Fluid Resuscitation in Surgical Patients

José L. Pascual MD, PhD, FACS, FRCS(C)
Assistant Professor of Surgery
Critical Care Medicine & Trauma
Fluid resuscitation – why?

- End organ perfusion (O$_2$)
- An empty heart will arrest in minutes
- Need to replenish blood loss by fluid – any fluid…
- A resuscitation fluid needs to
  - Resemble blood/plasma chemically
  - Stay in the vasculature
Classification of Fluids

- Crystalloid vs. colloid
- Biologically active vs. synthetic
- Isotonic, hypotonic, hypertonic
- Acidic vs alkaline
Fluid administration physiology
Historical perspective
Ringer, Sidney

A further contribution regarding the influence of the different constituents of the blood on the contraction of the heart.

*Journal of Physiology* 1883; 4: 29-42

Penfield, Wilder G.

The treatment of severe and progressive hemorrhage by intravenous injections.

*American J of Physiology* 1919; 48: 121-132

**Isotonic Crystalloids**
Ashbaugh DG et al.
Acute respiratory distress in adults.

Canizaro, et al.
The infusion of Ringer's lactate solution during shock. Changes in lactate, excess lactate, and pH. (4:1)

‘Danang lung’, ‘shock lung’ and ‘traumatic wet lung’.
Isotonic Resuscitation – 24 hours later
The ‘Danang lung’ - ARDS
Isotonic Crystalloids

- Normal Saline
- Lactated Ringer’s
- Normosol
- Hartmann’s Solution
- 1/2NS, 2/3:1/3

Alexis Hartmann (1898–1964)
Crystalloids (1)

NS
- Na: 154
- Cl: 154
- K: 0
- Ca: 0
- Lactate: 0
- Osmol: 308
- pH: 5.6

Blood
- Na: 140
- Cl: 103
- K: 4.5
- Ca: 9.4
- Lactate: 0-4
- Osmol: 273
- pH: 7.4

RL
- Na: 130
- Cl: 109
- K: 4
- Ca: 3
- Lactate: 28
- Osmol: 273
- pH: 6.6
### Crystalloids (2)

<table>
<thead>
<tr>
<th>Solution</th>
<th>Na</th>
<th>Cl</th>
<th>K</th>
<th>Ca</th>
<th>Lactate</th>
<th>Osmol</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hartmann’s</td>
<td>131</td>
<td>111</td>
<td>5</td>
<td>2</td>
<td>29</td>
<td>278</td>
<td>7.3</td>
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<tr>
<td>Blood</td>
<td>140</td>
<td>103</td>
<td>4.5</td>
<td>9.4</td>
<td>0-4</td>
<td>273</td>
<td>7.4</td>
</tr>
<tr>
<td>Normosol</td>
<td>140</td>
<td>98</td>
<td>5</td>
<td>3</td>
<td>27</td>
<td>295</td>
<td>7.4</td>
</tr>
</tbody>
</table>

**Note:**
- Normosol contains additional electrolytes such as Mg and Acetate.
## Dextrose

<table>
<thead>
<tr>
<th></th>
<th><strong>D5W</strong></th>
<th><strong>Blood</strong></th>
<th><strong>D5½NS</strong></th>
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<tbody>
<tr>
<td>Na</td>
<td>0</td>
<td>140</td>
<td>77</td>
</tr>
<tr>
<td>Cl</td>
<td>0</td>
<td>103</td>
<td>77</td>
</tr>
<tr>
<td>K</td>
<td>0</td>
<td>4.5</td>
<td>0</td>
</tr>
<tr>
<td>Ca</td>
<td>0</td>
<td>9.4</td>
<td>0</td>
</tr>
<tr>
<td>Lactate</td>
<td>0</td>
<td>0-4</td>
<td>0</td>
</tr>
<tr>
<td>Osmol</td>
<td>252</td>
<td>290</td>
<td>280</td>
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<tr>
<td>pH</td>
<td>4.0</td>
<td>7.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Dex</td>
<td>5g/100ml</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Effects of Intravenous Fluid Restriction on Postoperative Complications: Comparison of Two Perioperative Fluid Regimens

