



Review

Warming strategies for preventing hypothermia and shivering during cesarean section: A systematic review with network meta-analysis of randomized clinical trials



Wei-An Chen^{a,b}, Chih-Chung Liu^{c,d}, Zandi Mnisi^e, Chien-Yu Chen^{c,d,*}, Yi-No Kang^{f,g,**}

^a School of Medicine, College of Medicine, Taipei Medical University, Taipei, Republic of China (Taiwan)

^b Department of Medical Education, Taichung Veterans General Hospital, Taichung, Republic of China (Taiwan)

^c Department of Anesthesiology, Taipei Medical University Hospital, Taipei, Republic of China (Taiwan)

^d Department of Anesthesiology, School of Medicine, College of Medicine, Taipei Medical University, Taipei, Republic of China (Taiwan)

^e Health Research Unit, Ministry of Health, Swaziland

^f Evidence-Based Medicine Center, Wan Fang Hospital, Taipei Medical University, Taipei, Republic of China (Taiwan)

^g Institute of Health Policy and Management, College of Public Health, National Taiwan University, Taipei, Republic of China (Taiwan)

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ABSTRACT

Background: Hypothermia and shivering are undesirable morbidities that occur commonly during cesarean section. Although some active warming strategies, such as the use of forced-air, mattresses, and fluid warming, can attenuate such adverse events, no studies have yet performed multiple contrast assessments of these strategies. We, therefore, conducted a network meta-analysis to simultaneously assess the effects of various warming strategies for cesarean section and assist clinicians in making informed decisions.

Methods: We searched databases for randomized clinical trials that investigated the effects of warming strategies during cesarean section, with primary outcomes targeted on shivering and hypothermia. Trial quality was assessed using the Cochrane Risk of Bias Tool. Quantitative synthesis was performed using consistency model and surface under the cumulative ranking curve (SUCRA). Results were presented as risk ratio (RR) with 95% confidence interval (CI).

Results: We identified 18 trials wherein 1953 women underwent a cesarean section. These trials performed 11 active warming strategies for 1620 women, and the other 333 women were in the non-active warming group. According to SUCRA, the combination of forced-air, fluids, and warmed gown warming could be a better strategy for reducing shivering rates compared with the other strategies (SUCRA = 88.5), albeit with an insignificant result. Conduction mattress warming (SUCRA = 89.4) and combination of conduction mattress and fluids warming (SUCRA = 80.2) were better strategies than others in reducing hypothermia. No evidence showed inconsistency or small study effects in our results.

Conclusions: In clinical practice, forced-air-based warming strategies can be considered to prevent shivering, and conduction mattress-based warming strategies can be used to reduce hypothermia in women undergoing cesarean section.

1. Introduction

Anesthesia may impair thermoregulatory control, resulting in morbidities such as shivering and hypothermia [1]. Such stressors not only increase the risk of blood loss and wound infection but also lead to further complications during the postoperative period [2]. Notably, 30%–60% of women who receive regional anesthesia during cesarean

delivery suffer from hypothermia [1].

According to National Institute for Health and Care Excellence (NICE) guidelines, inadvertent perioperative hypothermia is defined as a core temperature less than 36.0 °C, and the NICE guideline CG65 provides a good overview on warming for surgery. Relevant guidance provides a framework that includes forced-air warming and conduction mattress warming to improve perioperative thermal management [3,4].

* Corresponding author. Department of Anesthesiology, Taipei Medical University Hospital, Taipei, Republic of China (Taiwan).

** Corresponding author. Center for Evidence-Based Medicine, Department of Education, Taipei Medical University Hospital, Department of Anesthesiology, Taipei Medical University Hospital, No. 252, Wu-Hsing Street, Taipei, 11031, Republic of China (Taiwan).

E-mail address: academicnono@gmail.com (Y.-N. Kang).

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Abbreviations

AB	Forced-air and warmed blanket warming
AF	Forced-air and fluids warming
AFB	Forced-air, fluids, and warmed blanket warming
AFG	Forced-air, fluids warming, and warmed gown warming
CAW	Combined active warming strategy
CI	Confidence interval

FB	Fluids and warmed blanket warming
FG	Fluids and warmed gown warming
FM	Fluids and conduction mattress warming
NICE	National Institute for Health and Care Excellence
RCT	Randomized clinical trial
RR	Risk ratio
SAW	Single active warming strategy
SUCRA	Surface under the cumulative ranking curve

However, the NICE guideline CG65 indicated that current evidence is insufficient to prove whether combined warming strategy is more clinically effective than a single active warming strategy [4]. It only recommends active heating for operations lasting over 30 min, but unfortunately, the updated guideline (NICE CG65, 2016 version) still does not cover pregnant women and patients treated with therapeutic hypothermia [3,4]. As we know, cesarean section sometimes needs more than 30 min, especially elective cesarean section.

Complications associated with perioperative hypothermia in the non-obstetric population include shivering, surgical site infection, myocardial ischemia, altered drug metabolism, coagulopathy, prolonged hospitalization, reduced skin integrity, and reduced patient satisfaction. However, in the obstetric population, the neonatal temperature has also been linked to maternal temperature at the time of birth [5].

Several studies have widely discussed various strategies to prevent shivering and hypothermia in women undergoing cesarean delivery. These studies investigated the effect of different types of anesthesia [6]; evaluated the difference between drugs for induction [7]; and compared perioperative active warming interventions, such as warmed IV fluids, forced-air warming, conduction mattress warming, blanket warming, and gown warming [5]. Perioperative active warming interventions are easily controlled and are considered a crucial strategy to prevent shivering and hypothermia. However, the efficacies of the interventions remain ambiguous according to the conclusion of a systematic review conducted by Campbell and colleagues published in the Cochrane Database Systematic Review [8]. Although other recent meta-analyses regarding the effect of active warming during cesarean delivery gave a simplified account of complex interventions and concluded that forced-air warming or fluid warming should be used for elective cesarean delivery, it did not provide a comparison of all active warming strategies. Consequently, its results were statistically heterogeneous and might be affected by a small study effect (Egger's test $P = .001$) [9].

