The management of temperature during hypothermic cardiopulmonary bypass: I – Canadian survey

Howard J. Nathan MD FRCP, Gilbert Lavallée RN CPC

During hypothermic cardiopulmonary bypass (CPB) patients are cooled, usually to between 30–32°C, and, after myocardial blood flow is restored, they are rewarmed with blood heated in the pump-oxygenator. We audited our local practice by recording tympanic and nasopharyngeal temperatures in 11 patients undergoing hypothermic CPB. We found that, during rewarming, nasopharyngeal and tympanic temperatures commonly exceeded 38°C although temperature measured in the bladder was <37°C. A survey of cardiac surgery centres in Canada suggested that most centres induce hyperthermia in highly perfused tissues during rewarming, sometimes inadvertently. This may be of some importance because it has become widely appreciated by neuroscientists that mild degrees of brain cooling (2–5°C) are capable of conferring dramatic protection from ischaemic brain injury and, conversely, mild temperature elevation may be markedly deleterious. If control of brain temperature is considered desirable then we would suggest that nasopharyngeal temperature be monitored during rewarming on CPB.

Pendant la circulation extracorporelle (CEC) hypothermique, les patients sont ordinairement refroidis à 30°–32° C et, une fois le débit coronarien rétabli, réchauffés avec le sang du circuit de CEC. Nous avons contrôlé notre pratique usuelle en enregistrant les températures tympanique et oropharyngée chez 11

patients opérés pour revascularisation myocardique. Nous avons trouvé que, pendant le réchauffement, les températures nasopharyngée et tympanique dépassaient généralement 38° quoique la température mesurée dans la vessie ait été inférieure à 37° C. Une enquête réalisée sur la chirurgie cardiaque au Canada montre que dans la plupart des centres, l'hyperthermie est induite dans les tissus à perfusion élevée pendant le réchauffement et, cela, parfois par mégarde. Ce facteur a son importance parce qu'il est maintenant reconnu que le refroidissement cérébral, même s'il est minime (2–5° C), peut protéger efficacement du dommage cérébral ischémique et qu'au contraire, une augmentation de la température, même légère, peut être très nuisible. Comme il est désirable que la température cérébrale soit contrôlée, nous suggérons le monitoring de la température nasopharyngée pendant le réchauffement sous CEC.

Key words

TEMPERATURE: hypothermia, hypothermic;
SURGERY: cardiac, cardiopulmonary bypass;
COMPLICATIONS: neurological.

From the Department of Anaesthesia, University of Ottawa Heart Institute, Ottawa, Ontario, Canada.

Address correspondence to: Dr. Howard J. Nathan, Department of Anaesthesia, HIRC, H341A, University of Ottawa Heart Institute, 1053 Carling Avenue, Ottawa, Ontario, Canada K1Y 4E9.

Presented in part at the Annual Meeting of the Canadian Cardiovascular Society, Edmonton, Alberta, 1994.

Accepted for publication 14th April, 1995.

In our practice of hypothermic cardiopulmonary bypass (CPB) we have noticed that the faces of some of our patients became covered with perspiration during rewarming. We wondered if, despite the fact that their bladder temperature was <37°C, their brains may have been hyperthermic. This may be of some importance because it has become widely appreciated by neuroscientists that mild degrees of brain cooling (2–5°C) are capable of conferring dramatic protection from ischaemic brain injury and, conversely, mild temperature elevation may be markedly deleterious.¹ During hypothermic CPB patients are cooled and later are rewarmed at a time when they are at risk of ischaemic brain damage due to micro- or macroemboli, as well as hypotension, haemodilution, and other factors associated with CPB.^{2,3} To investigate the possibility that we were inadvertently causing brain hyperthermia we audited our local practice of hypothermic CPB. We then surveyed other Canadian centres to determine if our practice was atypical.

Methods

Beginning in August 1992 we audited our temperature management in a convenience sample of 11 patients se-

lected from our cardiac surgical population. Tympanic temperature was measured but not displayed to the perfusionist who, as per our routine management, monitored temperature from thermistors in the Foley catheter, oxygenator inlet and outlet. The usual management at the time was to cool to a bladder temperature of 30–32°C during cardiac anoxia and then rewarm to 36–37°C (bladder) before separation from CPB.

In April 1993 we surveyed the 30 adult cardiac surgery centres in Canada. Questionnaires were mailed to the chief perfusionist at each institution requesting details of their local temperature management during CPB. To obtain a high response rate non-responders were contacted by telephone. Weighted average temperatures are reported in the results. These were calculated for each temperature measurement site (e.g., bladder) by multiplying the temperature reported by an institution by the number of patients operated on at that institution, summing over all institutions, and then dividing by the total number of patients.

Results

Figure 1 illustrates the increase in tympanic and bladder temperatures of 11 patients during rewarming on CPB. To allow a common time scale for the plot, the peak temperature for each patient is aligned at time 0 and the temperatures are displayed for 30 min before and following the peak. The bladder temperature increased smoothly from 31.4°C to 36.6°C. To accomplish this, blood was heated in the oxygenator sufficiently to raise tympanic temperature to a mean peak of 38.6°C (range 37.7 to 39.7°C). Although bladder temperature increased smoothly toward 37°C this was accomplished by heating blood well above 37°C resulting in brain hyperthermia.

