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Resistive Heating during Off-Pump Coronary Bypass Surgery

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Summary : *Background :* Maintaining normothermia during off-pump coronary artery bypass (OPCAB) surgery is difficult. The purpose of the present study is to determine the effect of the Inditherm Patient Warming System (IPWS) with standard institutional care during OPCAB surgery.
Methods : A control cohort of 10 patients undergoing OPCAB surgery received standard conventional therapy. A study cohort of another 10 patients then underwent similar procedures with the additional use of the IPWS. The nasopharyngeal and rectal temperatures of the two groups were compared during the 4-hour study period.
Results : During the 4-hour study period after induction, the Inditherm patients demonstrated significantly improved core body temperatures compared to the control group : lowest rectal temperature : 35.8 ± 0.4° C vs. 34.8 ± 0.6° C ($p < 0.01$) and lowest nasopharyngeal temperature : 35.5 ± 0.4° C vs. 34.7 ± 0.5° C ($p < 0.01$), respectively. The between-group rectal and nasopharyngeal temperature differences reached statistical significance after 70 minutes, 36.2 ± 0.5° C vs. 35.7 ± 0.2° C ($p < 0.01$) and after 60 minutes 35.8 ± 0.4° C vs. 35.4 ± 0.1° C ($p < 0.01$), respectively. At the end, the rectal core temperatures were 36.1 ± 0.6° C vs. 34.9 ±0.6° C ($p < 0.01$) and the nasopharyngeal temperatures were 35.8 ± 0.6° C vs. 34.8 ± 0.5° C ($p < 0.01$) in the study and the control groups, respectively.
Conclusion : The combination of the IPWS with standard thermal care provides higher core temperatures during OPCAB surgery.

Key words : Heart, coronary artery bypass ; hypothermia ; temperature, regulation.

INTRODUCTION

In contrast with coronary artery bypass surgery on-pump, off-pump procedures challenge anaesthesiologists with the problem of perioperative hypothermia. Under anaesthesia, the thermoregulatory system becomes less sensitive to changes in body temperature (1). Cardiac surgery also provides a favourable environment for the occurrence of body-core hypothermia because of the extensive prepping and draping and exposure of a large body surface area to a cool ambient temperature over a long period of time. Moreover, large amounts of relatively cold fluids are administered. During on-pump surgery, these events can be avoided by the use of the heat exchanger to achieve optimum management of the body temperature throughout the procedure.

Once core hypothermia occurs, a series of pathophysiological events take place (2-5) that anaesthesiologists want to avoid. Increasing the body-core temperature improves cardiac output and minimizes cardiac injury (6-7). Unfortunately, this goal is seldom met due to the inadequacy of currently available medical devices and strategies. In addition to maintaining an elevated ambient temperature and the warming of ventilated gases and infused fluids, such strategies include the use of water blankets and forced air warming (FAW) of non-exposed body parts. All of these techniques have variable degrees of success and have consistent financial consequences. The purpose of this study is to demonstrate that our standard thermal care during OPCAB surgery can be improved by the routine use of a resistive-heating device called the Inditherm Patient Warming System (Inditherm PLC, Rotherham, England).

MATERIAL AND METHODS

Twenty patients undergoing OPCAB surgery between 19 December 2005, and 19 January 2006 entered the study after approval of our institutional review board. Except for temperature management, all of the patients were treated identically (same operating room using standard equipment and standardized surgical and anaesthesia strategies).

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No changes of planned surgical procedures occurred, and none of the patients had to be converted to an on-pump procedure.

