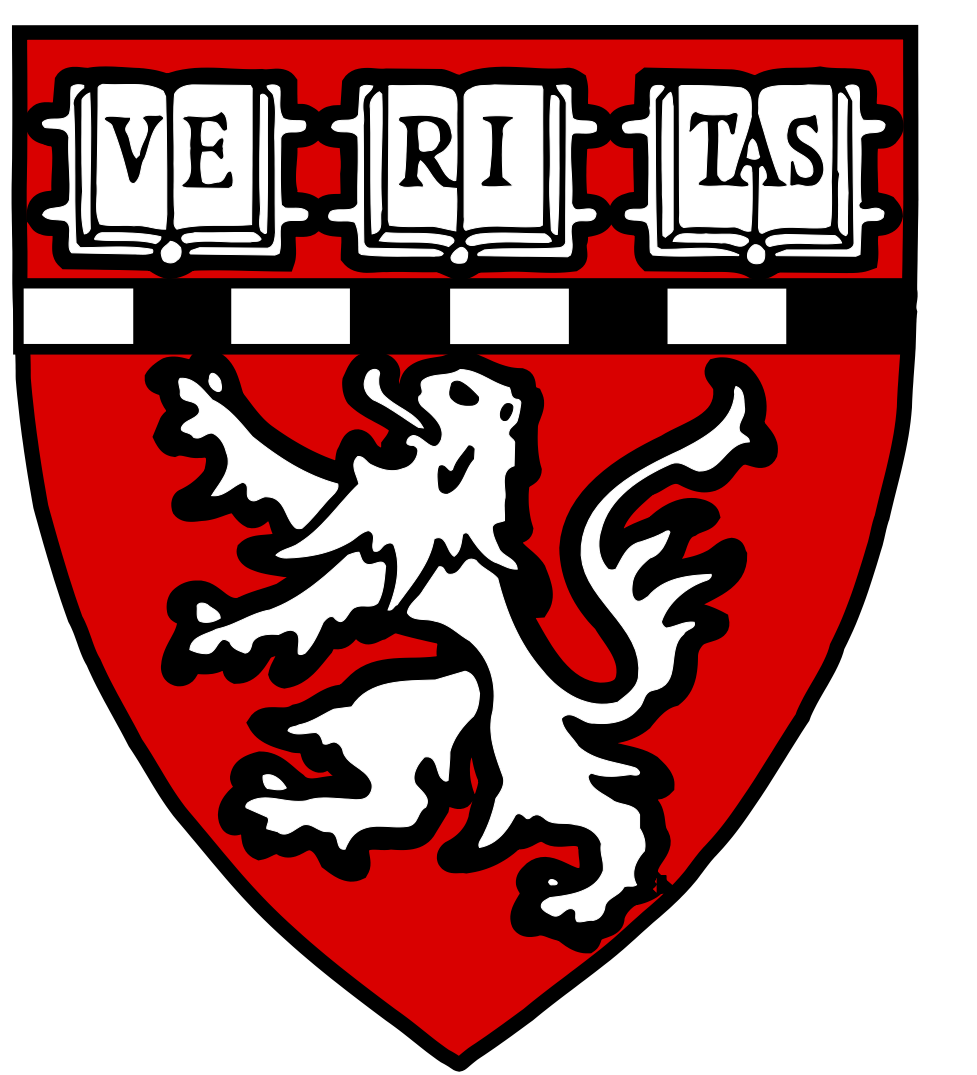




NON-INVASIVE CARDIAC OUTPUT MONITOR CAN DETECT AND TREND HEMODYNAMIC CHANGES IN CHILDREN WITH INFECTIONS

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ABSTRACT

Introduction: Electrical Cardiometry is a non-invasive method to assess cardiac output (CO). We present the first prospective study using this CO technology in children with infections.

Hypothesis: We hypothesize that this method can detect changes in cardiac index (CI) and systemic vascular resistance index (SVRI) in children with infections and low mean arterial pressure (MAP).

