Special Article

The American College of Critical Care Medicine Clinical Practice Parameters for Hemodynamic Support of Pediatric and Neonatal Septic Shock: Executive Summary

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The American College of Critical Care Medicine (ACCM), which honors individuals for their achievements and contributions to multidisciplinary critical care medicine, is the consultative body of the Society of Critical Care Medicine (SCCM) that possesses recognized expertise in the practice of critical care. The College has developed administrative guidelines and clinical practice parameters for the critical care practitioner. New guidelines and practice parameters are continually developed, and current ones are systematically reviewed and revised.

Key Words: hemodynamics; newborn; pediatric; septic shock

This is an executive summary of the update of the 2002 and 2007 American College of Critical Care Medicine (ACCM) hemodynamic support guidelines for pediatric and newborn septic shock.

THE PATIENT POPULATION, INTERVENTION OF INTEREST, COMPARATOR, AND OUTCOMES OF INTEREST QUESTION ADDRESSED: IS THERE NEW INFORMATION SUPPORTING CHANGING THE 2007 RECOMMENDATIONS?

Since 2007, there has been a major effort in the United States to test the first-hour recommendations in pediatric academic centers in the American Academy of Pediatrics collaborative Septic Shock consortium which is dedicated to quality improvement in septic shock recognition and treatment. There have been four studies conducted in tertiary pediatric emergency departments that have examined adherence to ACCM/Pediatric Advanced Life Support (PALS) guidelines for sepsis resuscitation in the first hour (1–4). Together, these studies demonstrated incomplete adherence to recommended goals for administration of IV fluids, antibiotics, and vasoactive agents. Subsequent quality-directed efforts from these studies showed improvement in both process metrics (e.g., decreased time to administration of IV fluids, antibiotics, and peripheral vasoactive agents) and outcome metrics, including hospital and PICU length of stay and mortality. Importantly, all quality improvement studies were predicated on rapid identification of patients with suspected septic shock to trigger rapid clinician evaluation and implementation of appropriate resuscitation efforts. Multiple elements have been incorporated into trigger tools with success by several institutions (5, 6); however, there has been notable variation in the algorithms used at each institution, and none have sufficient evidence to fully endorse as a specific tool. Given the complexity of resource allocation and implementation, it appears reasonable that each institution could locally develop their trigger tool while further studies refine the derivation and validation of an optimally sensitive and specific sepsis trigger tool.

From the best practice model standpoint, Paul et al (4) implemented a hospital-wide quality improvement initiative to improve compliance with all five elements of the ACCM/PALS guidelines first-hour recommendations: 1) recognition, 2) establishing IV access, 3) starting IV fluids and resuscitation as needed, 4) administering antibiotics, and 5) starting vasoactive agents if needed. Achievement of 100% compliance required a number of human interaction interventions including use of time clocks set to have time going from 0 to 60 minutes rather than from 60 to 0 minutes, that resulted in an increase in number of cases between death occurrences ($p < 0.05$) with an overall reduction in hospital mortality from 4.0% to 1.7%.

Han et al (7) analyzed the international Global Sepsis Initiative database which included children from "resource-rich" settings in Europe, North America, and South America in order to derive "three-element" bundles associated with improved outcomes. The first-hour/emergency department three-element bundle included 1) reversal of shock defined by normal blood pressure and capillary refill less than 3 seconds, 2) provision of antibiotics, and 3) provision of Dextrose 10 g/dL and sodium containing IV fluid infusion. The stabilization /PICU three-element bundle included 1) reversal of shock defined by maintaining normal mean arterial pressure (MAP) minus central venous pressure (CVP) (MAP – CVP) for age as means to measure perfusion pressure and central

Recognition Bundle (see AAP Trigger tool example Figure 2)

- Screen patient for septic shock using an institution trigger tool.
- Clinician assessment within 15 minutes for any patient who screens positive in the trigger tool.
- Initiate *Resuscitation Bundle* within 15 minutes for patient identified by the trigger tool whom the assessing clinician confirms suspicion

Resuscitation Bundle[6] (see Algorithm Figure 3 and 4)

- Attain IV/IO access within 5 minutes.
- Appropriate fluid resuscitation begun within 30 minutes.
- Initiation of broad-spectrum empiric antibiotics within 60 minutes.
- Begin peripheral or central inotrope infusion therapy for fluid-refractory shock within 60 minutes.

