Anesthesiology
1997 87:1318-23
© 1997 American Society of Anesthesiologists, Inc.
Lippincott-Raven Publishers

Mild Intraoperative Hypothermia Prolongs Postanesthetic Recovery

Rainer Lenhardt, M.D., Elvine Marker, M.D.,† Veronika Goll, M.D.,† Heinz Tschernich, M.D.,† Andrea Kurz, M.D.,‡ Daniel I. Sessler, M.D.,§ Edith Narzt, M.D.,† Franz Lackner, M.D.||*

Background: **Intraoperative hypothermia is common and persists for several hours after surgery. Hypothermia may prolong immediate recovery by augmenting anesthetic potency, delaying drug metabolism, producing hemodynamic instability, or depressing cognitive function. Accordingly, the authors tested the hypothesis that intraoperative hypothermia prolongs postoperative recovery.**

Methods: **Patients undergoing elective major abdominal surgery (n = 150) were anesthetized with isoflurane, nitrous oxide, and fentanyl. They were randomly assigned to routine thermal management (hypothermia) or extra warming (normothermia). Postoperative surgical pain was treated with patient-controlled analgesia. Fitness for discharge from the postanesthesia care unit was evaluated at 20-min intervals by investigators blinded to group assignment and postoperative core temperatures. Scoring was based on a modification of a previously published system that included activity, ventilation, consciousness, and hemodynamic responses. Patients were considered fit for discharge when they sustained a score of 80% (13 points) for at least two consecutive measurement periods.**

Results: **Morphometric characteristics and anesthetic management were similar in each group. Final intraoperative core temperatures differed by ≈2°C: 34.8 ± 0.6 *versus* 36.7 ± 0.6°C (mean ± SD, $P < 0.001$). Postoperative pain scores and postoperative use of patient-controlled opioid were similar. Hypothermic patients required ≈40 min longer (94 ± 65 *vs.* 53 ± 36 min) to reach fitness for discharge, even when return to normothermia was not a criterion ($P < 0.001$). Duration of recovery in the two groups differed by ≈90 min when a core temperature >36°C was also required ($P < 0.001$).**

Conclusion: **Maintaining core normothermia decreases the duration of postanesthetic recovery and may, therefore, reduce costs of care. (Key words: Temperature: core. Thermoregulation. Hypothermia. Anesthesia: recovery, duration. Postanesthesia care.)**

* Research Fellow, University of California, San Francisco.

† Resident, Department of Anesthesia and Intensive Care, University of Vienna.

‡ Attending Anesthesiologist, Associate Director Outcomes Research, University of Vienna.

§ Professor, University of California, San Francisco; Professor, Ludwig Boltzmann Institute for Clinical Anesthesia and Intensive Care; Director Outcomes Research and Vice-Chair, Department of Anesthesia and General Intensive Care, University of Vienna.

|| Professor and Vice-Chair, Department of Anesthesia and General Intensive Care, University of Vienna.

Received from the Department of Anesthesia, University of California, San Francisco, California; the Outcomes Research Laboratory, Department of Anesthesia and General Intensive Care, University of Vienna, Vienna, Austria; and the Ludwig Boltzmann Institute for Clinical Anesthesia and Intensive Care, Vienna, Austria. Submitted for publication March 27, 1997. Accepted for publication July 8, 1997. Supported by National Institutes of Health grant GM49670; by Fonds zur Förderung der Wissenschaftlichen Forschung, Vienna, Austria; and by the Joseph Drown (Los Angeles, California), Max Kade (New York, New York), Erwin-Schrödinger (Vienna, Austria), J. William Fulbright (Washington, DC), and Anesthesia Patient Safety (Ermire, Pennsylvania) foundations. Mallinckrodt Anesthesiology Products (St. Louis, Missouri) donated the thermocouples. Major corporate funding for the Outcomes Research Laboratory is provided by Augustine Medical, Apotheus Laboratories, and Fairville Medical Optics. The authors do not consult for, accept honoraria from, or own stock or stock options in any anesthesia-related company. Presented in part at the 1996 Annual meeting of the American Society of Anesthesiologists, October 21-25, Atlanta, Georgia.

