Fluid Resuscitation and Sepsis

Speakers:

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Fluid Resuscitation in Pediatric Septic Shock: Evidence & Controversies

Mark Piehl, MD, MPH
Pediatric Intensivist, WakeMed Children’s, Raleigh, NC
Associate Professor of Pediatrics, University of North Carolina at Chapel Hill

Disclosure:
Founder & Chief Medical Officer, 410 Medical, Producer of LifeFlow device
SEPTIC SHOCK

- Early goals of treatment:
  - rapid reversal of hypotension
  - restoration of perfusion
- ACCM & PALS specify fluid delivery goals for septic shock
- Effective resuscitation is difficult
- Guidelines often not met
IMPROVING PEDIATRIC SEPSIS OUTCOMES

A multi-year collaborative for children’s hospitals to reduce sepsis mortality and morbidity across all levels of care.
CASE #1

- 6mo several days viral illness
- Fever, not eating well
- Unresponsive and gray in crib
- On ED arrival mottled, weak cry
- Cap refill > 4 sec
- HR 245
- BP 68/30
CASE #2

- 11yo previously healthy girl
- Temp 106, cough, L flank pain
- CXR & RUS negative
- WBC 20,000; UA negative
- HR 140’s, BP 78/40
- 3 x 1000ml fluid boluses
- BP drops to 80/35, unresponsive
THE PROBLEM: SHOCK

- Imbalance between oxygen supply and demand
- Inadequate CO
- Decreased oxygen delivery to tissues

$O_2$ supply $> O_2$ demand
Three big categories:

- Hypovolemic
- Distributive
- Cardiogenic
SEPTIC SHOCK

Distributive

Hypovolemic

Cardiogenic
HOW TO RECOGNIZE SEPTIC SHOCK?

2017 ACCM Guidelines

PALS Guidelines

Identify Signs of Septic Shock

- Altered mental status
- Altered perfusion
- Altered heart rate
- Altered temperature
- Hypotension (may or may not be present)

0 min

Recognize decreased mental status and perfusion. Begin high flow O₂ and establish IO/IV access according to PALS.

5 min

If no hepatomegaly or rales / crackles then push 20 mL/kg isotonic saline boluses and reassess after each bolus up to 60 mL/kg until improved perfusion. Stop for rales, crackles or hepatomegaly. Correct hypoglycemia and hypocalcemia. Begin antibiotics.
HOW TO RECOGNIZE SHOCK?
RECOGNIZE SHOCK BEFORE HYPOTENSION!

Opportunity to intervene

% of normal BP

Compensated shock

Decompensated shock

SVR

BP

HR

CO
RECOGNIZE SHOCK BEFORE HYPOTENSION!

Opportunity to intervene

Hypotension = SBP < 70 + (2 x age)
Initial Stabilization

• Monitor and support airway, breathing, and circulation
• Monitor heart rate, blood pressure, and pulse oximetry
• Establish vascular access (IV or IO); draw blood for culture and lab studies, including glucose and calcium — do not delay antibiotic or fluid therapy
• **Antibiotics:** give broad spectrum antibiotics
• **Fluid boluses:** Give 20 mL/kg isotonic crystalloid (10ml/kg for neonates and those with pre-existing cardiovascular compromise). Assess carefully after each bolus. Repeat as necessary to treat shock. Stop if rales, respiratory distress, or hepatomegaly develops
• **Goals of therapy:** improved mental status, normalization of heart rate and temperature, adequate systolic and diastolic blood pressure, and improved perfusion

American Heart Association, PALS Provider Manual 2015
2017 ACCM Guidelines

- Rapid fluid boluses of 20 mL/kg by push or rapid infusion device
- Goal is normal perfusion & BP
- Observe for signs of fluid overload
- In the absence of findings of fluid overload, may require 40-60mL/kg or more in 1st hour
REVERSING SHOCK IMPROVES OUTCOME

- All patients who received >40ml/kg in 1st hour survived
- Successful early reversal of shock results >9 fold increase in survival
- Each hour of persistent shock doubles mortality
SEPSIS PROTOCOLS IMPROVE OUTCOME

Earlier fluid resuscitation reduces:

- Mortality
- Organ dysfunction
- Hospital & ICU length of stay
• 5-component sepsis bundle
• 60ml/kg in 15 min = perfect
• 60ml/kg in 60 min = adequate
• Adherence was low (37% & 11%)
• When guidelines met, 57% shorter LOS
• Barriers to fluids included:
  - lack of guideline knowledge
  - inability to deliver fluid quickly
Paul, Pediatrics 2014

- QI intervention to improve adherence to PALS septic shock guidelines
- Focused on fluids as key driver impacting sepsis bundle adherence
- Compliance increased 37% to 100%
- Mortality decreased 4.8% to 1.7%
- “Use of appropriate fluid delivery device associated with fluid adherence and bundle adherence”
“IV fluid administration systems for pediatric fluid therapy do not deliver fluid as quickly as required for some forms of shock. To facilitate rapid delivery:”

- Place a 3-way stopcock in line
- Deliver fluid by using a 30- or 60ml syringe to push through the stopcock
- Or use a pressure bag (beware of air embolism!) or rapid infusion device
SO HOW TO AVOID TOO MUCH FLUID?

• Reassess after each bolus:
  - Mental status
  - HR, BP
  - Pulses, cap refill

• If heart failure suspected give 10ml/kg & reassess

• Look for signs of volume overload or heart failure:
  - Tachycardia
  - Gallop
  - Hepatomegaly
  - Crackles
IVC ULTRASOUND
Sepsis with IVC collapse

Normal
US-GUIDED SHOCK MANAGEMENT

- US-guided vs standard management in pediatric septic shock
- Fluid boluses for IVC > 50% collapse
- Results:
  - Faster reversal of shock
  - More fluid early, less in 24 hours
  - Less volume overload
  - Shorter PICU stay (8 vs 14 days!)
  - Lower mortality
Mortality after Fluid Bolus in African Children with Severe Infection


Fluid Bolus Over 15–20 Versus 5–10 Minutes Each in the First Hour of Resuscitation in Children With Septic Shock: A Randomized Controlled Trial

Jhuma Sankar, MD; Jawad Ismail, MD; M. Jeeva Sankar, MD, DM; Suresh C.P., MD; Rameshwar S. Meena, MD.

Objectives: To compare the effect of administration of 40–60 mL/kg of fluid as fluid boluses in aliquots of 20 mL/kg each over 15–20 minutes with that over 5–10 minutes each on the composite outcome of need for mechanical ventilation and/or impaired oxygenation—increase in oxygenation index by 5 from baseline in the initial 6 and 24 hours in children with septic shock.

Design: Randomized controlled trial.

Setting: Pediatric emergency and ICU of a tertiary care institute.

Participants: Children (<18 yr old) with septic shock.

Interventions: We randomly assigned participants to 15–20 minutes bolus (study group) or 5–10 minutes bolus groups (control group).

Key Words: duration of bolus; fluid bolus; fluid overload; septic shock.

Conclusion: Children receiving fluid boluses over 5–10 minutes each had a higher risk of intubation than those receiving boluses over 15–20 minutes each. Notwithstanding the lack of difference in risk of mortality and the possibility that a lower threshold of intubation and mechanical ventilation was used in the presence of fluid overload, our results raise concerns on the current recommendations of administering boluses over 5–10 minutes each in children with septic shock. (Pediatr Crit Care Med 2017; XX:00–00)

Malbrain, Principles of Fluid Management and Stewardship in Septic Shock, Ann Int Care 2018
• African children with severe febrile illness and impaired perfusion
• Fluid bolus group higher mortality
African children with severe febrile illness and impaired perfusion

Fluid bolus group higher mortality

Important to note:

- 60% had dengue & malaria
- 30% had hgb < 5mg/dl
- No ICU, HFNC, ventilators, vasopressors
- Control group had 7% mortality
- Hypotensive patients not randomized
FLUID CHOICE?