A Randomized Assessor-Blinded Multicenter Trial

Birgitte Brandstrup, MD, PhD,* Hanne Tønnesen, MD, DMSc,* Randi Beier-Holgersen, MD,‡
Else Hjortse, MD,† Helle Ørding, MD, DMSc,§ Karen Lindorff-Larsen, MD,†† Morten S. Rasmussen,
MD,† Charlotte Lanng, MD,‡ Lene Wallin, MD, DMSc,§ and The Danish Study Group on
Perioperative Fluid Therapy (Lene H. Jacobsen, MD, PhD,** Christina O. Gammelby, MD ‡

Results: The restricted intravenous fluid regimen significantly reduced postoperative complications both by intention-to-treat (33% versus 51%, P = 0.013) and per-protocol (30% versus 56%, P = 0.003) analyses. The numbers of both cardiopulmonary (7% versus 24%, P = 0.007) and tissue-healing complications (16% versus 31%, P = 0.04) were significantly reduced. No patients died in the restricted group compared with 4 deaths in the standard group (0% versus 4.7%, P = 0.12). No harmful adverse effects were observed.

Conclusion: The restricted perioperative intravenous fluid regimen aiming at unchanged body weight reduces complications after elective colorectal resection.

Little is known about the influence of perioperatively administered intravenous fluid volume on the outcome of surgery. We found 5 randomized trials evaluating effects of intraoperative fluid volume on recovery time and well-being after outpatient surgery,3-5 and 4 randomized trials showing oral postoperative hydration to be safe.6-8 No trials were designed to evaluate the effects of the combined intraoperative and postoperative intravenous fluid volume on surgical complications or death. Current fluid therapy in major sur-
Comparison of Two Fluid-Management Strategies in Acute Lung Injury

RESULTS
The rate of death at 60 days was 25.5 percent in the conservative-strategy group and 28.4 percent in the liberal-strategy group (P=0.30; 95 percent confidence interval for the difference, −2.6 to 8.4 percent). The mean (±SE) cumulative fluid balance during the first seven days was −136±491 ml in the conservative-strategy group and 6992±502 ml in the liberal-strategy group (P<0.001). As compared with the liberal strategy, the conservative strategy improved the oxygenation index ([mean airway pressure × the ratio of the fraction of inspired oxygen to the partial pressure of arterial oxygen] × 100) and the lung injury score and increased the number of ventilator-free days (14.6±0.5 vs. 12.1±0.5, P<0.001) and days not spent in the intensive care unit (13.4±0.4 vs. 11.2±0.4, P<0.001) during the first 28 days but did not increase the incidence or prevalence of shock during the study or the use of dialysis during the first 60 days (10 percent vs. 14 percent, P=0.06).

CONCLUSIONS
Although there was no significant difference in the primary outcome of 60-day mortality, the conservative strategy of fluid management improved lung function and shortened the duration of mechanical ventilation and intensive care without increasing nonpulmonary-organ failures. These results support the use of a conservative strategy of fluid management in patients with acute lung injury. (ClinicalTrials.gov number, NCT00281268.)
Premier Health Care Alliance (260 hospitals)

IS vs. BF; Sepsis, no surgery, ICU patients

53,000 patients, 3,500 BS

BF: lower mortality (0.86 [0.78-0.94])

Mortality was progressively lower if larger proportions of balanced fluids.

No diff: ARF, RRT, ICU LOS, LOS
What is hypertonic saline?

- Crystalline sodium salt dissolved in $\text{H}_2\text{O}$
- 7.5% HTS: 75g NaCl/L of water
- Seawater has a salinity 3.5%
- Plasma has a salinity of 0.9%
- 7.5% HTS is 9 X saltier than plasma
- Concentrations used clinically:
  - 3%
  - 5%
  - 7.5%
  - 23.4%
Hypertonic Crystalloids

3% HTS
- Na: 513
- Cl: 513
- K: 0
- Ca: 0
- Lactate: 0
- Osmol: 1097
- pH: 4.0

Blood
- Na: 140
- Cl: 103
- K: 4.5
- Ca: 9.4
- Lactate: 0-4
- Osmol: 290
- pH: 7.4

7.5% HTS
- Na: 1197
- Cl: 1197
- K: 0
- Ca: 0
- Lactate: 0
- Osmol: 2396
- pH: 4.2
Hypertonic fluids
HTS - Animal studies

...a potent transcapillary osmotic gradient which mobilizes intracellular and interstitial fluid into the vascular compartment

