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Warming of intravenous and irrigation fluids for preventing inadvertent perioperative hypothermia (Review)

Campbell G, Alderson P, Smith AF, Warttig S

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[Intervention Review]

Warming of intravenous and irrigation fluids for preventing inadvertent perioperative hypothermia

Gillian Campbell[1], Phil Alderson[2], Andrew F Smith[3], Sheryl Warttig[2]

[1]Department of Anaesthesia, Ninewells Hospital, Dundee, UK. [2]National Institute for Health and Care Excellence, Manchester, UK. [3]Department of Anaesthesia, Royal Lancaster Infirmary, Lancaster, UK

Contact: Gillian Campbell, Department of Anaesthesia, Ninewells Hospital, Dundee, DD1 9SY, UK. gillian.campbell5@nhs.net.

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ABSTRACT

Background

Inadvertent perioperative hypothermia (a drop in core temperature to below 36°C) occurs because of interference with normal temperature regulation by anaesthetic drugs, exposure of skin for prolonged periods and receipt of large volumes of intravenous and irrigation fluids. If the temperature of these fluids is below core body temperature, they can cause significant heat loss. Warming intravenous and irrigation fluids to core body temperature or above might prevent some of this heat loss and subsequent hypothermia.

Objectives

To estimate the effectiveness of preoperative or intraoperative warming, or both, of intravenous and irrigation fluids in preventing perioperative hypothermia and its complications during surgery in adults.

Search methods

We searched the Cochrane Central Register of Controlled Trials (CENTRAL) (2014, Issue 2), MEDLINE Ovid SP (1956 to 4 February 2014), EMBASE Ovid SP (1982 to 4 February 2014), the Institute for Scientific Information (ISI) Web of Science (1950 to 4 February 2014), Cumulative Index to Nursing and Allied Health Literature (CINAHL) EBSCOhost (1980 to 4 February 2014) and reference lists of identified articles. We also searched the Current Controlled Trials website and ClinicalTrials.gov.

Selection criteria

We included randomized controlled trials or quasi-randomized controlled trials comparing fluid warming methods versus standard care or versus other warming methods used to maintain normothermia.

Data collection and analysis

Two review authors independently extracted data from eligible trials and settled disputes with a third review author. We contacted study authors to ask for additional details when needed. We collected data on adverse events only if they were reported in the trials.

Main results

We included in this review 24 studies with a total of 1250 participants. The trials included various numbers and types of participants. Investigators used a range of methods to warm fluids to temperatures between 37°C and 41°C. We found that evidence was of moderate quality because descriptions of trial design were often unclear, resulting in high or unclear risk of bias due to inappropriate or unclear randomization and blinding procedures. These factors may have influenced results in some way. Our protocol specified the risk of hypothermia as the primary outcome; as no trials reported this, we decided to include data related to mean core temperature. The only secondary outcome reported in the trials that provided useable data was shivering. Evidence was unclear regarding the effects of fluid warming on bleeding. No data were reported on our other specified outcomes of cardiovascular complications, infection, pressure ulcers, bleeding, mortality, length of stay, unplanned intensive care admission and adverse events.

Researchers found that warmed intravenous fluids kept the core temperature of study participants about half a degree warmer than that of participants given room temperature intravenous fluids at 30, 60, 90 and 120 minutes, and at the end of surgery. Warmed intravenous fluids also further reduced the risk of shivering compared with room temperature intravenous fluids

Investigators reported no statistically significant differences in core body temperature or shivering between individuals given warmed and room temperature irrigation fluids.

Authors' conclusions

Warm intravenous fluids appear to keep patients warmer during surgery than room temperature fluids. It is unclear whether the actual differences in temperature are clinically meaningful, or if other benefits or harms are associated with the use of warmed fluids. It is also unclear if using fluid warming in addition to other warming methods confers any benefit, as a ceiling effect is likely when multiple methods of warming are used.

PLAIN LANGUAGE SUMMARY

Warmed fluids for preventing hypothermia during operations

During surgical operations, patients may become cold as the result of a combination of factors including the action of anaesthetic drugs, the presence of uncovered skin and the administration of cold fluids into the veins or to parts of the body where surgery is taking place to wash them. Becoming cold during surgery can be unpleasant and can cause excessive shivering after the operation. It can also cause heart problems and bleeding problems and can contribute to problems with pressure sores and wound healing and longer hospital stay. This review seeks to find out whether warming the fluids given into veins or used to wash parts of the body may prevent patients from becoming cold.

We searched medical databases up until February 2014 to find studies comparing warmed fluids with unwarmed fluids and other methods of warming the patient. We found 24 relevant trials with 1250 adult patients undergoing all types of surgery. We did not include studies for which it was intended that the patient would become cold (such as to facilitate heart bypass surgery). We had intended to collect data on which patients became hypothermic (when their body temperature dropped to below 36 degrees Celsius), but no trials reported this, so we collected data on patient temperatures at various time points throughout surgery.

We found evidence of moderate quality showing that if patients had the fluids they were given into their veins warmed up, they were about half a degree Celsius warmer and shivered less than those who received unwarmed fluids; however, we were unable to show a significant difference in patients who received warmed fluids to wash out parts of their bodies.

We have demonstrated that warming fluids does keep adult patients warmer; however it is unclear whether this alone can make a difference in the severe complications that becoming cold may cause.

SUMMARY OF FINDINGS

Summary of findings for the main comparison.   Warmed intravenous fluids for preventing inadvertent perioperative hypothermia

Warmed intravenous fluids for preventing inadvertent perioperative hypothermia

Patient or population: patients with inadvertent perioperative hypothermia
Settings: any
Intervention: warmed IV fluids

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	Number of participants (studies)	Quality of the evidence (GRADE)
	Assumed risk	Corresponding risk			
	Control	Warmed IV fluids			
Core temperature at 30 minutes after induction degrees Celsius	Mean temperature at 30 minutes in the control groups was **36.0°C**	Mean temperature at 30 minutes in the intervention groups was **0.41 higher** (0.24 to 0.57 higher)	-	374 (9 studies)	⊕⊕⊕⊝ **Moderate**[a]
Core temperature at 60 minutes after induction degrees Celsius	Mean temperature at 60 minutes in the control groups was **35.9°C**	Mean temperature at 60 minutes in the intervention groups was **0.51 higher** (0.33 to 0.69 higher)	-	312 (8 studies)	⊕⊕⊕⊝ **Moderate**[a]
Core temperature at 90 minutes after induction degrees Celsius	Mean temperature at 90 minutes in the control groups was **35.9°C**	Mean temperature at 90 minutes in the intervention groups was **0.54 higher** (0.04 to 1.04 higher)	-	109 (3 studies)	⊕⊕⊕⊝ **Moderate**[a]
Core temperature at 120 minutes after induction degrees Celsius	Mean temperature at 120 minutes in the control groups was **35.8°C**	Mean temperature at 120 minutes in the intervention groups was **0.74 higher** (0.31 to 1.17 higher)	-	149 (4 studies)	⊕⊕⊕⊝ **Moderate**[a]
Core temperature at end of procedure/arrival to PACU - simple design degrees Celsius	Mean temperature at end of procedure/arrival to PACU - simple design in the control groups - was **35.7°C**	Mean temperature at end of procedure/arrival to PACU - simple design in the intervention groups was **0.63 higher** (0.28 to 0.98 higher)	-	682 (11 studies)	⊕⊕⊕⊝ **Moderate**[a]
Patient-reported outcome: shivering	**Study population**		**RR 0.39** (0.23 to 0.67)	428 (9 studies)	⊕⊕⊕⊝ **Moderate**[a]

various tools	**370 per 1000**	**144 per 1000** (85 to 248)			
	Median				
	440 per 1000	**172 per 1000** (101 to 295)			

*The basis for the **assumed risk** (e.g. median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
CI: Confidence interval; **RR:** Risk ratio.

