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Ain-Shams Journal of Anesthesiology (2023) 15:9
https://doi.org/10.1186/s42077-023-00308-8

Ain-Shams Journal of Anesthesiology

ORIGINAL ARTICLE Open Access

A study on the effect of preoperative warming on post-induction core temperature and incidence of postoperative shivering in patients under general anesthesia

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Abstract

Background Inadvertent perioperative hypothermia (IPH) defined as core temperature below 36.0 °C is a common complication of general anesthesia with prevalence up to 70%. Warming of peripheral tissues prior to induction of anesthesia reduces the central to peripheral temperature gradient, thereby minimizing central heat loss due to heat redistribution, after induction of anesthesia. This study aimed to evaluate the effect of prewarming on post-induction core temperature and incidence of perioperative inadvertent hypothermia leading to postanesthetic shivering (PAS) in patients undergoing general anesthesia.

This is a single-arm study performed after authorization from the scientific review committee (IRB no.:10/2015/05) in a cohort of patients between the ages of 18 and 65 years in ASA I and II physical status, undergoing GA for elective surgeries lasting less than 3 h. Rates of IPH and PAS in 60 patients who were warmed before anesthesia over a 30-min period with a forced-air warmer set at 38.0 °C were compared with existing data from an equal number of cohorts who received only intraoperative warming, during similar surgical procedures according to routine GA.

Comparisons between the two groups were made using the Student's *t*-test and chi-square test. A paired *t*-test or Wilcoxon's signed rank test was applied for pairwise comparisons. The results were considered statistically significant when the *P*-value was < 0.05.

Results The mean decrease in core temperature in the unwarmed group was 0.7 °C (+/- 0.23) compared with a 0.2 °C decrease (+/- 0.06) in the prewarmed group of patients. A total of 31.70% of patients in the unwarmed group developed IPH compared with one patient (1.7%) in the prewarmed group shortly after onset. Twenty-six patients (43.30%) in the unwarmed group had hypothermia at the end of surgery, compared with one patient (1.7%) in the prewarmed group. Shivering was observed in 46% of patients in the unwarmed group, while no shivering was observed in the prewarmed group.

Conclusions Preoperative warming is an effective intervention to reduce the frequency of core temperature drops after induction of anesthesia, thereby preventing inadvertent perioperative hypothermia and the incidence of post-operative shivering.

Keywords General anesthesia, Prewarming, Perioperative hypothermia, Shivering, Thermoregulation

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Background

In humans, core temperature is maintained within a narrow range of 36.5 to 37.5 °C, even under adverse environmental conditions, through a combination of behavioral and autonomic responses. General anesthesia suppresses all behavioral responses and has the potential to disrupt autonomic responses (Sessler 1997). Consequently, inadvertent perioperative hypothermia (IPH) is common. Inadvertent perioperative hypothermia (IPH) defined as core temperature below 36.0 °C is a common complication of general anesthesia (GA) with prevalence up to 70% (Harper et al. 2008).

Perioperative thermal discomfort is often cited by patients as the worst aspect of their postoperative experience. Hypothermia develops because the operating room environment is typically cold; however, the alteration in thermoregulatory responses induced by anesthesia is the most important factor. Redistribution of core body heat to the peripheries contributes more to central hypothermia than actual heat loss in most patients (Sessler 2016).

Primary outcome studies have shown that mild hypothermia prolongs postanesthesia recovery time and hospital stay (Leslie and Sessler 2003; Lenhardt et al. 1997; Buggy and Crossley 2000; Kurz et al. 1996), triples the rate of surgical site infections (Kurz et al. 1996), triples the rate of adverse cardiac events (Valeri et al. 1992), and increases surgical blood loss and the need for blood transfusions (Rajagopalan et al. 2008).

IPH develops due to decreased metabolic heat production, heat loss in the cold operating room environment, intravenous fluids and irrigating fluids, derangement of thermoregulation, and redistribution of heat from the core to the peripheries due to anesthesia. Heat redistribution occurs after induction of anesthesia, which explains the drop in core temperature to 1.6 °C (Sessler and Todd 2000). During general anesthesia, the metabolic rate is reduced by 15–40%. Although intraoperative forced-air rewarming can effectively restore core temperatures within 2 h, the physiology of heat redistribution makes them unsuitable for short-term procedures (Matsukawa et al. 1995). However, warming peripheral tissues prior to induction of anesthesia reduce the central to peripheral temperature gradient, thereby minimizing central heat loss due to heat redistribution (Hynson and Sessler 1992).