Stabilization Bundle (see Algorithm Figure 3 and 4)

- Use multimodal monitoring to optimize fluid, hormonal, and cardiovascular therapies to attain hemodynamic goals
- Confirm administration of appropriate antimicrobial therapy and source control

Performance Bundle

- Measure adherence to Trigger, Resuscitation, and Stabilization Bundles
- Perform root cause analysis to identify barriers to adherence
- Provide an action plan to address identified barriers

Figure 1. Example of recognition, resuscitation, stabilization, and performance bundles. IO = intraosseous line.

venous oxygen saturation at right atrial/vena cava junction level ($ScvO_2$) greater than 70%, 2) timely provision of the appropriate antibiotic to which the organism is sensitive and source control, and 3) maintenance of effective tidal volumes between 6 and 8 mL/kg in children mechanically ventilated with acute respiratory distress syndrome. Reversal of shock was associated with use of the 2007 ACCM/PALS guidelines in both the resuscitation and stabilization bundles.

Ventura et al (8) demonstrated that resuscitation of fluid refractory septic shock with peripheral epinephrine infusion, until central access was attained, reduced mortality from 20% to 7% compared with peripheral dopamine. Use of peripheral epinephrine was associated with maintenance of higher blood pressures and fewer episodes of nosocomial infection compared with dopamine.

KEY NEW RECOMMENDATIONS

The major new recommendation in the current update is that hemodynamic support of septic shock now be addressed at the institutional level and at the caregiver level.

BUNDLES IN NEW ACCM GUIDELINES

The new guidelines recommend that each institution implement their own adopted or home-grown bundles that include the following:

1) "Recognition bundle" containing a trigger tool for rapid identification of patients with suspected septic shock at that institution,
2) "resuscitation and stabilization bundle" to drive adherence to consensus best practice at that institution, and
3) "performance bundle" to monitor, improve, and sustain adherence to that best practice and to identify and overcome perceived barriers to the pursuit of best practice principles.

The new guidelines provide examples of each bundle (**Fig. 1**) for consideration and review by each hospital's expert committee.

We recommend that each institution develop a "recognition bundle" to optimize identification of patients at risk for septic shock that is based on vital sign abnormalities and high-risk criteria.