Methods: We enrolled 22 healthy children admitted with the primary diagnosis of infections that had MAP less than 95thile for age. Heart rate (HR), CI and stroke index (SI) were measured using the CO monitor (Cardiotronic Inc., La Jolla CA) in a double-blinded study. MAP was obtained at time of CO recording. CO was assessed over a 5 minute period within 24 hours of admission (INITIAL) and again within 24 hours of discharge (FINAL). Children were categorized as those who did not require critical care (INPATIENT) and those who required critical care (CRITICAL). We compared the changes in all variables in each group by repeated measures two-way ANOVA with comparison to INITIAL.

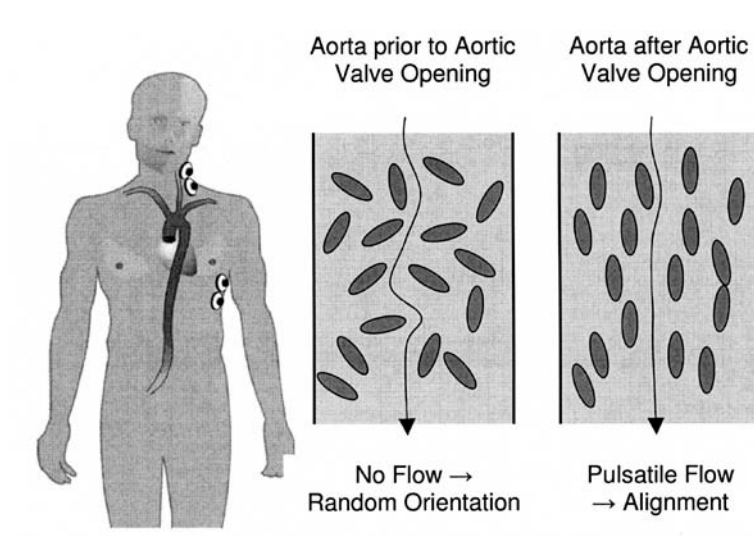
Results: 22 subjects (10 INPATIENT/12 CRITICAL) were studied. There were no changes in the INPATIENT group. In contrast, in the CRITICAL group both HR and CI decreased with concurrent increases in both MAP and SVRI (see Figure; mean \pm SEM, * = significant $p < 0.05$). SI was unchanged.

Conclusions: Our results show that this CO technology is sufficiently sensitive to detect the resolution of high CO and low SVRI state in critically ill children, even though blood pressure had improved prior to INITIAL recording.

HYPOTHESIS

Non invasive CO monitoring can detect and trend hemodynamic changes in children with infections with normal MAP

METHODS



This is a sub-study within a larger ongoing prospective study of hemodynamic changes in hospitalized patients as characterized by non-invasive Aesculon CO monitor (Cardiotronic Inc., La Jolla CA).

Patients were eligible for the study if they were previously healthy and required hospitalization for acute illness. We obtained daily recordings for each patient with the CO monitor from admission to discharge. We analyzed hemodynamic changes including Heart Rate (HR), Mean Arterial Blood Pressure (MAP), Cardiac Index (CI), Stroke Index (SI) and Systemic Vascular Resistance Index (SVRI) within the subset of patients with infections.

The device measures changes in electrical impedance due to variations in alignment of red blood cells during the cardiac cycle.

DATA ANALYSIS

Data for this analysis were collected and categorized as those who did not require critical care (INPATIENT) and those who required critical care (CRITICAL). Demographic variables were analyzed for differences between groups using chi-square tests for categorical variables and the Mann-Whitney test for differences in medians.