A reduction in drop in core temperature has been demonstrated in several prewarming studies (Kurz et al. 1993). But the optimal time of effective preheating is unknown. Most studies on prewarming practised longer duration of active prewarming, ranging from 60 to 120 min (Chan and Venus 2016; Sessler et al. 1995; Ziolkowski et al. 2017). Sessler and colleagues estimate that 30 to 60 min is sufficient, using the FAW device (Sessler et al. 1995). The efficacy of a shorter prewarming time of 30 min before induction was therefore examined in our study.

This study aimed to evaluate the outcome of reducing the temperature gradient from the periphery to the core by pre-induction heating using forced-air heaters (FAW), on post-induction core temperatures, and the occurrence of inadvertent hypothermia resulting in postoperative shivering.

Methods

After getting approval of the hospital institutional review board (IRB no.: 10/2015/05), all patients in the study were briefed on the procedure, and written informed consent was obtained for the same. Patients under general anesthesia for elective surgeries lasting less than 3 h, aged 18 to 65 years, were included in the study. The study was conducted over a period of 6 months from January 2017 to June 2017. Patients with American Society of Anesthesiologists (ASA PS) grades 3 and 4 and/or who have received drugs that interfere with intraoperative thermoregulation, namely clonidine, tramadol, pethidine, dexmedetomidine, and those who underwent surgery lasting more than 3 h were excluded from the study (Fig. 1). On admission of patients to the preoperative holding zone, pre-induction warming was initiated with forced-air warmer (Covidien™ Warm Touch Convective warming unit) set at 38 °C for 30 min. Management of induction of anesthesia, maintenance, and reversal of anesthesia were done at the discretion of the attending anesthesiologist. Forced-air warming was maintained throughout the surgical period at 38 °C. The FAW blanket was removed after extubation immediately before transferring the patient to the PACU.

The baseline core temperature and the core temperature at induction were recorded. Core temperatures were also recorded over a 20-min period using a nasopharyngeal thermistor (Philips Medizin Systeme). The thermistor was inserted nasally at a length equal to the distance between the alae of the nose and the tragus. These patients were also observed in the recovery room for 30 min (10 min apart) for the development of postoperative shivering as graded on the PAS scale described by Crossley and Mahajan (Table 1). The data obtained above were compared with data obtained from 60 patients who were observed and evaluated for similar complications after routine GA.

Based on the study by Andrezejwoski et al. (2008), corresponding to the fall in core temperature at 40 min, with an 80% power and 95% confidence interval, the minimum sample required for the present study was 54 in each group. By considering additional dropouts of 10%, the sample size was fixed at 120 (60 in each group).

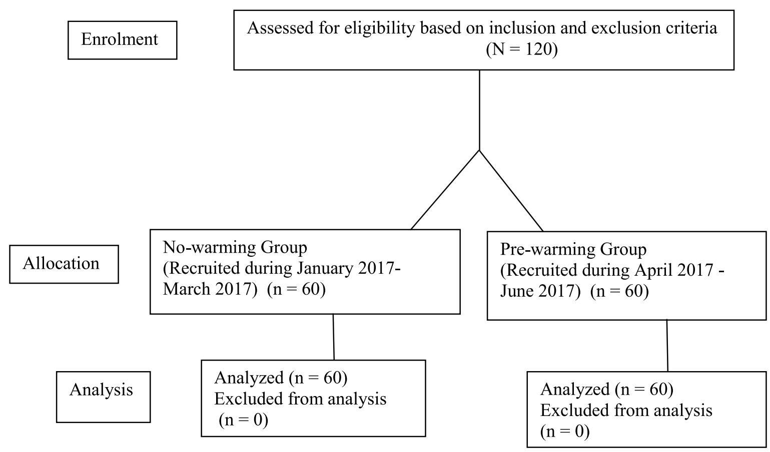

Fig. 1 Flowchart for patient recruitment

Table 1 PAS scale by Crossley and Mahajan

Grade	Description
0	No shivering
1	No visible muscle activity, but one or more of piloerection, peripheral vasoconstriction, or peripheral cyanosis (other causes excluded)
2	Muscular activity in only one muscle group
3	Moderate muscular activity in more than one muscle group, but not generalized shaking
4	Violent muscular activity that involves the entire body