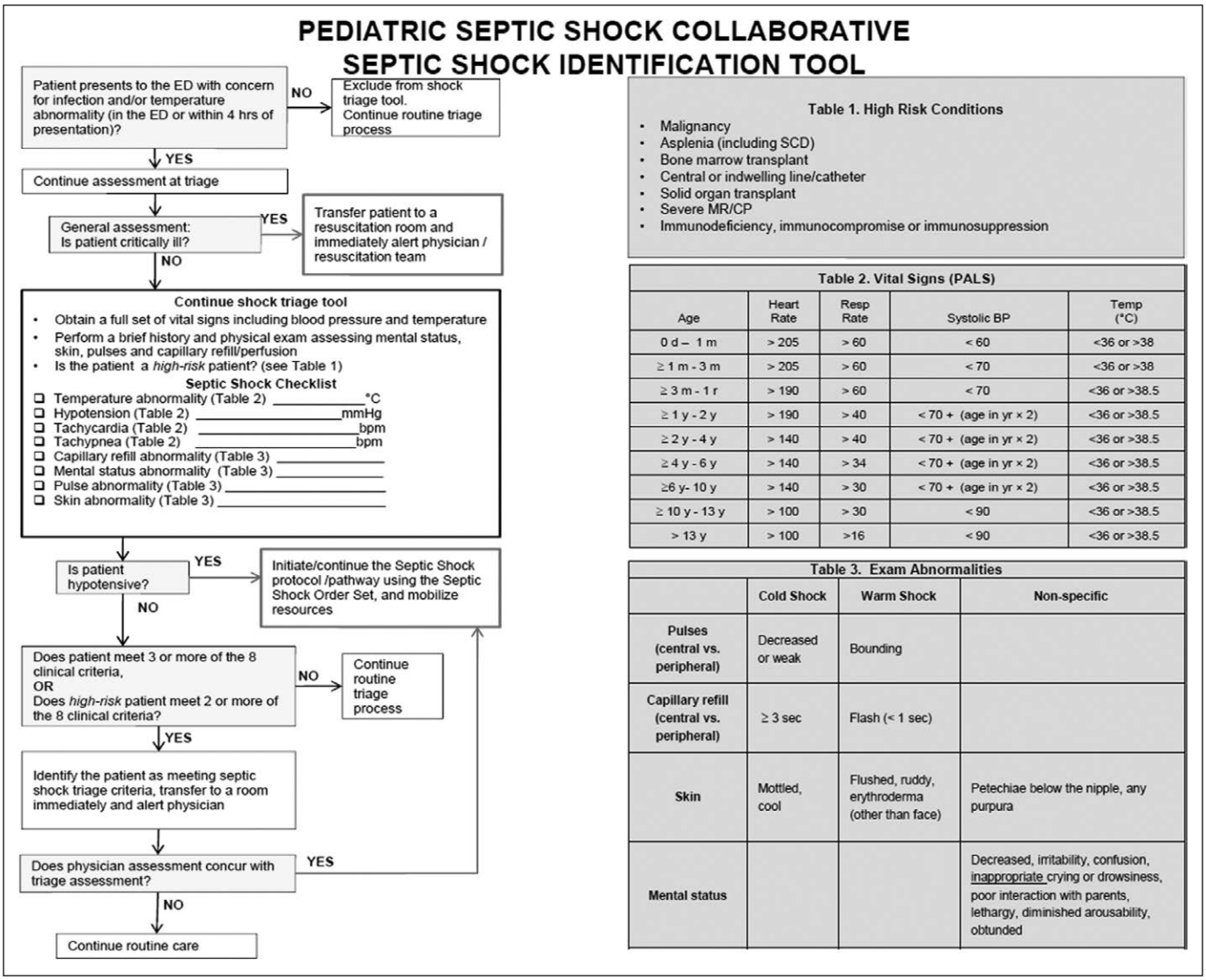

Figure 2. American Academy of Pediatrics trigger tool for early septic shock recognition. BP = blood pressure, CP = cerebral palsy, ED = emergency department, PALS = Pediatric Advanced Life Support, SCD = sickle cell disease.

