Cardiothoracic Anesthesia, Respiration and Airway

Brief report: The declining incidence of cerebral hyperthermia during cardiac surgery: a seven-year experience in 6,334 patients

[Rapport sommaire : l'incidence décroissante de l'hyperthermie cérébrale pendant la cardiochirurgie, sept ans d'expérience auprès de 6 334 patients]

William B. Corkey MD, Barbara Phillips-Bute PhD, Bruno Baudet BS, Joseph P. Mathew MD, Mark F. Newman MD, Hilary P. Grocott MD FRCPC

Purpose: Cerebral hyperthermia during rewarming from hypothermic cardiopulmonary bypass (CPB) commonly occurs and has been associated with postoperative neurocognitive dysfunction. Increased awareness of this has likely led to changes in rewarming strategies, including the reduction of rewarming rates and lowering of target rewarming temperatures. As a result, we hypothesized that the maximum temperature reached during cardiac surgery has decreased at our institution over time.

Methods: We retrospectively reviewed the maximum intraoperative nasopharyngeal (NP) temperature in 6,334 patients having undergone cardiac surgery utilizing hypothermic CPB from January 1993 to June 2000. The incidence of cerebral hyperthermia (defined by a NP temperature > 38°C) was examined over time using Chi-square testing and the relationship between maximum temperature and date of surgery was studied using linear regression.

Results: Maximum temperature decreased over time ($P < 0.0001$; $r^2 = 0.40$) having the greatest reduction from January 1993 to December 1996 (0.34°C temperature drop per year), while from January 1997 to June 2000, it continued to decrease, but at a slower rate (0.10°C per yr; $P < 0.0001$). The incidence of cerebral hyperthermia decreased over time with 83% of the first 10% of patients and 3% of the latter 10% of patients during the study period having a maximum temperature > 38°C ($P < 0.0001$).

Conclusion: The incidence of cerebral hyperthermia has decreased at our institution suggesting that a change in temperature management has occurred at our institution from January 1993 to June 2000 thereby outlining a temporal evolution in temperature management during CPB.

Objectif : *L'hyperthermie cérébrale se manifeste souvent pendant le réchauffement qui suit la circulation extracorporelle (CEC) et elle a été associée à une dysfonction neurocognitive postopératoire. De meilleures connaissances ont fait changer les stratégies de réchauffement, entre autres par la réduction de la vitesse du réchauffement et la baisse des températures cibles du réchauffement. Nous avons donc émis l'hypothèse que la température maximale atteinte pendant la cardiochirurgie avait diminué avec le temps à notre institution.*

Méthode : *Nous avons fait une revue rétrospective de la température nasopharyngienne (NP) peropératoire maximale chez 6 334 patients qui avaient subi une intervention cardiaque avec l'usage de la CEC hypothermique entre janvier 1993 et juin 2000. L'incidence d'hyperthermie cérébrale (définie par une température NP > 38 °C) a été vérifiée dans le temps avec le test du $\times^2$ et la relation entre la température maximale et la date de l'intervention chirurgicale a été étudiée selon une régression linéaire.*

Résultats: *La température maximale a baissé avec le temps ($P < 0,0001$; $r^2 = 0,40$), surtout entre janvier 1993 et décembre 1996 (une chute de 0,34 °C par année), mais de janvier 1997 à juin 2000, elle a continué à monter, plus lentement (de 0,10 °C par année ; $P < 0,0001$). Pendant la période étudiée, l'hyperthermie cérébrale a diminué avec le temps, touchant 83 % des premiers 10 % de patients et 3 % des derniers 10 % ayant une température maximale > 38°C ($P < 0,0001$).*

Conclusion : *L'incidence d'hyperthermie cérébrale a diminué à notre institution, ce qui montre qu'un changement dans le contrôle de la température serait survenu entre janvier 1993 et juin 2000, indiquant ainsi une évolution temporelle du contrôle de la température pendant la CEC.*

From the Department of Anesthesiology, Duke University Medical Center, Durham, North Carolina, USA.

Address correspondence to: Dr. Hilary P. Grocott, Department of Anesthesiology, Duke University Medical Center, Box 3094 DUMC, Durham, NC, 27710, USA. Phone: 919-681-5024; Fax: 919-681-8993; E-mail: h.grocott@duke.edu

Accepted for publication January 19, 2005.

Revision accepted February 24, 2005.

CEREBRAL hyperthermia commonly occurs during rewarming from hypothermic cardiopulmonary bypass (CPB) and has been associated with increased neurocognitive dysfunction after cardiac surgery.[1] Rewarming from hypothermic CPB is principally accomplished by delivering energy to the blood as it circulates through the heat exchanger of the CPB apparatus. Elevated arterial inflow temperatures (> 37°C) have been used extensively in the past to facilitate a more rapid rewarming from hypothermic CPB. As the brain receives a large proportion of the output from the CPB pump, higher inflow temperatures rapidly, and disproportionately to the rest of the body, heat the brain.