Hemodynamic variables were analyzed using repeated measures two-way ANOVA to test for changes across time (initial vs. final) and group (inpatient vs. critical) on the variables of interest (MAP, HR, CI, SI, and SVRI). The Bonferroni correction was used to compute p-values for post-hoc tests of initial vs. final within each group. Significant p-values ($< .05$) are indicated by *

SUBJECT CHARACTERISTICS

Table 1: Subject Demographics (N=49)

	Inpatient (N=25)		Critical (N=24)	
	N	N	Median	Range
Gender				
Male	14	15		
Female	11	9		
Diagnosis*				
Other Infection	23	9		
Pneumonia	2	15		
Age (Years)	9.1	9.8	9.8	(0.06-16.8)
Body Surface Area (m²)	0.97	1.1	1.1	(0.17-2.0)
Time to Initial CO Reading (Hours)*	19.6	10.7	10.7	(3.1-28.7)
Length of Stay (Days)*	3.0	6.0	6.0	(1.5-25.7)

*Significant difference between inpatient and critical, $p < .05$

RESULTS

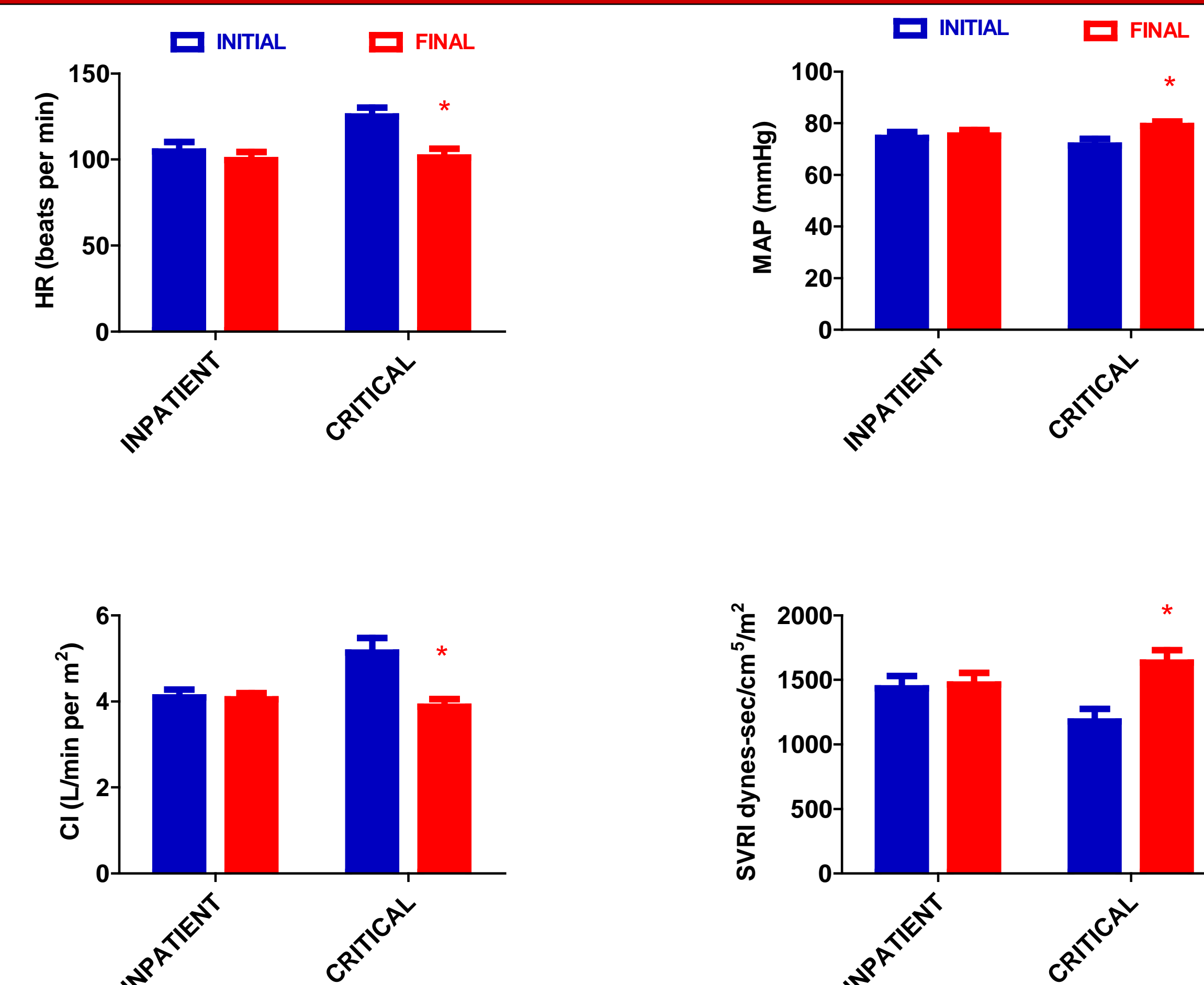


Figure 1: All patients except one had normal MAP at INITIAL CO recording. Despite normalization of MAP, the CO monitor was able to detect changes in CI and SVRI from INITIAL to FINAL in the CRITICAL group. SI did not change.

Table 2: Results of two-way ANOVA post-hoc tests on HR, CI, SI, SVRI, and MAP

	Inpatient (N=25)			Critical (N=24)		
	Initial	Final	p-value	Initial	Final	p-value
HR	105	100	>.05	125	101	<.001
CI	4.1	4.1	>.05	5.1	3.9	<.001
SI	41	42	>.05	40	39	>.05
SVRI	1434	1465	>.05	1178	1634	<.001
MAP	74	75	>.05	71	79	<.05

