Determination of cardiac output in critically ill children: Are we any closer to the ideal methodology?*

“The most important thing is to strive towards a goal which is not immediately visible. That goal is not the concern of the mind, but of the spirit”—Antoine de Saint-Exupery, Flight to Arras, 1942

Methodologies for cardiac output determination in critically ill children in the intensive care setting have been both difficult and unfulfilling. The methodologies include invasive, semi-invasive, and noninvasive methodologies. The clinical standard, and one of the best known invasive methodologies, is the pulmonary artery thermodilution technique, which is a validated methodology but is severely restricted in its clinical application due to its invasive nature and patient size limitations (1). Semi-invasive techniques involve the presence of central venous and/or arterial catheters and are exemplified by the transpulmonary thermodilution technique (2) or the lithium dilution technique (3). Finally, the noninvasive techniques truly do not require catheters and include Doppler techniques (4) and thoracic bioreactance or bioimpedance methodology (5).

The ideal methodology for cardiac output determination in the intensive care milieu, aside from being noninvasive, would include all of the following seven elements: 1) continuous (vs. intermittent) measurements on a second-to-second basis; 2) high degree of accuracy and precision; 3) relative independence from operator technique and intra/interobserver variability; 4) measurements for all patient sizes (from low birth-weight neonates to adult-sized pediatric patients); 5) applicable to wide range of cardiac outputs, especially low cardiac output determinations; 6) rapid (seconds to minutes) measurement response to changes such as pharmacologic interventions; and finally 7) available for congenital heart defects and the myriad of complex palliative and corrective surgeries (such as the Norwood operation).

In this issue of Pediatric Critical Care Medicine, Crittendon and colleagues (6) described a semi-invasive ultrasound dilution technique to determine cardiac output in which blood ultrasound velocities of venous and arterial blood are calculated with body temperature isotonic saline as an indicator. This study examined this innovative technique that involved in situ arterial and venous catheters with ultrasound sensors to attain ultrasound dilution curves by using an extracorporeal arterial-venous loop. A major limitation of this study includes that the study patient population (median age of 8 yrs) had structurally normal hearts with normal cardiac output range (mean cardiac index of 3.1 L/min). Although this new semi-invasive technique uses a physiologic indicator and existing arterial and venous catheters, this promising new technique has only a few of the seven aforementioned ideal elements for the perfect cardiac output determination methodology.

There is a continual clarion call for a reliable and reproducible noninvasive methodology for assessing cardiac output for critically ill children. First, the investigative efforts for the ideal cardiac output determination methodology in the intensive care setting must continue until this goal is finally met. Second, the recent advent of near-infrared spectroscopy (7), which focuses on in vivo tissue oxygenation (rather than direct cardiac output determination), may provide a paradigm shift in the assessment strategy of the cardiopulmonary system by evaluating oxygen consumption/delivery and tissue perfusion. Finally, the future intensive care unit will need to have not merely methodologies for cardiopulmonary assessment, but also an artificial intelligence capability to respond to the collected clinical data and cognitive load with machine learning, fuzzy logic, and knowledge engineering (8).

Anthony C. Chang, MD, MBA, MPH
Director
Heart Institute
Children’s Hospital of Orange County
Orange, CA

REFERENCES


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*See also p. 42.

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