>4,000</td>
<td>7,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>24</td>
<td>Abdomen</td>
<td>180</td>
<td>0/0</td>
<td>6,500</td>
<td>8,500</td>
<td>Recovered</td>
</tr>
<tr>
<td>25</td>
<td>Abdomen</td>
<td>—</td>
<td>0/0</td>
<td>2,500</td>
<td>11,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>26</td>
<td>Chest</td>
<td>70</td>
<td>0/0</td>
<td>5,500</td>
<td>13,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>27</td>
<td>Thor-abd.</td>
<td>205</td>
<td>0/0</td>
<td>4,000</td>
<td>8,000</td>
<td>Expired, unknown</td>
</tr>
<tr>
<td>28</td>
<td>Abdomen</td>
<td>105</td>
<td>0/0</td>
<td>5,500</td>
<td>9,000</td>
<td>Expired, uncontrolled hemorrhage</td>
</tr>
<tr>
<td>29</td>
<td>Extrem.</td>
<td>125</td>
<td>0/0</td>
<td>12,000</td>
<td>16,000</td>
<td>Expired, uncontrolled hemorrhage</td>
</tr>
<tr>
<td>30</td>
<td>Extrem.</td>
<td>330</td>
<td>80/60</td>
<td>2,500</td>
<td>6,000</td>
<td>Expired cardiac arrest</td>
</tr>
<tr>
<td>31</td>
<td>Extrem.</td>
<td>90</td>
<td>80/60</td>
<td>5,500</td>
<td>9,500</td>
<td>Expired, postoperative shock</td>
</tr>
<tr>
<td>32</td>
<td>Extrem.</td>
<td>85</td>
<td>40/0</td>
<td>5,500</td>
<td>11,500</td>
<td>Expired, undetermined</td>
</tr>
<tr>
<td>33</td>
<td>Abdomen</td>
<td>180</td>
<td>50/30</td>
<td>12,000</td>
<td>28,000</td>
<td>Expired, uncontrolled oozing</td>
</tr>
</tbody>
</table>

Averages: 150, 4,400, 7,600
HISTORY OF PREHOSPITAL SHOCK RESUSCITATION

WW I  WW II  Korea  Vietnam  OIF/OEF  ?

50 years of Blood  40 years of Clear Fluids  Back to the future???
WHAT HISTORY TELLS US ABOUT CRYSTALLOIDS

Ongoing discussion for a 100 years
In the INTERIN BETWEEN WARS always controversies what replacement fluid to choose.
In the post war conclusions, made up by the physicians who actually took the heat and did not sit in the warm research laboratories: SAME CONCLUSION EVERY POSTWAR UPDATE!!

BLOOD IS GOOD – CRYSTALLOIDS ARE BAD
Fluid Resuscitation from Hemorrhagic Shock

“The historic role of crystalloid and colloid solutions in trauma resuscitation represents the triumph of hope and wishful thinking over physiology and experience.”

LTC Andre Cap

J Trauma, 2015

There is an increasing awareness that fluid resuscitation for casualties in hemorrhagic shock is best accomplished with fluid that is identical to that lost by the casualty - whole blood.
Rapid evacuation

POI

Civilian emergency response systems

Early resuscitation + TXA

Hemorrhage control

Tactical emergency medicine??

MTF (Kir kapasitet)
Shock is bad for you
Level of shock is correlated with outcome


Level of shock – correlated with level of coagulopathy and inflammation

Hess et al, J Trauma 2008 (ACOTS)

Hypoperfusion is probably the primary initiator of coagulopathy (ACoT)

THE BIG PICTURE
Prevention of further oxygen debt accumulation

Repayment of oxygen debt

Minimization of the time to oxygen debt resolution

Definitions

- **Shock:**
  - *A physiologic state where oxygen delivery (DO₂) is not sufficient to meet the metabolic requirements (VO₂) of the body.*

- **Critical DO₂**
  - *Level of DO₂ below which anaerobic metabolism begins and cellular function deteriorates*
  - *Lactate increases*