Address correspondence to Dr. Sessler: Department of Anesthesia, 374 Parnassus Avenue, University of California, San Francisco, California 94143-0648. Reprints will not be available. Address electronic mail to: sessler@vaxine.ucsf.edu

A COMPLICATION attributed to typical mild intraoperative hypothermia is prolonged duration of postanesthetic recovery.[1] Delayed recovery is, perhaps, not surprising because mild hypothermia increases anesthetic potency,[2,3] decreases drug metabolism,[4] reduces cognitive performance,[5] and is associated with cardiovascular instability.[6] Some authors report delayed postanesthetic recovery in patients who become mildly hypothermic,[1] whereas others failed to identify an effect of temperature.[7,8] Limitations of these studies include failure to randomly assign intraoperative temperatures,[1,7] determination of discharge fitness by unblinded investigators,[1,7] and trivial core temperature differences.[7]

Intraoperative hypothermia is most likely in patients undergoing complicated and long operations, or in those who are elderly, have little body fat, or have preexisting illnesses.[9-13] However, each of these factors confounds evaluation of postanesthetic recovery because the oldest, sickest patients, and those having the most extensive operations are also most likely to require prolonged recovery time. Failure to randomly assign intraoperative thermal management is therefore a major bias in any study evaluating complications of hypothermia.

An additional limitation of retrospective studies is that temperature monitoring sites and methods were typically not uniform, often unspecified, and frequently of insufficient accuracy. Furthermore, specific criteria for discharge usually were not enforced; lack of rigid discharge criteria is especially problematic because the personnel evaluating fitness for discharge were not masked to core temperature. In other cases, a specific core temperature may have been required for discharge, producing a substantial potential bias because hypothermic patients are usually fit for discharge (using temperature-independent criteria) long before core temperature returns to normal.

Thus not one prospective, randomized, masked investigation has evaluated the effect of intraoperative temperature on discharge time from the postanesthetic care unit. Accordingly, we tested the hypothesis that mild intraoperative hypothermia prolongs the duration of postanesthetic recovery. We used a prospective, randomized study design; investigators evaluated fitness for discharge using specific criteria and were masked to group assignment and postoperative core temperatures.

Methods

With approval from the institutional review board at the University of Vienna and written informed patient consent, we studied patients ages 18–80 yr who were undergoing elective abdominal surgery. A sample size calculation indicated that 150 patients would provide an 80% chance of identifying a 10-min difference in the two temperature management groups (two-tailed alpha = 0.01, sigma = 35 min).

All patients were classified as American Society of Anesthesiologists physical status I–III (generally healthy or stable systemic disease). Most were undergoing colon resection with or without abdominal-peritoneal pull-through, but gastrectomies also were included. Patients scheduled for minor abdominal surgery (such as cholecystectomies, polypectomy, isolated colostomy, hernia repair, or appendectomy) were excluded. Approximately 100 of the patients participated in a simultaneous thermoregulatory protocol.[14]

Protocol

Patients were not given preanesthetic medication. Anesthesia was induced with sodium thiopental (3–5 mg/kg), fentanyl (4 μg/kg), and vecuronium bromide (0.1 mg/kg). Subsequently, fentanyl was infused in all patients at a rate of 3 μg/kg/h. No additional opioid was given, and the infusion was discontinued at the beginning of wound closure. Isoflurane administration (in 60% nitrous oxide) was titrated to maintain a mean arterial blood pressure within 20% of preinduction values. Isoflurane administration was discontinued at the end of wound closure in all cases. Patients were hydrated according to the protocol: 15 $ml \cdot kg^{-1} \cdot h^{-1}$ of crystalloid throughout surgery, with blood loss replaced by crystalloid at a 4:1 ratio or colloid at a 2:1 ratio.

At the time of anesthetic induction, patients were assigned to two temperature management groups using computer-generated random codes maintained in sealed and numbered opaque envelopes: (1) extra warming (normothermia), where core temperature was maintained near 36.5°C at a current US hospital cost of about $30; and (2) routine thermal management (hypothermia), where core temperature was allowed to decrease to ≈34.5°C.[15,16] Ambient temperatures were maintained near 22°C. Temperatures were not controlled after operation: Patients were covered with a single cotton blanket and none was actively warmed. The patients were not informed of their group assignments. Allogeneic blood was administered at the discretion of the attending surgeon, who was blinded to group assignment and patient temperature. Postoperative pain was treated with the opioid piritramide delivered by a patient-controlled analgesia apparatus. Postoperative shivering was not treated.

Measurements

Core temperatures were measured at the tympanic membrane (Mon-a-Therm; Mallinckrodt Anesthesiology Products, St. Louis, MO) and values were recorded before operation, at 10-min intervals during operation, and at 20-min intervals during recovery. End-tidal isoflurane and carbon dioxide concentrations were recorded at 10-min intervals during anesthesia. Arterial blood pressure and heart rates were similarly recorded during and after anesthesia. Oxyhemoglobin saturation (S_pO_2) was determined by pulse oximetry.