Data was entered in Microsoft Excel, and Statistical Package for the Social Sciences (SPSS; Windows ver. 28.0, SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Quantitative data was described as mean and standard deviation and qualitative data by frequency distribution. Normality was assessed using Kolmogorov–Smirnov one-sample test. Comparison of qualitative variables was assessed and analyzed by chi-square test. Comparison of quantitative variables was done by Students' *t*-test. Paired *t*-test was done for pairwise comparison for normally distributed variables and Wilcoxon signed rank test for non-normal variables. Results were considered statistically significant when *P*-value of < 0.05 was obtained.

Results

The two groups were found to be comparable in terms of mean baseline temperature measured immediately after patient admission in the preoperative patient waiting area with 36.91 °C in the unwarmed group and 36.95 °C in the prewarmed group. IPH, defined as core temperature below 36.0 °C, was significantly higher in the unwarmed group than in the actively warmed group of patients. A total of 31.70% in the unwarmed group developed IPH compared with one patient (1.7%) in the prewarmed group shortly after onset (Table 2, Fig. 2). While comparing core temperatures at the end of surgery during reversal, 43.30% (26 patients) developed hypothermia in the unwarmed group, requiring active warming in the recovery room compared with one patient alone (1.7%) in the prewarmed group (Table 3).

There was a statistically significant decrease in temperature from baseline up to 100 min after induction in the unwarmed group, while in the prewarmed group the temperature drop was remedied within 40 min after induction (Table 4, Table 5).

In the unwarmed group, 46% of the patients had shivering with visible muscle activity, of which 22% required drug treatment. In the preheated group, no patient exhibited muscle activity, although grade 1 shivering was observed in 3 patients (5.3%) (Fig. 3).

Discussion

One of the major causes of discomfort in patients recovering from general anesthesia is postanesthesia shivering (Crossley and Mahajan 1994). Mild perioperative hypothermia does not necessarily precede the onset of postanesthesia shivering, but it does tend to

Table 2 Demographic data of two groups

			Age				Total	*p*-value
			Up to 40	41–50	51–60	> 60		
Group	Not warmed	Count	9	20	30	1	60	0.672
		% within group	45.0%	48.8%	54.5%	25.0%	50.0%	
	Prewarmed	Count	11	21	25	3	60	
		% within group	55.0%	51.2%	45.5%	75.0%	50.0%	
Total		Count	20	41	55	4	120	
		% within group	100%	100%	100%	100%	100.0%	
			Sex		Total		*P*-value	
			Male	Female				
Group	Not warmed	Count	6	54	60		0.408	
		% within group	40.0%	51.4%	50.0%			
	Prewarmed	Count	9	51	60			
		% within group	60.0%	48.6%	50.0%			
Total		Count	15	105	120			
		% within group	100%	100%	100.0%			
			ASA		Total		*P*-value	
			1	2				
Group	Not warmed	Count	23	37	60		0.046	
		% within group	63.9%	44.1%	50.0%			
	Prewarmed	Count	13	47	60			
		% within group	36.17%	55.9%	50.0%			
Total		Count	36	84	120			
		% within group	100%	100.0%	100.0%			
Variables		Group	*N*	Mean	Std. deviation		*P*-value	
BMI		Not warmed	60	24.65	3.49		0.811	
		Pre warmed	60	24.81	3.60			