- Normal saline
- Lactated Ringers
- Balanced solutions
- Albumin

PRomPT BOLUS
PRagMatic Pediatric Trial of Balanced vs nOrmaL Saline FlUId in Sepsis

promptbolus.research.chop.edu
CASE #1

• 6mo with several days viral illness
• Unresponsive and gray in crib
• In ED HR 245, unresponsive
• cap refill > 4 sec
• ph 6.7, lactate 9
### CASE #1

- 40ml/kg pushed
- HR 221 to 170
- 200ml/kg total
- Lactate < 2 in 4 hours
- No pressors needed

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<th>Temperature</th>
<th>Rectal Temperature</th>
<th>HR</th>
<th>SBP</th>
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<th>MAP</th>
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CASE #2

- 11yo, temp 106, cough, L flank pain
- CXR & RUS negative
- WBC 20,000; UA negative
- HR 140’s, BP 78/40
- 3 x 1000ml fluid boluses
- On ward BP 80/35, unresponsive
CASE #2

- 15L HFNC started
- 400ml pushed in 2 minutes
- HR 130’s
- BP 100/60
- Much more alert
- Norepinephrine started
- Off oxygen in 12 hours
- Off norepi in 2 days
IMPROVING THE SLOPE OF RESUSCITATION

- Early fluid delivery, reversal of shock and hypotension
- Stabilization, titration of vasopressors
- De-resuscitation: further fluid intake minimized, diuresis
- Standard care: slow initial shock reversal, long-term fluid overload

Time

0  6  12  18  24

Fluids
CONCLUSIONS

• Septic shock is an emergency
• Quick recognition and treatment can save lives
• Start with fluid bolus of 20ml/kg
• Repeat until shock reversed
• Frequent reassessment!
• Start vasopressors early
Tailored Volume Resuscitation in the Critically Ill is Achievable

Heath E Latham, MD
Associate Professor
Fellowship Program Director
Pulmonary and Critical Care
- Disclosure
  - Cheetah Medical
Objectives

• Describe the goal of resuscitation in shock.
• Recognize potential adverse outcomes of over resuscitation of the critically ill.
• Increase awareness of guided volume resuscitation strategies.
• Recognize applications and limitations of bioreactance derived hemodynamic monitoring.
• Recognize applications and limitations of pulse contour analysis derived hemodynamic monitoring.
• Describe potential benefits of volume targeted resuscitation to limit volume overload.
Clinical Case

- AR is a 72 yo 80 Kg female admitted from a SNF with a 1 day history of altered mental status and fevers. She is hypotensive on presentation with evidence of a UTI from an indwelling foley. She has a history of ischemic cardiomyopathy with an EF of 20% and chronic renal failure with crt of 2.4. She is given two 500mL boluses of fluid and abx in the ED and admitted to the ICU.
- First bolus resulted in 20% improvement in SV
- Second bolus resulted in 8% improvement in SV
- Post fluid vitals: T 39, BP 80/40, HR 95 (NSR), RR 28
Surviving Sepsis Campaign Guidelines

1. Severe Sepsis and Septic Shock are medical emergencies, and treatment and resuscitation should begin immediately. (BPS)

2. We recommend that, in the resuscitation from sepsis-induced hypoperfusion, at least 30 mL/Kg of IV crystalloid fluid be given within the first 3 hours
   • Strong recommendation, low quality of evidence

SSC. Crit Care Med. 2017; 45:486-552.
30 ml/Kg seems to be standard practice...