Fitness for discharge was evaluated using a modification of the Aldrete and Kroulik scoring system (table 1).[17] The score was based on activity, ventilation, consciousness, and hemodynamic responses; 0, 1, or 2

Table 1. Fitness for Discharge Scoring System

	0 Point	1 Point	2 Points
Activity	No movement	No purposeful movement	Raises one arm on command
Respiration	Apnea	Dyspnea or limited breathing	Breathes deeply and coughs freely
Sp_{O_2} on room air (%)	<90	90–95	>95
Consciousness	Unresponsive	Arouses to verbal stimuli	Fully awake
Blood pressure	> or <50% of baseline	20–50% of baseline	0–20% of baseline
Heart rate (beats/min)	<45 or >120	45–49 or 101–120	50–100
Gastrointestinal tract	Little or no vomiting	Severe nausea and vomiting	Vomiting within 30 min
Renal function	Anuria	$\leq$0.3 ml · kg^{-1}h^{-1}	>0.3 ml · kg^{-1}h^{-1}

Fitness for discharge was evaluated by investigators masked to group assignment and core temperature, using a modification of the Aldrete and Kroulik scoring system. The total score was determined by summing the individual indicators of recovery, for which 0, 1, or 2 points were assigned. A score ≥13 (80%) sustained for a least two measurements at 20-min intervals defined temperature-independent fitness for discharge. Temperature-dependent recovery was defined by a sustained score ≥13 and core temperature >36°C.

points were assigned for each of eight responses. We made no effort to evaluate actual discharge times. All qualitative assessments were made by physicians blinded to the patients' group assignments and core temperatures; these observers saw the patients for the first time in the postanesthesia care unit.

Data Analysis

Outcomes were evaluated on an intention-to-treat basis. We prospectively defined two major outcomes: (1) fitness for discharge, defined by a recovery score ≥13 (80%) sustained for at least two measurement periods; and (2) fitness for discharge and normothermia, defined by a sustained score ≥13 and a core temperature >36°C. Times required to sustain scores ≥12 and ≥14 were also determined. Initial postoperative measurements were made after transport to the postanesthetic care unit and nursing stabilization, a time designated as 20 elapsed min.

Potential confounding factors were evaluated using unpaired, two-tailed *t* tests and chi-square analysis. Duration of recovery was analyzed using Wilcoxon tests. Duration of recovery was also evaluated using Kaplan-Meier "survival" analyses. Finally, a stepwise, multiple linear regression with backward elimination quantified the relative contribution of major factors potentially influencing fitness for discharge (age, duration of surgery, core temperature, and postoperative piritramide use); $P < 0.25$ was required to retain variables in the regression. This analysis differs from the others in considering actual core temperature, rather than group assignment, and other factors that might contribute.

Previous data indicate that time to discharge is normally distributed.[18] Consequently, all results are presented as mean ± SD. Because we defined two major outcomes, a $P < 0.025$ was required for each. Potential confounding factors and other results were considered significant when $P < 0.05$.

Results

Morphometric characteristics, types and duration of surgery, and anesthetic management were similar in the patients given routine thermal management (n = 74) and extra warming (n = 76). According to the study protocol, final intraoperative core temperatures differed significantly: 34.8 ± 0.6°C *vs.* 36.7 ± 0.6°C, respectively ($P < 0.001$, table 2). As is typical,[14] postoperative core temperature in the hypothermic patients increased ≈0.5°C/h, whereas core temperature in the normothermic patients remained nearly constant.

Hypothermic patients required ≈40 min longer than those assigned to normothermia to reach a sustained score ≥13 (our prospective criterion for discharge fitness; $P < 0.001$). Core temperature in the hypothermic patients required 134 ± 60 min to reach 36°C. Consequently, they required ≈90 min longer than the normothermic patients to reach both a sustained score ≥13 and a core temperature >36°C ($P < 0.001$). The hypothermic patients also required significantly longer to sustain recovery scores of 14 and 15 (table 3). Prolonged recovery was also apparent using Kaplan-Meier "survival" analyses (figs. 1, 2).

Stepwise linear regression indicated that final intraoperative core temperature and age contributed significantly to recovery duration (fitness for discharge), but piritramide use and duration of surgery did not (table 4).