Therefore, our study aimed to identify the easiest interventions, such as forced-air warming, intravenous fluid warming, conduction mattress warming, warmed gown warming, warmed blanket warming, and combined warming strategies that have the highest efficacy to prevent shivering and hypothermia in women undergoing cesarean delivery.

2. Materials and methods

This research was conducted by a team comprising an anesthesiologist and an experienced evidence-based medicine researcher. The anesthesiologist had some experience in systematic reviews [10,11], and the experienced researcher had some experience in network meta-analyses [12,13]. The experienced researcher had also participated in some surgical and human reproduction studies [14–16]. We conducted a prospective systematic review with network meta-analysis and reported the methods and outcomes accordant with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [17] and the AMSTAR (Assessing the methodological quality of systematic reviews) Guidelines. The protocol of this study has been registered on PROSPERO (CRD42018114514).

2.1. Eligible criteria and study selection

Randomized controlled trials that investigated the association between warming strategies and hypothermia and shivering events were considered the eligible studies. The EndNote X7 software for windows was used for reference management. All reference exported from the databases were imported into the EndNote for the screening process. After removing duplicates, the title and abstract of remaining references were screened for eligibility. If multiple articles were based on the same trial, we included only the one with the complete data set. Full texts of eligible studies were retrieved. If the references appeared irrelevant or ambiguous to the subject of this systematic review, full-text articles were also retrieved. Full-text articles were independently reviewed by two authors (Y.N.K. and W.A.C.). When the full text was unavailable, the authors reviewed abstracts and further information that was provided by databases. A disagreement between the authors was resolved by a third author (C.Y.C.).

2.2. Information sources and search strategy

A computerized literature search was designed and conducted in MEDLINE through PubMed (1946 to April 2019). Then, the search strategy was adapted to EMBASE (1947 to April 2019) and Cochrane Library Database of Systematic Reviews (1996 to April 2019) to identify randomized clinical trial (RCT) that investigated warming strategies for cesarean section. The search keywords used were natural language; medical subject heading (MeSH term and Emtree); and word variations of the terms warm, heat, hot. The initial search strategy and Boolean algebra was established for use in PubMed and subsequently adapted for searching in EMBASE and the Cochrane Library Database of Systematic Reviews. Two Boolean operators, “OR” and “AND”, were used in keywords combinations. The search strategy and results are presented in Supplementary 1. This systematic review also screened reference lists of included studies and relevant review articles for records that might be missing. No language and date limitations were applied to all searches.

2.3. Assessment of risk of bias

The risk of bias in the included studies was assessed using the Cochrane Risk of Bias Tool, which comprises the following seven items: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other sources of bias [18]. The quality of the included studies was individually evaluated using the appraisal tools by two reviewers. A third reviewer resolved any disagreement.

2.4. Measurement of outcome data

All the authors reviewed the included RCTs, and two of us (W.A.C. and Y.N.K.) individually extracted relevant information and outcome data. The relevant information included location, sample size, age, gestational age, baseline temperature, warming time, anesthesia type, fluid volume, duration of surgery, and measurement of temperature.

The outcomes of this systematic review were shivering and hypothermia. These two outcomes were measured by the number of events.

2.5. Statistical analysis

The quantitative synthesis was contrast-based network meta-analyses in a random-effects model. We reported results of both shivering and hypothermia in risk ratio (RR) with 95% confidence interval (CI). The surface under the cumulative ranking curve (SUCRA) was conducted as supporting evidence for clinical practice because the SUCRA portrays the effects through a hierarchy of intervention ranking among warming strategies. The SUCRA provides each warming strategy a probability of the most effective ranking, eventually helping the clinical practice by demonstrating the effects among interventions.

The small study effect and inconsistency were tested to examine the quality of network meta-analysis. The detection of small study effect in this study involved two parts: comparison-adjusted funnel plot and Egger's regression intercept. We examined the comparison-adjusted funnel plot because it can present a scatterplot of the difference between the study-specific effect sizes from the corresponding comparison-specific summary effect. In addition, we estimated Egger's regression intercept to support the comparison-adjusted funnel plot. The

Egger's regression intercept reflects small study effect when the symmetric is not around zero [19]. We used Lu-Ades' loop inconsistency test to examine the inconsistency of network meta-analysis in this study. This method can examine the loop inconsistency between direct and indirect comparisons in a network meta-analysis. A statistically significant difference in all analysis was determined when 95% CI marginally crossed or failed to cross the value 1 or P value < .05.

To examine the influence from anesthesia type (general or neuraxial anesthesia) on our pooled estimates, we further conducted meta-regression in consistency model by using percentage of general anesthesia case in each trial. We completed all the analyses in the STATA version 14 for Microsoft Windows.

3. Results

The comprehensive search returned 1053 references from three electrical databases including PubMed (n = 285), EMBASE (n = 762), and the Cochrane Library (n = 6). We removed 261 duplications from these references. After title and abstract screening, 761 references were excluded based on the eligibility criteria. Then, we found and read the full texts of the remaining 31 references. Of these, six were not RCTs and were, therefore, removed. The final 23 references met the eligible criteria. These 23 references reported outcomes from 18 RCTs, which