<table>
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<tr>
<th>Trial</th>
<th>Time to randomization (hours)</th>
<th>Fluids received prior to randomization (mL)</th>
<th>Fluids Received prior to randomization (mL/kg)</th>
<th>Between 0 and 6 h after randomization (mL)</th>
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<td>NA</td>
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<td>ProCESS</td>
<td>3.0</td>
<td>2083 ± 1405</td>
<td>28 ± 21</td>
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<td>ARISE</td>
<td>2.7</td>
<td>2591 ± 1331</td>
<td>34.7 ± 20.1</td>
<td>1713 ± 1401</td>
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<td>PROMISE</td>
<td>2.5</td>
<td>1790 (1000, 2500)</td>
<td>24*</td>
<td>2022 ± 1271</td>
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<td>Variables</td>
<td>All Patients</td>
<td>( \leq 30 \text{ min} )</td>
<td>31–120 min</td>
<td>( &gt; 120 \text{ min or No Fluids in First 6 hr} )</td>
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<td>5,336</td>
<td>2,388</td>
<td>3,458</td>
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<td>All in-hospital mortality, ( n ) (% 95% CI)</td>
<td>2,241 (20.0)</td>
<td>949 (17.8)</td>
<td>446 (18.7)</td>
<td>846 (24.5)</td>
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<td>(16.8–18.8)</td>
<td>(17.2–20.3)</td>
<td>(23.1–25.9)</td>
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<td>60-d in-hospital mortality</td>
<td>2,219 (19.8)</td>
<td>941 (17.6)</td>
<td>444 (18.6)</td>
<td>834 (24.1)</td>
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<td>(17.1–20.2)</td>
<td>(22.7–25.6)</td>
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<td>28-d in-hospital mortality</td>
<td>2,029 (18.1)</td>
<td>889 (16.7)</td>
<td>414 (17.3)</td>
<td>726 (21.0)</td>
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<td>ICU LOS (d) (ICU admitted only, ( n = 5,185 ))</td>
<td>12.8</td>
<td>10.4 (9.4–11.3)</td>
<td>10.9 (9.6–12.3)</td>
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<td>(95% CI)</td>
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<td>Hospital LOS (d), (95% CI)</td>
<td>14.9</td>
<td>12.8 (12.3–13.3)</td>
<td>13.1 (12.4–13.8)</td>
<td>19.6 (18.4–20.7)</td>
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<td>Mean percentage lactate clearance, ( % ) (95% CI), ( n )</td>
<td>5,963 (19.7)</td>
<td>(23.8) (22.3–25.2)</td>
<td>(23.0) (20.5–25.5)</td>
<td>(9.5) (6.7–12.4)</td>
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<td>(3,055)</td>
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<td>(1,624)</td>
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<td>Hospital mortality</td>
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<td>Heart failure</td>
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<td>1.01 (0.93–1.09)</td>
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<td>Crystalloid volume in first 6 hr (L), mean (SD)</td>
<td>1.6 (1.2)</td>
<td>2.1 (1.1)</td>
<td>1.8 (1.0)</td>
<td>0.8 (1.1)</td>
</tr>
<tr>
<td>Volume/kg in first 6 hr (mL/kg), mean (SD)</td>
<td>23 (19)</td>
<td>29 (17)</td>
<td>27 (17)</td>
<td>11 (17)</td>
</tr>
<tr>
<td>&lt; 5 mL/kg (or no fluids in first 6 hr), n (%)</td>
<td>2,169 (19.4)</td>
<td>101 (1.9)</td>
<td>59 (2.5)</td>
<td>2,009 (58.1)</td>
</tr>
<tr>
<td>5–19.9 mL/kg, n (%)</td>
<td>3,224 (28.8)</td>
<td>1,612 (30.2)</td>
<td>923 (38.7)</td>
<td>689 (19.9)</td>
</tr>
<tr>
<td>20–35 mL/kg, n (%)</td>
<td>3,254 (29.1)</td>
<td>1,990 (37.3)</td>
<td>819 (34.3)</td>
<td>445 (12.9)</td>
</tr>
<tr>
<td>&gt; 35 mL/kg, n (%)</td>
<td>2,535 (22.7)</td>
<td>1,633 (30.6)</td>
<td>587 (24.6)</td>
<td>315 (9.1)</td>
</tr>
</tbody>
</table>
Goal of Resuscitation

- Achieve Adequate Perfusion Pressure
  - MAP > 65 mmHg
    - Volume Replacement
    - Vasopressors
    - Inotropic
- Improve Microcirculatory Flow
  - Rapidly treat underlying cause of shock
- Limit Tissue Edema
What’s the Goal of Fluid Resuscitation?

• Improve Stroke Volume/Cardiac Output
• Fluid Responsiveness in Severe Sepsis/Septic Shock?
  • Approx 50%
  • Cavallaro et al. Inten Care Med. 2010; 36:1475-83
What are the Consequences?

What are the Consequences?