- **Compensated Shock:**
  - *A physiologic state where DO₂ is decreased but oxygen extraction increases to continue to meet VO₂ demands of the body.*

---

**Oxygen requirement (VO₂) beyond oxygen supply (DO₂) organ failure**

Definitions

• Oxygen deficit:
  • *The difference between the metabolic demand and supply at a certain time.*

• Oxygen debt:
  • *The magnitude and length of the oxygen deficit.*
  • “The time spent below critical DO2”
Ficks equation
\[D_{O2} = 1.34 \times Hgb \times SaO_2 \times CO\]
Poiseuille's law

\[ F = \frac{\Delta P}{R} = \frac{(P_A - P_V)}{R} \]
No cellular damage
Bolus – Immediate 100% Repayment

Minimal/moderate cellular damage
Bolus – Immediate 64% Repayment

Severe organ injury, early death
Bolus – Immediate 28% Repayment


“TOO LITTLE, TOO LATE!”
HEMODYNAMIC RESPONSES TO SHOCK IN YOUNG TRAUMA PATIENTS: NEED FOR INVASIVE MONITORING.

ABOU-KHALIL B¹, SCALEA TM, TROOSKIN SZ, HENRY SM, HITCHCOCK R

One of many clinical studies showing improved mortality/morbidity related to $D_0_2/V_0_2$ ratio.

Long list of publications supporting this ”fact”

Including multiple studies using different animal models
Table 3. Mean hemodynamic profiles of 39 patients