- ↑ preload
- ↓ tissue edema
- ↑ MAP, CO, DO$_2$
- ↑ urinary output
- ↑ contractility, dp/dt$_{max}$, SW
14 double blind, prospective, RCT (HTS/HSD)

HSD (615) > survival vs control (618): 7/8 trials

OR 1.20 (0.94-1.57) p=0.07
Prehospital Hypertonic Saline Resuscitation of Patients With Hypotension and Severe Traumatic Brain Injury
A Randomized Controlled Trial

1998-2002, 229 pts in Melbourne
EMS, GCS<9, SBP<100mmHg
DB, RCT,
250cc HTS or RL
With routine resuscitation
30d, 6m survival and GOS equal

Cooper, DJ et al JAMA 2004
• Multicenter pre hospital, blinded
• SBP <70mmHg / 70-90 + HR>108
• 250cc of HTS vs. NS - 853 pts (62% blunt)
• Terminated (futility, safety)
• Same mortality unless no blood products (HTS: 11% vs NS: 5%)
• More bleeding? Less recognition of shock?

Bulger et al Ann Surg 2011
Clinical Experience Using 5% Hypertonic Saline as a Safe Alternative Fluid for Use in Trauma

Joseph J. DuBose, MD, Leslie Kobayashi, MD, Alfredo Lozorno, MD, Pedro Teixeira, MD, Kenji Inaba, MD, Lydia Lam, MD, Peep Talving, MD, PhD, Bernardino Branco, MD, Demetrios Demetriades, MD, PhD, and Peter Rhee, MD, MPH

- 51 trauma pts, 500cc 5% HTS, ED (1hr)
- Matched to non-HTS cohort
- No difference pH, INR, PFR (8hr/24hr)
- 8hr-[Na+]: 150.1 vs. 143.1 mgdL, p =0.001, X 3d
- No sequelae of hypernatremia.
- No difference in mortality

Rhee et al *Journal of Trauma*, May 2010
Retrospective in Open Abdomen DC patients

- 3% saline @ 30cc/hr vs. IS @ 125cc/hr
- 3.9 vs. 7.8 L, p< 0.001
- Closure time: 34 vs. 49 hours, p<0.001
- EPFC – HTS: 100%, IS: 76%

Harvin, JA et al J Trauma 2013
Colloids

- Biologically Active
  - Plasma
  - Platelets
  - PRBCs
  - Albumin
- Synthetic
  - Starches
  - Dextrans
  - Gelatins
Biologically Active Colloids

- Blood products
  - Plasma
  - Platelets
  - PRBCs
- Albumin
A MULTICENTER, RANDOMIZED, CONTROLLED CLINICAL TRIAL OF TRANSFUSION REQUIREMENTS IN CRITICAL CARE

PAUL C. HÉBERT, M.D., GEORGE WELLS, PH.D., MORRIS A. BLAJCHMAN, M.D., JOHN MARSHALL, M.D., CLAUDIO MARTIN, M.D., GIUSEPPE PAGLIARELLO, M.D., MARTIN TWEEDDALE, M.D., PH.D., IRWIN SCHWEITZER, M.SC., ELIZABETH YEŞİR, M.SC., AND THE TRANSFUSION REQUIREMENTS IN CRITICAL CARE INVESTIGATORS FOR THE CANADIAN CRITICAL CARE TRIALS GROUP*
T.R.C.C. Trial

- 838 normovolemic ICU patients Hb < 9.0
  - 418 transfused when Hb < 7.0 (7-9)
  - 420 transfused when Hb < 10.0 (10-12)
- Excluded: actively bleeding, post cardiac Sx

- Overall 30d mortality: 18.7 vs 23.3 (ns)
- If APACHE<20: 8.7 vs 16.1 (0.03)
- If young: 5.7 vs 13 (0.02)
- In hospital mortality: 22.2 vs 28 (0.05)

Hebert et al, NEJM 1999
Transfusion of fresh frozen plasma in critically ill surgical patients is associated with an increased risk of infection

Babak Sarani, MD, FACS; W. Jonathan Dunkman, BA; Laura Dean; Seema Sonnad, PhD; Jeffrey I. Rohrbach, RN, MSN; Vicente H. Gracias, MD, FACS

Crit Care Med 2008 Vol. 36, No. 4
Figure 1. Patients who received fresh frozen plasma (FFP) were significantly more likely to develop an infection than those who did not receive FFP in a univariate model ($p < .01$).
TBI: Hb 10 = 7 (favorable neuro outcome)

HB 7: < VTE

Severe sepsis/septic shock: HB 9 = 7
Albumin
Human albumin administration in critically ill patients: systematic review of randomised controlled trials

Cochrane

Conclusions: There is no evidence that albumin administration reduces mortality in critically ill patients with hypovolaemia, burns, or hypoalbuminaemia and a strong suggestion that it may increase mortality. These data suggest that use of human albumin in critically ill patients should be urgently reviewed and that it should not be used outside the context of rigorously conducted, randomised controlled trials.