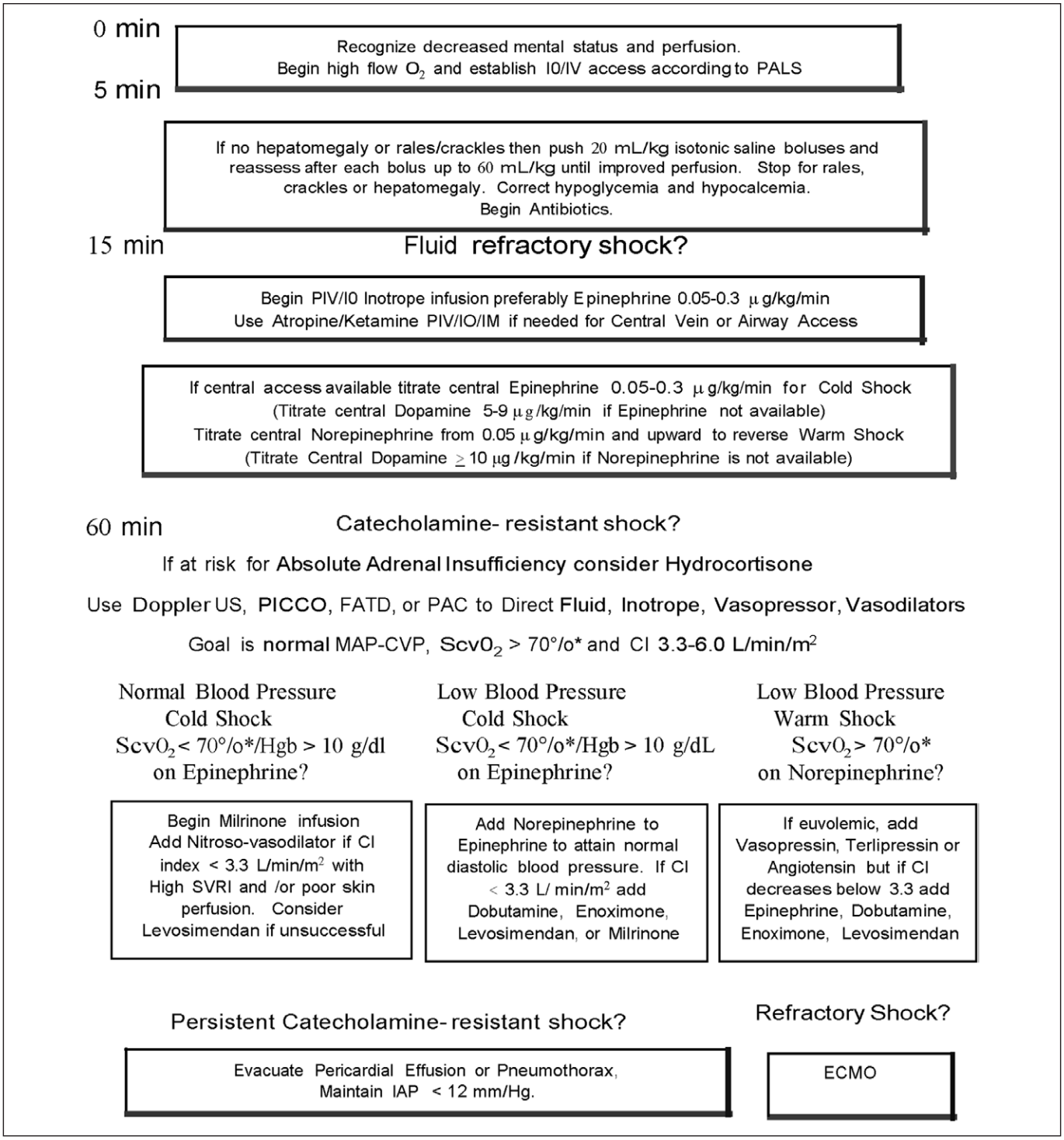

Figure 3. American College of Critical Care Medicine algorithm for time sensitive, goal-directed stepwise management of hemodynamic support in infants and children during resuscitation and stabilization. Proceed to next step if shock persists. 1) First-hour goals—restore and maintain heart rate thresholds, capillary refill less than or equal to 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 (mean arterial pressure [MAP] minus central venous pressure [CVP]) for age, central venous oxygen saturation at right atrial/vena cava junction level ($Scvo_2$) greater than 70% (*except congenital heart patients with mixing lesions for whom this is too high), and cardiac index (CI) > 3.3 < 6.0 L/min/m^2 in PICU. ECMO = extracorporeal membrane oxygenator, FATD = femoral artery thermodilution catheter, Hgb = hemoglobin, IM = intramuscular, IO = intraosseous line, PAC = pulmonary artery catheter, PALS = Pediatric Advanced Life Support, PICCO = pulse index contour cardiac output catheter, PIV = peripheral IV line, SVRI = systemic vascular resistance index, US = ultrasound.

