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The Effectiveness of Blanket Warmer, Warm Intravenous Fluids, and Operating Room Temperature Modification in Preventing Perioperative Hypothermia

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ABSTRACT

Hypothermia is a dangerous condition where the body temperature drops drastically (<36°C). If not promptly addressed, it can be life-threatening, with a mortality rate of approximately 21% for moderate hypothermia and 40% for severe hypothermia. This literature review aims to identify the most effective preventive measures to be implemented in the operating room to prevent perioperative hypothermia. This study utilized a literature review method, analyzing articles from two databases, PubMed and Science Direct. After applying relevant keywords, a total of 401 articles were obtained. These articles were then identified, screened, and examined for eligibility, resulting in 12 included articles. Nine articles reported that warm intravenous fluids, warm irrigation fluids, electric warming blankets, warming mattresses, and operating room temperature modifications were significantly beneficial in preventing perioperative hypothermia. In comparison, two articles found no significant benefit in prevention. There needs to be a consensus among the reviewed articles regarding the most effective preventive measures for perioperative hypothermia. Additionally, none of the articles examined the combined use of all three interventions to prevent hypothermia in perioperative patients.

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INTRODUCTION

Surgery is a procedure that starts with an incision to open a part of the body and ends with stitching the wound to close it. It is estimated that around 234 million major surgical procedures are done worldwide every year. Every surgical procedure can lead to complications. The average death rate associated with inpatient surgeries varies from 0.5% to 7%. About 2 to 3 out of 10 patients experience complications after elective surgery (Shaydakov & Tuma, 2023).

Surgical procedures impact a patient's body, one of which is their body temperature or the occurrence of a lower-than-normal body temperature, known as hypothermia. Hypothermia is defined as a core body temperature below 36°C and is further classified as mild hypothermia (34°C-36°C), moderate (32°C-34°C), and severe (<32°C) (Simegn et al., 2021). Perioperative hypothermia has always been a clinical challenge when treating patients undergoing surgical procedures (Giuliano & Hendricks, 2017). According to the National Institute for Health and Care Excellence, perioperative hypothermia is when the core body temperature is lower than 36°C. The reported prevalence of perioperative hypothermia ranges from 50% to 90% of all surgical patients, occurring when the body's ability to maintain an average temperature is reduced. In the United States, hypothermia affects around six million surgical patients each year (Fatemi et al., 2016). Most patients can tolerate mild hypothermia, which is not significantly associated with morbidity or mortality. The mortality rate for moderate hypothermia is estimated at 21% and even higher for severe hypothermia, reaching up to 40% (Watson, 2018).

Many contributing factors can lead to perioperative hypothermia in a patient's body, such as the type of anesthesia procedure that

disrupts the heat regulation mechanism by the thermoregulatory system (Becerra et al., 2021). Patients undergoing abdominal surgery are at high risk of experiencing perioperative hypothermia. Abdominal surgery is one of the major surgeries, which requires the administration of general anesthesia or a combination of general and epidural anesthesia, requires a longer duration of operation compared to minor operations, and also has a significant exposure of the open body cavities during surgery (Becerra et al., 2021). According to the Risk of Inadvertent Perioperative Hypothermia (RIPOH) scale, abdominal surgery has a score of 8.99, indicating a high risk of developing hypothermia during the surgery (Giuliano & Hendricks, 2017).

Hypothermia has various consequences or impacts. Hypothermia can change drug pharmacokinetics and impair enzyme activity, thereby reducing and slowing metabolism and prolonging the action of many drugs used to induce or maintain anesthesia. During hypothermia, the body redistributes blood from the intestines, extremities, kidneys, and liver to vital organs, reducing the distribution volume of various intravascular drugs. Furthermore, carbon dioxide partial pressure increases as core body temperature decreases, resulting in a lower pH. Drugs ionize more when pH shifts occur, affecting their distribution volume.