Fluid resuscitation with colloid or crystalloid solutions in critically ill patients: a systematic review of randomised trials

Gill Schierhout and Ian Roberts

Results: Resuscitation with colloids was associated with an increased absolute risk of mortality of 4% (95% confidence interval 0% to 8%), or four extra deaths for every 100 patients resuscitated. The summary effect measure shifted towards increased mortality with colloids when only trials with adequate concealment of allocation were included. There was
A Comparison of Albumin and Saline for Fluid Resuscitation in the Intensive Care Unit

The SAFE Study Investigators*
S.A.F.E Trial

- MRCT DB
- ICU heterogeneous population
- Albumin vs. Saline
- NS (3500) or 4% Albumin (3497) X 28d
- Primary outcome 28-d mortality

- 729 vs. 726 deaths, RR: 0.99
- New organ failure, MOFS, LOS, Ventilator dependence, RRT

S.A.F.E. Study Investigators, NEJM 2004
Table 3. Primary and Secondary Outcomes.*

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Albumin Group</th>
<th>Saline Group</th>
<th>Relative Risk (95% CI)</th>
<th>Absolute Difference (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status at 28 days — no./total no. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dead</td>
<td>726/3473 (20.9)</td>
<td>729/3460 (21.1)</td>
<td>0.99 (0.91 to 1.09)</td>
<td></td>
<td>0.87</td>
</tr>
<tr>
<td>Alive in ICU</td>
<td>111/3473 (3.2)</td>
<td>87/3460 (2.5)</td>
<td>1.27 (0.96 to 1.68)</td>
<td></td>
<td>0.09</td>
</tr>
<tr>
<td>Alive in hospital†</td>
<td>793/3473 (22.8)</td>
<td>848/3460 (24.5)</td>
<td>0.93 (0.86 to 1.01)</td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>Length of stay in ICU — days</td>
<td>6.5±6.6</td>
<td>6.2±6.2</td>
<td>0.24 (−0.06 to 0.54)</td>
<td></td>
<td>0.44</td>
</tr>
<tr>
<td>Length of stay in hospital — days†</td>
<td>15.3±9.6</td>
<td>15.6±9.6</td>
<td>−0.24 (−0.70 to 0.21)</td>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>Duration of mechanical ventilation — days</td>
<td>4.5±6.1</td>
<td>4.3±5.7</td>
<td>0.19 (−0.08 to 0.47)</td>
<td></td>
<td>0.74</td>
</tr>
<tr>
<td>Duration of renal-replacement therapy — days</td>
<td>0.48±2.28</td>
<td>0.39±2.0</td>
<td>0.09 (−0.0 to 0.19)</td>
<td></td>
<td>0.41</td>
</tr>
<tr>
<td>New organ failure — no. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.85†</td>
</tr>
<tr>
<td>No failure</td>
<td>1397 (52.7)</td>
<td>1424 (53.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 organ</td>
<td>795 (30.0)</td>
<td>796 (29.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 organs</td>
<td>369 (13.9)</td>
<td>361 (13.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 organs</td>
<td>68 (2.6)</td>
<td>75 (2.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 organs</td>
<td>18 (0.7)</td>
<td>17 (0.6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 organs</td>
<td>2 (0.1)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Death within 28 days according to subgroup — no./total no. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients with trauma</td>
<td>81/596 (13.6)</td>
<td>59/590 (10.0)</td>
<td>1.36 (0.99 to 1.86)</td>
<td></td>
<td>0.06</td>
</tr>
<tr>
<td>Patients with severe sepsis</td>
<td>185/603 (30.7)</td>
<td>217/615 (35.3)</td>
<td>0.87 (0.74 to 1.02)</td>
<td></td>
<td>0.09</td>
</tr>
<tr>
<td>Patients with acute respiratory distress syndrome</td>
<td>24/61 (39.3)</td>
<td>28/66 (42.4)</td>
<td>0.93 (0.61 to 1.41)</td>
<td></td>
<td>0.72</td>
</tr>
</tbody>
</table>