GRADE Working Group grades of evidence.
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

[a]Most trials had unclear risk of bias with some likelihood of selection bias.

Summary of findings 2. Warmed irrigation fluids for preventing inadvertent perioperative hypothermia

Warmed irrigation fluids for preventing inadvertent perioperative hypothermia

Patient or population: patients with inadvertent perioperative hypothermia
Settings: any
Intervention: warmed irrigation fluids

Outcomes	**Illustrative comparative risks* (95% CI)**		**Relative effect (95% CI)**	**Number of participants (studies)**	**Quality of the evidence (GRADE)**
	Assumed risk	**Corresponding risk**			
	Control	**Warmed irrigation fluids**			
Temperature at end of procedure / arrival in PACU	Mean temperature at end of procedure/arrival to PACU - simple design in the control groups was **36.2°C**	Mean temperature at end of procedure/arrival to PACU in the intervention groups was **0.24 higher** (-0.06 to 0.55 higher)		310 (5 studies)	⊕⊕⊕⊝ **Moderate[a]**
Event rate of shivering various tools	**Mean control group risk from studies**		**RR 0.09** (0.01 to 1.55)	102 (2 studies)	⊕⊕⊕⊝ **Low[a,b]**
	100 per 1000	**9 per 1000**			

		(1 to 155)
	Control group risk from study with events	
	217 per 1000	**20 per 1000** (2 to 336)

*The basis for the **assumed risk** (e.g. median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
CI: Confidence interval; **RR:** Risk ratio.

GRADE Working Group grades of evidence.
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

[a]Most trials had unclear risk of bias, with some concern that selection bias may result.
[b]Quality of data has been downgraded further as the result of imprecision.

BACKGROUND

Inadvertent perioperative hypothermia occurs because of interference with normal temperature regulation by anaesthetic drugs and exposure of skin for prolonged periods. Several interventions have been proposed to maintain body temperature by reducing heat loss or causing active warming, or both.

Description of the condition

Regulation of temperature

Body temperature is usually maintained between 36°C and 37.5°C by balancing the body's heat losses and gains. Heat is gained as a product of metabolism, including that associated with muscular activity. Heat is lost through convection, conduction and radiation from the skin, by evaporation through sweating and, to a lesser extent, through the respiratory tract. To maintain this balance, information from temperature sensors in deep tissues and in the skin is processed in the brain. Heat loss is increased mainly through sweating and increased blood flow through the skin. Heat loss is reduced by reducing blood flow through the skin and by increasing heat production, mainly by inducing muscular activity (shivering) and increasing the basal metabolic rate (the background rate of energy used by a person at rest).

A useful concept involving heat regulation is that the body has a central compartment comprising the major organs, where temperature is tightly regulated, and a peripheral compartment, where temperature varies widely. Typically the periphery may be 2°C to 4°C cooler than the core compartment.

Effects of perioperative care and anaesthesia on thermal regulation

Exposure of the skin during the perioperative period can increase heat loss. Furthermore, cool intravenous and irrigation fluids and possibly inspired or insufflated (blown into body cavities) gases may directly cool patients. During exposure to cold, blood vessels are vasoconstricted (narrowed). Sedatives and anaesthetic agents inhibit the normal response to cold, effectively resulting in improved blood flow to the peripheries and increased heat loss. During the early part of anaesthesia, these effects are seen as a rapid decrease in core temperature caused by redistribution of heat from the central to the peripheral compartment. This early decrease is followed by a more gradual decline, reflecting ongoing heat loss. With epidural or spinal analgesia, peripheral blockade of vasoconstriction (narrowing of blood vessels) below the level of the nerve block results in vasodilatation (widening of blood vessels) and therefore greater ongoing heat loss and reduced heat production due to anaesthesia.

Risk of inadvertent perioperative hypothermia varies widely, for example, reports from audits describe a risk of 1.5% (Al-Qahtani 2011) to 20% (Harper 2008). Individuals who are most susceptible to heat loss include the elderly, patients with greater anaesthetic risk (American Society of Anesthesiologists (ASA) grade III to IV), people with cachexia (loss of body mass due to increased metabolic rate associated with cancer and other chronic conditions), burn victims, patients with hypothyroidism and those affected by corticoadrenal insufficiency.

Perioperative hypothermia complications

By altering various systems and functions, hypothermia may result in increased morbidity. Patients often comment on subsequent shivering upon awakening from anaesthesia as one of the most uncomfortable immediate postoperative experiences. Shivering originates as a response to cold and is the result of involuntary muscular activity with the objective of increasing metabolic heat (Sessler 2001).

Cardiac complications are the principal causes of morbidity during the postoperative phase. Prolonged ischaemia (reduced blood flow) is usually associated with cellular damage; for this reason, it seems likely that treating factors that can lead to such complications, like body temperature, is important. Hypothermia stimulates the release of noradrenaline, causing peripheral vasoconstriction and hypertension (Sessler 1991; Sessler 2001) - factors that favour or increase the chances of myocardial ischaemia (with reduced blood supply to the heart muscle). It appears that the increased risk of cardiac complications can be reversed by maintenance of normothermia (Frank 1997).

Some studies have shown that intraoperative hypothermia accompanied by vasoconstriction constitutes an independent factor that slows wound healing and increases the risk of surgical wound infection (Kurz 1996; Melling 2001).

Even moderate hypothermia (35°C) can alter physiological coagulation mechanisms by affecting platelet function and modifying enzymatic reactions. Decreased platelet activity results in increased bleeding and a greater need for transfusion (Rajagopalan 2008). Moderate hypothermia can also reduce the metabolic rate, manifesting as a prolonged effect of certain drugs that are used during anaesthesia and some uncertainty about their effects. This is particularly significant for elderly patients (Heier 1991; Heier 2006; Leslie 1995).

For the above reasons, inadvertent non-therapeutic hypothermia is considered an adverse effect of general and regional anaesthesia (Bush 1995; Putzu 2007; Sessler 1991). Body temperature is therefore frequently monitored to assist maintenance of normothermia during surgery and timely detection of the appearance of unintended hypothermia.

Description of the intervention

The objective of preserving patients' body heat during anaesthesia and surgery is to minimize heat loss by reducing radiation and convection from the skin, evaporation from exposed surgical areas and cooling caused by the introduction of cold intravenous fluids, irrigation fluids or cold gases for respiration or insufflation of body cavities.