Procedure

General anaesthesia was induced with midazolam (0.1 mg kg^{-1}), sufentanyl (1 µg kg^{-1}), cisatracurium (0.4 mg kg^{-1}), and propofol TCI (2 µg ml^{-1}). Maintenance of anaesthesia was done with propofol TCI (2 µg ml^{-1}) in combination with sevoflurane 0.5% -1%. Nasopharyngeal and rectal temperature monitoring was commenced immediately after tracheal intubation. These temperatures were recorded every 5 minutes in the automated anaesthesia record system (Datex Instrumentarium, Helsinki, Finland). The study period was defined as the first 4 hours following the initial temperature measurement. The OPCAB surgery included sternotomy, the use of a stabilisation system, intracoronary stents, and partial occlusion clamps on the ascending aorta to perform a proximal vein graft anastomosis.

Temperature management

All the patients were pre-warmed by 15 minutes of forced-air warming (FAW) with a lower body cover positioned over the lower abdomen and legs and the warming unit set on "high" (Bair Hugger, Augustine Medical, Inc). This FAW blanket was then covered with a standard blanket covering the entire body surface of the patient. This prewarming period started as soon as the patient was on the operating table. For the Inditherm group, the mattress was initially set on 42° C, which was not the case for the control cohort. The Inditherm Patient Warming System is a resistive heating mattress, which is placed under the patient (Inditherm, OTM1). The full-size mattress (1900 × 585 × 40 mm) was used. Following the standard procedure, in order to keep the period of heat deprivation as short as possible, the FAW cover stayed in place after the induction of anaesthesia until the entire surgical team was ready for standard prepping and draping. Ventilation was mechanically controlled to maintain PET CO_2 near 40 mmHg. Respiratory gases were delivered via a semi-closed circle system with a fresh gas flow of 2.5 L min^{-1} (Primus, Drager). Inspiratory gases were humidified by a heat-and-moisture exchanger positioned between the Y-piece of the circle system and the endotracheal tube. All intravenous fluids were warmed up, and the total amount of fluids administered was recorded. The room temperature was set on 21° C and was automatically registered every 5 minutes. Immediately after vein harvesting, a sterile FAW blanket was placed on the legs of all patients. The time episode of effective FAW was rigorously recorded.

Statistical methods

Differences among the groups were compared using one-way analysis of variance and the Scheffé F test, if appropriate. Single measurements were analysed with Student's *t* test. The results are presented as means ± 1.96 SEM. A *p*-value less than 0.05 was considered statistically significant.

Table 1

Demographic and morphometric characteristics. None of the values differed significantly between the two groups

	Study group		Control group		P-value
	mean	std	mean	std	
Age (y)	71.1	7.03	69.9	7.64	0.72
Weight (kg)	78.8	9.14	77.5	14	0.81
Height (cm)	171.8	4.87	167.7	6.78	0.14
BSA (M2)	1.9	0.09	1.9	0.16	0.28
EF (%)	65.7	11.2	66	15.5	0.96
M/F	7/3		7/3		
Fluids (ml)	2850	241.5	2885	420.3	0.82
Skin-skin (min)	238.3	28.5	232.3	38.6	0.70
FAW time (min)	123.6	40	131.5	43.2	0.68
Blood loss (ml)	959.4	245.8	955.7	616.3	0.99
Environment (° C)	20.18	0.39	20.07	0.25	0.50

BSA = body surface area, EF = ejection fraction, M = male, F = female, FAW time = forced air warming time.

Table 2

	Study group		Control group		P-value
	mean	std	mean	std	
Rectal temperature Minimum	35.77	0.4191	34.84	0.5542	0.000501
Nasopharyngeal temperature Minimum	35.45	0.4170	34.70	0.5033	0.001921
Rectal temperature End	36.05	0.6115	34.88	0.5613	0.000304
Nasopharyngeal temperature End	35.75	0.6187	34.78	0.5391	0.001506

