

Pediatric Sepsis Management: A Thoughtful Approach

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Background¹

- Mortality for children with sepsis ranges from 4% to as high as 50%, depending on
 - Illness severity
 - Risk factors
 - Geographic location
- The majority of children who die of sepsis suffer from refractory shock and/or multiple organ dysfunction syndrome, with many deaths occurring within the initial 48 to 72 hours of treatment
- Early identification and appropriate resuscitation and management are therefore critical to optimizing outcomes for children with sepsis.

Screening¹

- In children who present as acutely unwell, we *suggest* implementing systematic screening for timely recognition of septic shock and other sepsis-associated organ dysfunction
- We *recommend* implementing a protocol/guideline for management of children with septic shock or other sepsis-associated organ dysfunction
- We *recommend* obtaining blood cultures before initiating antimicrobial therapy in situations where this does not substantially delay antimicrobial administration

Screening Tools²

Davis et al

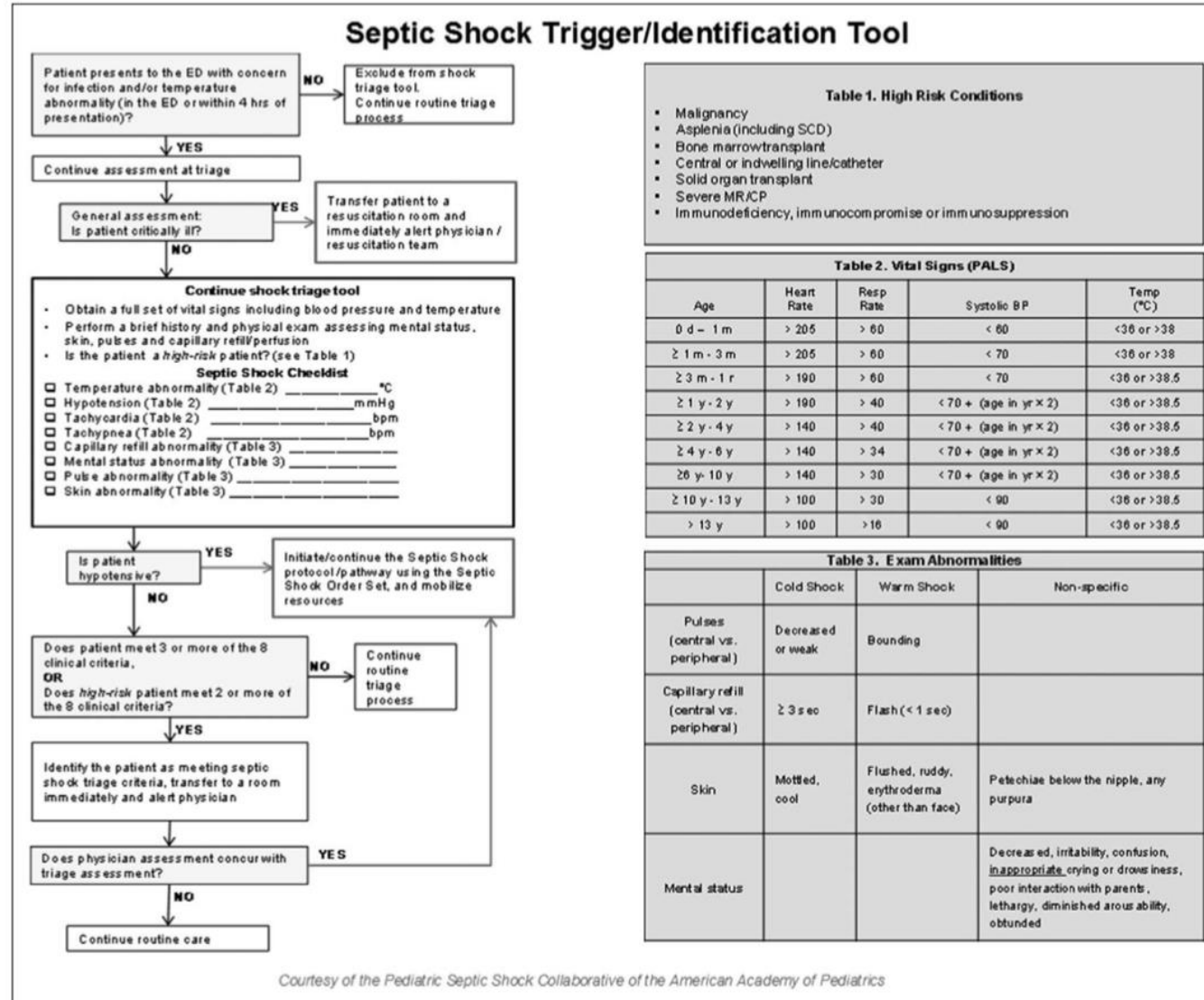


Figure 3. American Academy of Pediatrics trigger tool for early septic shock recognition.