Moreover, hypothermia causes a significant decrease in plasma coagulation. Like other enzymes, coagulation factors require an optimal proper temperature range. Hypothermia reduces enzyme capacity and enzyme activity and causes coagulopathy. For example, a decrease in core temperature of just 1°C is associated with increased bleeding events (16%) and transfusion requirements (22%). The risk of transfusion significantly increases with the duration and severity of perioperative hypothermia. Even mild perioperative hypothermia is a significant and independent risk factor for surgical wound infection. Perioperative hypothermia showed a higher occurrence of infectious complications even up to eight weeks after the procedure. The effects of perioperative hypothermia contribute to delays in being released from the post-anesthetic care unit. Patients who experience hypothermia after significant abdominal surgery require approximately 40 more minutes before they are deemed fit for discharge from the post-anesthesia care unit (Rauch et al., 2021). Meanwhile, perioperative hypothermia also causes various complications, including cardiac irregularities, wound healing disturbances, increased surgical site infections, shivering, delayed postoperative recovery, elevated ICU admissions, extended hospital stays, and coagulopathy. As a result, it elevates economic burdens for patients and the general public (Simegn et al., 2021).

Therefore, various efforts are necessary to prevent or minimize the occurrence of perioperative hypothermia. Active temperature management is required throughout all periods, including pre-surgery, intra-surgery, and post-surgery, to reduce the risk of perioperative hypothermia (Rauch et al., 2021). Based on various previous studies, giving warm blankets, electric blankets, circulating water garments, heated air mattresses, air heating systems, and other methods can minimize extreme body temperature drops in patients. Additionally, another approach is to provide warm intravenous fluids to reduce the occurrence of hypothermia. However, it is worth noting that some previous studies have found specific methods to be effective, while others may be less effective in preventing hypothermia (Simegn et al., 2021). So far, based on the literature review conducted by the authors, there have been only a limited number of studies and publications that compare various measures to identify the most effective approach to preventing perioperative hypothermia.

The purpose of this literature review is to identify the findings of various studies that have focused on specific interventions for perioperative patients to prevent the occurrence of hypothermia. These interventions include providing warm blankets, administering warm intravenous fluids, using heated operating table pads, and adjusting the operating room temperature. This literature review is expected to provide insights into the unique conditions of the operating room, the patients undergoing surgery, the types of surgical procedures performed, and the preventive and management measures for perioperative hypothermia.

METHOD

This study was conducted using the literature review method. A literature review is a scientific approach aimed at analyzing, evaluating, synthesizing, and criticizing research findings on a specific topic or subject that have been published online and in print. The selected articles/journals were research outcomes involving perioperative patients as respondents. Inclusion criteria included experimental studies, articles published in English, publication dates

from 2013 to 2023, peer-reviewed journals, and open-access availability. Article searching was carried out using various databases such as PubMed and Science Direct, using English keywords such as "blanket warmer," "blower warmer," "electric warmer," "fluid warming," "temperature modification," "temperature management," and "hypothermia." Then, articles indicated as duplicates were removed to select those relevant to the research theme. The articles were then examined using a meticulous records screening technique to assess eligibility based on titles and abstracts. Finally, the chosen articles were discussed further in this study.

Based on the literature search conducted through publications in two databases (PubMed and Science Direct) using adjusted keywords, the researchers found 401 articles that matched these keywords. After checking for duplicates, one identical article was identified and removed, leaving 400 articles. The researchers then conducted screening using the Records screened technique (n = 89), examining the articles for eligibility by downloading and reading the full-text articles (n = 38). Eventually, several articles that matched the criteria were obtained for Studies included in evidence mapping (n = 12), aligning with the theme of the literature review. Assessment based on eligibility criteria resulted in 12 articles that could be used in the literature review.