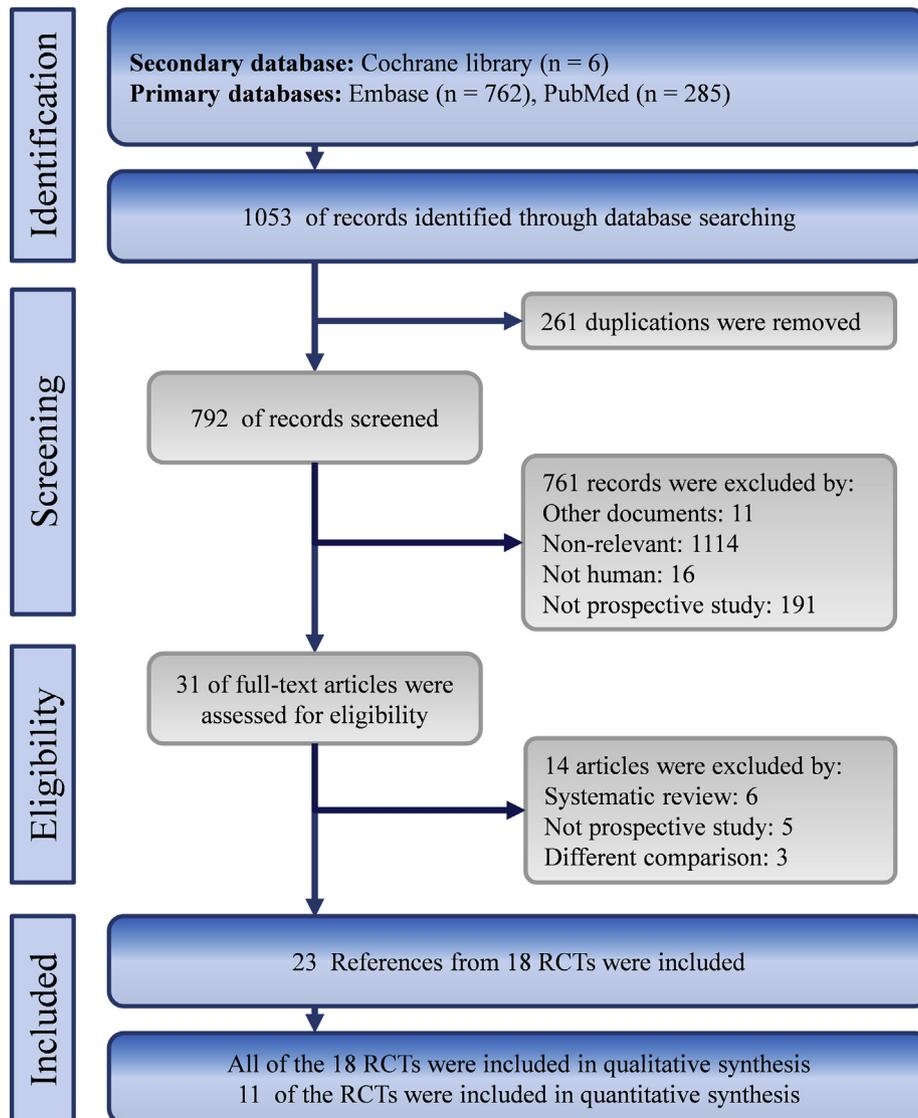


Fig. 1. Flowchart of the systematic review and meta-analysis according to PRISMA guidelines.

had investigated active warming strategies for cesarean section [1,5,20–40]. The process of evidence selection is shown in Fig. 1.

3.1. Study characteristics and quality

The 18 RCTs we included in this systematic review and meta-analysis randomized 1620 pregnant women into 11 active warming strategies and a non-active warming group (n = 333). Most of the eligible trials performed elective cesarean section. Of the 11 active warming strategies, four were single active warming strategies (SAW), and seven were combined active warming strategies (CAW). The SAW involved: (1) conduction mattress warming (n = 135); (2) forced-air warming (n = 30); (3) intravenous fluids warming (n = 562); and (4) warmed blanket warming (n = 51). The CAW involved: (1) CAW of forced-air and warmed blanket warming (CAW-AB; n = 51); (2) CAW of forced-air and fluids warming (CAW-AF; n = 80); (3) CAW of forced-air, fluids, and warmed blanket warming (CAW-AFB; n = 25); (4) CAW of forced-air, fluids warming, and warmed gown warming (CAW-AFG; n = 20); (5) CAW of fluids and conduction mattress warming (CAW-FM;

n = 287); and (6) CAW of fluids and warmed blanket warming (CAW-FB; n = 25); and (7) CAW of fluids and warmed gown warming (CAW-FG; n = 21). Table 1 shows the characteristics of the included studies, included years, location, sample size, active warming strategies, anesthesia type, patient age, and gestational age. Further information is provided in Supplementary 2 and 3.

3.2. Shivering

The shivering data of pregnant women who received different active warming strategies, as presented in the nine RCTs, compared non-active warming, conduction mattress warming, fluids warming, forced-air warming, CAW-AF, CAW-AFG, and CAW-FG [5,24–26,28,30,33,35,37,40]. The network meta-analysis showed no significant difference in shivering rates among the active warming strategies (Fig. 2), but the result demonstrated a trend of fewer shivering rates when CAW was compared with non-active warming (Supplementary 4). The SUCRA value based on cumulative ranking probabilities also showed that CAW-AFG might be a better strategy than

Table 1
Characteristics of included studies.

Part A									
Study	Area	Treatment			Sample size				
		Arm 1	Arm 2	Arm 3	Arm 1	Arm 2	Arm 3		
Bernardis et al.2016	South America	AFG	Fluid	N/A	20	20	N/A		
Butwick et al.2007	North America	Force-air	Control	N/A	15	15	N/A		
Chakladar et al.2014	Europe	Mattress	Control	N/A	58	58	N/A		
Chan et al.1989	North America	FG	Control	N/A	21	19	N/A		
Chung et al.2012	Asia	Force-air	Fluid	Control	15	15	15		
Chebbout et al.2017	Europe	AF	FM	Fluid	43	44	44		
Cobb et al.2016	North America	AF	Control	N/A	22	22	N/A		
Fallis et al.2006	Canada	AB	Blanket	N/A	32	30	N/A		
Goyal et al.2011	Asia	Fluid	Control	N/A	32	32	N/A		
Grant et al.2015	North America	FM	Fluid	N/A	243	241	N/A		
Horn et al.2002	North America	AF	Fluid	N/A	15	15	N/A		
Horn et al.2014	Europe	AB	Blanket	N/A	19	21	N/A		
Jørgensen et al.2000	Europe	Fluid	Control	N/A	57	56	N/A		
Munday et al.2018	Australia	AFB	FB	N/A	25	25	N/A		
Paris et al.2014	North America	Mattress	Fluid	Control	77	73	76		
Woolnough et al.2009	Europe	Fluid(C)	Fluid(H)	Control	25	25	25		
Yokoyama et al.2009	Asia	Fluid	Control	N/A	15	15	N/A		