* Plus–minus values are means ±SD. CI denotes confidence interval, and ICU intensive care unit.
† The data include the numbers of patients in the ICU or the length of stay in the ICU.
‡ Data were available for 2649 patients in the albumin group and 2673 patients in the saline group. New organ failure was defined as a Sequential Organ-Failure Assessment score of 0, 1, or 2 in any individual organ system at baseline, followed by an increase in the score to 3 or 4 in the same system.
§ The P value pertains to the comparison between the albumin and saline groups in the numbers of patients who had no new organ failure or new failure of one, two, three, four, or five organs.
Albumin Replacement in Patients with Severe Sepsis or Septic Shock

Pietro Caironi, M.D., Gianni Tognoni, M.D., Serge Masson, Ph.D., Roberto Fumagalli, M.D., Antonio Pesenti, M.D., Marilena Romero, Ph.D., Caterina Fanizza, M.Stat., Luisa Caspani, M.D., Stefano Faenza, M.D., Giacomo Grasselli, M.D., Gaetano Iapichino, M.D., Massimo Antonelli, M.D., Vieri Parrini, M.D., Gilberto Fiore, M.D., Roberto Latini, M.D., and Luciano Gattinoni, M.D., for the ALBIOS Study Investigators*

Abstract
1818 patients/100 ICUs: severe sepsis

28 day fluids

- Group 1: crystalloid + 20% Albumin
- Group 2: crystalloid alone

- Group 1:
  - Greater BP X 7 days
  - Negative fluid balance X 7 days

- No difference in 30/90 day mortality

Caironi et al, *NEJM* 2014
Synthetic Colloids

- Starches
  - Hydroxyethyl starch
    - Hetastarch
    - Pentastarch
  - Dextran
- Gelatins
Effects of fluid resuscitation with synthetic colloids or crystalloids alone on shock reversal, fluid balance, and patient outcomes in patients with severe sepsis: A prospective sequential analysis*

Ole Bayer, MD; Konrad Reinhart, MD; Matthias Kohl, PhD; Björn Kabisch, PhD; John Marshall, MD; Yasser Sakr, MD, PhD; Michael Bauer, MD; Christiane Hartog, MD; Daniel Schwarzkopf; Niels Riedemann,

Objective: To assess shock reversal and required fluid volumes. p = 252, only crystalloids p = 234. Severity scores, body

Conclusions: Shock reversal was achieved equally fast with synthetic colloids or crystalloids. Use of colloids resulted in only marginally lower required volumes of resuscitation fluid. Both low molecular weight hydroxyethyl starch and gelatin may impair renal function. (Crit Care Med 2012; 40:2543–2551)
Association of Hydroxyethyl Starch Administration With Mortality and Acute Kidney Injury in Critically Ill Patients Requiring Volume Resuscitation
A Systematic Review and Meta-analysis

Ryan Zarychanski, MD, MSc
Ahmed M. Abou-Setta, MD, PhD
Alexis F. Turgeon, MD, MSc
Brett L. Houston, BSc
Lauralyn McIntyre, MD, MSc
John C. Marshall, MD
Dean A. Fergusson, PhD, MHA

**Importance** Hydroxyethyl starch is commonly used for volume resuscitation yet has been associated with serious adverse events, including acute kidney injury and death. Clinical trials of hydroxyethyl starch are conflicting. Moreover, multiple trials from one investigator have been retracted because of scientific misconduct.

**Objectives** To evaluate the association of hydroxyethyl starch use with mortality and acute kidney injury.

**Data Sources** Randomized controlled trials from MEDLINE, EMBASE, CENTRAL, Global Health, HealthStar, Scopus, Web of Science, the International Clinical Trials Registry Platform (inception to October 2012), reference lists of relevant articles, and gray
Meta-analysis (HES vs crystalloid, albumin, gelatins)

- 38 trials
- 10,290 patients
- 7 trials by Boldt et al (scientific misconduct)

RR of death for HES
- 1.07 (1.00 – 1.14)

Renal failure
- 1.27 (1.09-1.47)

RRT
- 1.32 (1.15-1.50)