During surgery, patients may receive large volumes of intravenous and irrigation fluids. If these fluids are cold or are provided at room temperature, they can cause significant heat loss. Warming these fluids to body temperature or slightly above by using prewarmed fluids or in-line warming can prevent some of this heat loss and subsequent hypothermia. These fluids may be warmed by a number of different mechanisms. Warming is part of a series of interventions provided to minimize heat loss that can be classified as follows:

1. Interventions to decrease redistribution of heat and subsequent heat loss (i.e. preoperative pharmacological vasodilatation and prewarming of the skin before anaesthesia).
2. Passive warming systems aimed at reducing heat loss and thus preventing hypothermia, including changes in environmental temperature, passive insulation by covering exposed body surfaces and closed or semi closed anaesthesia circuits with low flows.
3. Active warming systems aimed at transferring heat to the patient. The effectiveness of these systems might depend on various factors such as the design of the machine, the type of heat transfer performed, placement of the system over the patient and total body area covered in the heat exchange. The following systems are used for active warming: infrared lights, electric blankets, mattresses or blankets with warm water circulation, forced air warming or convective air warming transfer, warming of intravenous and irrigation fluids, warming and humidifying of anaesthetic air and warming of carbon dioxide (CO_2) in laparoscopic surgery.Intravenous nutrients have been proposed as a way of inducing increased metabolism and thus energy production.

Why it is important to do this review

The clinical effectiveness of the different types of patient warming devices that can be used has been assessed in a very extensive guideline commissioned by the National Institute for Health and Care Excellence (NICE) in the UK (NICE 2008). The report concludes that evidence of clinical effectiveness and cost-effectiveness is sufficient for recommendations to be made on the use of forced air warming to prevent and treat perioperative hypothermia. Nevertheless, most of the data have been derived from intermediate outcomes such as temperature. The search for evidence covered studies reported to the year 2007 and so needs updating.

This review is one of several reviews conducted to explore this topic (Alderson 2014; Campbell 2012a; Warttig 2012). Cochrane reviews have covered warming of gases used in minimally invasive abdominal surgery (Birch 2011) and use of warmed and humidified inspired gases in ventilated adults (Kelly 2010); a review on active warming is in planning stages (Urrútia 2011). Remaining areas to be covered include the following.

1. Preoperative or intraoperative thermal insulation, or both.
2. Preoperative or intraoperative warming, or both, of intravenous and irrigation fluids.
3. Preoperative or intraoperative pharmacological interventions, or both, including intravenous nutrients.
4. Postoperative treatment for inadvertent hypothermia.

OBJECTIVES

To estimate the effectiveness of preoperative or intraoperative warming, or both, of intravenous and irrigation fluids in preventing perioperative hypothermia and its complications during surgery in adults.

METHODS

Criteria for considering studies for this review

Types of studies

We included randomized controlled trials (RCTs) or quasi-randomized controlled trials (such as allocation by alternation) of interventions used in the preoperative period (one hour before induction of anaesthesia), the intraoperative period (total anaesthesia time) or both.

Types of participants

We included adults (over 18 years of age) undergoing elective or emergency surgery (including surgery for trauma) under general or regional (central neuraxial block) anaesthesia, or both.

The following groups were not covered.

1. Patients who had been treated with therapeutic hypothermia (e.g. use of cardiopulmonary bypass).
2. Patients undergoing operative procedures under local anaesthesia.
3. Patients with isolated severe head injury resulting in impaired temperature control.
4. Patients with burns who are undergoing surgery (e.g. for skin grafting).

Types of interventions

For the purposes of this review, 'warmed intravenous fluids' includes all methods of warming fluids before administration to the patient. 'Warmed irrigation fluids' includes any irrigation fluids administered to a body cavity that is warmed by any method, such as in-line fluid warmers or a warming cabinet. We included studies in which intravenous fluid warming was commenced up to one hour before anaesthesia was commenced. We expected use of irrigation fluids to be exclusive to the intraoperative period.

Comparisons of interest include warmed intravenous fluids and irrigation fluids versus the following.

1. Other warmed fluid interventions.
2. Standard care: cotton sheets or blankets, wool blankets, other non-reflective textiles.
3. Thermal insulation or passive warming: reflective and non-reflective blankets, suits and head covering.
4. Active warming: forced air warmers, electric mattresses and blankets, radiant heaters, warm water mattresses or blankets.
5. Preoperative or intraoperative warming, or both, of inspired and insufflated gases.
6. Preoperative and intraoperative pharmacological interventions including ketamine, calcium channel blockers, intravenous nutrients and opiates.

We excluded studies that provided multiple interventions such as fluid warming and reflective blanket versus no fluid warming and no reflective blanket. We included studies in which the difference between groups consisted of only one intervention, such as fluid warming and reflective blanket versus no fluid warming and reflective blanket. Intravenous fluids and irrigation fluids were regarded as two separate interventions.

Types of outcome measures

Primary outcomes

1. Risk of hypothermia at any point during surgery and temperature at the end of surgery or on admission to postanaesthesia care (mild, core temperature 35.0°C to 35.9°C; moderate, 34.0 °C to 34.9 °C; severe, < 34.0°C) measured at the direct tympanic membrane, bladder, oesophagus, pulmonary artery, nasopharynx or rectum. As no data were found on rates of hypothermia, we made a post hoc decision to use data reporting mean core temperatures at various time points during and after surgery.
2. Major cardiovascular complications (cardiovascular death, non-fatal myocardial infarction, non-fatal stroke and non-fatal cardiac arrest).

Secondary outcomes

1. Infection and complications of the surgical wound (wound healing and dehiscence), as defined by study authors.
2. Pressure ulcers, as defined by study authors.
3. Bleeding complications (blood loss, transfusions, coagulopathy).
4. Other cardiovascular complications (bradycardia, new arrhythmias).
5. Patient-reported outcomes (i.e. shivering, anxiety, comfort in postsurgical wake-up, etc.).
6. All-cause mortality at the end of the study.
7. Length of stay (in postanaesthesia care unit, hospital).
8. Unplanned high dependency or intensive care admission.
9. Adverse effects including temperature greater than 37.5°C, burns or feeling too hot.

Search methods for identification of studies

We conducted a single search across the suite of reviews on this topic (thermal insulation, warmed fluids and treatment of inadvertent perioperative hypothermia) with the following strategy, which was refined following a cross-check with studies included in the UK National Institute for Health and Care Excellence (NICE) guidelines on this topic (NICE 2008).

Electronic searches

To identify eligible randomized clinical trials, we searched the following electronic databases in June 2011, June 2012, February 2013, November 2013 and February 2014: the Cochrane Central Register of Controlled Trials (CENTRAL) in *The Cochrane Library* (February 2014; see Appendix 1); MEDLINE Ovid SP (1956 to February 2014; see Appendix 2); EMBASE Ovid SP (1982 to February 2014; see Appendix 3); the Institute for Scientific Information (ISI) Web of Science (1950 to February 2014; see Appendix 4); and the Cumulative Index to Nursing and Allied Health Literature (CINAHL EBSCOhost) (1980 to February 2014; see Appendix 5). In searching the databases, we used both subject headings and free text terms with no language or date restrictions. We adapted our MEDLINE search strategy for searching all other databases.