Table 2. Morphometric Characteristics, Operations, Hemodynamic Responses, and Perioperative Management

	Normothermic	Hypothermic	*P*
Sex (M/F)	38/36	36/40	0.88
Weight (kg)	72 ± 14	71 ± 14	0.66
Height (cm)	170 ± 10	170 ± 10	1.00
Age (yr)	56 ± 17	55 ± 16	0.71
Operative site (colon/rectum/other)	34/30/30	32/18/26	0.63
Preoperative core temperature (°C)	36.8 ± 0.4	36.8 ± 0.4	1.00
Administered fentanyl (μg)	770 ± 340	821 ± 409	0.41
Intraoperative end-tidal isoflurane (%)	0.53 ± 0.15	0.51 ± 0.10	0.34
Intraoperative mean arterial blood pressure (mmHg)	91 ± 17	95 ± 18	0.16
Intraoperative heart rate (beats/min)	74 ± 17	76 ± 13	0.42
Intraoperative crystalloid (L)	3.6 ± 1.6	3.5 ± 1.2	0.66
Intraoperative colloid (L)	0.2 ± 0.3	0.2 ± 0.3	1.00
Red cell transfusion (yes/no)	11/63	21/55	0.17
Transfused blood (units)	0.4 ± 1.1	0.8 ± 1.2	0.4
Intraoperative ambient temperature (°C)	21.9 ± 1.2	22.1 ± 0.9	0.25
Intraoperative SP_{O_2} (%)	97.3 ± 1.5	97.5 ± 1.3	0.38
Final intraoperative core temperature (°C)	36.7 ± 0.6	34.8 ± 0.6	<0.001
Duration of surgery (h)	3.4 ± 1.2	3.2 ± 1.1	0.29
Postoperative SP_{O_2} (%)	98 ± 1	98 ± 1	1.00
Postoperative PCA piritramid (mg/h)	15.2 ± 9.1	16.4 ± 8.8	0.41

Data are mean ± SD. Two-tailed, unpaired *t* tests or chi-square analysis, as appropriate.

Discussion

Our major result is that ≈2°C intraoperative hypothermia significantly delayed fitness for discharge from the postanesthesia care unit. Even when core temperature *per se* was not considered a criterion for discharge, recovery was prolonged ≈40 min, nearly doubling recovery duration. This 40-min prolongation is similar to that reported previously in a nonrandomized, nonblinded study.[1] Core temperature in the hypothermic patients required ≈2 h to reach 36°C, which is similar to the time reported previously in similar (but different) patients.[19] Consequently, when fitness for discharge and normothermia were required, discharge was delayed ≈90 min in the unwarmed patients.

Prolonged recovery is potentially expensive because postanesthesia charges and costs are similar to those in intensive care units. We did not attempt a formal cost-benefit analysis. Nonetheless, reducing duration of recovery is a first step and, combined with appropriate personnel management, may eventually decrease costs of postanesthesia care. Some of the costs, including those for capital equipment and environmental maintenance, depend little on the number of patients or the

Table 3. Duration of Recovery (min)

	Normothermic	Hypothermic	P*
Sustained score ≥ 13	53 ± 36	94 ± 65	<0.001
T_{core} > 36°C	41 ± 41	134 ± 60	<0.001
Sustained score ≥ 13 and T_{core} > 36°C	66 ± 46	159 ± 57	<0.001
Sustained score ≥ 12	45 ± 26	61 ± 47	<0.001
Sustained score ≥ 14	88 ± 63	132 ± 74	<0.001

T_{core} = core temperature.
Data are mean ± SD.
* *P* values determined using Wilcoxon analysis.

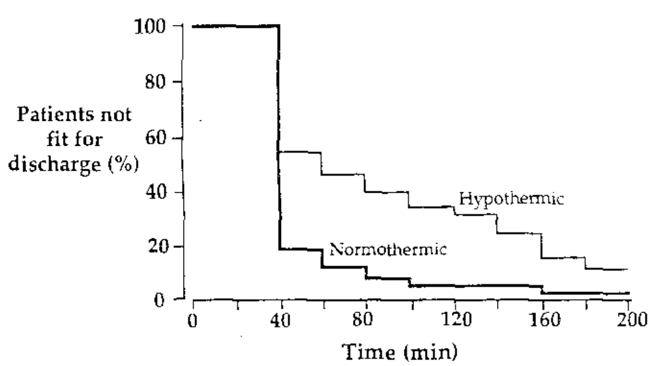

Fig. 1. Kaplan-Meier "survival" analysis showing the percentage of patients not sustaining a recovery score ≥13. The probability value, using a Wilcoxon analysis, was <0.0001.