Twenty-eight of 30 (93%) cardiac centres completed the questionnaire. Approximately 18,710 CPB cases in adults were performed at those centres during the year preceding the survey. In 19 centres exclusively hypothermic CPB was used, four used only normothermic CPB, and five performed both. Approximately 16,134 adult patients underwent hypothermic CPB and 2,576 underwent normothermic CPB. Figure 2 illustrates the proportion of centres measuring temperature at each of six sites (nasopharyngeal (NP), esophageal (ESO), rectal (R), bladder (BLAD), oxygenator outlet (OO) – oxygenated blood, oxygenator inlet (OI) – venous blood). Only four centres measured neither ESO nor NP temperature. Fifteen centres measured at sites (ESO or NP) reflecting temperature in rapidly rewarming tissue as well as at sites (R or NP) reflecting slowly rewarming tissue. No centre routinely measured tympanic temperature in adults.

The endpoint temperature for rewarming at the different measurement sites, in patients undergoing hypothermic CPB, is illustrated in Figure 3. The average

FIGURE 1 Tympanic and bladder temperatures during rewarming. Time 0 = maximum temperature achieved. Mean $\pm$ SD are shown.

FIGURE 2 Temperature monitoring sites in 30 adult cardiac surgery centres in Canada. Esophageal (Eso), nasopharyngeal (NP), rectal (Rec); bladder (Blad); oxygenator outlet (Oxy Out); oxygenator inlet (Oxy In).

ranged from a low of 35.5°C R to a high of 38.3°C at OO. The goal at some centres was to raise NP temperature to 38.5°C or to heat the blood at the oxygenator outlet to 39.5°C. We also asked for the highest temperature normally reached during rewarming. Figure 4 in-

FIGURE 3 Endpoints for rewarming. Range and weighted averages are indicated.

icates that, in most cases, during rewarming highly perfused tissue is made hyperthermic.

Discussion

The audit of tympanic temperature during rewarming revealed that the brain was inadvertently being made hyperthermic, a fact which was not appreciated because at our institution nasopharyngeal or tympanic temperature was not measured or controlled by the perfusionist. We audited tympanic temperature as it is believed to be the most accurate "non-invasive" monitor of brain temperature.^{4,5} Stone *et al.*⁶ recently compared temperature measured directly in the cerebral cortex with temperature measured at a variety of other sites during cooling and rewarming on CPB. The patients were undergoing intracranial surgery and CPB was established via the femoral vessels without opening the chest. No one site accurately reflected intracerebral temperature during cooling or rewarming. Probes in regions with high blood flow were most useful (NP, and ESOPH). During cardiac surgery with an open mediastinum ESOPH may not be reliable.

The high response rate for the survey suggests that the results are representative of recent practice of hypothermic CPB in Canada. It must be recognized, however, that the results are based on the perfusionists' self-report. Each centre did not formally review their practice for this purpose. It is probable that extremes of temperature have been under-reported. Only about half the centres monitor NP temperature and at those centres NP temperature is normally raised above 38°C during rewarming. The brain is a highly perfused organ and it is likely that at least parts of the brain quickly approach the temperature of the heated blood returning from the pump-

FIGURE 4 Highest temperature reached during rewarming. Raising highly perfused tissue temperature above 37°C is common practice at most Canadian centres.

oxygenator. Judging by the very high temperatures reported for blood leaving the oxygenator it is probable that centres that do not measure NP temperature are also inducing brain hyperthermia.

We conclude that contemporary management of hypothermic CPB commonly results in brain hyperthermia. If control of brain temperature is considered desirable then we would suggest that nasopharyngeal temperature be monitored.

Acknowledgements

We thank Geri Wells, Denise Wozny and Joanne Sweet BScN for their expert assistance.

References

- 1 Ginsberg MD, Globus MY-T, Dietrich WD, Busto R. Temperature modulation of ischaemic brain injury - a synthesis of recent advances. *Prog Brain Res* 1993; 96: 13-22.
- 2 Newman M, Frasco P, Kern F, Greeley WJ, Blumenthal JA, Reves JG. Central nervous system dysfunction after cardiac surgery. *Adv Card Surg* 1992; 3: 243-84.
- 3 Shaw PJ, Bates D, Carlidge NEF, *et al.* Neurologic and neuropsychological morbidity following major surgery: comparison of coronary artery bypass and peripheral vascular surgery. *Stroke* 1987; 18: 700-7.
- 4 Davis FM, Barnes PK, Bailey JS. Aural thermometry during profound hypothermia. *Anaesth Intensive Care* 1981; 9: 124-8.
- 5 Benzinger M. Tympanic thermometry in surgery and anesthesia. *JAMA* 1969; 209: 1207-11.
- 6 Stone JG, Young WL, Smith CR, *et al.* Do standard monitoring sites reflect true brain temperature when profound hypothermia is rapidly induced and reversed? *Anesthesiology* 1995; 82: 344-51.