The neurological side effects of cardiac surgery have been well studied in recent years.[2] Although their etiology is complex,[3] temperature is thought to play a role.[1,4,5] Elevated peak temperature, in concert with an increased rate of rewarming, has been associated with increased neurocognitive dysfunction following CPB.[1] Similarly, postoperative hyperthermia has also been reported to have adverse neurocognitive consequences.[4] These clinical deleterious effects of hyperthermia have been mirrored experimentally where the risk of damage after cerebral ischemia is increased by hyperthermia.[6] These factors suggest that either hyperthermia causes some *de novo* injury or further complicates injury once it has already occurred.

The past decade has seen multiple studies examining the impact of temperature on postoperative cerebral outcome with a resultant increased awareness of the importance of CPB temperature management strategies.[1,5,7,8] This increased awareness has likely led to an evolution of temperature management. As a result, we hypothesize that both the maximum temperature, as well as the incidence of cerebral hyperthermia, during cardiac surgery has decreased over time at our institution.

Methods

Following Institutional Review Board approval, we retrospectively collected data on all adult patients having had cardiac surgery utilizing mild hypothermic CPB from January 1993 to June 2000 at the Duke University Medical Center. Patients undergoing non-hypothermic CPB, off-pump cardiac surgery, and circulatory arrest procedures were excluded. During non-pulsatile CPB, patients were cooled to 28–34°C with nasopharyngeal (NP) temperature recorded in an automated anesthesia information system (Arkive® Information Management System; Arkive IMS Inc., San Diego, CA, USA).

TABLE Demographics and intraoperative data

Age (yr)	63 (12)
Male gender (%)	64
Height (cm)	170 (10)
Weight (kg)	81 (18)
Diabetes (%)	29
Hypertension (%)	64
Ejection fraction (%)	51 (14)
CABG (%)	80
Valve (%)	25
CPB time (min)	130 (71)
Cross-clamp time (min)	75 (45)

Values represent mean (standard deviation); n = 6,334. CABG = coronary artery bypass graft surgery; CPB = cardiopulmonary bypass.

The relationship between maximum NP temperature during CPB and surgery date was investigated using simple linear regression. The incidence of hyperthermia (> 38°C) in the earliest 10% of patients compared to the most recent 10% was compared using Chi-square testing. The rate by which maximum temperature changed was also compared, using a student's t test, between two time periods, 1993-1996 and 1997-2000. These dates were chosen as 1997 was the year that an institutional study investigating different rewarming strategies was initiated,[1] and we suspected that this might have influenced institutional temperature management practices. A P-value < 0.05 was considered significant.

Results

Intraoperative and demographic characteristics of the 6,334 patients included are presented in the Table. The Figure demonstrates that the maximum NP temperature decreased over time ($P < 0.0001$, $r^2 = 0.40$) with the greatest decrease from January 1993 to December 1996 (0.34°C per yr); from January 1997 to June 2000, it continued to decrease, but at a slower rate (0.10°C per yr; $P < 0.0001$). The incidence of hyperthermia also decreased, occurring in 83% of the first 10% of patients and only in 3% of the latter 10% ($P < 0.0001$).

Discussion

This study confirmed our hypothesis that maximum intraoperative NP temperature during rewarming from hypothermic CPB has decreased at our institution from January 1993 to June 2000; correspondingly, the incidence of hyperthermia also decreased. As was conventional practice, the majority (> 80%) of patients in the early years of the study were aggressively rewarmed,

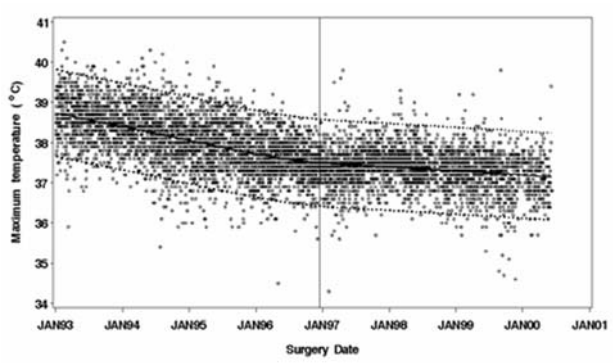

FIGURE Maximum intraoperative nasopharyngeal (NP) temperatures in 6,334 patients undergoing cardiac surgery with cardiopulmonary bypass from January 1993 (JAN93) to June 2000. The vertical line represents the time at which a rewarming study focusing on the effects of rewarming temperatures and outcome was initiated at our institution.[1] Although maximum NP temperature decreased throughout the study period ($P < 0.0001$; $r^2 = 0.40$), it had the greatest decrease over the time period from January 1993 to December 1996 (0.34°C per yr), while from January 1997 to June 2000, it continued to decrease, but at a slower rate (0.10°C per yr; $P < 0.0001$).