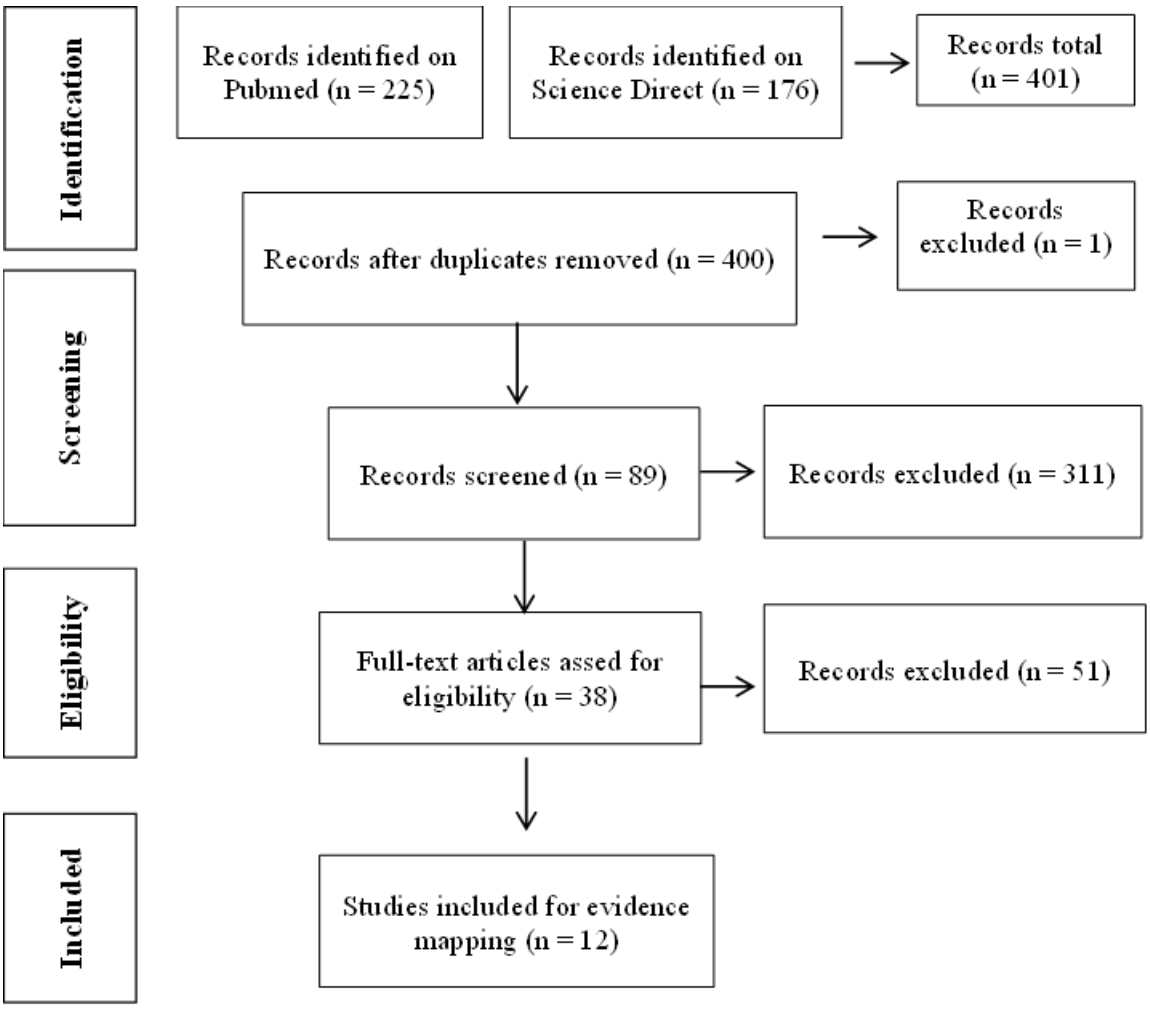

Figure 1. Search strategy using PRISMA

RESULTS

Table 1. The findings of the reviewed sources

No	Title and Author	Study	Participants	Interventions	Control	Primary Outcome	Secondary Outcomes	Results
1	Effects of combined warmed preoperative forced-air and warmed perioperative intravenous fluids on maternal temperature during cesarean section: a prospective, randomized, controlled clinical trial (Ni et al., 2020)	RCT	135 women undergoing elective cesarean deliveries	Preoperative forced-air warming+ perioperative intravenous fluid warming (n=69)	No active warming (n=66)	The core temperature change from baseline to end of the procedure	Thermal comfort scores, incidences of shivering and hypothermia, core temperature on arrival at post-anesthesia care unit, neonatal axillary temperature at birth, Apgar scores	Significantly different core temperature changes between groups (F=13.022, P<0.001). Higher thermal comfort scores in the intervention group (F=9.847, P=0.002). Lower incidence of perioperative hypothermia in the intervention group (20.6% vs. 51.6%, P<0.0001). Warming may prevent maternal hypothermia, reduce shivering, and improve thermal comfort in cesarean sections under spinal anesthesia.
2	Preventing hypothermia in outpatient plastic surgery by self-warming or forced-air-warming blanket (Tyvold, 2019)	RCT	112 consecutive patients planned for outpatient plastic surgery	Self-warming blanket (n=56)	Forced-air-warming blanket (n=56)	Core temperature during general anesthesia and postoperatively	Inadvertent perioperative hypothermia (core body temperature below 36.8°C)	During anesthesia, core temperature was significantly lower in the self-warming blanket group (P<0.0001). Higher incidence of hypothermia in the self-warming blanket group (47% vs. 25%, P=0.02). Underbody forced-air-warming blankets reduced heat loss more effectively, but neither intervention was sufficient to prevent inadvertent perioperative hypothermia.
3	Warmed Irrigation Fluid Does Not Decrease Perioperative Hypothermia During Arthroscopic Shoulder Surgery (Oh et al., 2014)	RCT	72 patients undergoing arthroscopic shoulder surgery	Warmed irrigation fluid (group W, n=36)	Room-temperature irrigation fluid (group RT, n=36)	Incidence of perioperative hypothermia, core body temperature changes during surgery, postoperative adverse effects	Postoperative weight change, prothrombin time, hemoglobin level, visual analog scale pain score	There was no significant difference in demographic, surgical data, or intraoperative hypothermia incidence between groups. Core body temperatures decreased during surgery and increased in the post-anesthesia care unit (PACU) without intergroup differences. All patients were normothermic within 1 hour of PACU arrival. There were no significant differences in postoperative outcomes (weight change, prothrombin time, hemoglobin level, pain score) between groups. Warmed irrigation fluid was