Part B									
Characteristics	Maternal age			Gestational age (weeks)			Baseline temperature		
	Arm 1	Arm 2	Arm 3	Arm 1	Arm 2	Arm 3	Arm 1	Arm 2	Arm 3
Bernardis et al.2016	28.4	29.1		NR	NR		36.55	36.40	
Butwick et al.2007	36	32		38	39		36.4	36.5	
Chakladar et al.2014	33.6	34.3		38.3	38.5		36.7	36.6	
Chan et al.1989	31.5	33.9		NR	NR		37.3	37.1	
Chung et al.2012	31.8	32.5	31.9	268.6 ^a	266.7 ^a	266.9 ^a	NR	NR	NR
Chebbout et al.2017	32.0	31.8	31.6	39	39	39	36.7	36.8	36.7
Cobb et al.2016	32	31		39	39		NR	NR	
Fallis et al.2006	30	30		38.6	38.5		36.8	36.7	
Goyal et al.2011	26.84	27.16		NR	NR		37.89	37.83	
Grant et al.2015	NR	NR		NR	NR		36.7	36.6	
Horn et al.2002	33	31		NR	NR		NR	NR	
Horn et al.2014	31	31		38	38		36.4	36.7	
Jørgensen et al.2000	30.4	29.9		NR	NR		NR	NR	
Munday et al.2018	31	36		NR	NR		36.6	36.8	
Paris et al.2014	32.44	31.93	30.87	39.07	39.05	39.19	36.70	36.73	36.79
Woolnough et al.2009	35.8	34.3	34.8	38.8	38.9	38.7	NR	NR	NR
Yokoyama et al.2009	32	34		NR	NR		36.9	37.0	

AB, combined active warming of forced-air and warmed blanket; AF, combined active warming of forced-air and fluids; AFB, combined active warming of forced-air, fluids, and warmed blanket; AFG, combined active warming of forced-air, fluids, and warmed gown; FB, combined active warming of fluids and warmed blanket; FG, combined active warming of fluids and warmed gown; FM, combined active warming of fluids and conduction mattress warming. N/A, not applicable.

^a Day. N/A, not applicable; NR, no report.

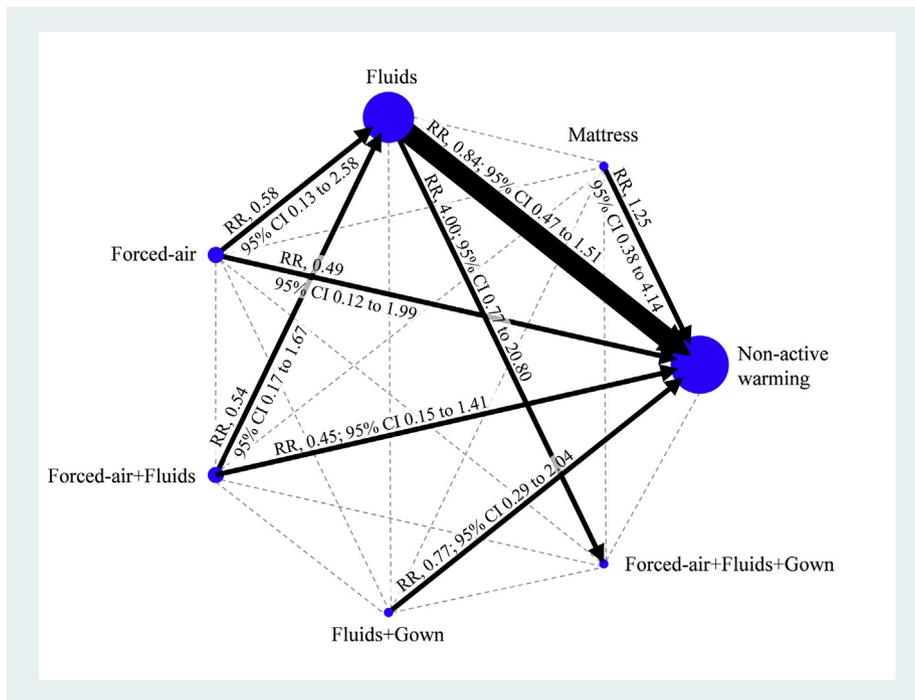


Fig. 2. Network plot of shivering among active warming strategies.

the other active warming strategies (SUCRA = 88.5; mean rank = 1.7). By contrast, non-active warming (SUCRA = 25.2; mean rank = 5.5) and conduction mattress warming (SUCRA = 20.5; mean rank = 5.8) may not effectively reduce shivering (Supplementary 5). No evidence detected inconsistency (loop inconsistency Chi-square = 2.62; $P = .11$) (Supplementary 6) or small study bias (Egger's test $t = -1.46$; $P = .178$) in the present network meta-analysis (Supplementary 7). We further examined how anesthesia type affects the result in network meta-analysis, and unfortunately, insufficient evidence to show the

influence from general anesthesia on the pooled result of shivering (Supplementary 8).