A positive fluid balance is an independent prognostic factor in patients with sepsis
Angéla Acheampong and Jean-Louis Vincent

Review of A Large Clinical Series
Association of Cumulative Fluid Balance on Outcome in Acute Lung Injury: A Retrospective Review of the ARDSnet Tidal Volume Study Cohort
Andrew L. Rosenberg, MD, Ronald E. DeChert, DrPH, Pauline K. Park, MD, and Robert H. Bartlett, MD; for the NIH NHLBI ARDS Network

Early Liberal Fluids for Sepsis Patients Are Harmful
Kelly Genga, MD1; James A. Russell, MD1,2
Other Volume Sensitive Outcomes?

- Retrospective Chart Review
  - Medical ICU
  - Severe Sepsis/Septic Shock
  - April 2014-September 2014
    - Usual Care (91) vs SV Guided Resuscitation (100)
    - Hypothesis: Guided Resuscitation < Fluid

## Other Volume Sensitive Outcomes?

<table>
<thead>
<tr>
<th>Demographics</th>
<th>SV-guided (%)</th>
<th>Usual care</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient no.</td>
<td>100</td>
<td>91</td>
<td>0.61</td>
</tr>
<tr>
<td>Age, y</td>
<td>60</td>
<td>59</td>
<td>1.00</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>49/51</td>
<td>45/45</td>
<td>0.87</td>
</tr>
<tr>
<td>SAPS II score</td>
<td>49.64 ± 1.60</td>
<td>49.25 ± 1.69</td>
<td></td>
</tr>
<tr>
<td>Admit SVI pre-challenge</td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(on vasopressors)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admit SVI post-challenge</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(on vasopressors)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admit SVI pre-challenge</td>
<td>37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no vasopressors)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admit SVI post-challenge</td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no vasopressors)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥10% SVI increase</td>
<td>53/100 (53)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(all patients)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lactate pre-challenge</td>
<td>3.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lactate post-challenge</td>
<td>2.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admit pulse</td>
<td>96</td>
<td>102</td>
<td>0.12</td>
</tr>
<tr>
<td>Admit BP</td>
<td>96/53</td>
<td>112/65</td>
<td>0.0001</td>
</tr>
<tr>
<td>Admit MAP</td>
<td>65</td>
<td>78</td>
<td>0.0001</td>
</tr>
<tr>
<td>Admit creatinine*</td>
<td>1.6</td>
<td>2.1</td>
<td>0.057</td>
</tr>
<tr>
<td>Admit lactate</td>
<td>2.82</td>
<td>3.25</td>
<td>0.27</td>
</tr>
</tbody>
</table>

ICU Fluid Balance

Other Volume Sensitive Outcomes?

Secondary Outcomes

- Mortality: 21% vs 20%
- ICU LOS:
  - 6 vs 9 Days (p = 0.03)
- Mechanical Ventilation
  - 29% vs 57% (p = 0.001)
  - MV Days: 6.3 vs 6.7 (p = 0.76)

Secondary Outcomes

- Vasopressors
  - 48% vs 57% (p = 0.25)
- Duration:
  - 32 vs 65 hrs (p = 0.001)
- Hemodialysis
  - 6% vs 19% (p = 0.01)