A Case Study...

You are in the ED caring for a 16 y/o previously well patient that you admitted earlier today for shock and hypotension. Following aggressive resuscitation with isotonic crystalloid, intubation and mechanical ventilation and placement of a central venous line (CVL), you placed her on an epinephrine infusion with subsequent improvement her blood pressure (70/35 → 100/68), perfusion (capillary refill ~ 2-3 seconds), lactate (6 → 1.5) and urine output (~1 cc/kg/hr). Her ABG shows a pH of 7.38, a pCO₂ of 45 and a PaO₂ of 95 with oxygen saturations of 100%. While you are congratulating yourself on a successful resuscitation you wonder...

What is the Secret of Life?

Delivery of Oxygen!

How do we describe that (mathematically speaking)?

$$DO_2 = CO \times CaO_2$$

$$CO = HR \times SV$$

$$CaO_2 = (1.34 \times Hgb \times SaO_2) + (0.003 \times PaO_2)$$

Ergo...

What is the Secret of Life?

$$DO_2 = HR \times SV \times [(1.34 \times Hgb \times SaO_2) + (\cancel{0.003 \times PaO_2})]$$

Dissolved oxygen

Preload = volume
Contractility= Starling, inotropes
Afterload = vasoactive agents

1. Low partial pressure of atmospheric oxygen e.g., high altitude
2. Hypoventilation
3. Ventilation-perfusion mismatch (V/Q)
4. Shunt (Extrapulmonary)
5. Impaired Diffusion

**Congratulations, you have now completed
50% of your PICU Fellowship!**

How do we Operationalize these concepts?