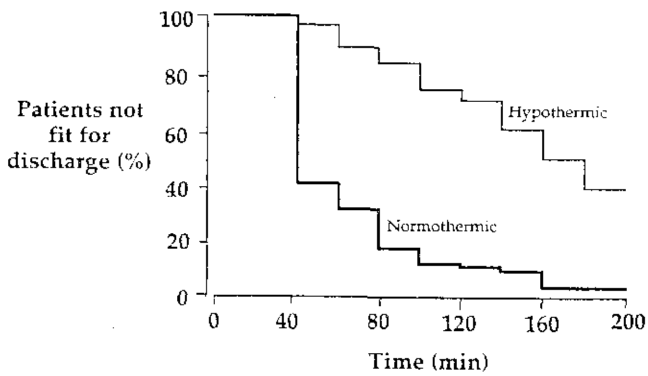

Fig. 2. Kaplan-Meier "survival" analysis showing the percentage of patients not sustaining a recovery score ≥13 and a core temperature >36°C. The probability value, using a Wilcoxon analysis, was <0.0001

average duration of recovery. Others are fixed on a per-patient basis, (*i.e.*, the purchase price of disposable nasal oxygen cannulae). Personnel costs, however, consume by far the largest fraction of postanesthesia care unit budgets. Decreasing recovery duration in an occasional patient is unlikely to permit decreased staffing. Even if the average time to discharge were significantly reduced, decreased staffing requirements would follow only if suitable scheduling changes were implemented.[18]

Whether a minimum core temperature should be required for discharge from the postanesthesia care unit remains controversial. Neither the American Society of Anesthesiologists nor the American Society of Post-Anesthesia Nurses currently have policies on the subject. Although there appear to be few data on which to base policy, minimum discharge temperatures have been established in many units. Prolonged recovery is, of course, only one complication associated with intraoperative hypothermia. Other major effects include an increased incidence of morbid cardiac events,[6] coagulopathy with increased requirement for allogeneic blood transfusion,[20] reduced resistance to surgical wound infections,[14] and prolonged hospitalization.[14] Consistent with these data, our hypothermic patients required significantly more allogeneic blood than did those kept normothermic. We would thus recommend that most surgical patients be kept normothermic, even if reduced postanesthetic care unit costs failed to provide a net savings.

Table 4. Correlates of Fitness for Discharge Using Multivariate Analysis (*P* Values)

	Score ≥ 13	Score ≥ 13 and T_{core} > 36
Final intraoperative core temperature	0.012	<0.001
Age	0.035	0.087
Duration of surgery	0.184	0.218

Final intraoperative core temperature and age contributed significantly to recovery duration (fitness for discharge), but piritramid use and duration of surgery did not.

Our current results contrast with a previous investigation in which we failed to identify a correlation between hypothermia and prolonged recovery.[8] Data in that study were collected prospectively, temperatures were recorded from the tympanic membrane, and fitness for discharge was determined by blinded investigators using specific criteria, which did not include core temperature. Intraoperative temperature management, however, was not randomly assigned (a lapse that would be expected to produce a false-positive bias). A major difference between the protocols is that only infants and children were included in our previous study, whereas only adults participated in our present investigation. Furthermore, most of the children had relatively minor procedures, whereas all the adults had major abdominal operations. Hypothermia thus appears to delay fitness for discharge minimally, if at all, in children recovering from minor procedures, but significantly prolongs recovery in adults after major surgery.

A limitation of our study is that we evaluated fitness for discharge: difference between the groups would likely have been less had actual discharge times been considered because they are determined by other factors, including availability of ward beds and transport personnel. Among these factors are nursing habits and protocols. For example, postanesthesia care nurses may believe, or even be instructed, that patients must be recovered for at least 1 h, even when less time would be sufficient. Any of these factors will reduce the potential benefit of early discharge resulting from maintaining intraoperative normothermia.

All our patients were recovering from major abdominal surgery; the effect of core temperature on fitness for discharge may have differed had we included smaller procedures. Similarly, core temperature may only minimally influence the fairly long period required to prepare outpatients for discharge to their homes. Temperatures in our two treatment groups differed by ≈2°C. Presumably, smaller differences would have influenced recovery less; conversely, recovery would likely have been prolonged even more in colder patients. And finally, the effects of temperature may have differed had we studied shorter-acting anesthetics such as desflurane or propofol.

