RDCR - HISTORY
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.

BEECHER HK. Anesthesiology. 1946
1900

- Karl Landsteiner
  - Identified the three human blood groups A, B and O (which he labeled C)
  - Blood transfusion between persons with the same blood group did not lead to the destruction of blood cells, whereas this occurred between persons of different blood groups.
  - First successful cross matched blood transfusion was performed by Reuben Ottenberg in New York in 1907

“A single kind of red cell is supposed to have an enormous number of different substances on it, and in the same way there are substances in the serum to react with many different animal cells. (...) The number of hypothetical different substances postulated makes this conception so uneconomical that the question must be asked whether it is the only one possible. ... We ourselves hold that another, simpler, explanation is possible.”
WW1

- Bruce L Robertson
  - Showed that direct transfusion of uncrossmatched blood from the veins of a donor to a patient could save the lives of many moribund casualties, even if a few died of acute hemolytic reactions.
  - 34 case reports – 62% Survival

“On the 13th June you took my leg off above the knee, and until I received blood from someone else you considered the betting about 3 to 1 on my pegging out […] Can you find time to let me know the name and address of the man who gave me blood? I should much like to write to him.”
- A. C. Tayler – August 14, 1917

“I should like to know Sir if the patient (I acted as blood donor for) is recovering alright.”
Gunner F. Birditt – July 22, 1917
Gordon Watson (1918), in a note attached to one of Robertson's papers, 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" followed by more serious collapse.

“CASE 22: [...] Pte. F. McL. Admitted July 4th, 1917. Had been buried by a shell seven hours previously. Was in a condition of shock and collapse from intra-abdominal injury and fracture of femur. Anti-shock measures for some hours produced slight improvement. [...] Blood transfusion (1.000 c.cm.). Before transfusion: pulse 180; blood pressure: systolic 80, diastolic 40. After transfusion: pulse 140; blood pressure: systolic 185, diastolic 80. [...] Evacuated to base in two weeks. Four weeks after operation a note was received from the base stating that the patient was in excellent condition and recovery seemed assured.”
«The transfusion of whole blood – A suggestion for its more frequent employment in war surgery»

«But the addition of salt solution to the circulation is at best only a temporary measure, and merely makes up for the loss of fluid, which is only one factor in the condition»

«The broad indications for blood transfusion are based on the fact that transfused blood is the best substitute for blood lost (...) In certain haemorrhages it has definitive haemostatic properties (...)»
WW1

- Oswald Hope Robertson
  - Stored, syphilis-tested, universal donor whole blood could be given quickly and safely in forward medical units.
  - Citrate as anticoagulant
  - Paved the way for blood banking
NORSOCOM
Marinejegerkommandoen

WWI
1914-1918

The crystalloid era
1975-2007

Vietnam war
1954-1975

WWII
1939-1945

Korean war
1950-1953

Interwar
1918-1939

The crystalloid era
1975-2007

Vietnam war
1954-1975

WWII
1939-1945

Korean war
1950-1953

Interwar
1918-1939
Interwar period

- The principles of World War I blood banking were continued during the Spanish Civil War by the Blood Transfusion Services of the Spanish Republican and Nationalist Armies.

- Experiments
  - Colloids
  - Gelatins
  - The development of freeze dried plasma

- US Forces entered WWII with FDP as primary resuscitation fluid
**WWII**

- American Surgeon General refused implementing whole blood program

- Random call outs from surgeons and surgical teams – need for whole blood program

- North African campaign (June 1940 – May 1943)
  - “British whole blood in US soldiers veins”

- 30,000 pints of group O whole blood would be needed for D-Day and the following month
  - Eventually in sept 1944 – US started to export whole blood to theatre
  - In the course of WW2 - 200,000 units were successfully transported to allied forces. Universal group O
  - Due to reports on minor transfusion reactions - Americans started to titer group O.
HK. BEECHER QUOTES 1946

- Pioneering American anesthesiologist
- Crystalloid solutions:
  - “These agents are primarily useful for the correction of dehydration. As "blood substitutes" they are not very effective, and are dangerous.”
- Plasma only while waiting for whole blood
  - Lack of oxygen carrying capacity
Korean war

- 1950-1953

- When American troops entered the Korean war, they had learned their lesson.