Searching other resources

To identify additional published, unpublished and ongoing studies, we searched the Science Citation Index and checked the references of relevant studies and reviews. We also searched the databases of ongoing trials, such as:

1. Current Controlled Trials; and
2. Clinicaltrials.gov.

Data collection and analysis

Selection of studies

For new searches, we (PA, GC and SW) independently sifted results of the literature searches to identify relevant studies such that each record was reviewed by two people. This was done once for all interventions, and the interventions were recorded on a data extraction form (see Appendix 6). If an article could not be excluded by review of the title and abstract, we retrieved a full copy of the article. We recorded reasons for exclusion and resolved disagreements about inclusion or exclusion by discussion involving another review author (AS) if necessary.

Data extraction and management

We (PA, GC and SW) independently extracted relevant data onto a data extraction form and resolved disagreements by discussion or by consultation with a clinical expert (AS).

One review author (GC) entered data into RevMan, and SW and PA checked for transcription errors.

We extracted the following data.

1. General information, such as title, study authors, contact address, publication source, publication year and country.
2. Methodological characteristics and study design.
3. Clinical and demographic characteristics of study participants.
4. Descriptions of the intervention and the control, including information on type of surgery, duration, surgical team experience and prophylactic antibiotic administration, when available.
5. Outcome measures, as noted above.
6. Results for each study group.

Assessment of risk of bias in included studies

We (PA, GC and SW) independently assessed risk of bias for each study (those included in the NICE guideline and newly identified studies) using the criteria outlined in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011). We resolved disagreements by discussion or by involving a third assessor (AS).

We considered trials as having low risk of bias if all of the following criteria were assessed as adequate. We considered trials as having high risk of bias if one or more of the following criteria were not assessed as adequate.

1. Random sequence generation (checking for possible selection bias). We described for each included study the method used to generate the allocation sequence when reported in sufficient detail to allow an assessment of whether it should produce comparable groups. We assessed the methods as adequate (any truly random process, e.g. random number table, computer random number generator); inadequate (any non-random process, e.g. odd or even date of birth, hospital or clinic record number); or unclear.

2. Allocation concealment (checking for possible selection bias). We described for each included study the method used to conceal the allocation sequence when reported in sufficient detail and determined whether intervention allocation could have been foreseen in advance of or during recruitment, or changed after assignment. We assessed the methods as adequate (e.g. telephone or central randomization, consecutively numbered sealed opaque envelopes); inadequate (open random allocation, unsealed or non-opaque envelopes, alternation, date of birth); or unclear.
3. Blinding of participants and personnel (checking for possible performance bias). We described for each included study the methods used, if any, to blind participants and personnel from knowledge of which intervention a participant received. We also provided information on whether the intended blinding was effective. When blinding was not possible, we assessed whether lack of blinding was likely to have introduced bias. Blinding was assessed separately for different outcomes or classes of outcomes. We assessed the methods as adequate; inadequate; or unclear.
4. Blinding of outcome assessment (checking for possible detection bias). We described for each included study the methods used, if any, to blind outcome assessors from knowledge of which intervention a participant received. We also provided information on whether the intended blinding was effective. Blinding was assessed separately for different outcomes or classes of outcomes. We assessed the methods as adequate; inadequate; or unclear.
5. Incomplete outcome data (checking for possible attrition bias through withdrawals, dropouts and protocol deviations). We described for each included study and for each outcome the completeness of data, including attrition and exclusions from the analysis. We stated whether attrition and exclusions were reported, the numbers included in the analysis at each stage (compared with the total number of randomly assigned participants), reasons for attrition or exclusion when reported and whether missing data were balanced across groups or were related to outcomes. When sufficient information was reported or supplied by the trial authors, we planned to include missing data in the analyses. We considered intention-to-treat (ITT) analysis as adequate if all dropouts or withdrawals were accounted for, and as inadequate if the number of dropouts or withdrawals was not stated, or if reasons for dropouts or withdrawals were not stated.
6. Selective reporting. We reported for each included study which outcomes of interest were and were not reported. We did not search for trial protocols.
7. Other bias. We described for each included study any important concerns that we have about other possible sources of bias. We assessed whether each study was free of other problems that could put it at risk of bias: yes; no; or unclear.

With reference to (1) to (7) above, we considered the likely magnitude and direction of bias when study findings are interpreted. We planned to explore the impact of the level of bias by undertaking sensitivity analyses (see Sensitivity analysis).

The quality of data for each outcome was assessed according to GRADE (Grades of Recommendation, Assessment, Development and Evaluation) principles and was ranked as high, moderate, low or very low. To make this assessment, we considered risk of bias, imprecision, inconsistency, indirectness and publication bias. Quality of the evidence was downgraded from high if flaws were identified in any of these domains.

Measures of treatment effect

We analysed dichotomous data using risk ratios (RRs) and continuous data using mean differences (MDs). For both, we used 95% confidence intervals (CIs) around the point estimate.

Unit of analysis issues

All trials were randomized by individual, and outcome data were reported for participants.

Dealing with missing data

We analysed available data on an ITT basis.

Assessment of heterogeneity

Before obtaining pooled estimates of relative effects, we carried out a statistical heterogeneity analysis by assessing the value of the I^2 statistic, thereby estimating the percentage of total variance across studies that is due to heterogeneity rather than to chance (Higgins 2002). We considered a value greater than 30% as a sign of important heterogeneity, and if present, we sought an obvious explanation for the heterogeneity by considering the design of the trials. We also considered heterogeneity in terms of the clinical importance of variations in temperature and the overall pattern of direction of effect.

Assessment of reporting biases

We recorded the number of included studies that reported each outcome but did not use statistical techniques to try to identify the presence of publication bias. We planned that if we identified more than 10 studies for a comparison, we would generate a funnel plot and analyse it by visual inspection.

Data synthesis

We used DerSimonian and Laird random-effects model meta-analyses of risk ratios in RevMan 5.3 for dichotomous data and mean differences for continuous data. Pooled estimates had a 95% confidence interval

Subgroup analysis and investigation of heterogeneity

We performed subgroup analysis for pregnant women. Data were insufficient to allow additional subgroup analyses (such as type/duration of anaesthesia, timing of application of the intervention, participant age, American Society of Anesthesiologists (ASA) score, urgency of surgery, type of surgery, prewarmed versus in-line warmed fluids and temperature of the fluid).

Sensitivity analysis

We planned to carry out sensitivity analysis according to study methodological quality (for trials with low risk of bias) but did not complete this because of lack of variation in study quality.

Summary of findings tables

We constructed a 'Summary of findings' table by choosing seven of the 10 outcomes for which we found the most clinically useful data, but including the two primary outcomes, irrespective of whether we found any useful data.