3.3. Hypothermia

The hypothermia events were presented in non-active warming, conduction mattress warming, fluids warming, forced-air warming, CAW-AF, and CAW-FM [5,21,24,26,33,34]. The result showed significant differences in fewer hypothermia rates when active warming

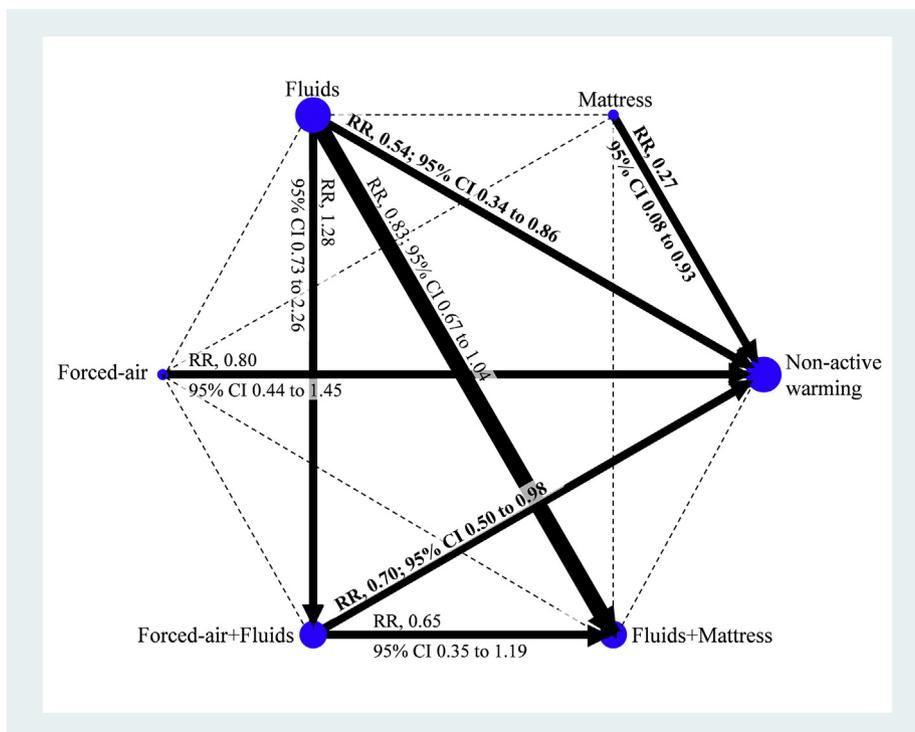


Fig. 3. Network plot of hypothermia among active warming strategies.

was compared with non-active warming except forced-air warming. When non-active warming was the reference, conduction mattress warming (RR 0.27, 95% CI: 0.08 to 0.93), fluids warming (RR 0.54, 95% CI: 0.34 to 0.86), CAW-AF (RR 0.70, 95% CI: 0.50 to 0.98), and CAW-FM (RR 0.45, 95% CI: 0.27 to 0.75) were associated with lower hypothermia rates. Although the network meta-analysis showed no significant difference in hypothermia rates among the active warming strategies (Fig. 3; Supplementary 9), the SUCRA value implied that conduction mattress warming (SUCRA = 89.4; mean rank = 1.5) and CAW-FM (SUCRA = 80.2; mean rank = 2.0) might be better strategies. The SUCRA value also indicated that non-active warming (SUCRA = 5.6; mean rank = 5.7) should be avoided in preventing hypothermia (Supplementary 10). No evidence showed any inconsistency (loop inconsistency Chi-square = 0.04; $P = .98$) (Supplementary 11) in these outcomes, and no small study effect was detected in this network meta-analysis (Egger's test $t = 1.41$; $P = .209$; Supplementary 12). In our meta-regression, current evidence did not detect influence from general anesthesia in the pooled result of hypothermia (Supplementary 13).

4. Discussion

4.1. Key findings

Optimal active warming strategies in women undergoing elective cesarean section need to reduce events of shivering and hypothermia for better performance of the operation and subsequent recovery. Reducing shivering and hypothermia can potentially reduce complications related to them, such as wound infection, shock, maternal mortality, and prolonged hospitalization. Suitable active warming may also reduce the risk of neonatal hypothermia, mortality, or hospitalization period. In addition, optimal active warming intervention allows a medical facility to gain the best warming efficacy at the lowest cost worldwide. Therefore, our systematic analysis summarized the worldwide efforts, during the last three decades, to identify optimal active warming strategies for these women. Our result suggested that forced-air warming based strategies have a better outcome in reducing shivering, and the CAW-AFG seems to be the best strategy to prevent shivering. On the other hand, conduction mattress warming based strategies have a better outcome in reducing hypothermia. These outcomes are as per the recommendation of intraoperative hypothermia based on the NICE guidelines, although the guidelines did not cover the cesarean section [3,4]. Forced-air warming and conduction mattress warming are considered the standard strategies per the guidelines. Unfortunately, few trials mentioned about adverse event (no infection or mortality). Only two trials mentioned similar nausea and vomiting in active warming and non-active warming groups [21,37].

Regarding reducing the shivering during cesarean section, our result showed that forced-air-based warming might be a crucial intervention, especially the CAW-AFG. The skin is the predominant source of heat loss during surgery, although significant evaporation can also occur through large surgical incisions. Even though a high temperature (above 25 °C) in an operating room can maintain normothermia in a patient undergoing surgery, it may make the gowned surgeons uncomfortable when they are working under hot operating room lights [41]. Therefore, forced-air warming targeting the patients' skin temperature is generally the most effective available method, which corresponds to the physiological mechanisms of thermoregulation wherein the thermoregulatory neural cells respond more to change in skin temperature.

Nevertheless, the result of our systematic review showed that the conduction mattress-based warming is efficient in reducing hypothermia, and the CAW-FM seems to be the best warming strategy. Because each liter of intravenous fluid infused into the adult patient at ambient temperature or each unit of blood infused at 4 °C decreases the mean body temperature by approximately 0.25 °C, heating fluids to

nearly 37 °C can prevent hypothermia [41]. Fluid warming can be administered before undetected or mild hypothermia progresses throughout surgery to sufficiently control shivering-causing hypothermia.