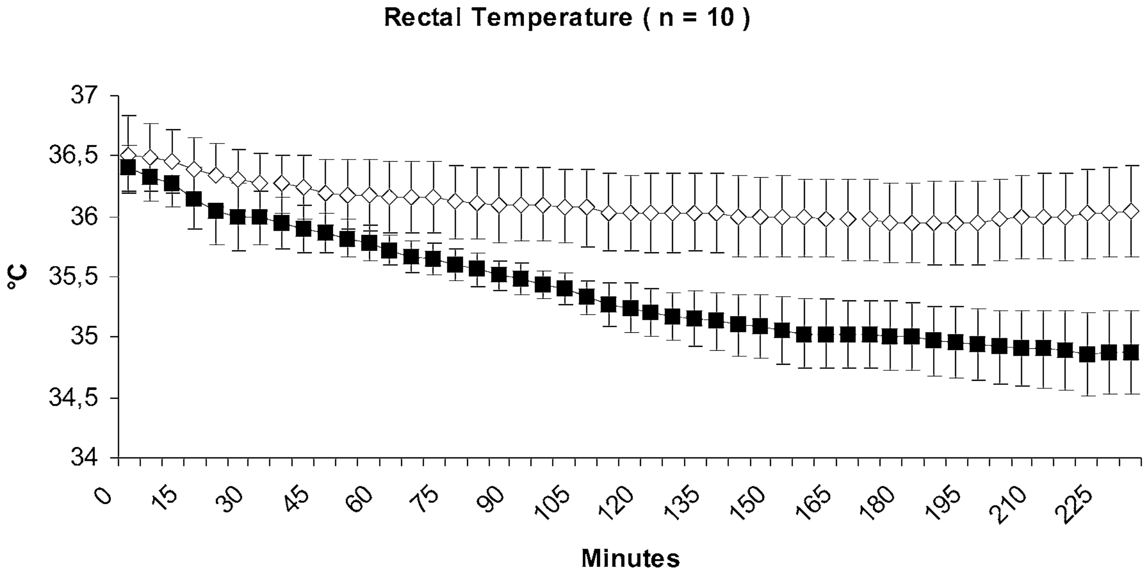

Fig. 1. — Rectal temperatures as a function of time in patients assigned to the study group (open symbols) or control group (closed symbols). N = 10 for both groups. Temperature changes in the study group differed significantly from those in the control group after 70 elapsed minutes. The results are presented as means ± 1.96 SEM.

RESULTS

The demographic and morphometric characteristics were similar. The surgical factors, ambient temperature, fluid balance, and time period of effective FAW blanket use were also comparable (Table 1).

During the 4-hour study period after induction, the IPWS patients demonstrated significantly better core-body temperatures than did the control group (Table 2). The between-group differences in rectal and nasopharyngeal temperatures reached statistical significance after 70 minutes (Fig. 1) and after 60 minutes (Fig. 2), respectively. The decrease in core temperature was less pronounced in the IPWS group throughout the study period. After 190 minutes, the core temperatures increased slightly in the IPWS group while they further decreased in the control group. By the end, the core temperatures were significantly higher in the study group (Table 2).

DISCUSSION

Redistribution is a rapid core-to-peripheral transfer of heat that typically occurs during the first hour of anaesthesia (8). Avoiding this phenomenon is difficult, but it can be done by combining pharmacological vasodilation and prewarming prior to induction (9). This could account for the small temperature drop of less than 1° C in both of the groups during the first hour of anaesthesia.

Another specific problem in OPCAB surgery is the limited time-window during which sterile FAW blankets can be placed on the legs of the patients. Vein harvesting is time-consuming, which prohibits the use of FAW blankets. This can be

