



IMPACT OF ACTIVE CORE REWARMING ON BIOELECTRICAL IMPEDANCE AND POSTOPERATIVE RECOVERY IN LAPAROSCOPIC CHOLECYSTECTOMY

Dr. Bahe Akshay Bapan*

*Assistant Professor, Department of Anesthesia, Sri Lakshmi Narayana Institute of Medical Science, Pondicherry, India.

Abstract

Postoperative hypothermia is a common complication after general anesthesia, with significant impacts on patient recovery, particularly in cardiovascular health. This study evaluates the effects of active core rewarming on postoperative recovery, focusing on bioelectrical impedance (BI) changes and shivering reduction in patients undergoing laparoscopic cholecystectomy. A total of 120 patients were divided into control and experimental groups, receiving passive external rewarming and active core rewarming, respectively. Active core rewarming was associated with significantly lower bioelectrical impedance values, reduced shivering, and better hemodynamic stability compared to the control group. The results suggest that BI is closely linked to core temperature and may serve as a useful noninvasive tool to monitor the resolution of hypothermia in postoperative patients. This study supports the clinical advantages of active core rewarming in minimizing postoperative complications, particularly in patients with cardiovascular risks.

Keywords: Postoperative Hypothermia, Bioelectrical Impedance, Core Rewarming, Shivering, Laparoscopic Cholecystectomy, Cardiovascular Health, Anesthesia Recovery

Introduction

Postoperative hypothermia is a clinically relevant complication that is common when a patient is in recovery after general anesthesia [1]. Postoperative hypothermia etiology has been a debatable issue with the same being always associated with variables that include impaired metabolic homeostasis, poor nitrogen equilibrium, degree of tissue violence, hemorrhage, and multiple organ dysfunction syndromes [2,3]. These causes can be the result of inherent biological factors or unplanned external factors which cause unintentional hypothermia. Postoperative hypothermia has several clinical sequelae, which are severe catabolic disorders [4], aggravated nitrogen disequilibrium, increased vulnerability to nosocomial infections, poor wound healing, coagulopathy, myocardial ischemia, and a continuum of cardiac dysfunctions [5]. Cardiovascular complications in particular have been linked with high mortality particularly in patients with existing coronary artery disease [6]. Physiologically speaking body temperature control is coordinated by various hierarchical components in the nervous system the hypothalamus being the major thermoregulatory center. The key process that has been involved in postoperative hypothermia is the inhibitory impact of general anesthetics and sedative drugs on hypothalamic thermoregulatory centre; the mechanisms underlying such inhibition are yet to be fully identified [7]. In addition, the effect of postoperative hypothermia on the electrophysiological features of the central nervous system, myocardium, and neuromuscular apparatus have been well recorded. It has been shown (empirically) that hypothermia reduces the passive electrical characteristics of tissues, which is reflected in changes in membrane

resting potential, impedance, and signal amplitude, and it simultaneously deteriorates neuromuscular transmission [8]. These biological-physiological alterations can be measured by noninvasive electrophysiological techniques. Bioelectrical impedance (BI) is a conventional noninvasive modality that has been used to assess intravascular fluid compartments and total body composition. BI allows measuring resistance, reactance, and impedance of different parts of the body such as the arms, legs, and trunk using bi-electrode configurations on the hands and feet [9]. BI has been successfully used clinically to observe the signs of perturbations of cells as connexin dephosphorylation and uncoupling via calcium were observed during ischemic events [10]. This cellular disjunction is one of the major factors of the high rate of ventricular arrhythmias and eventual cardiogenic failure. Since ischemia and coagulopathy are common occurrences in patients undergoing a prolonged hypothermic state (especially in trauma patients or those with coronary artery disease) [11], BI monitoring in hypothermic patient cohorts undergoing surgery might provide valuable information on the optimization of therapeutic approaches. Active core rewarming has been shown to provide quantifiable advantages to speedily restore normalcy of temperatures, particularly in patients who are severely injured. Active core rewarming methods were used in patients that had experienced laparoscopic cholecystectomy under balanced inhalational anesthesia to assess whether or not BI parameters are regulated by core body temperature in the current study.

Methodology

The sample used consisted of 120 patients, including 104 females and 16 males aged 40 to 80 years of age, who underwent elective laparoscopic cholecystectomy, with 60 subjects being selected to participate in either of the two groups. The control group involved 60 patients and was given passive external rewarming, which involved the use of parenteral solutions at ambient room temperature with the use of a cotton blanket. The experimental group which also included 60 patients was active core rewarming, which consisted of the use of warmed parenteral solutions of 38.5°C and a cotton blanket.