In conclusion, ≈2°C intraoperative core hypothermia *per se* delayed postanesthetic recovery ≈40 min, even when return to normothermia was not a discharge criterion. Postoperative core temperatures increased slowly. Consequently, when a core temperature >36°C also was required, discharge was delayed ≈90 min in the hypothermic patients. Maintaining core normothermia is thus likely to decrease time in the postanesthesia care unit and may reduce the costs of care.

The authors thank Marc Schroeder, M.D., for his assistance.

References

1. Hines R, Barash PG, Watrous G, O'Connor T: Complications occurring in the postanesthesia care unit: A survey. Anesth Analg 1992; 74:503-9

2. Eger II EI, Johnson BH: MAC of I-653 in rats, including a test of the effect of body temperature and anesthetic duration. Anesth Analg 1987; 66:974-6

3. Vitez TS, White PF, Eger EI II: Effects of hypothermia on halothane MAC and isoflurane MAC in the rat. ANESTHESIOLOGY 1974; 41:80-1

4. Leslie K, Sessler DI, Bjorksten AR, Moayeri A: Mild hypothermia alters propofol pharmacokinetics and increases the duration of action of atracurium. Anesth Analg 1995; 80:1007-14

5. Webb P: Impaired performance from prolonged mild body cooling, Underwater Physiology VIII: Proceedings of the Eighth Symposium on Underwater Physiology. Edited by AJ Bachrach, MM Matzen. Bethesda, MD, Undersea Medical Society, 1984, pp 391-400

6. Frank SM, Fleisher LA, Breslow MJ, Higgins MS, Olson KF, Kelly S, Beattie C: Perioperative maintenance of normothermia reduces the incidence of morbid cardiac events: A randomized clinical trial. JAMA 1997; 277:1127-34

7. Fetzer-Fowler SJ, Huot S: The use of temperature as a discharge criterion for ambulatory surgery patients. J Post Anesth Nurs 1992: 7:398-403

8. Bissonnette B, Sessler DI: Mild hypothermia does not impair postanesthetic recovery in infants and children. Anesth Analg 1993; 76:168-72

9. Sato S, Okubo N, Yamashita S, Yamamoto S, Kumagai M, Kihara S, Nakayama H: Age-related decrease in toe-thumb temperature difference with lumbar epidural anaesthesia. Can J Anaesth 1994; 41:579-82

10. Carli F, Gabrielczyk M, Clark MM, Aber VR: An investigation of factors affecting postoperative rewarming of adult patients. Anaesthesia 1986; 41:363-9

11. Vassilieff N, Rosencher N, Sessler DI, Conseiller C: The shivering threshold during spinal anesthesia is reduced in the elderly. ANESTHESIOLOGY 1995; 83:1162-6

12. Kurz A, Sessler DI, Narzt E, Lenhart R: Morphometric influences on intraoperative core temperature changes. Anesth Analg 1995; 80:562-7

13. Kurz A, Plattner O, Sessler DI, Huemer G, Redl G, Lackner F: The threshold for thermoregulatory vasoconstriction during nitrous oxide/isoflurane anesthesia is lower in elderly than young patients. ANESTHESIOLOGY 1993; 79:465-9

14. Kurz A, Sessler DI, Lenhardt RA, Study of Wound Infections and Temperature Group: Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. N Engl J Med 1996; 334:1209-15

15. Alfonsi P, Hongnat JM, Lebrault C, Chauvin M: The effects of pethidine, fentanyl and lignocaine on postanesthetic shivering. Anaesthesia 1995; 50:214-7

16. Carli F, Kulkarni P, Webster JD, MacDonald IA: Post-surgery epidural blockade with local anaesthetics attenuates the catecholamine and thermogenic response to perioperative hypothermia. Acta Anaesthesiol Scand 1995; 39:1041-7

17. Aldrete JA, Kroulik D: A postanesthetic recovery score. Anesth Analg 1970; 49:924-34

18. Dexter F, Tinker JH: Analysis of strategies to decrease postanesthesia care unit costs. ANESTHESIOLOGY 1995; 82:94-101

19. Kurz A, Sessler DI, Narzt E, Bekar A, Lenhardt R, Huemer G: Postoperative hemodynamic and thermoregulatory consequences of intraoperative core hypothermia. J Clin Anesth 1995; 7:359-66

20. Schmied H, Kurz A, Sessler DI, Kozek S, Reiter A: Mild intraoperative hypothermia increases blood loss and allogeneic transfusion requirements during total hip arthroplasty. Lancet 1996; 347:289-92