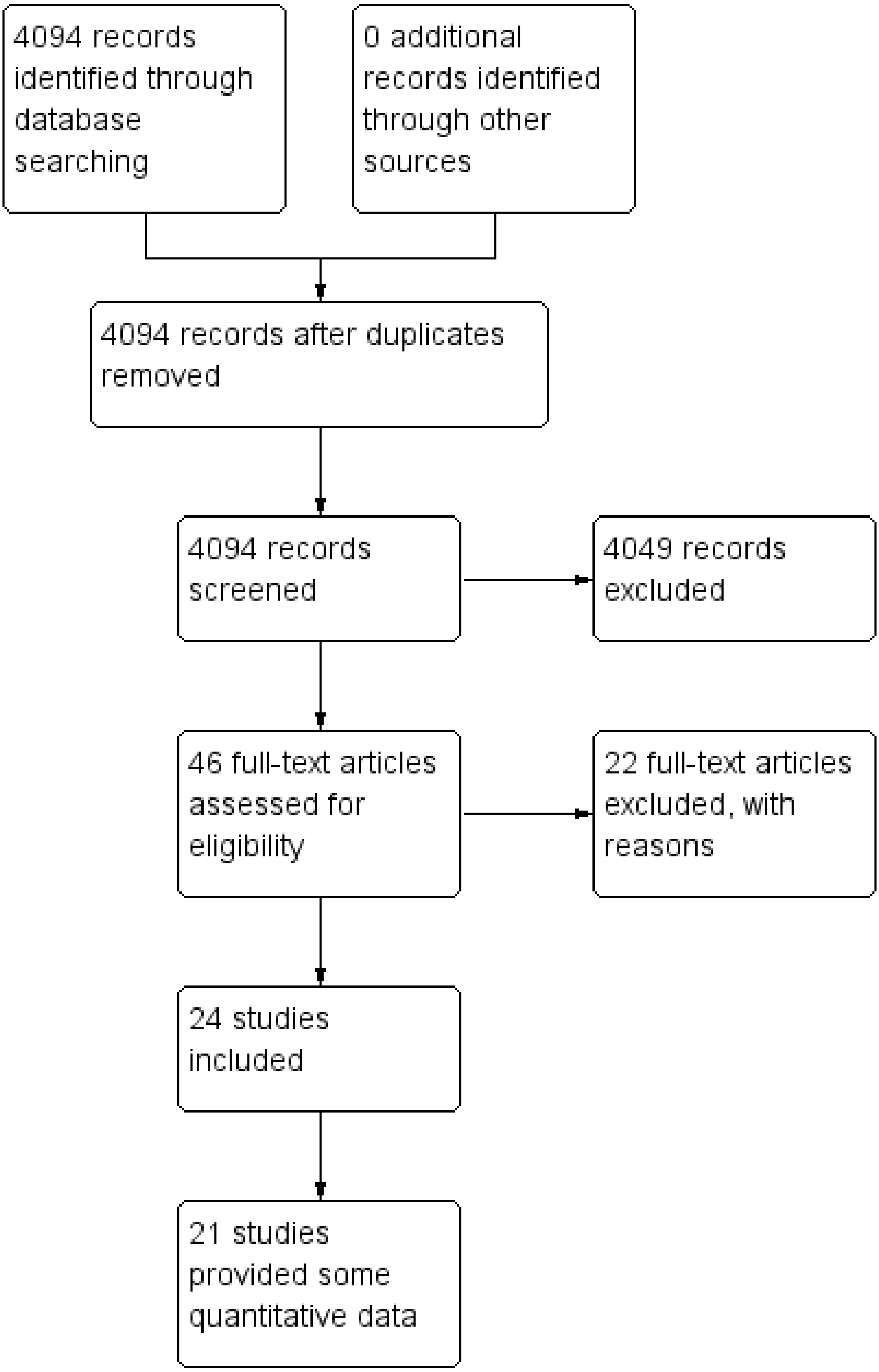
RESULTS

Description of studies

Results of the search

We carried out the search for this review as part of a single search for three related reviews on prevention and treatment of perioperative hypothermia (Alderson 2014; Campbell 2012a; Warttig 2012). Figure 1 summarizes the search results, combined for searches conducted in June 2011, June 2012, February 2013, November 2013 and February 2014. These searches identified a total of 4094 hits. For this review, we retrieved 46 papers for consideration and included 24 studies in the review, 21 of which provided some quantitative data.

Figure 1. Study flow diagram.



We tried to contact the authors of three studies (Andrzejowski 2010; Demir 2002; Moore 1997) to clarify details but were unable to contact them or found that they were not able to provide further information.

Included studies

A total of 24 studies with 1250 participants are included in this review, but only 21 of these contributed useable quantitative outcome data to the analyses (1150 participants). The other three studies presented data as inadequately labelled graphs, percentage changes in temperature or differences between baseline and minimum temperature. We have listed the excluded studies in the Excluded studies section. A total of 1190 participants were involved in the studies included in the analyses. Nine studies (Camus 1996; Demir 2002; Kelly 2000; Moore 1997; Shao 2012; Smith 1998b; Xu 2010; Yamakage 2004; Yokoyama 2009) had 20 or fewer participants in each arm. Two studies were conducted in the UK, five in the USA, two in Japan, three in Korea, two in China, two in Iran and one in each of France, Brazil, Turkey, Denmark, Canada, Germany and Nigeria. All surgeries were elective and were provided for patients classified as ASA I to III. A mix of general and regional anaesthesia was reported. Surgeries were both major and minor and included abdominal, gynaecological, urological and orthopaedic. One study (Jeong 2008) included participants who underwent off-pump cardiac surgery. Most studies excluded patients with medical morbidity, such as thyroid disease, acute illness and central causes for abnormal temperature regulation.

Seventeen studies contributed data on comparisons of warmed and unwarmed intravenous fluids (Andrzejowski 2010; Camus 1996; Chung 2012; De Mattia 2013; Hasankhani 2007; Jeong 2008; Jorgenson 2000; McCarroll 1986; Muth 1996; Oshvandi 2011; Shao 2012; Smith 1998a; Smith 1998b; Woolnough 2009; Xu 2010; Yamakage 2004, Yokoyama 2009). Six of these included 372 women (Chung 2012; Jorgenson 2000; McCarroll 1986; Oshvandi 2011; Woolnough 2009; Yokoyama 2009) undergoing elective caesarean section and formed a separate subgroup. Yamakage 2004 was the only study that looked at hydroxyethyl starch solutions as well as haemodilutional autotransfusion. We included these data in the meta-analysis, but it is worth noting that starch solutions have been withdrawn from use in the UK.

Five studies compared warmed and unwarmed irrigation fluids for a variety of operations - arthroscopic knee surgery (Kelly 2000), arthroscopic shoulder surgery (Kim 2009), gynaecological laparoscopy (Moore 1997) and transurethral resection of the prostate (Jaffe 2001). One trial of 160 participants undergoing elective abdominal procedures (Shao 2012) had a complex design, with 32 treatment groups, each receiving some combination of five different interventions. From this, we pooled results in which intravenous fluid or warmed irrigation fluid was the only difference. Eligible studies were insufficient to allow any subgroup analysis in the warmed irrigation comparison.

For one trial (Woolnough 2009), we pooled two groups with warmed fluid - one with pre-warmed fluid and the other with in-line fluid warming. This was also the case for Andrzejowski 2010, although those data were unsuitable for meta-analysis.