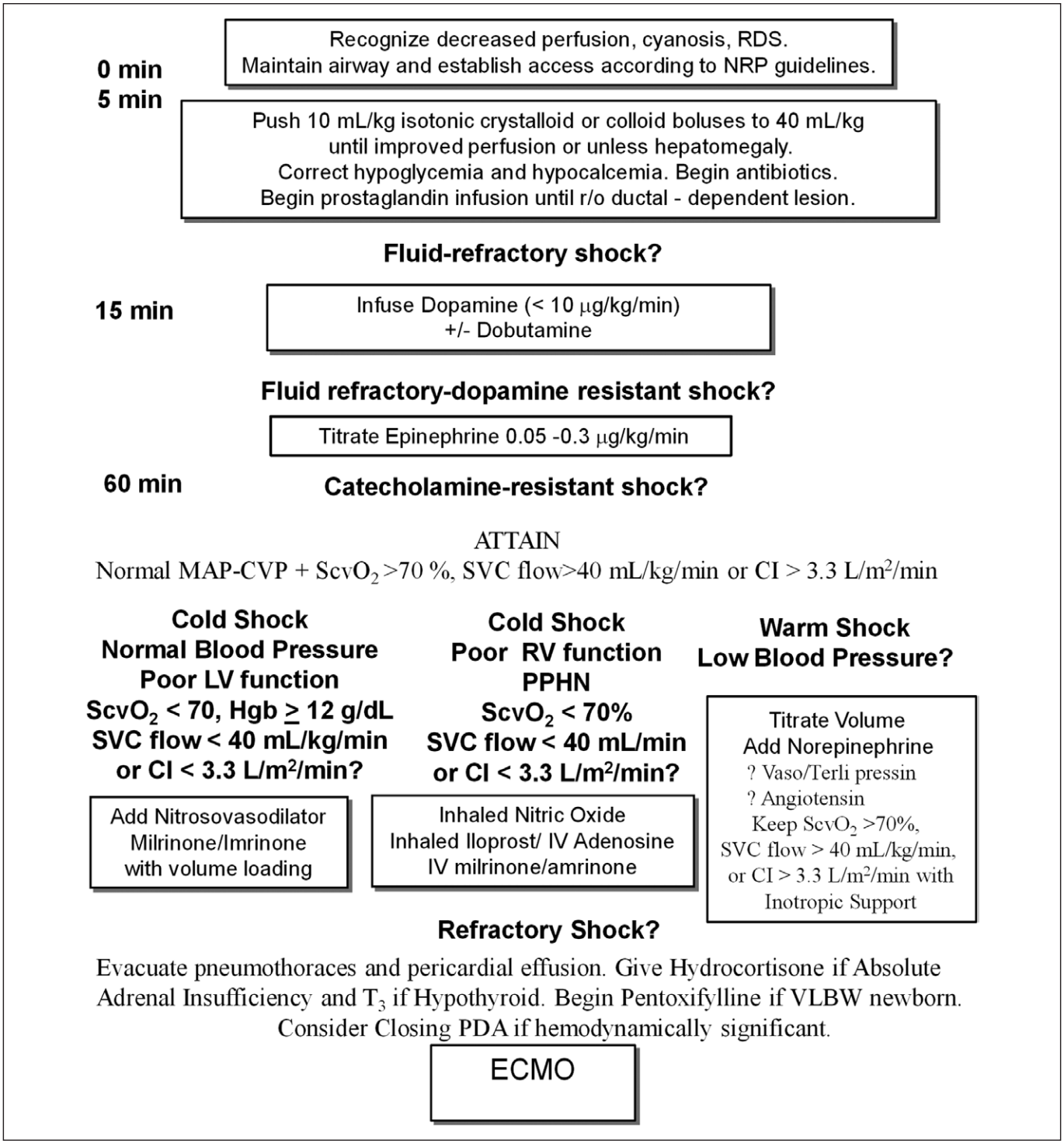

Figure 4. American College of Critical Care Medicine Algorithm for time sensitive, goal-directed stepwise management of hemodynamic support in newborns during resuscitation and stabilization. Proceed to next step if shock persists. 1) First-hour goals—restore and maintain heart rate thresholds, capillary refill less than or equal to 2 s, and normal blood pressure in the (first hour) and 2) subsequent ICU goals—restore normal perfusion pressure (mean arterial pressure [MAP] minus central venous pressure [CVP]), pre- and postductal oxygen saturation difference less than 5%, and either central venous oxygen saturation at right atrial/vena cava junction level ($Scvo_2$) greater than 70% (*except in congenital heart patients with mixing lesions), superior vena cava (SVC) flow greater than 40 mL/kg/min or cardiac index (CI) greater than 3.3 L/min/m^2 in NICU. ECMO = extracorporeal membrane oxygenator, LV = left ventricle, NICU = neonatal ICU, NRP = neonatal resuscitation program, PDA = patent ductus arteriosus, PPHN = persistent pulmonary hypertension, RDS = respiratory distress syndrome, RV = right ventricle, T3 = tri-iodothyronine, VLBW = very low birth weight.

The "recognition bundle" should contain the following:

1) A trigger tool (example given in **Fig. 2**) for rapid identification of patients with suspected septic shock. Elements that are recommended for use in a trigger tool include vital signs, physical examination, and at-risk populations.
2) Rapid clinician assessment within 15 minutes for any patient that is identified by the trigger tool.
3) Activation of a sepsis "resuscitation bundle" within 15 minutes for patients with suspected septic shock.

We recommend that each institution also develop or adopt a first-hour "resuscitation and stabilization bundle" to optimize time to completion of first hour and stabilization tasks when a patient with suspected septic shock is identified. The resuscitation bundle is done to drive adherence to consensus best practice.

The resuscitation bundle (examples in **Figs. 3** and **4**) may contain the following:

1) Intraosseous line or IV access within 5 minutes of diagnosis.
2) Appropriate fluid resuscitation initiated within 30 minutes of diagnosis.
3) Initiation of broad-spectrum antibiotics within 60 minutes of diagnosis.
4) Blood culture if it does not delay antibiotic administration.
5) Appropriate use of peripheral or central inotrope within 60 minutes of diagnosis.

The stabilization bundle (examples in Figs. 3 and 4) may contain the following:

1) Multimodal monitoring to guide fluid, hormonal, and cardiovascular therapies to attain a normal MAP − CVP for age ($55 + 1.5 \times$ age in yr) as a measure of adequate perfusion pressure, $ScvO_2$ greater than 70% and/or cardiac index 3.3–6.0 L/min/m^2.
2) Administration of appropriate antibiotic therapy and source control.

We recommend that each institution develop or adopt a "performance bundle" to identify barriers to attaining the recognition, resuscitation, and stabilization bundle goals.

The "performance bundle" should contain the following:

1) Measurement of adherence and achievement of goals and individual components.
2) Ways to monitor, improve, and sustain adherence to best practice.

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