## SV Guided Resuscitation

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Results</th>
<th>Confidence intervals</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net-fluid balance – 4 h</td>
<td>$-360.91 \text{ mL}$</td>
<td>$-727.16 \text{ to } -5.340$</td>
<td>0.053</td>
</tr>
<tr>
<td>Net-fluid balance – 24 h</td>
<td>$-1391.95 \text{ mL}$</td>
<td>$-2150.96 \text{ to } -632.95$</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Net-fluid balance – 48 h</td>
<td>$-1485.26 \text{ mL}$</td>
<td>$-2496.60 \text{ to } -473.92$</td>
<td>0.004</td>
</tr>
<tr>
<td>Net-fluid balance – ICU LOS</td>
<td>$-2779.17 \text{ mL}$</td>
<td>$-4686.48 \text{ to } -871.86$</td>
<td>0.005</td>
</tr>
<tr>
<td>In-hospital mortality</td>
<td>OR 0.58</td>
<td>0.23–1.47</td>
<td>0.25</td>
</tr>
<tr>
<td>ICU LOS – survivors</td>
<td>$-2.55 \text{ days}$</td>
<td>$-4.98 \text{ to } -0.12$</td>
<td>0.040</td>
</tr>
<tr>
<td>Mechanically ventilated</td>
<td>OR 0.34</td>
<td>0.15–0.80</td>
<td>0.01</td>
</tr>
<tr>
<td>Ventilator days</td>
<td>$-2.15 \text{ days}$</td>
<td>$-5.24 \text{ to } -0.97$</td>
<td>0.17</td>
</tr>
<tr>
<td>Vasopressor initiated</td>
<td>OR 0.57</td>
<td>0.26–1.24</td>
<td>0.15</td>
</tr>
<tr>
<td>Vasopressor duration</td>
<td>$-27.94 \text{ h}$</td>
<td>$-51.16 \text{ to } -4.74$</td>
<td>0.02</td>
</tr>
<tr>
<td>Acute dialysis initiated</td>
<td>OR 1.11</td>
<td>0.08–15.74</td>
<td>0.94</td>
</tr>
</tbody>
</table>

---

SV Guided Resuscitation

- 30 mL/Kg?
- Retrospective ED Sepsis/Septic Shock Cohort
  - 120 patients
    - NICOM assessed SV responsiveness
    - 63% SV responsive at presentation
    - Divided based on fluids stopped based on SV data
SV Guided Resuscitation

<table>
<thead>
<tr>
<th>Were fluids stopped before 30 ml/kg based on NICOM?</th>
<th>Yes (n=50)</th>
<th>No (n=70)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total IVFs in 3 hours (ml)</td>
<td>1678.0</td>
<td>2200.7</td>
<td>0.0051</td>
</tr>
<tr>
<td>Volume in ml/kg</td>
<td>19.98</td>
<td>29.47</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>NEWS score</td>
<td>7.2</td>
<td>6.9</td>
<td>0.5959</td>
</tr>
<tr>
<td>Vasopressors Required</td>
<td>22/50 (44%)</td>
<td>21/70 (30%)</td>
<td>0.1148</td>
</tr>
<tr>
<td>Vasopressor Duration (hr)</td>
<td>37.18</td>
<td>54.33</td>
<td>0.2715</td>
</tr>
<tr>
<td>Mechanically Ventilated</td>
<td>1/50 (2%)</td>
<td>6/70 (8.6%)</td>
<td>0.2367</td>
</tr>
<tr>
<td>Acute Hemodialysis</td>
<td>1/50 (2%)</td>
<td>2/70 (2.9%)</td>
<td>1.0000</td>
</tr>
<tr>
<td>Hospital LOS (days)</td>
<td>6.78</td>
<td>7.39</td>
<td>0.5956</td>
</tr>
<tr>
<td>Hospital Mortality</td>
<td>4/50 (8%)</td>
<td>9/70 (12.9%)</td>
<td>0.3987</td>
</tr>
</tbody>
</table>
Tailored Resuscitation

Technology
- Bioreactance
  - NICOM
  - Starling
- Doppler Derived
  - Bedside US
  - USCOM
- Pulse Contour Analysis
  - Flotrack/EV1000
  - LiDCO
  - PiCCO

Challenge Technique
- Volume Expansion
  - 500mL w/in 30 min
- Passive Leg Raise (PLR)
Bioreactance

- Completely Non-Invasive
  - 4 Electrodes on Chest
    - Assess change in current
  - Spontaneous Breathing
  - Mobile Patient
  - Updates every minute

Bioreactance

• Tested in Various Settings
  • ER
  • ICU
  • Pregnancy
  • Pulmonary HTN
• Not Effect by External Electronics
• Applicable in Non-Physician Algorithms

• Limitations
  • Electrode Durability
  • Inaccurate
    ▪ Severe AI
    ▪ Thoracic Aneurysms
    ▪ Balloon Pump
    ▪ LVAD
Pulse Contour Analysis