4.2. The contribution of forced-air and conduction mattress warming

As we know, forced-air warming and conduction mattress warming have a similar mechanism in preventing temperature loss—by directly changing the skin temperature. The processing of thermoregulatory information consists of three components: thermosensors and afferent neural pathways, the integration of thermal inputs, and effector pathways for autonomic and behavioral regulation [42]. For afferent input and central control, the skin surface, deep abdominal and thoracic tissue, spinal cord, hypothalamus, and other portions of the brain each contribute approximately 20% of the input involved in autonomic thermoregulatory control [41]. For an efferent response, skin temperature is crucial in thermoregulatory behavioral regulation because thermosensitive or thermoresponsive neural cells appear to be more responsive to changes in skin temperature [41,42].

Generally, an additional 1 °C is required to activate intraoperative shivering when thermal discomfort prompts behavioral changes. This response is to hold metabolic heat in the body core and prevent lowering of body temperature through thermoregulatory vasoconstriction, which prevents cutaneous heat loss [42]. However, when patients undergo regional anesthesia, it impairs both central and peripheral thermoregulation [41]. In regional anesthesia, the regulatory system incorrectly judges the skin temperature in blocked areas to be abnormally high. In the blocked region, the regulatory system can tolerate a lower core temperature without responses than in normal situation [42]. This anesthesia-caused inhibition also leads to substantial core hypothermia through a mass of the vasodilated legs. Therefore, when patients receive spinal or epidural anesthetics, the body cannot normally reestablish core temperature equilibrium, and hypothermia tends to progress throughout surgery [41].

When behavioral compensations and maximal arteriovenous shunt vasoconstriction are insufficient to maintain core temperature, normal thermoregulatory shivering will be activated as a last-resort defense [42]. Because the core temperature is rarely monitored and patients usually do not feel cold during spinal and epidural anesthesia, hypothermia is often undetected and can cause shivering. Shivering under regional anesthesia has no protective effect because it produces relatively little heat owing to the restriction of the small muscle mass cephalad to the block [41].

4.3. Comparison with the previous systematic review

Before our study, a previous meta-analysis identified 13 RCTs and found some significant results showing the effects of active warming for cesarean section, but the pairwise meta-analysis showed vast heterogeneity (I-square = 92%) and publication bias (Egger's test $p = .001$) [9]. These problems were probably because of the combination of different warming strategies in a simple model. For instance, the trial by Chan and his colleagues categorized the group with an extra gown warming as a standard procedure, whereas the control group did not accept the same treatment [25]. In another example, Fallis and his team classified the group that got combined care of forced-air and a warmed blanket as having got the care of forced-air only when they detected shivering [32]. These heterogeneities of treatments are potential factors affecting the shivering and hypothermia.

By contrast, our study updated evidence using more RCTs with larger sample size than the previous meta-analysis and conducted a consistency model to clarify the effects among the complex active warming strategies. Our work is the very first network meta-analysis of 18 RCTs that compared multiple active warming strategies without any inconsistency and small study effect. Moreover, through further

analysis of SUCRA ranking, we manifested the effects among the active warming strategies.

4.4. Limitation and clues for future study

Despite this study having some advantages, it had several limitations. First, our study could not put CAW-AB, CAW-AFB, and CAW-FB in network meta-analysis because of the lack of comparison between them and these active warming strategies being unavailable in the consistency model in the trials we included. We only observed some trends from qualitative information. Therefore, more trials comparing CAW-AB, CAW-AFB, CAW-FB, and other active warming strategies are needed in the future. Second, the included trials differed in warming time, anesthesia type, warming temperature, temperature measurement, and assessment time. We only found information of anesthesia type from all the trials, but they reported other potential factors incompletely. Thus, we can only analyze the influence from anesthesia type on our pooled results. Other factors may also influence the effect of active warming in women undergoing a cesarean section. Therefore, further trials on this topic are required to clarify the effect of these factors on active warming in cesarean section. Third, despite SUCRA being a supporting method, it may still mislead because of a substantial degree of imprecision in the ranking [43]. Nevertheless, the limitation of SUCRA may not affect our outcomes because the consistency model in this study showed apparent trends with some significant findings. The clear ranks and statistical significances are more reliable and informative to clinical practice than previous evidence.

5. Conclusion

In summary, anesthesia-related shivering and hypothermia during cesarean section could be reduced by using various active warming strategies. Forced-air-based warming strategy could be considered for preventing shivering, and conduction mattress warming based warming strategy could be used for preventing hypothermia in women undergoing cesarean sections. Active warming can increase the quality of cesarean section through reducing shivering and hypothermia, but we anticipate further studies to reveal other outcomes about blood loss, transfusion, thrombosis, or shock.

Ethical approval

No ethical approval is needed for this network meta-analysis, because we used published data.

Sources of funding

This network meta-analysis does not received funding.

Author contribution

Conceptualization: Zandi Mnisi, Yi-No Kang.

Data curation: Wei-An Chen, Chih-Chung Liu, Yi-No Kang.

Formal analysis: Yi-No Kang.

Investigation: Wei-An Chen, Chih-Chung Liu, Zandi Mnisi, Chien-Yu Chen, Yi-No Kang.

Methodology: Chien-Yu Chen, Yi-No Kang.

Supervision: Zandi Mnisi, Chien-Yu Chen.

Visualization: Yi-No Kang.

Writing – original draft: Wei-An Chen, Yi-No Kang.

Writing – review & editing: Chih-Chung Liu, Zandi Mnisi, Chien-Yu Chen, Yi-No Kang.

Conflicts of interest

The authors declare that they have nothing to disclose regarding

financial or non-financial conflicts of interest with respect to this manuscript.

Trial registry number

Registry used: PROSPERO.

Registration ID: CRD42018114514.