No	Title and Author	Study	Participants	Interventions	Control	Primary Outcome	Secondary Outcomes	Results
								not superior to room-temperature fluid in reducing perioperative hypothermia.
4	The effects of a forced-air warming system plus an electric blanket for elderly patients undergoing transurethral resection of the prostate (Zhang et al., 2018)	RCT	Elderly TURP Patients Trial	443 elderly male patients undergoing elective TURP with subarachnoid blockade	Group E (electric blankets set to 38°C, n=128), Group F (forced-air warmer set to 38°C, n=155),)	Group FE (forced-air warmer plus electric blankets, both set to 38°C, n=160	Shivering and shivering grades	Hemodynamic changes, esophageal temperature, recovery time, incidences of adverse effects, patient and surgeon satisfaction
5	Comparison of two forced-air warming systems for prevention of intraoperative hypothermia in carcinoma colon patients: a prospective randomized study (Gulia et al., 2020)	RCT	60 patients undergoing elective laparoscopic colon surgeries	Underbody forced air warming blanket (n=30)	Over-body forced air warming blanket (n=30)	Core temperature at different time points during surgery, incidence of postoperative shivering, time to reach Aldrete Score of 10 in the postoperative period	Vitals, clinically meaningful differences in outcomes	Core temperature was higher with underbody blankets at 60, 90, 120, and 150 minutes. The time to reach the Aldrete Score of 10 was less in the underbody blanket group in the post-anesthesia care unit. There are no clinically meaningful differences in any outcomes. Underbody and over-body blankets were comparably effective in preventing hypothermia in laparoscopic colorectal surgery under general anesthesia.
6	Warming infusion improves perioperative outcomes of elderly patients who underwent bilateral hip replacement (Ma et al.,2017)	RCT	64 elderly patients undergoing bilateral hip replacement	Warming infusion group (infusion fluid heated to 35°C, n=32)	Control group (room temperature infusion fluid, n=32)	Time to spontaneous breath, eye-opening, consciousness recovery, and extubation	Length of hospital stay, VAS score, postoperative complications, Steward score, incidence of shivering, postoperative cognitive dysfunction	There was no significant difference in demographic data and intraoperative blood transfusion rate between groups. The warming infusion group had a shorter time to recovery milestones, lower Steward score, lower VAS score, and decreased incidence of shivering and postoperative cognitive dysfunction. Pre-warmed infusion reduced perioperative hypothermia and improved outcomes in elderly patients during bilateral hip replacement.
7	Thermal suit in preventing unintentional intraoperative hypothermia during general anesthesia: a randomized controlled trial	RCT	100 patients undergoing robotic-assisted laparoscopic radical prostatectomy	Thermal Suit group (n=50)	Control group (conventional hospital cotton clothes, n=50)	Temperature change during surgery, intraoperative and post-anesthesia care unit temperatures	Foot dorsum temperatures, core temperatures, axillary temperatures, skin temperatures on the finger	There was no significant difference between groups in mean core temperatures, axillary temperatures, or skin temperatures on the finger. Foot dorsum temperatures were lower in the Thermal Suit group. Intraoperative temperature changes were similar.