commonly reaching temperatures > 38°C. Seven years later, however, very few (< 3%) patients were hyperthermic. Since NP temperature is considered a surrogate for brain temperature, particularly during rewarming, reduction in peak NP temperature represents a reduction in overall cerebral hyperthermia. Jugular bulb (JB) temperature may be an even better site to monitor brain temperature.[9] We have previously demonstrated that during rewarming, when temperature gradients between the brain and other body sites are greatest, NP temperature may still lag behind and underestimate peak JB temperatures. If we take into account this NP to JB temperature relationship, then there may have been an even greater degree of cerebral hyperthermia in those early years.

There has been increasing emphasis on neurological outcomes after cardiac surgery over the past two decades. These neurological side effects include stroke, as well as more subtle but much more frequent neurocognitive complications.[2] The deleterious effects of hyperthermia on the brain have been well documented with multiple mechanisms contributing to injury.[6] Altering temperature management to reduce hyperthermia, therefore, has the potential to greatly impact outcome in these patients.

The time during which this study took place represented a period of increasing investigation of neurocognitive dysfunction after cardiac surgery with the impact of temperature management being a common theme.[1,5,7,8] Mild hypothermia practices (32–34°C) increasingly replaced moderate hypothermia (26–30°C) used more frequently in the past. This change in temperature management reduced the need for aggressive rewarming, and with it, the frequent overshoot in cerebral temperature.[1]

In the present study, a difference in the rate of temperature decrease is noted between the time period of 1993 to 1996 (0.34°C per yr) as compared with the later period of 1997 to 2000 (0.10°C per yr). A study addressing the effects of rewarming rate (and peak rewarming temperatures) on outcome after cardiac surgery was in progress at our institution during that time.[1] We speculate that in doing that study, the planning, preparation, and discussion surrounding it may have influenced our overall rewarming practices. Research is known to increase exposure and education of practitioners to relevant issues--here, the importance of strict temperature management. This phenomenon, the Hawthorne effect, is one in which a group that is singled out for special study has its performance positively affected.[10] Thus, awareness of rewarming techniques and the implications on neurocognitive outcome may have been heightened by that study possibly leading to more regulated rewarming techniques and with it, a decrease in cerebral hyperthermia.

References

1 *Grigore AM, Grocott HP, Mathew JP, et al.* The rewarming rate and increased peak temperature alter neurocognitive outcome after cardiac surgery. Anesth Analg 2002; 94: 4–10.

2 *Arrowsmith JE, Grocott HP, Reves JG, Newman MF.* Central nervous system complications of cardiac surgery. Br J Anaesth 2000; 84: 378–93.

3 *Grocott HP, Homi HM, Puskas F.* Cognitive dysfunction after cardiac surgery: revisiting etiology. Semin Cardiothorac Vasc Anesth 2005 (in press).

4 *Grocott HP, Mackensen GB, Grigore AM, et al.* Postoperative hyperthermia is associated with cognitive dysfunction after coronary artery bypass graft surgery. Stroke 2002; 33: 537–41.

5 *Nathan HJ, Wells GA, Munson JL, Wozny D.* Neuroprotective effect of mild hypothermia in patients undergoing coronary artery surgery with cardiopulmonary bypass. A randomized trial. Circulation 2001; 104(Suppl I): I85–91.

6 *Busto R, Dietrich WD, Globus MY, Ginsberg MD.* The

importance of brain temperature in cerebral ischemic injury. Stroke 1989; 20: 1113–4.
7 *McLean RF, Wong BI, Naylor CD, et al.* Cardiopulmonary bypass, temperature, and central nervous system dysfunction. Circulation 1994; 90(5Pt2): II250–5.
8 *Grigore AM, Mathew J, Grocott HP, et al.* Prospective randomized trial of normothermic versus hypothermic cardiopulmonary bypass on cognitive function after coronary artery bypass graft surgery. Anesthesiology 2001; 95: 1110–9.
9 *Grocott HP, Newman MF, Croughwell ND, White WD, Lowry E, Reves JG.* Continuous jugular venous versus nasopharyngeal temperature monitoring during hypothermic cardiopulmonary bypass for cardiac surgery. J Clin Anesth 1997; 9: 312–6.
10 *Holden JD.* Hawthorne effects and research into professional practice. J Eval Clin Pract 2001; 7: 65–70.