- 400,000 units of universal whole blood group O.

- Far forward resuscitation – low titer group O.

- Massive transfusion introduced for the first time
  - >10 units /24h
ANNALS OF SURGERY

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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>
<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>40/40</td>
<td>—</td>
<td>—</td>
<td>Recovered</td>
</tr>
<tr>
<td>5</td>
<td>Abdomen</td>
<td>60</td>
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<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>
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<td>4,000</td>
<td>Recovered</td>
</tr>
<tr>
<td>7</td>
<td>Abdomen</td>
<td>185</td>
<td>60/30</td>
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<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>80/0</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>70/0</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 oozeing</td>
</tr>
</tbody>
</table>

**Averages**: 150 4,400 7,600
Vietnam war 1954-1975

The crystalloid era 1975-2007

Interwar 1918-1939

WWI 1914-1918

WWII 1939-1945

Korean war 1950-1953

Vietnam war 1954-1975
Vietnam War

- In early 1965, during the Vietnam War, a decision was made to only ship universal donor, low-titer, group O whole blood to the war zone.

- As blood requirements increased, the policy was changed to allow for the shipment of nongroup O whole blood.

- Exclusive use of low-titer, group O whole blood utilized by forward medical personnel where pretransfusion testing and compatibility testing could not be performed.

- At the peak of US involvement between September 1967 and February 1969, 230,323 whole blood units (all ABO groups included) were transfused.

- During this time period, 24 hemolytic transfusion reactions were documented:
  - Caused by accidental high titer group O transfusion.

- The experience in Vietnam served to reinforce the concept that the transfusion of universal donor low-titer group O whole blood was a safe practice.
The crystalloid era 1975-2007

Vietnam war 1954-1975

Korean war 1950-1953

WWII 1939-1945

Interwar 1918-1939

WWI 1914-1918
1975-1993

- "Quiet period" no major military conflicts.
- Civilian period implementation of crystalloid based resuscitation strategies in hemorrhagic shock
  - Based largely on paper by Carrico and Shires
  - However – the actual paper recommended minimal crystalloid (by today’s standards) while readying the whole blood transfusions for the seriously injured patient in shock
- Misinterpretation of Carrico data from 1976?
1993

- The largest ground combat battle since Vietnam occurred in Mogadishu Somalia.
  - 18 Americans were killed
  - 73 wounded.

- Tactical combat casualty care
  - Treat the Casualty
  - Prevent Additional Casualties
  - Complete the Mission

- TCCC: treating the leading causes of preventable combat death:
  - Extremity Hemorrhage
  - Tension Pneumothorax
  - Airway Obstruction
2007-16

- Lessons from OEF OIR.
- Damage control resuscitation principles 2007
  - Hemostatic resuscitation
  - Permissive hypotension
  - Damage control surgery
2012-2016

- Military and civilian implementation of hemostatic resuscitation principles
  - Early forward resuscitation with blood products

