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Title : SYSTEMATIC OVERESTIMATION OF PEDIATRIC CARDIAC OUTPUT

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Introduction. The potential value of measuring cardiac output in pediatric patients has led to the development of catheter systems employing the thermodilution technique. This study defines an important source of possible error in the correction factor for the amount of heat gained (C_T) by iced injectate (0°C, D5W) during passage through pediatric catheter systems. C_T error results in significant overestimation of cardiac output ($\dot{Q}$) and occurs when body temperature blood is withdrawn before the injection as has been recommended by many investigators.

Method. In previous work with thermal dilution catheters, the withdrawal of body temperature blood (BTB) preceding the injection of iced injectate was recommended by Fronek and Silove (1,2); the purpose was to make constant the temperature of the dead space fluid filling the injection lumen of the catheter. With the use of smaller thermal dilution catheter systems in pediatric patients, withdrawal of BTB prior to injection of iced injectate appeared to elevate the measured cardiac index by some systematic error. Two catheter systems were studied. The first was a five French (5Fr), 60 cm, flow-directed catheter consisting of four lumens. The second catheter system consisted of two discrete catheters: a 2.5 French 45 cm, closed single lumen catheter containing lead wires and a thermistor located near the catheter tip, and a 3.5 French (3.5Fr), 30 cm single lumen catheter for right atrial pressure measurement and cold indicator injection. C_T measurements were performed with a 37°C waterbath as a model system with the injection catheters immersed to lengths specified by the manufacturer. The volume and temperature of the injectate delivered (T_ID) through a given catheter was collected and measured in an insulated chamber with a fast response thermistor (110 millisecond). The thermistor was calibrated over a range of 0-25°C with a precision thermometer accurate to ±0.1°C. C_T was calculated using the formula $C_T = (T_B-T_ID)/(T_B-T_I)$, where T_B, T_I are the temperature of the bath (37°C) and injectate (0°C), respectively. At each injectate volume at least 10 C_T measurements were done, 5 determinations were made prefilling the catheter with 1 ml 0°C D5W (C_T0) and 5 after prefilling the catheter with 1 ml 37°C D5W (C_T37). 20 seconds were allowed to pass between prefilling and actual injection.

Results. Table 1 presents the C_T0 and C_T37 values averaged at each volume, and the C_T values published by the catheter manufacturer (C_TM) for the 3.5 Fr and 5 Fr catheter sytems. The Δ0% and Δ37% are the per cent differences of C_T0 and C_T37 compared to C_TM, $\Delta0\% = (C_TM-C_T0)/C_T0$, $\Delta37\% = (C_TM-C_T37)/C_T37$.

The difference between C_T37 and C_TM (Δ37%) was significant at all measured injectate volumes with the 5 Fr catheter, (as much as 58.2% at the 1 ml volume); and with the 3.5 Fr catheter at 1 ml volume, 10.8%. The C_T0 determinations measured in this study agreed with the C_TM values at almost all injectate volumes for the 3.5 and 5 Fr catheter systems. The largest differences between C_T0 and C_TM (Δ0%) were with the 3.5 Fr catheter at 1 and 2 ml volumes, resulting in differences of 4.7% and 3.2% respectively. All other C_T0 vs C_TM differences (Δ0%) were 1.2% or less.

Conclusion. The Δ37% difference indicates that if a thermal dilution cardiac output measurement were calculated using C_TM values and the catheter prefilled with BTB at 37°C, the cardiac output would be overestimated for a given injectate volume by the Δ37% listed in table 1. The worst cases were with the 5 Fr at injectate volumes of 1 and 2 ml; $\dot{Q}$ would be overestimated by 58.2% and 26.1% respectively. Overestimation of $\dot{Q}$ in rapid serial measurements would also occur if the withdrawal of BTB after the injection were performed, as has been recommended to reduce the cooling effect of cold injectate remaining in injection lumen. When using iced injectate, it appears that C_TM is only accurate when the pediatric catheter is prefilled with 0°C injectate.

Table 1

	Vol	C_T0	C_T37	C_TM	Δ0%	Δ37%
5 FR	1	0.570	0.361	0.571	0.2	58.2
	2	0.734	0.578	0.729	-0.7	26.1
	3	0.787	0.712	0.792	0.6	11.2
	5	0.831	0.780	0.835	0.5	7.1
3.5 Fr	1	0.804	0.760	0.842	4.7	10.8
	2	0.867	0.858	0.895	3.2	4.3
	5	0.916	0.912	0.927	1.2	1.6

1. Fronek, A., Ganz, V.: Measurement of flow in single blood vessels including cardiac output by local thermodilution. Circulation Research 8, 175 (1960).

2. Silove, E., Cantez, T., Wells, B.: Thermodilution measurement of left and right ventricular outputs. Cardiovascular Research 5,174 (1971).