A major issue was that a wide range of co-interventions were used in the studies, such as active warming or warmed inspired gases, but we included only studies for which warmed fluid was found to be the only difference between the two groups. A wide range of methods of warming included prewarmed fluids and various devices for in-line warming; fluids were warmed to a range of temperatures between 37°C and 41°C. All methods of warming and temperatures were considered as a single group. (See Characteristics of included studies for details of studies.)

Excluded studies

We excluded 22 studies largely because reading of full text revealed that the comparison was not included in the review. (See Characteristics of excluded studies for details of studies.)

Ongoing studies

We identified no ongoing studies.

Studies awaiting classification

We identified no studies awaiting classification.

Risk of bias in included studies

We have presented summaries of the judgements for risk of bias in Figure 2 and Figure 3. We have provided details of included studies in the Characteristics of included studies section.

Figure 2. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

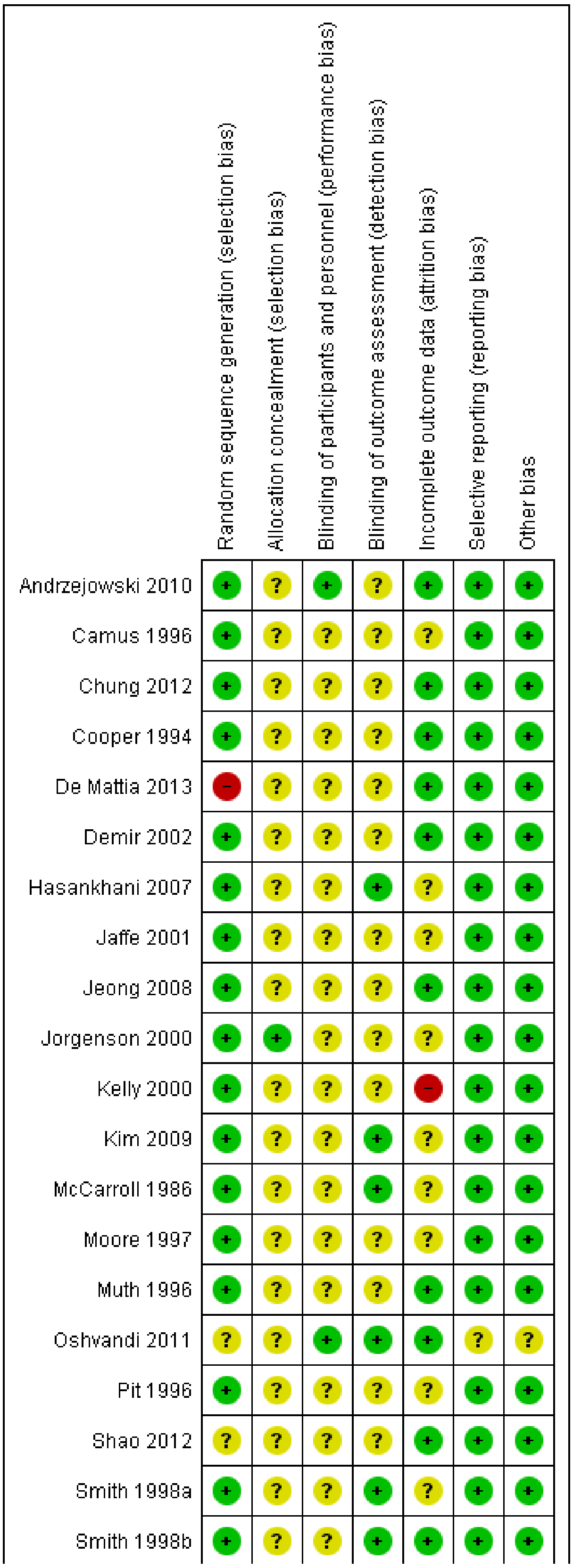


Figure 2. (Continued)

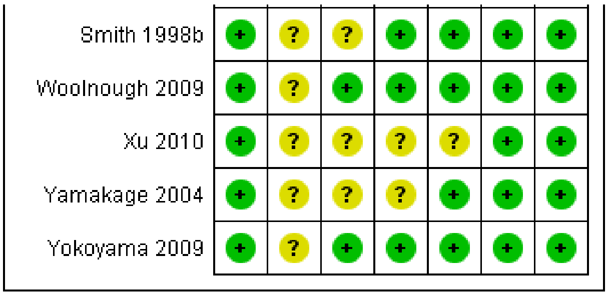
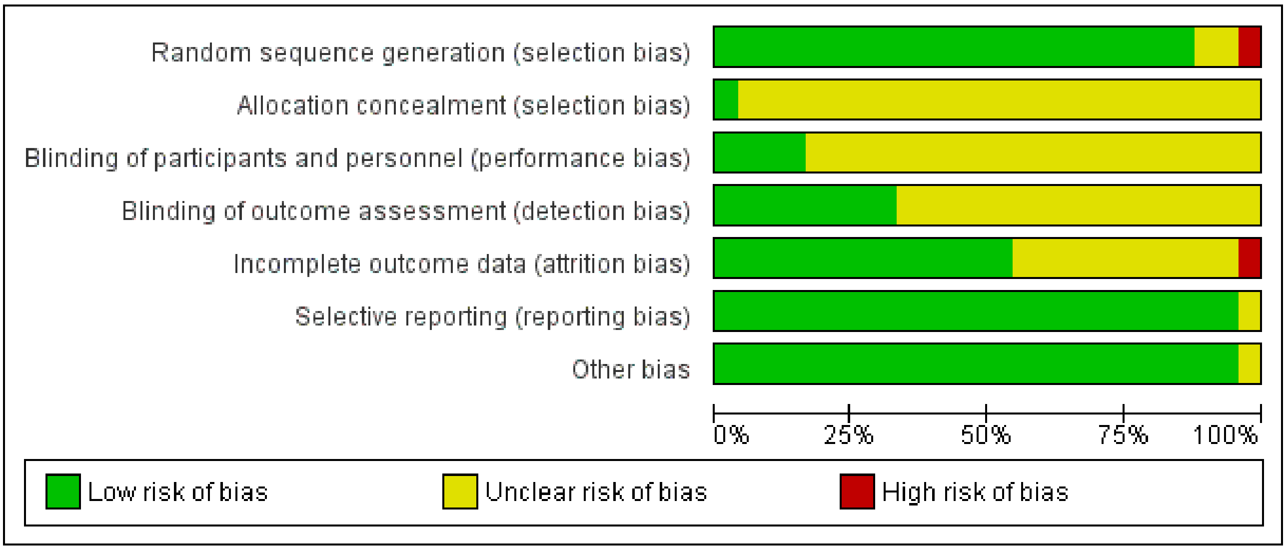


Figure 3. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.



Allocation

Reporting of allocation concealment was largely unclear, making it difficult for review authors to come to an overall view of the likelihood of selection bias. No obvious imbalances in the groups can be seen in the tables of demographic data, but this does not rule out selection bias.

Blinding

We made an overall judgement about performance and detection bias, as no clear indication suggested that blinding was different for different outcomes. Most trials did not report blinding, perhaps because it is difficult to blind participants (particularly under regional analgesia only) and clinicians to the intervention used.

Incomplete outcome data

The trials were of fairly short duration and were conducted in highly controlled environments; attrition did not occur to any serious extent. Risk of bias due to attrition was therefore low.