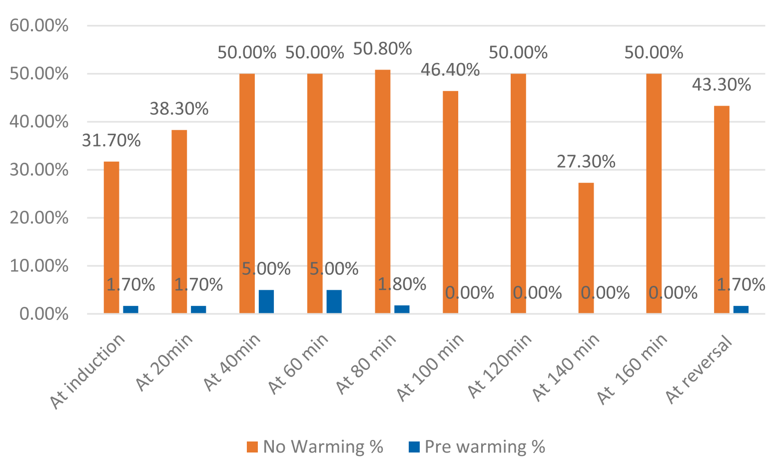

Fig. 2 Comparison of the sample based on the frequency of occurrence of inadvertent perioperative hypothermia (core temperature < 36 °C)

Table 3 Comparison of the sample based on the frequency of occurrence of inadvertent perioperative hypothermia (core temperature < 36 °C)

	Category				
	No warming		Prewarming		*p*-value
	N	%	*N*	%	
At induction	19	31.70%	1	1.70%	0.001
At 20 min	23	38.30%	1	1.70%	0.001
At 40 min	30	50.00%	3	5.00%	0.001
At 60 min	30	50.00%	3	5.00%	0.001
At 80 min	30	50.80%	1	1.80%	0.001
At 100 min	26	46.40%	0	0.00%	0.001
At 120 min	15	50.00%	0	0.00%	0.001
At 140 min	3	27.30%	0	0.00%	0.228
At 160 min	2	50.00%	0	0.00%	0.167
At reversal	26	43.30%	1	1.70%	0.001

Table 4 Mean change in intraoperative core temperature in 20-min interval post induction in comparison with baseline temperature in not-warmed groups

	Group	*N*	Mean	Std. deviation	*p*-value
Pair 1	Baseline core temp	60	36.91	0.22	0.0001
	Core temperature at induction	60	36.17	0.45	
Pair 2	Baseline core temp	60	36.91	0.22	0.0001
	At 20	60	36.08	0.42	
Pair 3	Baseline core temp	60	36.91	0.22	0.0001
	At 40	60	36.03	0.41	
Pair 4	Baseline core temp	60	36.91	0.22	0.0001
	At 60	60	36.03	0.42	
Pair 5	Baseline core temp	59	36.90	0.22	0.0001
	At 80	59	36.03	0.41	
Pair 6	Baseline core temp	56	36.91	0.22	0.0001
	At 100	56	36.03	0.40	
Pair 7	Baseline core temp	30	36.92	0.22	0.4720
	At 120	30	34.96	5.94	
Pair 8	Baseline core temp	11	37.05	0.18	0.0910
	At 140	11	36.21	0.45	
Pair 9	Baseline core temp	4	37.00	0.23	0.0100
	At 160	4	35.90	0.58	

N Number of samples at particular time intervals

Table 5 Mean change in intraoperative core temperature in 20-min interval post induction in comparison with baseline temperature-prewarmed group

	Group	*N*	Mean	Std. deviation	*p*-value
Pair 1	Baseline core temp	60	36.952	0.195	0.0001
	Core temperature at induction	60	36.753	0.259	
Pair 2	Baseline core temp	60	36.952	0.195	0.0010
	At 20	60	36.697	0.254	
Pair 3	Baseline core temp	60	36.952	0.195	0.0040
	At 40	60	36.658	0.291	
Pair 4	Baseline core temp	60	36.952	0.195	0.2290
	At 60	60	36.44	0.641	
Pair 5	Baseline core temp	57	36.956	0.198	0.0080
	At 80	57	36.642	0.233	
Pair 6	Baseline core temp	41	36.973	0.190	0.8820
	At 100	41	36.635	0.203	
Pair 7	Baseline core temp	20	37.020	0.191	0.0460
	At 120	20	36.665	0.235	
Pair 8	Baseline core temp	8	36.988	0.230	0.2450
	At 140	8	36.613	0.323	
Pair 9	Baseline core temp	5	37.060	0.261	0.6130
	At 160	5	36.780	0.205	