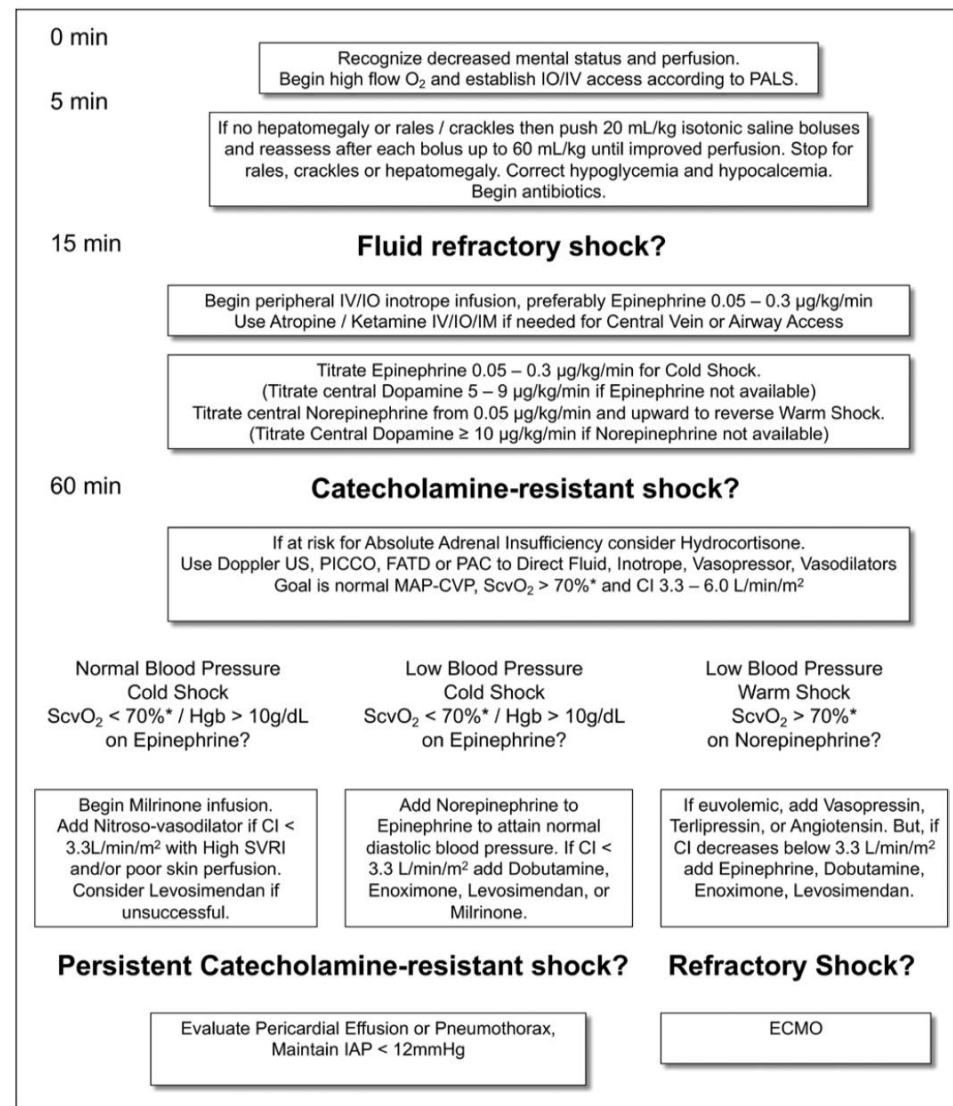


Figure 2. American College of Critical Care Medicine algorithm for time-sensitive, goal-directed stepwise management of hemodynamic support in infants and children. Proceed to next step if shock persists. 1) First-hour goals—restore and maintain heart rate thresholds, capillary refill ≤ 2 s, and normal blood pressure in the first hour/emergency department. 2) Subsequent ICU goals—if shock not reversed proceed to restore and maintain normal perfusion pressure (MAP – CVP) for age, ScvO₂ > 70% (* except congenital heart patients with mixing lesions), and cardiac index > 3.3 < 6.0 L/min/m² in PICU.

Recognition: 0 - 5 Minutes

0 min

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

5 min

Screening Tools²

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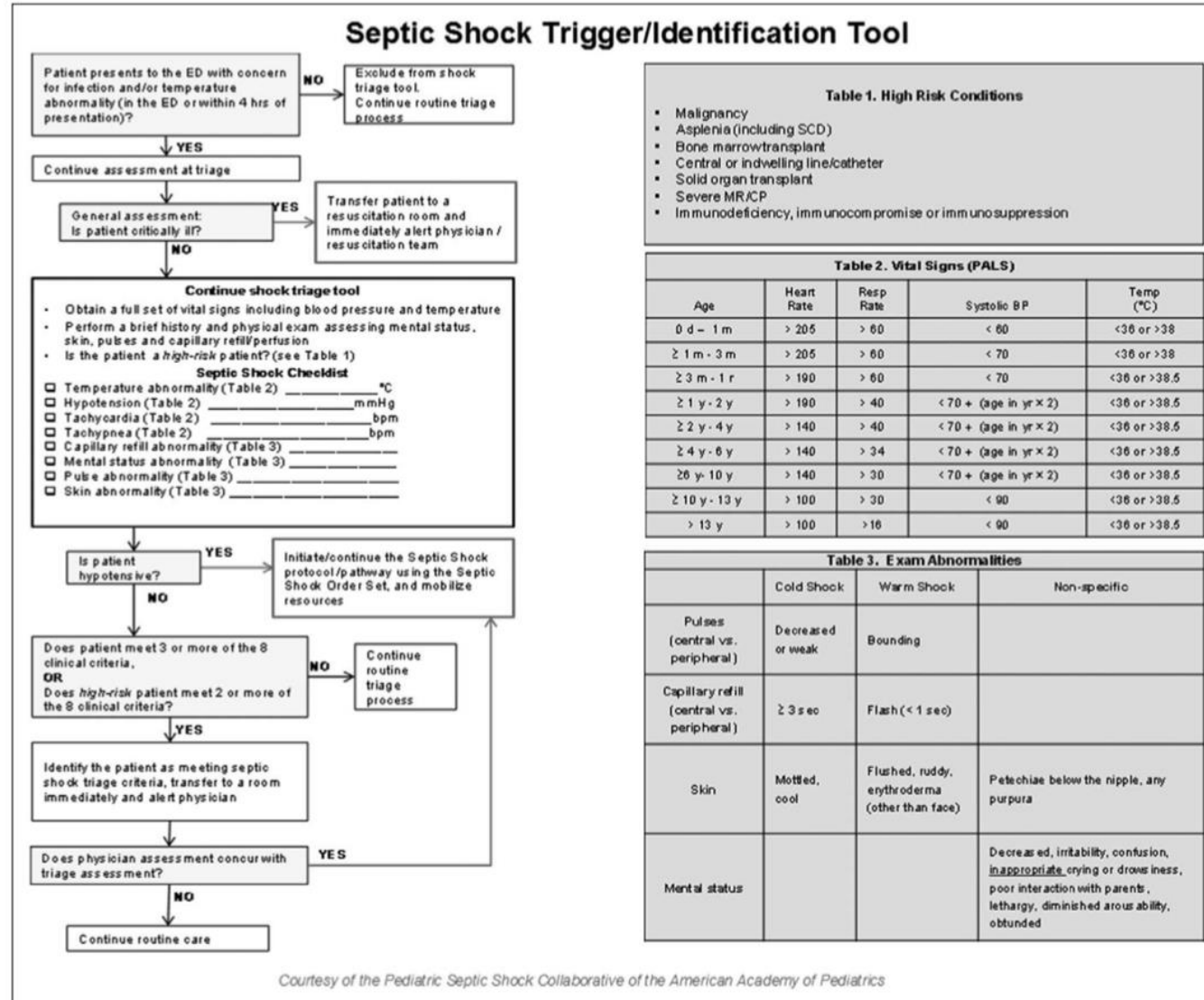