Anesthesia technique

Anesthesia was done and balanced inhalation anesthesia was introduced with adjunctive agents: (a) Midazolam as premedication; (b) atropine, fentanyl, cisatracurium, and propofol as induction agents (c) fentanyl and sevoflurane as maintenance agents. The regimens of dosing were dependent on weight. The continuous measurements were made on the hemodynamic, respiratory, blood-gas, and biochemical variables using a Cardiocap 5 monitoring system [12]. Heart rate, blood pressure, electrocardiogram, arterial blood gases, respiratory rate, and esophageal temperature were measured during the operation period. The control cohort was nourished with parenteral fluids at room temperature (1250±250 mL) during the procedure, and the experimental cohort was nourished with fluids heated to 38.2° C by a fluid warmer during and postoperative period. A cotton blanket was used to cover both groups of cohorts in the postoperative period. The control group had a long postanesthesia care unit stay among patients.

Physiological evaluation

Hemodynamic, hematologic and biochemical measurements, namely blood pressure, arterial blood gas composition, complete blood count, blood glucose, and serum potassium were measured at three different times namely before the operation, right before the forceps performed the cholecystectomy and 30 minutes after the operation. Thoracic temperature, respiratory frequency, cardiac frequency, electrocardiographic tracings, mean arterial pressure, oxygenation saturation, arterial partial pressure of CO₂, and the existence of postoperative shivering were monitored continuously, being measured after 30 minutes interval within a two-hour period.

Statistical analysis

All the values were in the form of means (s). The two-mean comparison formula was used with 80% power and $\alpha = 0.06$, $Z\beta = 0.931$ and $Z\alpha = 2.756$ and $S = 35$ ohms and $d = 25$ ohms to determine the sample size of the BI measurements. The Mann-Whitney U test was used to examine differences in incidence of shivering in groups at each time point. Heart rate, mean arterial blood pressure, respiratory rate, body temperature and BI were measured repeatedly with time and an ANOVA of components of two-way repeated-measures was used to analyze these parameters. PSPPIRE version 0.6 which is Linux based and has a significant level of p of $P < 0.05$ was used to carry out statistical tests.

Results

Active core rewarming effects

As expected, the body temperature of the control cohort was kept at 36.5° C on average and 0.5°C on standard deviation, whereas, it gradually rose to 36°C up to 37°C in the active core rewarming cohort, starting 30 mins following the initiation of treatment. Active core rewarming cohort maintained BI values at around 69±4°C consistently over the duration of the observation period which was significantly lower than when observed by the control cohort. The values of BI increased in the control cohort to 96±10 ohm minutes post-recovery of the anesthesia state, and then decreased to 75± 5 ohm, which was about 30 percent higher than the results of the active core rewarming cohort.

The percentage of control patients shivering was 34 percent at the baseline, 66 percent at 30 minutes, and it went back to 34percent at the end of the study. Patients receiving active core rewarming on the other hand had a prolonged 50% reduction in shivering activity in the course of the experiment compared to controls.

Patients undergoing active core rewarming registered a mean arterial blood pressure that was 20mmHg lower compared to what was in the control cohort. Their mean respiration rates were also still low throughout the research period. There were no statistically significant intergroup differences in pH, oxygen partial pressure, carbon dioxide partial pressure, arterial oxygenation ratio, arterial oxygen saturation ($P < 0.05$) and in the biochemical parameters as stated in Table 1. Patients of the control group showed a significant rise of serum potassium level during the postoperative period but this was not the case in the anesthesia care unit (Table 1).

Table 1: Physiological and Biochemical Parameters in Control and Active Core Rewarming Groups During Postoperative Recovery

Measured Parameter	Conventional External Warming Method (Average ± SD, n = 60)			Enhanced Internal Warming Method (Average ± SD, n = 60)		
	Before Surgery	During Surgery	After Surgery	Before Surgery	During Surgery	After Surgery
Cardiac Rate	79.8 ± 3.1	65.5 ± 2.9	79 ± 2*	80.2 ± 3.1	68.9 ± 3	72 ± 2*
Breathing Rate	16.1 ± 1.4	12.5 ± 1.17	17 ± 1	18.5 ± 1.4	12.6 ± 1.2	18 ± 1
Core Temperature	37.3 ± 1.05	36.9 ± 1.06	36 ± 1	37.38 ± 1.07	37.54 ± 1.57	37 ± 1
Upper Arterial Pressure (mmHg)	134.9 ± 4.5	105.1 ± 4.8	127 ± 3*	125.8 ± 3.1	111.1 ± 4.1	117 ± 3*
Lower Arterial Pressure (mmHg)	81.7 ± 2.8	65.0 ± 2.9	78 ± 2	77.4 ± 2.8	63.3 ± 2.9	70 ± 2*
Blood Oxygen Level (%)	93.1 ± 1.6	99.4 ± 1.1	96 ± 1.1	93 ± 1.52	99.5 ± 1.2	97 ± 1.1
Arterial CO2 Level (mmHg)	35 ± 1.0	31.3 ± 1.6	41.2 ± 1.7	36 ± 1.4	32 ± 1.5	42.1 ± 1.4