<table>
<thead>
<tr>
<th></th>
<th>At 1 Hr</th>
<th>At 8 Hrs</th>
<th>p Value (1 Hr vs. 8 Hrs)</th>
<th>At 24 Hrs</th>
<th>p Value (8 Hrs vs. 24 Hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp (°F)</td>
<td>96 ± 0.42</td>
<td>97.5 ± 0.3</td>
<td>.0001</td>
<td>99 ± 0.25</td>
<td>.03</td>
</tr>
<tr>
<td>MAP (mm Hg)</td>
<td>106 ± 3</td>
<td>103 ± 2.5</td>
<td>NS</td>
<td>103 ± 4.3</td>
<td>NS</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>104 ± 3.7</td>
<td>101 ± 4</td>
<td>NS</td>
<td>96 ± 2.6</td>
<td>NS</td>
</tr>
<tr>
<td>CVP (mm Hg)</td>
<td>11 ± 0.85</td>
<td>11 ± 0.85</td>
<td>NS</td>
<td>11 ± 0.64</td>
<td>NS</td>
</tr>
<tr>
<td>PAOP (mm Hg)</td>
<td>12 ± 0.89</td>
<td>12 ± 0.84</td>
<td>NS</td>
<td>13 ± 0.76</td>
<td>NS</td>
</tr>
<tr>
<td>Hct (%)</td>
<td>37 ± 2.1</td>
<td>35 ± 1.5</td>
<td>NS</td>
<td>35 ± 1.2</td>
<td>NS</td>
</tr>
<tr>
<td>CI (L/min/m²)</td>
<td>3.1 ± 0.19</td>
<td>4.5 ± 0.19</td>
<td>.001</td>
<td>5.4 ± 0.15</td>
<td>.01</td>
</tr>
<tr>
<td>SVRI (dyne-sec/cm².m²)</td>
<td>3102 ± 94.1</td>
<td>1990 ± 58.6</td>
<td>.001</td>
<td>1433 ± 0.15</td>
<td>.015</td>
</tr>
<tr>
<td>PVRI (dyne-sec/cm².m²)</td>
<td>370 ± 7</td>
<td>190 ± 7.6</td>
<td>.001</td>
<td>138 ± 9</td>
<td>.01</td>
</tr>
<tr>
<td>$\dot{D}O_2$I (mL/min/m²)</td>
<td>496 ± 34.9</td>
<td>732 ± 38.2</td>
<td>.001</td>
<td>993 ± 46.4</td>
<td>.001</td>
</tr>
<tr>
<td>$\dot{V}O_2$I (mL/min/m²)</td>
<td>128 ± 7.1</td>
<td>183 ± 7.9</td>
<td>.001</td>
<td>236 ± 10.2</td>
<td>.001</td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
<td>5.1 ± 0.56</td>
<td>3.4 ± 0.31</td>
<td>.04</td>
<td>2.2 ± 0.22</td>
<td>.001</td>
</tr>
<tr>
<td>SVO₂ (%)</td>
<td>69 ± 8.2</td>
<td>74 ± 4.2</td>
<td>.03</td>
<td>79 ± 3.1</td>
<td>.5</td>
</tr>
<tr>
<td></td>
<td>At 1 Hr</td>
<td></td>
<td>p Value</td>
<td>At 24 Hrs</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------</td>
<td>------------</td>
<td>---------</td>
<td>----------------</td>
<td>------------</td>
</tr>
<tr>
<td></td>
<td>Survivor</td>
<td>Nonsurvivor</td>
<td></td>
<td>Survivor</td>
<td>Nonsurvivor</td>
</tr>
<tr>
<td>MAP (mm Hg)</td>
<td>106 ± 3.6°</td>
<td>105 ± 4.5</td>
<td>NS</td>
<td>102 ± 2.6</td>
<td>101 ± 3.5</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>104 ± 8.3</td>
<td>105 ± 7.2</td>
<td>NS</td>
<td>104 ± 9.1</td>
<td>105 ± 11.1</td>
</tr>
<tr>
<td>CVP (mm Hg)</td>
<td>12 ± 1</td>
<td>11 ± 1.4</td>
<td>NS</td>
<td>13 ± 0.83</td>
<td>12 ± 1.4</td>
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<tr>
<td>PAOP (mm Hg)</td>
<td>11 ± 0.9</td>
<td>13 ± 0.99</td>
<td>NS</td>
<td>11 ± 0.7</td>
<td>13 ± 1.7</td>
</tr>
<tr>
<td>Hct (%)</td>
<td>38 ± 2.3</td>
<td>36 ± 3.1</td>
<td>NS</td>
<td>34 ± 2.1</td>
<td>35 ± 1.2</td>
</tr>
<tr>
<td>CI (L/min/m²)</td>
<td>3.2 ± 0.18</td>
<td>3 ± 0.62</td>
<td>NS</td>
<td>5.7 ± 0.15</td>
<td>5.2 ± 0.46</td>
</tr>
<tr>
<td>SVRI (dyne-sec/cm⁵.m²)</td>
<td>3010 ± 266</td>
<td>3202 ± 308</td>
<td>NS</td>
<td>1531 ± 53.9</td>
<td>1358 ± 58.1</td>
</tr>
<tr>
<td><strong>PVRI (dyne-sec/cm⁵.m²)</strong></td>
<td>301 ± 18.4</td>
<td>532 ± 36.1</td>
<td>.001</td>
<td>105 ± 14.3</td>
<td>165 ± 12.2</td>
</tr>
<tr>
<td><strong>DoI (mL/min/m²)</strong></td>
<td>519 ± 55.1</td>
<td>428 ± 80.1</td>
<td>.02</td>
<td>1098 ± 76.1</td>
<td>895 ± 78.2</td>
</tr>
<tr>
<td><strong>VoI (mL/min/m²)</strong></td>
<td>129 ± 8.8</td>
<td>127 ± 10</td>
<td>NS</td>
<td>278 ± 14.1</td>
<td>168 ± 20.1</td>
</tr>
<tr>
<td>Lactate (mg/dL)</td>
<td>4.1 ± 0.62</td>
<td>7.7 ± 1.2</td>
<td>.001</td>
<td>1.9 ± 0.19</td>
<td>4.2 ± 0.72</td>
</tr>
<tr>
<td>(mmol/L)</td>
<td>73 ± 3.3</td>
<td>63 ± 4.1</td>
<td>.03</td>
<td>81 ± 4.2</td>
<td>78 ± 3.1</td>
</tr>
</tbody>
</table>
DAMAGE CONTROL RESUSCITATION
TEMPORARY HEMORRHAGE CONTROL
PERMISSIVE HYPOTENSION
HEMOSTATIC RESUSCITATION
DAMAGE CONTROL SURGERY
(DAMAGE CONTROL RADIOLOGICAL INTERVENTION)
RESTORING ORGAN PERFUSION
PRESURGICAL MANAGEMENT
PERMISSIV HYPOTENSJON

“PRESERVING COAGULATION, REDUCING BLEEDING WHILE SACRIFICING PERFUSION”
Not a treatment Necessary evil??