Zarichanski et al, JAMA 2013
Figure 3. Renal Replacement Therapy and Hydroxyethyl Starch

<table>
<thead>
<tr>
<th>Source</th>
<th>HES</th>
<th>Control</th>
<th>RR (95% CI)</th>
<th>Weight, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Events Total</td>
<td>No. of Events Total</td>
<td>RR (95% CI)</td>
<td>Favors HES</td>
<td>Favors Control Intervention</td>
</tr>
<tr>
<td>Berard et al,26 1995</td>
<td>5</td>
<td>4</td>
<td>1.23 (0.34-4.48)</td>
<td></td>
</tr>
<tr>
<td>Schortgen et al,3 2001</td>
<td>13</td>
<td>11</td>
<td>1.16 (0.56-2.40)</td>
<td></td>
</tr>
<tr>
<td>Brunkhorst et al,44 2008</td>
<td>81</td>
<td>51</td>
<td>1.62 (1.19-2.21)</td>
<td></td>
</tr>
<tr>
<td>McIntyre et al,22 2006</td>
<td>3</td>
<td>1</td>
<td>2.71 (0.31-23.93)</td>
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</tr>
<tr>
<td>Du et al,35 2011</td>
<td>1</td>
<td>0</td>
<td>3.00 (0.13-69.70)</td>
<td></td>
</tr>
<tr>
<td>James et al,4 2011</td>
<td>2</td>
<td>3</td>
<td>0.66 (0.11-3.78)</td>
<td></td>
</tr>
<tr>
<td>Viachou et al,37 2010</td>
<td>0</td>
<td>0</td>
<td>Not estimable</td>
<td></td>
</tr>
<tr>
<td>Pernar al,53 2012</td>
<td>47</td>
<td>65</td>
<td>1.34 (1.00-1.79)</td>
<td></td>
</tr>
<tr>
<td>Myburgh et al,54 2012</td>
<td>235</td>
<td>198</td>
<td>1.20 (1.00-1.44)</td>
<td></td>
</tr>
<tr>
<td>Guidet et al,52 2012</td>
<td>21</td>
<td>11</td>
<td>1.83 (0.93-3.59)</td>
<td></td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>4629</td>
<td>4629</td>
<td>1.32 (1.15-1.50)</td>
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</tr>
</tbody>
</table>

Total events 448 342

Heterogeneity: $\chi^2 = 5.07; (P = .76); I^2 = 0%$

Test for overall effect: $Z = 4.08, (P < .001)$

The varying sizes of the boxes represent the weight in the analysis. HES indicates hydroxyethyl starch. Risk ratios (RRs) are derived by a random-effects model using Mantel-Haenszel tests.

Table 4. Outcomes Measures

Zarichanski et al, JAMA 2013
Authors’ conclusions

There is no evidence from randomised controlled trials that resuscitation with colloids reduces the risk of death, compared to resuscitation with crystalloids, in patients with trauma, burns or following surgery. Furthermore, the use of hydroxyethyl starch might increase mortality. As colloids are not associated with an improvement in survival and are considerably more expensive than crystalloids, it is hard to see how their continued use in clinical practice can be justified.
Conclusions

- Intravascular depletion leads to organ injury and cardiac arrest
- NS and RL are not perfectly physiologic and in excess will cause morbidity and death
- Hypertonic crystalloids should be used with caution
- Colloids result in more sustained repletion but may be harmful in the ICU
- Blood products should be avoided unless absolutely necessary
Case 1

- 33 y/o female MVC
- A: intact, B: Intact
- C: HR 120, BP: 100/50
- Abdomen tender distended
- FAST positive
Case 2

- 55 y/o male
- POD 0 for Whipple for adenocarcinoma
- “Wet” in OR
- HR 120 (denies pain), CVP 0
- Low urine output
- INR 1.7, Hb 8
Case 3

- 77 y/o male
- POD 3 for AAA repair
- Tachycardic, mildly hypotensive
- Stable Hb 10, coags normal
Case 4

- 18 y/o male, police drop off
- GSW to torso X2
- Ashen, HR 150, bp 50 palp
- Weak carotid pulses
Case 5

- 27 y/o female, TBI and pelvic # 7d ago
- HR102, BP 110/70, CVP 2, lactate normal
- Urine output 40, 30, 10, 10cc
- HB 9.9, INR 1.1
- Has already received 5L crystalloid in last 2 days