Intracardiac temperature monitoring in infants after cardiac surgery

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Background: Hyperthermia after cerebral ischemia is associated with worse neurologic outcome. Our goals were 3-fold: (1) to describe the postoperative temperature course in infants after cardiac surgery, (2) to compare intracardiac temperature monitoring with traditional monitoring in infants, and (3) to determine variables that influence the patients' temperatures.

Methods: Longitudinal temperature data were collected for 100 infants undergoing cardiac surgery. Intra-atrial, nasopharyngeal, esophageal, rectal, and axillary temperatures were recorded in all patients.

Results: The mean age at the time of operation was 128 ± 166 days, and the mean weight was 5.1 ± 2.4 kg. Circulatory arrest was used for 54 patients. In the operating room, the maximum intra-atrial temperature (37.5°C ± 0.6°C) was significantly greater than both the simultaneous esophageal temperature (36.9°C ± 1.9°C, $P = .03$) and nasopharyngeal temperature (36.3°C ± 2.5°C, $P < .001$). In the cardiac intensive care unit, intra-atrial temperature was significantly greater than both axillary and rectal temperatures. During the first 24 postoperative hours, intra-atrial temperature was greater than 38°C in 48 (48%) patients, rectal temperature was greater than 38°C in 36 (36%) patients, and axillary temperature was greater than 38°C in 7 (7%) patients.

Conclusions: In patients less than 2 years of age undergoing cardiac surgery requiring cardiopulmonary bypass, intra-atrial temperature peaked 4 to 6 hours after leaving the operating room. Traditional methods of temperature monitoring significantly underestimate core temperature after cardiac surgery in infants. Use of intracardiac temperature monitoring might result in avoidance of cerebral hyperthermia.

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J.W.G. is supported by the Fannie E. Rippel Foundation.

Received for publication March 11, 2005; revisions received Sept 8, 2005; accepted for publication Sept 8, 2005.

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J Thorac Cardiovasc Surg 2006;131:614-20

0022-5223/$32.00

doi:10.1016/j.jtcvs.2005.09.044

Surgical results for infants undergoing repair and palliation of congenital heart disease have improved dramatically over the past several decades. Current mortality rates for complex neonatal cardiac surgery are reported at less than 5% at some institutions.[1] Management now emphasizes minimizing associated morbidity. Optimizing long-term neurologic outcome is presently the focus of both clinical and research interests.

Cerebral hypothermia continues to be the mainstay of neurologic protection during the circulatory arrest period frequently used for repair or palliation of many

Abbreviations and Acronyms

CICU	= cardiac intensive care unit
CPB	= cardiopulmonary bypass
DHCA	= deep hypothermic circulatory arrest
T_{ATR}	= intra-atrial temperature
T_{ES}	= esophageal temperature
T_{NP}	= nasopharyngeal temperature
T_{R}	= rectal temperature

congenital heart lesions.[2] Although the ideal temperature and optimal rates of cooling and warming remain controversial, the concept that the dramatic attenuation of cerebral cellular metabolism and enzymatic function during hypothermia provides a significant degree of neuroprotection is universally accepted. Mild-to-moderate hypothermia after warm ischemia has been shown to be beneficial in both animal models[3-5] and human trials.[6,7] The benefit of hypothermia after cardiac surgery with hypothermic ischemic arrest has not yet been prospectively studied and remains controversial.[8,9] However, all management strategies attempt to avoid hyperthermia.

This observational study is the first to report the use of an intra-atrial thermister in a large number of infants. The purpose of the present study was 3-fold: (1) to describe the postoperative temperature course in infants after cardiac surgery, (2) to compare intracardiac temperature monitoring with traditional and more widely used temperature monitoring, and (3) to identify variables that influence central temperature in the postoperative period in infants.