Evidence???


WHAT ABOUT DELAYED EVACUATION?
HOW LONG IN THE LOW-FLOW STATE??
EVIDENCE?

  - 30% Bloodloss – SBP 80mmHg – Mean survival - 2 h

  - 35% Bloodloss – SBP 80mmHg vs 110mmHg – Mean survival hypotensive group - 3 h
  - Significantly shorter survival in the hypotensive group

  - 35% Bloodloss SBP 65 vs 80 vs 90mmHg
    • Increased mortality and persistent BD and low StO2
WHAT TARGETS?
HYPOTENSION IS 100 MM HG ON THE BATTLEFIELD
BRIAN J. EAISTRIDGE, M.D.*, JOSE SALINAS, PH.D., CHARLES E. WADE, PH.D.,
LORNE H. BLACKBOURNE, M.D.

![Graph showing mortality rate vs systolic blood pressure](image-url)
HYPOTENSION IS 100 MM HG ON THE BATTLEFIELD
BRIAN J. EASTRIDGE, M.D.*, JOSE SALINAS, PH.D., CHARLES E. WADE, PH.D.,
LORNE H. BLACKBOURNE, M.D.
The Euthanasia Coaster would kill its passengers through prolonged cerebral hypoxia, or insufficient supply of oxygen to the brain. The ride's seven inversions would inflict 10 g on its passengers for 60 seconds. Depending on the tolerance of an individual passenger to g-forces, the first or second inversion would cause cerebral anoxia, rendering the passengers brain dead.
PERMISSIVE HYPOTENSION

\[ D_{O_2} = 1.34 \times HGB \times S_{A0_2} \times CO \]
# Ideal Resuscitation Fluid

<table>
<thead>
<tr>
<th>Volume</th>
<th>Hemostatic</th>
<th>O2 Carrying Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystalloid</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Colloid</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Plasma</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>1:1:1</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Whole Blood</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>
HEMOSTATIC RESUSCITATION


- 106 study patients receiving at least 4 U of PRBC
  - 27 received 8 U to 11 U of PRBC
  - 31 received more than 12 U of PRBC
  - Average admission lactate was 6.2 mEq/L
  - Patients with high lactate (≥5 mEq/L) on admission did not clear lactate until hemorrhage control was achieved.
- On admission, 43% of the patients were coagulopathic
- There was no improvement in any ROTEM parameter during ongoing bleeding.
PREHOSPITAL OXYGEN DEBT REPAYMENT, HOW DO YOU DO IT?
Identifying the patient

• Vital signs?

• Systolic blood pressure?
  
  • Surrogate for cellular perfusion?
  
  • Undertriage 0-5%
  
  • Overtriage 15-50%

• Lacks sensitivity/specificity for predicting patient outcomes and the need for resuscitative care

• **MECHANISM OF INJURY!!**


Point of care lactate

- Elevated lactate is predictive of poor outcomes in the in-hospital setting.

- P-LAC is superior to other early surrogates for hypoperfusion (SBP and shock index) in predicting the need for RC in trauma patients with 70 mm Hg < SBP < 100 mm Hg.

- Trends associated with the effectiveness of resuscitation, even with normal vital signs.