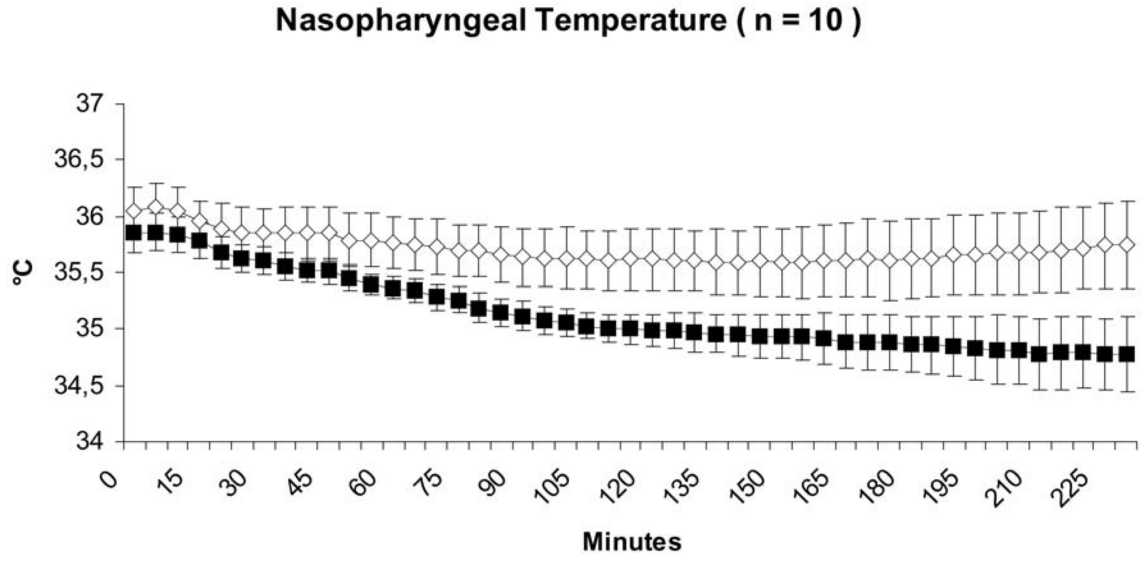

Fig. 2. — Nasopharyngeal temperatures as a function of time in patients assigned to the study group (open symbols) or control group (closed symbols). N = 10 for both groups. Temperature changes in the study group differed significantly from those in the control group after 60 elapsed minutes. The results are presented as means ± 1.96 SEM.

compensated for with resistive heating mattress placed under the patient (see our study group). Although the periods of time FAW blankets were in use were comparable for both groups, core temperatures dropped significantly only in the control group.

A recent study by Stanley and co-workers (10) has shown that the Artic Sun System can produce spectacular results of significantly less of hypothermia on average. However, this system is very expensive and is not reusable. It also requires continuous attention since the hot circulating water in the system might be associated with possible "pressure-heat necrosis". However, no such cases have as yet been reported with the Artic Sun. In addition, a recent study by Woo and colleagues (11) has shown an improved outcome of OPCAB surgery when active thermoregulation with the Arctic Sun was applied. Our results show that combining resistive heating with routine thermal care including prewarming, warming of all fluids, and using heat-and-moisture exchangers, low-flow anaesthesia, and FAW blankets on the legs after harvesting the veins resulted in better core-temperature maintenance during OPCAB surgery. Maintaining the ambient temperature of the operating theatre could be another valuable adjuvant, but we did not use it in our study.

Another advantage of a resistive heating tool is the large patient contact area provided by the flexible polymer technology. Moreover, no disposables are needed. Negishi and co-workers (12) have recently shown that resistive heating and forced air warming are similarly effective in open abdominal surgery lasting for approximately 4 hours. The efficacy of active clinical warming systems is proportional to the available skin surface in contact with the device. This might also account our favourable results.

The primary limitation of this study is the non-randomized design, which could be a source of unmeasured bias. However, this particular design with two consecutive cohorts has also been applied by others (10). To minimize this drawback, we arranged maximal standardization of the anaesthetic and surgical management (medication, equipment, team, and operating room). In summary, the adverse effects of mild hypothermia are well documented. Combining routine thermal care as administered in our Institution with resistive heating almost covering the patient's entire back surface elevated the core temperatures significantly. This system not only allows one to prolong the time window for heating the patient during OPCAB surgery but also enlarges the available body surface for heating. More controlled studies are needed to confirm those findings.

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