CO MONITOR CAN TRACK DIFFERENT HEMODYNAMIC STATES DESPITE NORMAL MAP

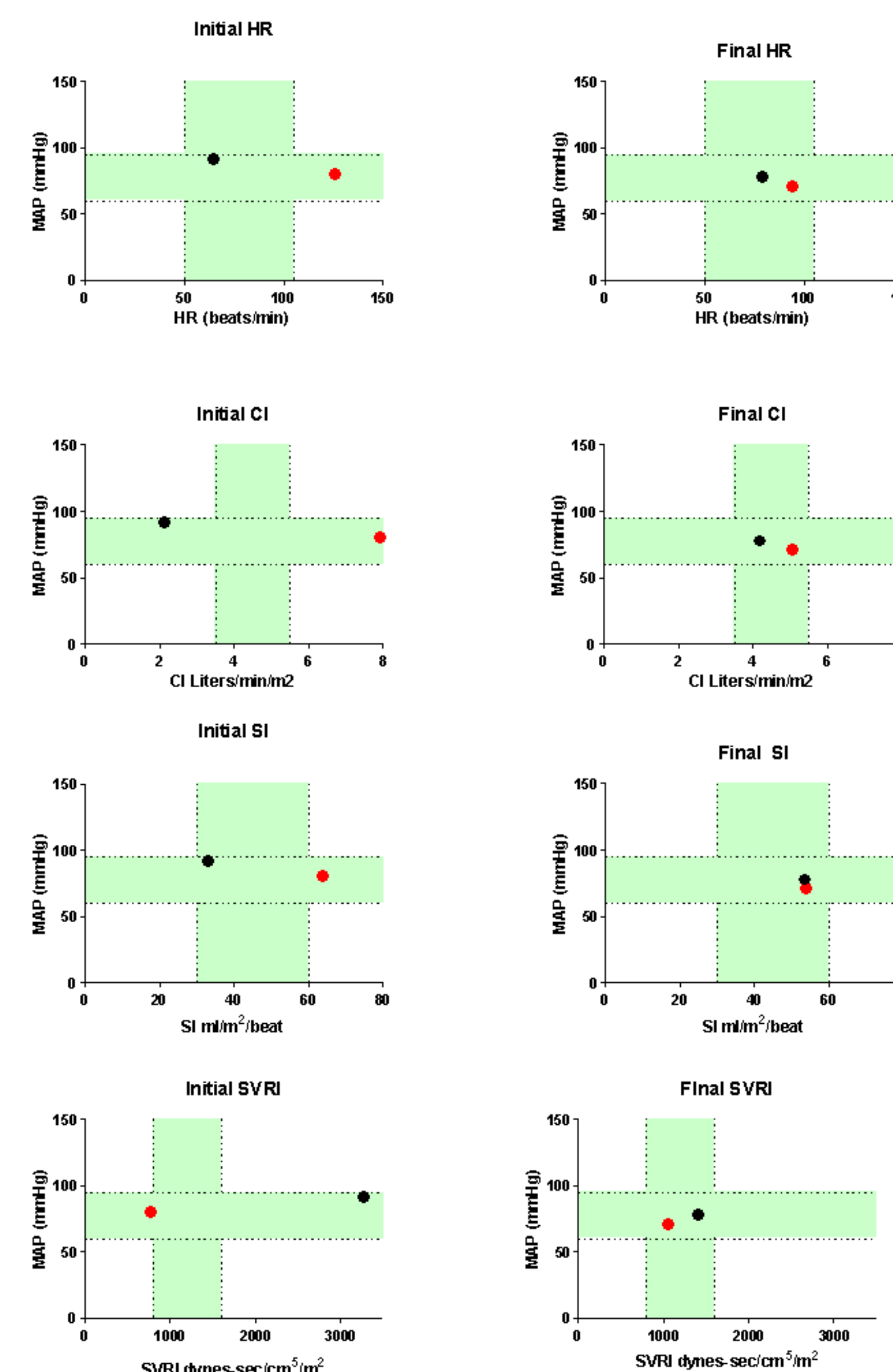


Figure 2: The left graphs show two patients, one with high CI and low SVRI (red circle) and the other with low CI and high SVRI (black circle) at INITIAL after normalization of MAP.

Data for individual patients was plotted for each hemodynamic variable. Areas shown in green represent putative normal values for children derived from the literature.

Legend

- Patient A had pneumonia
- Patient B had cellulitis

The right graphs demonstrate that in both patients all hemodynamic variables are within normal range at FINAL. Of note, SI was also observed to change from INITIAL to FINAL in these patients.

ILLUSTRATION OF INDIVIDUAL HEMODYNAMIC TREND

Figure 3: Ten year old male admitted to the ICU with septic shock. He had a right-sided pneumonia and required multiple fluid boluses, vasoactive agents and mechanical support for uncompensated shock and respiratory failure. He was the only patient in this cohort that did not have normal MAP at INITIAL. His daily hemodynamic data is plotted below. The CO monitor was able to trend hemodynamic changes during the course of medical interventions (Table 3) and all hemodynamic variables were within normal range at FINAL.