Hyperlink to the registration:

[https://www.crd.york.ac.uk/PROSPERO/display_record.php?](https://www.crd.york.ac.uk/PROSPERO/display_record.php?RecordID=114514)

[RecordID=114514.](https://www.crd.york.ac.uk/PROSPERO/display_record.php?RecordID=114514)

Guarantor

Wei-An Chen, Chih-Chung Liu, Zandi Mnisi, Chien-Yu Chen, Yi-No Kang.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Data statement

Due to this study used published data from the included randomized controlled trials investigating the topic of active warming for preventing hypothermia and shivering during cesarean section, the raw data would not be shared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijssu.2019.09.006>.

References

- [1] K. Yokoyama, M. Suzuki, Y. Shimada, T. Matsushima, H. Bitō, A. Sakamoto, Effect of administration of pre-warmed intravenous fluids on the frequency of hypothermia following spinal anesthesia for Cesarean delivery, *J. Clin. Anesth.* 21 (2009) 242–248.
- [2] P. Kiekkas, M. Pouloupoulou, A. Papahatzis, P. Souleles, Effects of hypothermia and shivering on standard PACU monitoring of patients, *AANA J.* 73 (2005) 47–53.
- [3] NICE, Inditherm Patient Warming Mattress for the Prevention of Inadvertent Hypothermia, NICE London, 2011.
- [4] N.I.C.E. Hypothermia, Prevention and Management in Adults Having Surgery, National Institute for Health and Care Excellence, 2016.
- [5] B. Cobb, Y. Cho, G. Hilton, V. Ting, B. Carvalho, Active warming utilizing combined IV fluid and forced-air warming decreases hypothermia and improves maternal comfort during cesarean delivery: a randomized control trial, *Anesth. Analg.* 122 (2016) 1490–1497.
- [6] C.M. Harper, R. Alexander, Hypothermia and spinal anaesthesia, *Anaesthesia* 61 (2006) 612.
- [7] G.F. Lema, E.G. Gebremedhn, A.H. Gebregzi, Y.T. Desta, A.A. Kassa, Efficacy of intravenous tramadol and low-dose ketamine in the prevention of post-spinal anesthesia shivering following cesarean section: a double-blinded, randomized control trial, *Int. J. Women Health* 9 (2017) 681–688.
- [8] G. Campbell, P. Alderson, A.F. Smith, S. Warttig, Warming of intravenous and irrigation fluids for preventing inadvertent perioperative hypothermia, *Cochrane Database Syst. Rev.* (2015) Cd009891.
- [9] P. Sultan, A.S. Habib, Y. Cho, B. Carvalho, The Effect of patient warming during Caesarean delivery on maternal and neonatal outcomes: a meta-analysis, *Br. J. Anaesth.* 115 (2015) 500–510.
- [10] C.T. Lee, Y.C. Lin, Y.C. Yeh, T.L. Chen, C.Y. Chen, Effects of levosimendan for perioperative cardiovascular dysfunction in patients receiving cardiac surgery: a meta-analysis with trial sequential analysis, *Intensive Care Med.* 43 (2017) 1929–1930.
- [11] A.H. Liao, Y.C. Lin, C.H. Bai, C.Y. Chen, Optimal dose of succinylcholine for laryngeal mask airway insertion: systematic review, meta-analysis and metaregression of randomised control trials, *BMJ open* 7 (2017) e014274.
- [12] C.C. Kao, Y.S. Lin, H.C. Chu, T.C. Fang, M.S. Wu, Y.N. Kang, Association of renal function and direct-acting antiviral agents for HCV: a network meta-analysis, *J. Clin. Med.* 7 (2018).
- [13] E.Y. Lin, Y.K. Kuo, Y.N. Kang, Effects of three common lumbar interbody fusion procedures for degenerative disc disease: a network meta-analysis of prospective studies, *Int. J. Surg.* 60 (2018) 224–230.
- [14] L.S. Chen, W.C. Chen, Y.N. Kang, C.C. Wu, L.W. Tsai, M.Z. Liu, Effects of transabdominal preperitoneal and totally extraperitoneal inguinal hernia repair: an update