Sensitivity/Specificity

SBP >70
SBP<100

Guyette, Francis X., et al.
Probability of resuscitative care
The detrimental effects of positive pressure ventilation during low-flow states

• Ventilatory requirements during low flow states is limited

• Positive pressure ventilation impairs perfusion

Positive pressure ventilation

- Intrathoracic pressure negative
- Drop in pressure in the vena cava
- Diaphragm moves downward
- Increase in pressure in the vena cava
Positive pressure ventilation

INSUFFLATION
Increased intra-thoracic pressure
Decreased venous return

EXPIRATION
Decreased intra-thoracic pressure
Increased venous return

SVC
IVC
RV
PA
PV
LA
Spontaneous breathing
What fluid?
WHY IS 1:1:1 THERAPY PROBABLY INFERIOR TO WHOLE BLOOD?

DILUTION
Standard Amounts of Anti-coagulants and Additives in Reconstituted Whole Blood vs Whole Blood

Component Therapy per Unit:
- 6 x RBC: 6 x 120 ml = 720 ml
- 6 x FFP: 6 x 50 ml = 300 ml
- 1 x aPLT: 1 x 35 ml = 35 ml

Total = 1055 ml

Whole Blood per Unit:
- 6 x 63 ml = 378 ml

Total: 378 ml

3 times the volume of anticoagulant and additives in 1:1:1 compared to whole blood
WHOLE BLOOD VS RECONSTITUATED WHOLE BLOOD
(1:1:1)

• CO 2-3 L/min vs. 6 L/min in healthy 80 kg Soldier
• 1:1:1 gives Hgb 9g/L (DO2 = 413ml/min)
• WB gives Hgb 13/L (DO2 = 597ml/min)
• Normal DO2 (CO = 6, Sat = 98%, Hgb 13) = 1103
• Critical DO2 in healthy volunteers (CO = 6, Sat = 98%, Hgb 5) = 378

Cardenas et al. J Trauma 2014
Transfusing 1:1:1
CO 3, Hb 9

Transfusing WB
CO 3, Hb 13

Normal
CO 6, Hb 14
EFFICACY

Warm fresh whole blood
Short term stored cold whole blood

Better RBC’s??
  – “Storage lesion”
  – NO mediated vasoconstriction

Cold stored platelets – better?

BEST TREATMENT FOR HEMORRHAGE/SHOCK/ATC?

What we are doing now that is associated with improved outcomes?

Aggressive hemorrhage control

- Hemostatic dressings, tourniquets

TXA

Early resuscitation that delivers functionality of WB (WB or 1:1:1)

- Increasing use of plt & cryo (1:1:1:1)
- Reduced RBC age
- ROTEM-guided DCR?
- Permissive hypotension?

Reduced crystalloid/colloid

Minimize time to surgery
KEY POINTS

Oxygen Debt - important predictor of death and organ failure and is directly linked to the coagulopathy of trauma

Major emphasis in the field is to prevent further accumulation of oxygen debt

Oxygen Debt must be repaid to a certain level over a certain period of time to reduce mortality and organ injury

Oxygen debt is mirrored by level of lactate and length of time it is elevated

Clearance of lactate is associated with repayment of oxygen debt, point of care lactate might be helpful in triage and as a monitor during resuscitation prehospitaly
KEY POINTS

Positive pressure ventilation may be detrimental during permissive hypotension.

Whole blood may be superior to component therapy in permissive hemostatic resuscitation.

Listen to the medics – implement only what is doable – and what helps the patient.
Hess et al, J Trauma 2008 (ACOTS)


HYPOTHERMIA
Simplicity
### THE MEDIC: NEW GEAR??

<table>
<thead>
<tr>
<th>Duty Position</th>
<th>Average Fighting Load (lbs)</th>
<th>Average FL % Body Weight</th>
<th>Average Approach March Load (lbs)</th>
<th>Average AML % Body Weight</th>
<th>Average Emergency Approach March Load (lbs)</th>
<th>Average EAML % Body Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combat Medic</td>
<td>54.53 lbs</td>
<td>31.08%</td>
<td>91.72 lbs</td>
<td>51.58%</td>
<td>117.95 lbs</td>
<td>69.88%</td>
</tr>
</tbody>
</table>
Hemoglobin levels matter?

1996: FIS (International ski federation) - decision to take pre-race Hgb measurements and exclude men with Hgb>18.5 g/l and women with Hgb>16.5 g/l from participation in the race.