Arterial O2 Level (mmHg)	65.6 ± 2.4	297.9 ± 2.2	77.1 ± 2.5	66.4 ± 2.8	323.9 ± 10.1	67 ± 2.4
Bicarbonate (mmol/L)	21.6 ± 1.2	18.78 ± 1.5	21.5 ± 1.3	22.6 ± 1.2	20.7 ± 1.3	22.13 ± 1.21
Hemoglobin (mg/dL)	14.4 ± 1.3	13.8 ± 1.3	13.6 ± 1.3	14.5 ± 1.3	14.1 ± 1.3	13.9 ± 1.3
Red Cell Volume (%)	43.9 ± 2	42 ± 2	40.9 ± 1.1	43.6 ± 1.3	41.4 ± 1.9	41 ± 2
White Blood Cells (10³/cm³)	8.5 ± 3.8	8.3 ± 3.8	8.3 ± 3.8	8.9 ± 3.8	8.7 ± 4.1	8.8 ± 3.7
Blood Platelets (per mm³)	284567 ± 14030	275200 ± 13495	272200 ± 13818	327500 ± 10088	327467 ± 10007	327333 ± 10028
Blood pH Level	7.42 ± 1.01	7.36 ± 1.01	7.31 ± 1.01	7.39 ± 1.01	7.39 ± 1.01	8 ± 1.01
Potassium Level (mEq/L)	4.57 ± 1.04	4.96 ± 1.03*	5.08 ± 1.03*	4.58 ± 1.03	4.51 ± 1.03*	4.45 ± 1.04*
Blood Sugar (mg/dL)	96.87 ± 5.8	110.4 ± 6.4*	117.5 ± 6.2	94.7 ± 4.5	89.7 ± 5.2*	80.8 ± 3.7*

*Indicates statistically meaningful differences between the two warming approaches (P < 0.05)

Discussion

Our results indicate, to the best of our knowledge, that bioimpedance (BI) is directly affected by core temperature changes in patients who have experienced postoperative laparoscopic cholecystectomy. BI values were negatively correlated with the core body temperature, and none of them showed any statistically significant correlation with the duration of shivering. BI rose with decreasing core temperature, to a peak of 95±11. Omega as the nadir temperature (36.5 ±5 degreesC) was reached at the 60 minutes point of observation. Active core rewarming maintained core temperatures greater than 36.5° C at which BI values failed to increase (68±3 Omega). BI analysis is gaining credibility as a valid modality of measuring fluid balance, body composition and cellular dysfunction in a range of pathological status. We suggest that the increased BI in hypothermic postoperative patients is an indication of the underlying physiological, biochemical and cellular disequilibrium; the specific molecular and physiological processes that underlie this state will still require clarification. The long-term effects of CO 2 insufflation during laparoscopic surgery are prone to hypothermia, which is further aggravated by anaesthetic drugs and muscle relaxants, which impair the hypothalamic thermoregulation and induce shivering. This prolonged operation time in this cohort was probably a contributor to prolonged hypothermia, amplified hemodynamic reactions, and shivering in the patients undergoing passive rewarming. These changes in haemodynamics could be due to the adrenergic stimulation caused by the release of norepinephrine caused by cold which leads to peripheral vasoconstriction and systemic hypertension [13,14]. Modest though statistically significant rise in serum potassium concentrations was also observed in patients undergoing passive rewarming and this could be explained by the increased neuromuscular activity during shivering bouts. However, active core rewarming reportedly preserved closer-to-physiological temperatures [15], and haemodynamic strain, and minimized shivering, thus indicating that strict temperature regulation of the core prevents the effects of adrenergic responses, and maintains the integrity of passive electrical conductance.

Accordingly, changes in BI seem to be dependent on core temperature, and BI may become a promising tool to track the resolution of hypothermia in the case of postoperative patients, especially those at risk because of cardiovascular disorders. Resolution of BI monitoring with prevailing perioperative evaluations might help to administer therapeutic interventions earlier and hence promote clinical outcome and reduce the stay at the anaesthesia care unit.

Conclusion

This study demonstrates the beneficial effects of active core rewarming on postoperative recovery in patients undergoing laparoscopic cholecystectomy, particularly in terms of bioelectrical impedance, shivering reduction, and hemodynamic stability. The correlation between BI and core temperature changes highlights the potential of BI as a noninvasive tool to monitor hypothermia resolution. Active core rewarming offers significant advantages over passive rewarming methods by maintaining core body temperature more effectively and minimizing the associated complications. These findings underscore the importance of targeted temperature management in postoperative care, particularly for patients at risk of cardiovascular complications. Further research is needed to explore the molecular and physiological processes underlying these observations.

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