Selective reporting

We found no definitive evidence of selective reporting but did not seek out trial protocols. Few of the outcomes that we hoped to find were reported, but we are unclear whether the data were collected.

Other potential sources of bias

We identified no other definitive sources of potential bias.

Effects of interventions

See: **Summary of findings for the main comparison** Warmed intravenous fluids for preventing inadvertent perioperative hypothermia; **Summary of findings 2** Warmed irrigation fluids for preventing inadvertent perioperative hypothermia

Warmed intravenous fluids versus room temperature intravenous fluids

Primary outcomes

Risk of hypothermia

This outcome was not reported by any of the included trials. We made a post hoc decision to use mean core temperature as our primary outcome (Differences between protocol and review).

Major cardiovascular outcomes

This outcome was not reported by any of the included trials.

Core temperature

Our protocol specified risk of hypothermia as the primary outcome. As no trials reported this, we decided to include data related to mean core temperature instead, as this was reported by most of the included studies. We decided to summarize data by presenting weighted mean difference at 30, 60, 90 and 120 minutes after induction of anaesthesia and at the end of surgery/admission to the postanaesthesia care unit (PACU).

Important heterogeneity was present in most of the analyses (ranging from I^2 = 58% to 94%), but we decided to continue with pooling of results, as the absolute differences in individual trial results were relatively small and were in the same direction of effect. We also performed sensitivity analysis by removing outlying studies and found that inclusion or exclusion of outliers did not change the conclusions we would draw. Thus all included studies remained in all analyses.

30 minutes after induction

Nine trials (Camus 1996; McCarroll 1986; Oshvandi 2011; Smith 1998a; Smith 1998b; Woolnough 2009; Xu 2010; Yamakage 2004; Yokoyama 2009) (n = 374) compared warmed intravenous fluids versus room temperature intravenous fluids at 30 minutes after induction of anaesthesia (Analysis 1.1). Overall, among people undergoing all types of surgery, those receiving warmed intravenous fluids had a higher core temperature at 30 minutes than those receiving room temperature intravenous fluids, but this difference was less than half a degree (MD = 0.41°C, 95% CI 0.24 to 0.57; moderate-quality evidence). Important heterogeneity was present in the analysis (I^2 = 88%, P value < 0.001).

It was possible to perform planned subgroup analyses for this time point, but lack of data meant that this was possible only for the subgroup of women undergoing elective caesarean section, not for men and women undergoing all other types of surgery. Tests of subgroup differences showed no significant differences between the two subgroups (P value = 0.75).

60 minutes after induction

Eight trials (Camus 1996; Jeong 2008; Smith 1998a; Smith 1998b; Woolnough 2009; Xu 2010; Yamakage 2004; Yokoyama 2009) (n = 312) compared warmed intravenous fluids versus room temperature intravenous fluids at 60 minutes after induction of anaesthesia (Analysis 1.2). Overall, among people undergoing all types of surgery, those receiving warmed intravenous fluids were about half a degree warmer at 60 minutes than those receiving room temperature intravenous fluids (MD = 0.51°C, 95% CI 0.33 to 0.69; moderate-quality evidence). Again, important heterogeneity was present in the analysis (I^2 = 83%, P value < 0.001).

It was possible to perform planned subgroup analyses, but lack of data meant that this was possible only for a subgroup of women undergoing elective caesarean section, not for men and women undergoing all other types of surgery. Tests of subgroup differences showed no statistically significant differences between the two subgroups (P value = 0.69).

Demir 2002 also reported core temperature at 60 minutes after induction of anaesthesia for the warmed intravenous fluids group (n = 9, mean = 35.4°C) compared with the room temperature intravenous fluids group (n = 9, mean 35°C) but did not report measures of dispersion to enable inclusion in the meta-analysis.

90 minutes after induction

Three trials (Camus 1996; Smith 1998a; Xu 2004) (n = 109) compared warmed intravenous fluids versus room temperature intravenous fluids at 90 minutes after induction of anaesthesia (Analysis 1.3). A statistically significant difference in core temperature was noted, with participants in the warmed intravenous fluids group about half a degree warmer than those in the room temperature group (MD = 0.54°C, 95% CI 0.04 to 1.04; moderate-quality evidence).

Demir 2002 also reported core temperature at 90 minutes after induction of anaesthesia for the warmed intravenous fluids group (n = 9, mean = 35.4°C) compared with the room temperature intravenous fluids group (n = 9, mean 34.8°C) but did not report measures of dispersion to enable inclusion in the meta-analysis.

120 minutes after induction

Four trials (Camus 1996; Jeong 2008; Smith 1998a; Xu 2004) (n = 149) compared warmed intravenous fluids versus room temperature intravenous fluids at 120 minutes after induction of anaesthesia (Analysis 1.4). A statistically significant difference in core temperature was noted between the two groups, with participants in the warmed intravenous fluids group over half a degree warmer than those in the room temperature group (MD = 0.74°C, 95% CI 0.31 to 1.17; moderate-quality evidence). Important heterogeneity was present in the analysis (I^2 = 79%, P value < 0.001).

Demir 2002 also reported core temperature at 120 minutes after induction of anaesthesia for the warmed intravenous fluids group (n = 9, mean = 35.3°C) compared with the room temperature intravenous fluids group (n = 9, mean 34.6°C) but did not report measures of dispersion to enable inclusion in the meta-analysis.

End of surgery/arrival to post anaesthesia care unit (PACU)

A total of 11 trials (Camus 1996; De Mattia 2013; Hasankhani 2007; Jorgenson 2000; Muth 1996; Oshvandi 2011; Shao 2012; Smith 1998a; Smith 1998b; Xu 2010; Yokoyama 2009) (n = 682) compared warmed intravenous fluids versus room temperature intravenous fluids at end of surgery/arrival to the PACU (Analysis 1.5). A statistically significant difference in core temperature was noted between the two groups, with those in the warmed intravenous fluids group over half a degree warmer than those in the room temperature group (MD = 0.63°C, 95% CI 0.28 to 0.98; moderate-quality evidence). Important heterogeneity was evident in the result (I^2 = 96%, P value < 0.001).

Subgroup analysis was possible for women undergoing elective caesarean section compared with men and women undergoing all other types of surgery. Tests of subgroup differences showed no significant differences between the two subgroups (P value = 0.78).

Andrzejowski 2010 reported the core temperature difference at the end of surgery/arrival to PACU for intravenous fluids at room temperature (n = 25, median = 35.7°C), warmed by an in-line warmer (n = 25, median = 35.9°C), and warmed by a warming cabinet (n = 26, 36.1°C). Insufficient data were provided by the study to enable pooling of data in the main meta-analysis, but the study authors reported no significant differences in core temperature between groups (P value = 0.073).

Secondary outcomes

Bleeding complications

Four trials (Jeong 2008; Smith 1998a; Smith 1998b; Yamakage 2004) reported mean blood loss (Analysis 1.7). We did not pool these results because of the wide range of estimated mean differences and the high heterogeneity.