Materials and Methods

This was a prospective, consent-waived, clinical data collection trial approved by The Children's Hospital of Philadelphia Institutional Review Board. One hundred sequential patients less than 2 years of age undergoing cardiac surgery with cardiopulmonary bypass (CPB) with indwelling intracardiac thermister catheters (Edward Lifesciences, Irvine, Calif) were included. Demographic, anatomic, and procedural data were collected. Intraoperative data included temperature (intra-atrial [T_{ATR}], nasopharyngeal [T_{NP}], esophageal [T_{ES}], and rectal [T_{R}] temperatures), bypass, and aortic crossclamp and deep hypothermic circulatory arrest (DHCA) times in addition to rates and depth of cooling and rewarming. Postoperative temperatures (T_R, T_{ATR}, and axillary temperature [T_{AX}]) were recorded hourly for 4 hours (continuous rectal monitoring: Thermistor:YS1700, Level 1, Rockland, Mass; intermittent rectal or axillary monitoring: IVAC Temp-plus II, Alaris Medical Systems, San Diego, Calif), every 2 hours for 8 hours and then every 4 hours until discharge from the cardiac intensive care unit (CICU). T_{ATR} recordings were discontinued when the thermister catheter was removed. The timing of the removal of intracardiac catheters was at the discretion of the care-giving team. This was reflected in a decrease in the number of T_{ATR} data points: postoperative hour 16 (n = 100), postoperative hour 24 (n = 75), postoperative hour 40 (n = 50), postoperative hour 80 (n = 30), and postoperative hour 120 (n = 14). Additional variables that were believed to potentially influence the patients' temperatures were recorded: environmental temperature control, inotropic agents and vasodilators, transfusion of blood products, arterial blood gas data, and administration of base correction, acetaminophen, or ibuprofen.

Standard practice at our institution includes intraoperative placement of intracardiac catheters for pressure monitoring and vascular access. These catheters are preferentially placed in the right-sided atrium. Typically, 2 to 3 of these catheters are placed through the atrial cannulation site during decannulation. The 3F thermister catheters provide T_{ATR} monitoring. Placement of the intracardiac thermister was at the discretion of the surgeon. Intra-atrial catheters are removed simultaneously at the bedside when they are no longer deemed necessary. Most commonly, intracardiac catheters are removed after endotracheal extubation and after the patient has demonstrated the ability to maintain adequate enteral nutrition. These catheters are removed as early as the first postoperative morning in the older infants with less complex operations. No patient required surgical intervention related to the intracardiac catheter.

Operations were performed by 3 cardiac surgeons with a dedicated team of cardiac anesthesiologists. Alpha-stat blood gas management was used. Pump flow rates were not standardized for this study. DHCA was used at the surgeon's discretion. Before DHCA, patients underwent core cooling with topical hypothermia of the head to a T_{NP} of 18°C. Modified ultrafiltration was performed in 98 patients.

Routine CICU management was maintained for these patients. Normothermia was the routine temperature strategy. However, patients with accelerated junctional rhythm are often cooled slightly. Environmental temperature control with overhead warmers (Ohio-Infant Warmer System; Ohmeda, Columbia, Md), bear-huggers (Bair Hugger Model 500/OR; Augustine Medical Inc, Eden Prairie, Minn), and cooling blankets (Mul-T-Blanket; Gaymar Industries, Orchard Park, NY) were used in 49% of patients. Acetaminophen and ibuprofen were administered to 80% of patients for either hyperthermia or pain control. All patients received dopamine (3 $\mu g \cdot kg^{-1} \cdot min^{-1}$, n = 95, or 5 $\mu g \cdot kg^{-1} \cdot min^{-1}$, n = 5). Eighty-eight percent of patients received milrinone (0.25-1 $\mu g \cdot kg^{-1} \cdot min^{-1}$), 35% of patients received nitroprusside (0.5-5 $\mu g \cdot kg^{-1} \cdot min^{-1}$), 7% of patients received epinephrine or norepinephrine (0.01-0.1 $\mu g \cdot kg^{-1} \cdot min^{-1}$), and 26% of patients received bicarbonate to correct a metabolic acidosis.

Data analysis proceeded in 4 distinct phases. Phases I and II were exclusively descriptive, and phases III and IV comprised the inferential part of the study. Phase I consisted of generating simple descriptive statistics for all relevant variables. In phase II mean temperature values (T_{ATR}, T_R, and T_{AX}) were computed and plotted from CICU admission until postoperative hour 120. Difference values between T_{ATR} and simultaneous T_R ($T_{ATR} - T_R$) and T_{AX} ($T_{ATR} - T_{AX}$) values were computed and plotted over the same time interval. In phase III $T_{ATR} - T_R$ and $T_{ATR} - T_{AX}$ values were tested for statistical significance, specifically to find the points of greatest difference. In addition, single covariate logistical regression models were used to investigate the relationship between selected variables and T_{ATR}

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