No	Title and Author	Study	Participants	Interventions	Control	Primary Outcome	Secondary Outcomes	Results
	(Lauronen et al., 2017)							Post-anesthesia care unit temperature changes were minimal and did not differ between groups. The thermal suit did not provide additional benefits over conventional cotton clothes when standard preventive procedures were effective.
8	Effect of pre-warmed intravenous fluids on perioperative hypothermia and shivering after ambulatory surgery under monitored anesthesia care (Kim et al., 2014)	RCT	Female patients (35-80 years) undergoing short ambulatory urological surgery under monitored anesthesia care (MAC)	Pre-warmed IV fluids group (n=27)	Room temperature IV fluids group (n=26)	Perioperative core temperatures, postoperative shivering, subjective thermal comfort, use of forced-air warming interventions in the PACU	Incidence of hypothermia, the incidence of postoperative shivering	Mean core temperatures were significantly higher in the pre-warmed group after fluid administration, at the end of the operation, and on admission to PACU. There was a lower incidence of hypothermia and postoperative shivering in the pre-warmed group. Pre-warmed IV fluid improved postoperative recovery profile in female patients undergoing short ambulatory urological surgery under MAC.
9	Does the addition of active body warming to in-line intravenous fluid warming prevent maternal hypothermia during elective cesarean section? A randomized controlled trial (Chebbout et al., 2017)	RCT	132 women undergoing elective cesarean section with spinal anesthesia	No active body warming, forced air warming, Conduction mattress warming	In-line intravenous fluid warming for all participants	The mean core temperature on admission to the recovery room	Perioperative core temperature, thermal comfort, estimated blood loss, hemoglobin change, length of hospital stay, neonatal core temperature	There was no significant difference in mean core temperature between groups on admission to the recovery room. Maternal hypothermia was prevented in all groups. There is no added benefit of active body warming in preventing maternal hypothermia. There was no difference in mean neonatal core temperature, but a significant percentage of neonates were hypothermic across all groups.
10	Efficacy of intravenous fluid warming during goal-directed fluid therapy in patients undergoing laparoscopic colorectal surgery: a randomized controlled trial (Choi et al., 2016)	RCT	Adult patients undergoing laparoscopic colorectal surgery	Warmed IV fluids group	Room temperature IV fluids group	Drop in core temperature at 2 hours after the induction of anesthesia	-	There was a significantly smaller drop in core temperature in the warm fluids group compared to the control group 30 minutes after induction. IV fluid warming is associated with a smaller drop in core temperature in laparoscopic colorectal surgery incorporating goal-directed fluid therapy.
11	Comparison of the Effect of Forced-air Warming and Warmed	RCT	120 patients undergoing orthopedic surgery	Forced-air warming (38°C) group	Warmed intravenous fluid (37°C) group	Comfort score and shivering severity measured at	-	There was a significant difference in comfort scores between groups at all evaluation times. The control group

No	Title and Author	Study	Participants	Interventions	Control	Primary Outcome	Secondary Outcomes	Results
	Intravenous Fluid on the Comfort and Prevention of Shivering After Spinal Anesthesia in Patients Undergoing Orthopedic Surgery (Moheb et al., 2022)		with spinal anesthesia			multiple time points		had a higher comfort score than the intervention group. The warmed intravenous fluid group had a higher comfort score than the forced-air warming group. There was a significant difference in shivering severity between groups at the end of surgery, entrance to the recovery room, and 15 minutes after surgery. Forced-air warming was more effective in preventing shivering (90% had no shivering) compared to warmed intravenous fluid (65% had no shivering) and the control group (30% had no shivering). Non-pharmacological methods like forced-air warming and warmed intravenous fluid can provide comfort and prevent shivering in orthopedic patients undergoing spinal anesthesia. Forced-air warming is more effective than warmed intravenous fluid.
12	The efficacy of pre-warming on reducing intraprocedural hypothermia in endovascular coiling of cerebral aneurysms (Shin et al., 2015)	RCT	72 patients undergoing endovascular treatment of cerebral aneurysms in the interventional neuroradiology suite	Pre-warmed group (n=36)	Forced-air warming blanket set at 38°C (n=36)	Core temperature measured at various time points, incidence of hypothermia	-	The pre-warmed group showed a slightly higher base temperature post-intubation. Core temperatures were significantly higher in the pre-warmed group at multiple time points. The incidence of hypothermia was significantly lower in the pre-warmed group from T20 to T120. Pre-warming did not modify the overall temperature decrease trend but reduced the risk of intraprocedural hypothermia.