Figure 3. American Academy of Pediatrics trigger tool for early septic shock recognition.

Assessment and Intervention: 5-15 minutes

0 min	Recognize decreased mental status and perfusion. Begin high flow O ₂ 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.
15 min	Fluid refractory shock?

What is the Secret of Life?

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IVF Resuscitation¹

- In healthcare systems with availability of intensive care, we *suggest* administering up to 40-60 mL/kg in bolus fluid (10-20 mL/kg per bolus) over the first hour, titrated to clinical markers of cardiac output and discontinued if signs of fluid overload develop, for the initial resuscitation of children with septic shock or other sepsis-associated organ dysfunction.
- In healthcare systems with no availability of intensive care and *in the absence of hypotension*, we recommend against bolus fluid administration while starting maintenance fluids (strong recommendation, high quality of evidence).
- In healthcare systems with no availability of intensive care, *if hypotension is present*, we suggest administering up to 40 mL/kg in bolus fluid (10-20 mL/kg per bolus) over the first hour with titration to clinical markers of cardiac output and discontinued if signs of fluid overload develop

How should IVF be given?

- Pressure Bag?
- Pump?
- Fingers and Syringe?

“Look, Listen and Feel”

- Before each additional bolus of IVF:
 - Look for JVD
 - Listen for crackles and gallops
 - Feel for hepatomegaly

End Points of Resuscitation – “The Normals”

- “Normal” Heart Rate
- “Normal” Perfusion
- “Normal” Blood Pressure
- “Normal” Mental Status
- “Normal” (or establishment of) Urine Output

- ? “Normal Lactate”
 - “We were unable to issue a recommendation about using blood lactate values to stratify children with suspected septic shock or other sepsis-associated organ dysfunction into low-versus high-risk of having septic shock or sepsis¹.”

IVF Aren't Working!

What is the Secret of Life?

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15 min

Fluid refractory shock?

Begin peripheral IV/IO inotrope infusion, preferably Epinephrine 0.05 – 0.3 $\mu\text{g}/\text{kg}/\text{min}$
Use Atropine / Ketamine IV/IO/IM if needed for Central Vein or Airway Access

Titrate Epinephrine 0.05 – 0.3 $\mu\text{g}/\text{kg}/\text{min}$ for Cold Shock.
(Titrate central Dopamine 5 – 9 $\mu\text{g}/\text{kg}/\text{min}$ if Epinephrine not available)
Titrate central Norepinephrine from 0.05 $\mu\text{g}/\text{kg}/\text{min}$ and upward to reverse Warm Shock.
(Titrate Central Dopamine ≥ 10 $\mu\text{g}/\text{kg}/\text{min}$ if Norepinephrine not available)

60 min

Catecholamine-resistant shock?