N Number of samples at particular time intervals

predispose to it, and the more severe the hypothermia, the higher the incidence of postanesthesia shivering. Many studies show that during the first hour after anesthesia, a significant drop in body temperature leads to IPH in 48 to 70% of surgical patients receiving general anesthesia (Chan and Venus 2016). After induction of anesthesia, thermal redistribution occurs and causes a drop in core temperature up to 1.6 °C (Matsukawa et al. 1995). Preheating reduces the center to periphery temperature gradient, thereby minimizing central heat loss due to heat redistribution. The optimal time of effective preheating is unknown. Sessler and colleagues estimate that 30 to 60 min is sufficient, using the FAW device (Sessler et al. 1995). Effective prewarming of 30 min before induction was conducted in our study. Most studies on prewarming practised longer duration of active prewarming, ranging from 60 to 120 min (Chan and Venus 2016; Sessler et al. 1995; Ziolkowski et al. 2017). The efficacy of a shorter warm-up time was examined in this study. The mean baseline core temperature at 20-min intervals was also significantly higher at 20 min, 40 min, and 80 min after induction among patients who were actively prewarmed during the pre-anesthesia period, substantiating the role of prewarming in preventing redistribution hypothermia when compared to intraoperative warming. The temperature drop recorded at subsequent time intervals was smaller than in the unwarmed subjects (0.6 difference). However, this result lacked statistical significance and was caused by thermal recovery and restoration of core body temperature due to prolonged surgery, accompanied by intraoperative warming. Observations support

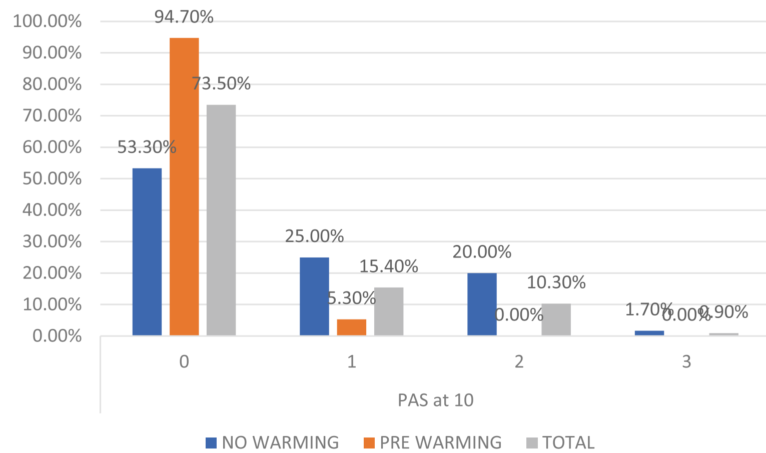

Fig. 3 Comparison of sample based on postanesthetic shivering at 10 min in PACU

the results of studies performed by (Just et al. 1993; Andrzejowski et al. 2008). In the aforementioned studies, significantly longer prewarming (1 h) was achieved. The prolonged warming time employed may be due to the lower ambient temperature of the study environment. These studies took place in temperate climates, where the average ambient temperature is much cooler than in the tropics.

Limitations of the study

Our study was limited by the lack of standardization of anesthesia care in the two groups.

The choice of drugs and their dosage for induction, maintenance, and reversal of cases was left to the discretion of the respective attending anesthesiologists, which could have influenced pain scores and could be considered as a limitation of the study. Another limitation of the study was the failure to account for comorbidities that might interfere with thermoregulation. More research is recommended to determine the optimal prewarming time. Other possible consequences of hypothermia, such as increased blood loss, transfusion requirements, length of hospital stay, incidence of surgical site infections, or cardiovascular adverse events, were not observed or taken into account.

Further randomized studies are needed to ratify the beneficial effects of prewarming.

Conclusions

It is vital that surgical patients receiving general anesthesia are maintained normothermic since inadvertent perioperative hypothermia and postoperative shivering can lead to many unfavorable complications. Preoperative warming is significantly diminishing the drop in perioperative core temperature, thereby reducing the chances of IPH and PAS.

Abbreviations

IPH	Inadvertent perioperative hypothermia
PAS	Postanesthetic shivering
GA	General anesthesia
IRB	Institutional review board
ASA	American Society of Anesthesiologists
FAW	Forced-air warming

Acknowledgements

The authors would like to thank all the Operation Theatre Technicians of the Regional Cancer Centre for their technical help.