Based on the literature search, 12 articles were found to be aligned with the research objective. These selected articles were then grouped based on their coverage of topics. These articles come from various countries, including China, India, Norway, Japan, Iran, South Korea, Finland, and Sheffield, UK. The population characteristics involve patients scheduled for surgical procedures in the operating room (age, gender, weight, height, duration of surgery, type of anesthesia, type of surgery).

The research design used in the 12 articles consisted of an Experimental Study and randomized controlled clinical trials, both with control groups and without control groups. The sample used in the studies included perioperative patients scheduled for various types of surgical procedures, such as orthopedic surgery, endovascular cerebral aneurysm surgery, laparoscopic cholecystectomy surgery, cesarean section surgery, abdominal tumor laparotomy surgery, urological surgery, and plastic surgery.

The research variables from various articles include warm infusion fluids, which are sterile liquids packaged in multiple types of containers with specific amounts, heated using specialized warming devices to reach a desired warm temperature, and can be monitored. Warm blankets are relatively thick cloth placed on the patient's body to help maintain their warmth. Warm irrigation fluids are sterile fluids heated using specific devices. They can be monitored and used as irrigation fluids during arthroscopy procedures in orthopedic surgery. Electric blankets are blankets connected to an electric power source that provides warmth and is placed on the patient's body. Heated mattresses are pads connected to an electric power source that provides warmth and is placed under the patient's body. Operating room temperature modifications involve efforts to create a comfortable environment in the operating room that prevents patients from feeling cold during surgery while maintaining the required standard operating room temperature. Hypothermia is a condition where the core body temperature drops below 36°C.y, abdominal tumor laparotomy surgery, urological surgery, and plastic surgery.

The instruments used in these articles are tools and devices used to monitor patient complaints, measure the patient's body temperature, and record the results. These include the shivering assessment questionnaire, tympanic temperature (Tpre), nasopharyngeal probe, digital thermometers, and checklists.

DISCUSSION

Based on the review of the 12 articles above, the following results were obtained: Non-pharmacological methods such as modifying the operating room temperature and administering warmed intravenous fluids can provide comfort and prevent shivering in patients undergoing orthopedic procedures. Operating room temperature modification is more effective than warmed intravenous fluids in providing comfort and preventing shivering in these patients. Preoperative warming for 30 minutes at 38°C does not alter the trend of patient temperature decline. Preoperative warming significantly reduces the risk of intraprocedural hypothermia. Warmed intravenous fluids are associated with a smaller decrease in core body temperature compared to room temperature intravenous fluid administration in colorectal laparoscopic surgery. Warmed intravenous fluid administration is sufficient to prevent hypothermia, but the additional active body warming method does not yield additional benefits. Placing a heated mattress beneath the body and covering the whole body is relatively effective in preventing hypothermia in colorectal laparoscopic surgery patients. Administering warmed intravenous fluids accelerates the postoperative recovery in patients undergoing urological surgery. Active warming does not provide additional benefits compared to conventional cotton blankets as long as standard hypothermia prevention procedures are properly implemented. Giving warmed intravenous fluids can reduce perioperative hypothermia incidents in elderly patients during bilateral hip replacement surgery. Operating room temperature modification combined with heated electric blankets is an effective method to maintain body temperature in elderly TURP patients. Warmed irrigation fluids are not better than room-temperature irrigation fluids in reducing perioperative hypothermia during arthroscopy procedures. Placing a heated mattress beneath the patient's body can reduce heat loss compared to using a heated blanket placed over the patient's body, and modifying the room temperature and giving warmed intravenous fluids before the surgical procedure can prevent hypothermia and enhance comfort in patients undergoing cesarean section.

CONCLUSION

Based on the review of the 12 articles, it can be concluded that several choices of

preventive measures for perioperative hypothermia in patients, such as giving warm intravenous fluids, warm irrigation fluids, warm electric blankets, warm mattresses, and operating room temperature modification, are reported to have significant benefits in some cases. At the same time, other studies suggest they might not have significant benefits. Additionally, there is no consensus among these articles on the most effective preventive measure for perioperative hypothermia, and none of the 12 articles have investigated the combined use of all three interventions to prevent perioperative hypothermia in patients.

The researchers hope that in the future, research on the effectiveness of giving blanket warmers, warm parenteral fluids, and modifying the operating room temperature will be carried out at once so that the outcome of the most effective treatment will be obtained to prevent perioperative hypothermia.

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