Warm vs. Cold Shock

- We ***suggest*** not using bedside clinical signs in isolation to categorize septic shock in children as “warm” or “cold” (weak recommendation, very low quality of evidence)¹.
 - “Many children who appeared to have “warm” shock by clinical examination had evidence of myocardial dysfunction, thus demonstrating the challenge of using clinical signs alone to direct therapy. Hence, we suggest not attempting to make this distinction using clinical assessments alone, although this categorical distinction may be helpful if advanced hemodynamic monitoring is available to assess patient physiology more accurately. Examples of advanced monitoring include
 - Invasive arterial blood pressure monitoring with pulse contour analysis
 - Ultrasound Doppler of the ascending or descending thoracic aorta
 - Cardiac ultrasound/echocardiography
 - Measurement of Scv_{o2}

What to do?

- We suggest using trends in blood lactate levels, in addition to clinical assessment, to guide resuscitation of children with septic shock and other sepsis-associated organ dysfunction (weak recommendation, very low quality of evidence)¹.
- Also, Strongly consider following SvO₂ as an additional marker for Oxygen Delivery...more to come...

I'm titrating my Fluids and
inotropes/vasopressors...Now what?!?!

Think About Glucocorticoids???

60 min

Catecholamine-resistant shock?

If at risk for Absolute Adrenal Insufficiency consider Hydrocortisone.
Use Doppler US, PICCO, FATD or PAC to Direct Fluid, Inotrope, Vasopressor, Vasodilators
Goal is normal MAP-CVP, ScvO₂ > 70%* and CI 3.3 – 6.0 L/min/m²

Confused? So am I...

- *We suggest* against using intravenous hydrocortisone to treat children with septic shock if adequate fluid resuscitation and vasopressor therapy are able to restore hemodynamic stability (weak recommendation, low quality of evidence)¹.
- *We suggest* that either intravenous hydrocortisone or no hydrocortisone may be used if adequate fluid resuscitation and vasopressor therapy are not able to restore hemodynamic stability (weak recommendation, low quality of evidence)¹.

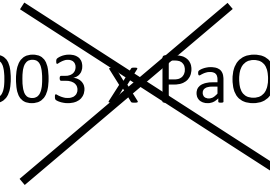
And that's all I have to say about that...



Just a little more...

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$$DO_2 = HR \times SV \times [(1.34 \times Hgb \times SaO_2) + (0.003 \times PaO_2)]$$



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What is the predominant dysfunction?

60 min

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Normal Blood Pressure
Cold Shock
ScvO₂ < 70%* / Hgb > 10g/dL
on Epinephrine?

Begin Milrinone infusion.
Add Nitroso-vasodilator if CI < 3.3L/min/m² with High SVRI and/or poor skin perfusion.
Consider Levosimendan if unsuccessful.

Low Blood Pressure
Cold Shock
ScvO₂ < 70%* / Hgb > 10g/dL
on Epinephrine?

Add Norepinephrine to Epinephrine to attain normal diastolic blood pressure. If CI < 3.3 L/min/m² add Dobutamine, Enoximone, Levosimendan, or Milrinone.

Low Blood Pressure
Warm Shock
ScvO₂ > 70%*
on Norepinephrine?

If euvolemic, add Vasopressin, Terlipressin, or Angiotensin. But, if CI decreases below 3.3 L/min/m² add Epinephrine, Dobutamine, Enoximone, Levosimendan.

Tighten up that Afterload!

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Warm Shock
ScvO₂ > 70%*
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Increase Afterload and Keep working on Contractility!

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Support the Heart by Giving it Less Work to Do!

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Conclusions

- Rapid recognition, timely interventions and continued reassessment are essential to the successful management of Pediatric Sepsis
- An understanding of physiologic concepts can help guide management of individual patients
- There are only 5 variables to manipulate to ensure adequate oxygen delivery:
 - Preload
 - Contractility
 - Afterload
 - Hemoglobin
 - Oxygen Saturations

Questions?



Questions are the path to learning

Select References

- ¹Surviving Sepsis Campaign International Guidelines for the Management of Septic Shock and Sepsis-Associated Organ Dysfunction in Children; Weiss, Scott L et al. *Pediatr Crit Care Med* 2020; 21:e52–e106.
- ²American College of Critical Care Medicine Clinical Practice Parameters for Hemodynamic Support of Pediatric and Neonatal Septic Shock; Davis, Alan L. et al. *Pediatr Crit Care Med* 2017; 45: 1061 - 1093

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