Authors' contributions

LA, MB, and SR did the concepts, design, definition of intellectual content, literature search, clinical study, experimental study, data acquisition, data analysis, statistical analysis, manuscript preparation, manuscript editing, and manuscript review. JKKM did the concepts, design, definition of intellectual content, data analysis, statistical analysis, manuscript editing, and manuscript review. LA, MB, and SR are the guarantors. The authors read and approved the final manuscript.

Funding

Nil.

Availability of data and materials

All data generated or analyzed during this study are included in this published article (and its supplementary information files).

Declarations

Ethics approval and consent to participate

The study was approved by the Institutional Review Board (IRB), Regional Cancer Centre, Thiruvananthapuram, IRB no. 10/2015/05 .The study was commenced after obtaining written informed consent from the patients.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Received: 15 June 2022 Accepted: 4 March 2023
Published online: 15 March 2023

References

Andrzejowski J, Hoyle J, Eapen G, Turnbull D (2008) Effect of prewarming on post-induction core temperature and the incidence of inadvertent perioperative hypothermia in patients undergoing general anesthesia. Br J Anaesth 101:627–631
Buggy DJ, Crossley AWA (2000) Thermoregulation, mild perioperative hypothermia and post-anaesthetic shivering. Br J Anaesth 84:615–628
Chan TN, Venus J (2016) The effect of 30 to 60 minutes of forced-air prewarming on maintaining intraoperative core temperatures during the first hour post-anesthesia induction in adult patients undergoing general anesthesia: a systematic review protocol. JBI Evid Synth 14:41–48
Crossley AWA, Mahajan RP (1994) The intensity of postoperative shivering is unrelated to axillary temperature. Anesthesia 49:205–207
Harper CM, Andrzejowski JC, Alexander R (2008) NICE and warm. Br J Anaesth 101:293–295
Hynson JM, Sessler DI (1992) Intraoperative warming therapies: a comparison of three devices. J Clin Anesth 4:194–199
Just B, Trévien V, Delva E, Lienhart A (1993) Prevention of intraoperative hypothermia by preoperative skin-surface warming. Anesthesiology 79:214–218
Kurz A, Kurz M, Poeschl G, Faryniak B, Redl G, Hackl W (1993) Forced-air warming maintains intraoperative normothermia better than circulating-water mattresses. Anesth Analg 77:89–95
Kurz A, Sessler DI, Lenhardt R (1996) Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. N Engl J Med 334:1209–1216
Lenhardt R, Marker E, Goll V, Tschernich H, Kurz A, Sessler DI, Lackner F (1997) Mild intraoperative hypothermia prolongs postanesthetic recovery. Anaesthesiology 87:1318–1323
Leslie K, Sessler DI (2003) Perioperative hypothermia in the high-risk surgical patient. Best Pract Res Clin Anaesthesiol 17:485–498
Matsukawa T, Sessler DI, Sessler AM, Schroeder M, Ozaki M, Kurz A, Cheng C (1995) Heat flow and distribution during induction of general anesthesia. Anaesthesiology 82:662–673
Rajagopalan S, Mascha E, Na J, Sessler DI (2008) The effects of mild perioperative hypothermia on blood loss and transfusion requirement. Anaesthesiology 108:71–77
Sessler DI (1997) Perioperative thermoregulation and heat balance. Ann NY Acad Sci 813:757–777
Sessler DI (2016) Perioperative thermoregulation and heat balance. Lancet 387:2655–2664
Sessler DI, Todd MM (2000) Perioperative Heat Balance. Anaesthesiology 92:578–578
Sessler DI, Schroeder M, Merrifield B, Matsukawa T, Cheng C (1995) Optimal duration and temperature of prewarming. Anaesthesiology 82:674–681
Valeri CR, Khabbaz K, Khuri SF, Marquardt C, Ragno G, Feingold H, Axford T (1992) Effect of skin temperature on platelet function in patients undergoing extracorporeal bypass. J Thorac Cardiovasc Surg J 104:108–116
Ziolkowski N, Rogers AD, Xiong W, Hong B, Patel S, Trull B, Jeschke MG (2017) The impact of operative time and hypothermia in acute burn surgery. Burns 43:1673–1681

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