- systematic review and meta-analysis of randomized controlled trials, *Surg. Endosc.* 33 (2019) 418–428.
- [15] Y.N. Kang, Y.W. Hsiao, C.Y. Chen, C.C. Wu, Testicular sperm is superior to ejaculated sperm for ICSI in cryptozoospermia: an update systematic review and meta-analysis, *Sci. Rep.* 8 (2018) 7874.
- [16] F.Y. Ku, C.C. Wu, Y.W. Hsiao, Y.N. Kang, Association of sperm source with miscarriage and take-home baby after ICSI in cryptozoospermia: a meta-analysis of testicular and ejaculated sperm, *Andrology* 6 (2018) 882–889.
- [17] B. Hutton, G. Salanti, D.M. Caldwell, A. Chaimani, C.H. Schmid, C. Cameron, et al., The PRISMA extension statement for reporting of systematic reviews incorporating network meta-analyses of health care interventions: checklist and explanations, *Ann. Intern. Med.* 162 (2015) 777–784.
- [18] J.P. Higgins, D.G. Altman, P.C. Gotzsche, P. Juni, D. Moher, A.D. Oxman, et al., The Cochrane Collaboration's tool for assessing risk of bias in randomised trials, *BMJ (Clinical research ed.)* 343 (2011) d5928.
- [19] A. Chaimani, J.P. Higgins, D. Mavridis, P. Spyridonos, G. Salanti, Graphical tools for network meta-analysis in STATA, *PLoS One* 8 (2013) e76654.
- [20] R.C.G.D. Bernardis, M.M. Siaulys, J.E. Vieira, L.A.S.T. Mathias, Perioperative warming with a thermal gown prevents maternal temperature loss during elective cesarean section. A randomized clinical trial, *Braz. J. Anesthesiol.* 66 (2016) 451–455.
- [21] A.J. Butwick, S.S. Lipman, B. Carvalho, Intraoperative forced air-warming during cesarean delivery under spinal anesthesia does not prevent maternal hypothermia, *Anesth. Analg.* 105 (2007) 1413–1419 table of contents.
- [22] A. Chakladar, M.J. Dixon, D. Crook, C.M. Harper, Actively warming patients with a mattress during Caesarean section reduces the incidence of hypothermia and attenuates fall in haemoglobin, *Anaesthesia* 67 (2012) 14.
- [23] A. Chakladar, M.J. Dixon, C.M. Harper, Warming mattress to prevent inadvertent perioperative hypothermia and shivering during elective Caesarean section, *Br. J. Anaesth.* 107 (2011) 290P–291P.
- [24] A. Chakladar, M.J. Dixon, D. Crook, C.M. Harper, The effects of a resistive warming mattress during caesarean section: a randomised, controlled trial, *Int. J. Obstet. Anesth.* 23 (2014) 309–316.
- [25] V.W. Chan, P.K. Morley-Forster, H.A. Vosu, Temperature changes and shivering after epidural anesthesia for cesarean section, *Reg. Anesth.* 14 (1989) 48–52.
- [26] R. Chebbout, R. Newton, M. Walters, I. Wrench, M. Woolnough, Does the addition of active body warming to in-line intravenous fluid warming prevent maternal hypothermia during elective caesarean section? A randomised controlled trial, *Int. J. Obstet. Anesth.* 31 (2017) 37–44.
- [27] S.H. Chung, D.H. Chun, Effect of preoperative forced air-warming and fluid warming during cesarean section under spinal anesthesia, *Reg. Anesth. Pain Med.* 36 (2011) E163.
- [28] S.H. Chung, B.S. Lee, H.J. Yang, K.S. Kweon, H.H. Kim, J. Song, et al., Effect of preoperative warming during cesarean section under spinal anesthesia, *Korean J. Anesthesiol.* 62 (2012) 454–460.
- [29] B. Cobb, G. Abir, B. Carvalho, Preoperative anterior thigh temperature does not correlate with perioperative temporal hypothermia during cesarean delivery with spinal anesthesia: secondary analysis of a randomized control trial, *Int. J. Obstet. Anesth.* 33 (2018) 40–45.
- [30] R.C. de Bernardis, M.M. Siaulys, J.E. Vieira, L.A. Mathias, Perioperative warming with a thermal gown prevents maternal temperature loss during elective cesarean section. A randomized clinical trial, *Braz. J. Anesthesiol.* 66 (2016) 451–455.
- [31] E.L. Duryea, D.B. Nelson, M.H. Wyckoff, E.N. Grant, W. Tao, N. Sadana, et al., The impact of operating room temperature on hypothermia and morbidity in preterm infants, *Am. J. Obstet. Gynecol.* 214 (2016) S204.
- [32] W.M. Fallis, K. Hamelin, J. Symonds, X. Wang, Maternal and newborn outcomes related to maternal warming during cesarean delivery, *J. Obstet. Gynecol. Neonatal Nurs.* : J. Obstet. Gynecol. Neonatal Nurs. 35 (2006) 324–331.
- [33] P. Goyal, S. Kundra, S. Sharma, A. Grewal, T.K. Kaul, M.R. Singh, Efficacy of intravenous fluid warming for maintenance of core temperature during lower segment cesarean section under spinal anesthesia, *J. Obstet. Anaesth. Crit. Care* 1 (2011) 73.
- [34] E.N. Grant, M.G. Craig, W. Tao, D.D. McIntire, K.J. Leveno, Active warming during cesarean delivery: should we SCIP it? *Am. J. Perinatol.* 32 (2015) 933–938.
- [35] E.P. Horn, F. Schroeder, A. Gottschalk, D.I. Sessler, N. Hiltmeyer, T. Standl, et al., Active warming during cesarean delivery, *Anesth. Analg.* 94 (2002) 409–414.
- [36] E.-P. Horn, B. Bein, M. Steinfath, K. Ramaker, B. Buchloh, J. Höcker, The incidence and prevention of hypothermia in newborn bonding after cesarean delivery: a randomized controlled trial, *Anesth. Analg.* 118 (2014) 997–1002.
- [37] H.S. Jørgensen, L.F. Bach, H.S. Helbo-Hansen, P.A. Nielsen, Warm or cold saline for volume preload before spinal anaesthesia for caesarean section? *Int. J. Obstet. Anesth.* 9 (2000) 20–25.
- [38] J. Munday, S. Osborne, P. Yates, D. Sturgess, L. Jones, E. Gosden, Preoperative warming versus no preoperative warming for maintenance of normothermia in women receiving intrathecal morphine for cesarean delivery: a single-blinded, randomized controlled trial, *Anesth. Analg.* 126 (2018) 183–189.
- [39] L.G. Paris, M. Seitz, K.G. McElroy, M. Regan, A randomized controlled trial to improve outcomes utilizing various warming techniques during cesarean birth, *J. Obstet. Gynecol. Neonatal Nurs.* : J. Obstet. Gynecol. Neonatal Nurs. 43 (2014) 719–728.
- [40] M. Woolnough, J. Allam, C. Hemingway, M. Cox, S.M. Yentis, Intra-operative fluid warming in elective caesarean section: a blinded randomised controlled trial, *Int. J. Obstet. Anesth.* 18 (2009) 346–351.
- [41] D.I. Sessler, Mild perioperative hypothermia, *N. Engl. J. Med.* 336 (1997) 1730–1737.
- [42] J. De Witte, D.I. Sessler, Perioperative shivering: physiology and pharmacology, *Anesthesiology* 96 (2002) 467–484.
- [43] L. Trinquart, N. Attiche, A. Bafeta, R. Porcher, P. Ravaud, Uncertainty in treatment rankings: reanalysis of network meta-analyses of randomized trials, *Ann. Intern. Med.* 164 (2016) 666–673.