**Study Population:** US military casualties in Afghanistan from April 1, 2012 to August 7, 2015

**Study Design:** Retrospective Cohort (not Pre-Post)
Gradual expansion of transfusion capability to different MEDEVACs

**Example:**
Cumulative MEDEVAC Count
- Not transfusing
- Transfusing

![Graph](image.png)
<table>
<thead>
<tr>
<th>Unadjusted Post-treatment Between-Group Differences</th>
<th>Transfused Pre-hospital</th>
<th>Not Transfused Pre-hospital</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>*KIA (%)</td>
<td>2 (3.8%)</td>
<td>58 (20.3%)</td>
<td>0.003*</td>
</tr>
<tr>
<td>*Died (KIA + DOW) within 24 hours of MEDEVAC take-off from POI (%)</td>
<td>2 (3.8%)</td>
<td>64 (22.4%)</td>
<td>0.001*</td>
</tr>
<tr>
<td></td>
<td><strong>6-fold benefit</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Died (KIA + DOW) within 30 days (%)</td>
<td>5 (9.4%)</td>
<td>77 (26.9%)</td>
<td>0.005*</td>
</tr>
<tr>
<td></td>
<td><strong>3-fold benefit, NNT ≤ 6</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Tranexamic Acid [TXA] (%)</td>
<td>48 (90.6%)</td>
<td>144 (50.3%)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Documented shock [SBP&lt;90, HR&gt;120 or shock index &gt;0.9] upon ED arrival (%)</td>
<td>N=52</td>
<td>N=233</td>
<td>0.110</td>
</tr>
<tr>
<td></td>
<td>39 (75%)</td>
<td>137 (63%)</td>
<td></td>
</tr>
<tr>
<td>*Massive Transfusion [&gt;10 units/24hrs] (%)</td>
<td>40 (75%)</td>
<td>119 (42%)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>ISS: Median (IQR)</td>
<td>29 (17, 36)</td>
<td>24 (17, 36)</td>
<td>0.179</td>
</tr>
<tr>
<td>AIS Score indicating torso hemorrhage (%)</td>
<td>22 (41.5%)</td>
<td>108 (37.8%)</td>
<td>0.646</td>
</tr>
</tbody>
</table>

*Statistically significant at <0.05 level by Fisher’s exact test.
2012

Clear fluids
Today

- Military
  - 75th ranger
  - 160th
  - NORNAVSOC

- Civillian
  - Royal Caribbean cruise lines
  - Norwegian HEMS 2015
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 reseach laboratories: SAME CONCLUSION EVERY POSTWAR UPDATE!!

**BLOOD IS GOOD – CRYSTALLOIDS ARE BAD**
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???
The crystalloid era 1975-2007

Interwar 1918-1939

Vietnam war 1954-1975

Korean war 1950-1953

WWII 1939-1945

WWI 1914-1918
FORWARD TO THE PAST

THOR
So what is the challenge ahead?
US Military Death Distribution

4,596 Combat Deaths (2001-11)

Died of Wounds (Level II and above)
506 deaths

<table>
<thead>
<tr>
<th>Killed in Action (Level I)</th>
<th>4,090 deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Pre-MTF Combat Deaths</td>
<td>4,090</td>
</tr>
<tr>
<td>Potentially Survivable Deaths</td>
<td>1,075 (26%)</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>984 (91.5)</td>
</tr>
<tr>
<td>Airway</td>
<td>69 (6.4)</td>
</tr>
<tr>
<td>Other</td>
<td>22 (2.0)</td>
</tr>
<tr>
<td>Potentially Survivable Hemorrhage</td>
<td>984 (24%)</td>
</tr>
<tr>
<td>Truncal</td>
<td>675 (17%)</td>
</tr>
<tr>
<td>Junctional</td>
<td>170 (4%)</td>
</tr>
<tr>
<td>Extremity</td>
<td>139 (3%)</td>
</tr>
</tbody>
</table>

Treat Hemorrhage/Shock/ATC

- 90% of combat deaths occur before reaching Role 2
- 75% of combat deaths are not preventable by medical intervention
- 25% of deaths are possibly preventable, and 90% of these are due to hemorrhage, mostly truncal

The implications for treatment are:
- Stop what bleeding you can
- Resuscitate active non-compressible bleeding to the best of your ability

**Well-trained troops can do this -- YOU!!!**
- US Army Rangers: 10.7% KIA & 1.7% DOW vs. 16.4% & 5.8% for DoD
- Ranger interventions mostly for hemorrhage control (dressing/TK); rare airway interventions

US Military at Risk of Exsanguination Iraq / Afghanistan 2001-2014

- 58,831 = Killed in Action + all wounded
  - 53,724 = survivors + died of wounds
  - 8,836 transfused, ≈ 50% Massive transfusion

- Frequency of life-threatening bleeding
  - 4000 requiring massive transfusion

- 1,300 KIA died of hemorrhage with survivable injuries

- These 5,300 casualties would have been the most likely to benefit from Blood Far Forward.