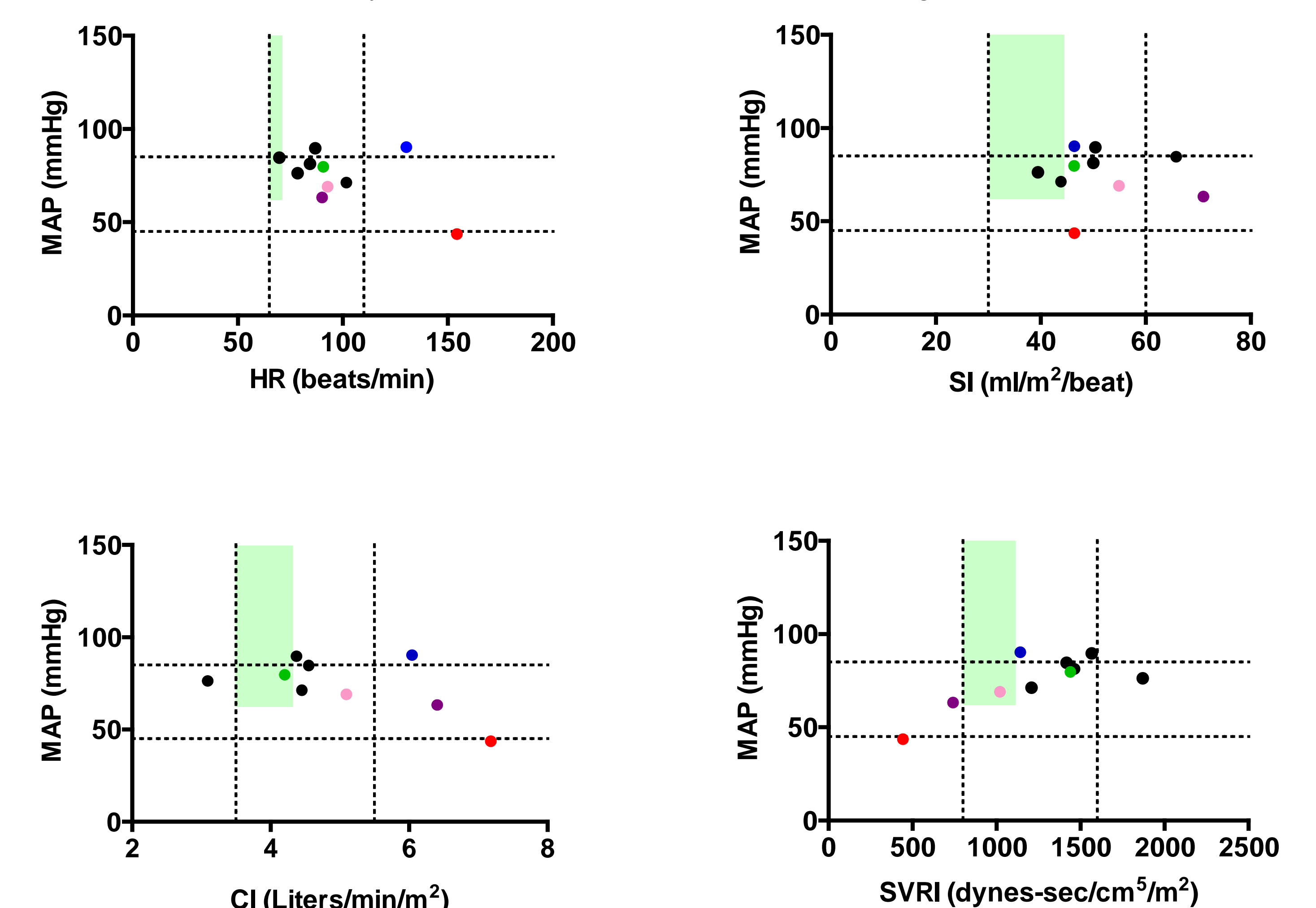


Table 3: Fluid, Vasoactive agents and Ventilatory Support by Study Day

	Initial (Day 1)	Day 2	Day 3	Day 4	Days 5-9	Final (Day 10)
Fluids (cc/kg/day)	NS Bolus	18	60	0	0	0
Vasoactive agents (mcg/kg/min)	Dopamine	20	7	5	5	0
	Epinephrine	0	0.05	0.04	0.02	0
	Norepinephrine	0.7	0.6	0	0	0
Mechanical Ventilation	Yes	Yes	Yes	Yes	Extubated on day 6	No

SUMMARY

- Non-invasive CO monitors can detect hemodynamic changes in critically ill children with infections despite normalization of MAP.
- The CO monitor is able to differentiate between high and low CI.
- The CO monitor is able to trend hemodynamic changes during medical interventions.

CONCLUSIONS

- Non-invasive CO monitoring may be useful in directing medical interventions in sepsis.
- Further studies of the utility of non-invasive CO monitoring in children presenting in the ED with shock is warranted.

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