Estimation of SV

• Area under the curve
  ▪ Systolic portion

• Presumed constants
  ▪ Vascular compliance
  ▪ Aortic impedance
  ▪ PVR

• Pulse Regularity
  ▪ Improves accuracy

\[
CO = \text{cal} \times \text{HR} \times \int_{\text{Systole}}^{\text{Diastole}} \left( \frac{P(t)}{R_p} + C_A(p) \frac{dP}{dt} \right) \, dt
\]

Pulse Contour Analysis

Advantages

• Simple to use
• Real time data
• Utilize arterial line already in place
• Continuous CO
• Non-physician resuscitation protocols

Disadvantages

• Requires excellent waveforms
• Re-calibration
• SVV Limited to Optimal Parameters
  ▪ Sinus Rhythm
  ▪ Vt >8 mL/Kg
  ▪ HR/RR > 3.6
  ▪ No Spontaneous Resp
Doppler Derived Stroke Volume

- Bedside US with Doppler
  - Echocardiography
  - Peripheral artery Doppler
- Esophageal Doppler
- USCOM Device
Bedside Ultrasound

Advantage of US in Shock

▪ Assess Cause of Shock
  ▪ Cardiac
  ▪ Pulmonary
  ▪ Septic

▪ Assess Volume Responsiveness
▪ Assess Therapeutic Result
Bedside Ultrasound

Disadvantage of US in Shock

- Competence of User
  - Training* in bedside ultrasound
  - Training* in doppler-based measurements
- Inter/Intra-observer Variability
- How Many Devices Are Needed
- No Form of Continuous Measurement
  - Nursing can’t monitor change in hemodynamics
Conclusion

• Guidelines Serve to Limit Care Variation
  • 30mL/Kg = Low Level of Evidence

• Mounting Evidence of Potential Harm From Excess Volume
  • Mortality
  • Secondary Outcomes

• Technology is Available for SV Guided Resuscitation

• Prospective RCT Are Needed to Further Assess the 30mL/Kg
Questions?

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Associate Professor of Pediatrics, University of North Carolina at Chapel Hill
Founder and Chief Medical Officer, 410 Medical Innovation
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Heath Latham, MD, FCCP
Associate Professor of Medicine
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Children’s Hospital Association 2019 Sepsis Webcast Series

Pediatric Prehospital Sepsis Screening and Management
April 10 @ 1 pm ET

A special event in partnership with Sepsis Alliance

Kathleen Brown, MD
George Washington University
Children’s National Health System

Lynn Babcock, MD, MS
University of Cincinnati
Cincinnati Children’s Hospital Medical Center
Webinar Series
Sepsis: Across the Continuum of Care

Pediatric Sepsis Week April 21 – 27

Surviving Pediatric Sepsis: What’s Next?
April 24 at 2 pm ET

Scott L. Weiss, MD MSCE FCCM
Assistant Professor, Children’s Hospital of Philadelphia,
University of Pennsylvania Perelman School of Medicine

Marnie Doubek, MD, FAAFP
Mother of Zachery, a pediatric sepsis survivor

Register: www.sepsiswebinar.org

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- Pediatric Nurses
- Nursing Students
- Sepsis Coordinators

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Deadline: April 26, 2019

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JUNE 1, 2019 | 9 AM
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STEPONSEPSIS.ORG
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To provide sepsis best-practice resources and guidance to sepsis coordinators and all health professionals across the country.

SCN activities support ongoing communication, education and network building among health professionals passionate about improved sepsis care.

Activities include:

- **Educational webinars** that highlight sepsis best practices in a variety of healthcare settings
- Active **discussion** and **peer support** via an online community
- **Training** and **education** opportunities
- **Resources drive** to find information on a range of topics, including core measures, clinical practice guidelines, patient screening and identification tools, education resources and more
Maternal Sepsis Day is May 15

**Maternal Sepsis Webinar**

May 15 at 2 pm ET

Speakers:
- Lori Olvera, DNP, RNC-OB, EFM-C
  Perinatal Education Sutter Medical Center

- Katarina Lanner-Cusin, M.D., FACOG
  Medical Director Women’s Services, Sutter Health
  Alta Bates Summit Medical Center

- Gracie Ramirez Maternal Sepsis Survivor

**Registration opens soon: www.sepsiswebinar.org**

*This webinar is made possible with unrestricted educational support from Siemens*
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