TITLE: REPRODUCIBILITY OF THERMODILUTION CARDIAC OUTPUT MEASUREMENTS IN CLINICAL PRACTICE

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Introduction. Poor reproducibility and wide variability are commonly seen in thermodilution cardiac output (TDCO) measurements in patients. There are no clinical studies that identify the optimum method to measure TDCO's.[1] Current recommendations for obtaining reproducible TDCO's are contradictory and are based solely on animal experimentation and anecdotal evidence.[2,3,4]

Methods. Thirty-two intensive care unit patients participated in this study that was approved by the Stanford University Hospital Committee for Human Experimentation. Criteria for inclusion in this study were: (1) indwelling 7F thermodilution pulmonary artery catheter (2) respiratory rate less than 25 breaths per minute, (3) PEEP less than 10 cm of water, (4) peak inspiratory pressure less than 35 cm of water, (5) hemodynamic stability for a minimum of one hour prior to the initiation of TDCO measurements and (6) informed consent. Patients were divided into three groups based on their respiratory status. Group I (n=12) were non-intubated patients without CPAP. Group II (n=12) were intubated patients receiving intermittent mandatory ventilation (IMV) without spontaneous overbreathing and Group III (n=8) were intubated patients receiving IMV with spontaneous overbreathing. A respiratory wave form and TDCO curve was recorded on a strip chart recorder (Hewlett-Packard). A respiratory wave form was obtained from patients in group I by measuring thoracic impedance via electrocardiographic leads (Hewlett-Packard apnea monitor). A respiratory wave form was obtained from intubated patients (Groups II and III) by transducing airway pressure using an 18 gauge catheter attached to the inspiratory limb of the ventilator circuit. Using 10 ml of room temperature normal saline, triplicate cardiac output measurements were made using 3 injection techniques for a total of 9 measurements per patient. In two techniques, injections were initiated at peak-inspiration and end-exhalation as indicated by the respiratory waveform. In the third technique, TDCO injections were initiated randomly with respect to the respiratory cycle. A random number table was used for the timing of the random injections. A latin squares technique was utilized to randomize the order of the three injection techniques. Prospective data elimination was only performed if there was a gross mechanical malfunction. The standard deviation for each set of triplicate TDCO measurements was determined. The data was then analyzed by comparing the population of triplicate standard deviations with an analysis of variance. Significance was determined at $p < 0.05$.

Results. TDCO measurements initiated at peak-inspiration or end-exhalation were significantly more reproducible than those measurements initiated at random (see table). This finding was consistent for all groups. The coefficient of variation for injections initiated at peak-inspiration or end-exhalation was always less than 4% in all groups. In contrast, the coefficient of variation for injections initiated randomly was greater than 10% in all groups. TDCO's ranged from 2.5 l/min to 13.3 l/min. Injection duration did not exceed 4 seconds. A total of 288 TDCO measurements were obtained in 32 patients. Three measurements required repeat injection because of gross technical difficulties (broken syringe or stopcock).

Conclusion. TDCO's are commonly used in clinical practice yet there is no data based on clinical trials that discuss the effect of the respiratory cycle on reproducibility. In the setting of the intensive care unit in a prospective, randomized study we demonstrated wide variation of TDCO's when initiation of injection was not timed with the respiratory cycle. In fact, there was a 3-fold increase in the standard deviation when comparing random TDCO's to TDCO's measured at specific phases of the respiratory cycle. Thus, to obtain optimally reproducible TDCO's in critically ill patients, initiation of injection should be performed at the same phase of the respiratory cycle.

Average Standard Deviation (l/min) of Measurements Initiated at Different Phases of the Respiratory Cycle

	Peak-Inspiration	End-Exhalation	Random
Group I	0.29	0.26	0.79*
Group II	0.30	0.22	0.91*
Group III	0.34	0.30	0.69*

*All values obtained with random injections were significantly greater ($P < 0.01$) than values obtained with peak-inspiration or end-exhalation injections.

References.

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