Woolnough 2009 reported blood loss in the room temperature group (n = 25, median = 0.5 L, range = 0.3 to 1.0), the cabinet-warmed group (n = 25, median = 0.5 L, range = 0.3 to 1.5) and the hotline-warmed group (n = 25, median = 0.5 L, range = 0.4 to 2.6).

Muth 1996 reported red cells transfused via cell saver in the warmed intravenous fluids group (n = 25) and in the group that received intravenous fluids delivered at room temperature (n = 25). No statistically significant differences were found between the two groups (MD = -38 mL, 95% CI -357.61 to 281.61).

Yokoyama 2009 reported combined blood/amniotic fluid loss in the warmed fluid group (n = 15) compared with the room temperature intravenous fluids group (n = 15) and found no statistically significant differences between the two groups (MD = -176 mL, 95% CI -470.29 to 118.29).

Shivering

Nine trials (Andrzejowski 2010; Camus 1996; Chung 2012; Hasankhani 2007; McCarroll 1986; Smith 1998a; Smith 1998b; Woolnough 2009; Xu 2004) (n = 428) comparing warmed intravenous fluids versus room temperature intravenous fluids reported shivering (Analysis 1.6). A statistically significant difference was noted between groups, with people in the warmed fluids group having lower risk of shivering than those in the room temperature group (RR 0.39, 95% CI 0.23 to 0.67; moderate-quality evidence). Heterogeneity was not statistically significant but reached our prespecified threshold (I^2 = 36%, P value = 0.13).

Subgroup analysis was possible for women undergoing elective caesarean section compared with men and women undergoing all other types of surgery. Tests of subgroup differences showed a reduction in shivering in the warmed fluids group, but this finding was not statistically significant (P value = 0.06).

Other secondary outcomes

No data were available on the following outcomes: infections and complications of the wound; pressure ulcers; other cardiovascular complications; all-cause mortality; length of stay; unplanned high dependency or intensive care admission; and adverse effects.

Warmed irrigation fluids versus room temperature irrigation fluids

Primary outcomes

Risk of hypothermia

This outcome was not reported by any of the included trials. We made a post hoc decision to use mean core temperature as our primary outcome. (See Differences between protocol and review.)

Major cardiovascular complications

This outcome was not reported by any of the included trials.

Core temperature

Our protocol specified risk of hypothermia as the primary outcome. As no trials reported this, we decided to include data related to mean core temperature instead.

Moore 1997 reported core temperature at various time points, but insufficient information on group size at the different time points was available, preventing meaningful analysis of these data.

60 minutes after induction

Kim 2009 reported mean core temperature for warmed irrigation fluid in comparison with room temperature irrigation at 60 minutes after induction of anaesthesia. A statistically significant difference in favour of warmed irrigation fluid was found (MD = 0.45°C, 95% CI 0.25 to 0.65; moderate-quality evidence).

Mean core temperature at end of surgery/arrival to PACU

Five trials (Jaffe 2001; Kelly 2000; Kim 2009; Moore 1997; Shao 2012) (n = 310) compared warmed irrigation fluids versus room temperature irrigation fluids (Analysis 2.1) and showed no statistically significant differences in core body temperature. Important heterogeneity was present (I^2 = 94%, P value < 0.001), but we decided to continue with pooling of results, as the absolute differences in individual trial results were relatively small and were generally in the same direction of effect. Inclusion or exclusion of an outlier did not change the conclusions that we would draw. Thus all included studies remained in the final analysis.

Secondary outcomes

Bleeding complications

Kim 2009 reported a mean decrease in haemoglobin for warmed irrigation fluid (n = 23) in comparison with room temperature irrigation fluid (n = 23). No statistically significant differences were found (MD -0.30 g/dL, 95% CI -0.68 to 0.08).

Patient-reported outcome: shivering

Two trials (Jaffe 2001; Kim 2009) compared warmed irrigation fluids versus room temperature irrigation fluids for rates of shivering (Analysis 2.2). No significant difference was noted between groups.

Secondary outcomes not reported

None of the included trials reported the following outcomes: infection and complications of the surgical wound; pressure ulcers; other cardiovascular complications; all-cause mortality; length of stay; unplanned high dependency or intensive care admission; and adverse effects.

Warmed fluids versus active warming

Primary outcomes

Rate of hypothermia

None of the included trials reported this outcome.

Major cardiovascular outcomes

None of the included trials reported this outcome.

Core temperature

Only one trial (Shao 2012) reported this outcome in relation to core temperature at end of surgery. In this trial, 80 participants were exposed to warm intravenous fluids, warm irrigation fluids or active warming (with or without additional interventions). We pooled the results for participants randomly assigned to any warm intravenous or irrigation fluids and compared them with those for participants randomly assigned to active warming. Overall, a statistically significant difference was noted between warmed fluids and active warming, favouring active warming. Participants in the warmed fluids group were about half a degree colder than those in the active warming group (MD -0.49, 95% CI -0.70 to -0.28).

Secondary outcomes

Shivering

Chung 2012 compared preoperative warming versus warmed intravenous fluids or versus a forced air warmer. The incidence of shivering was 2/15 in the warmed intravenous fluids group and 3/15 in the forced air warmer group. No difference was observed between the two groups in the number of people shivering.

Bleeding complications

Chung 2012 compared the effects of preoperative warming versus warmed intravenous fluids (n = 15) or versus a forced air warmer (n = 15) on mean blood loss. No statistically significant differences in blood loss were noted between the two groups (MD -80 mL, 95% CI -180.20 to 20.20).

DISCUSSION

Key data are summarized in Summary of findings for the main comparison and Summary of findings 2.

Summary of main results

No evidence was available on our two primary outcomes: 'risk of hypothermia' and 'major cardiovascular complications'. As a result of this, we made a post hoc decision to include evidence related to mean core temperature at different time points during surgery.

Warmed intravenous fluids

We found that warmed intravenous fluids kept people significantly warmer than room temperature intravenous fluids at 30, 60, 90 and 120 minutes after induction of anaesthesia, and at end of surgery/ arrival to the postanaesthesia care unit (PACU). Data quality was ranked as moderate largely as the result of incomplete reporting of trial design and resultant unclear risk of bias. A subgroup analysis was performed on participants undergoing caesarean section who showed a reduction in core temperature similar to the non-caesarean section group and a non-statistically significant reduction (P value = 0.06) in shivering in the warmed fluid group. Both pregnancy itself and rapid infusion of fluids may have affected these results.

The degree of warming produced by warming fluids may be related to both the volume infused and the rate at which it is delivered. Volume infused and duration of surgery are noted in the Description of studies. Generally, participants undergoing caesarean section had greater fluid turnover (approximately 2600 mL/h) than was seen in non-caesarean section participants, whose fluid turnovers ranged from 600 mL/h to 1000 mL/h, with only Muth 1996 reporting higher rates of infusion, at around 1200 mL/h. Subgroup analysis on fluid turnover alone was not possible; however, the subgroup of participants who underwent caesarean section did tend to have greater turnover of fluid during a relatively short procedure but did not show a statistically significant difference in core temperature or rates of shivering.

The magnitude of temperature difference at the end of surgery was only 0.6°C, and the difference did not reach 0.5°C until the 60-minute time point. This difference is small and may have only limited clinical significance. Core temperatures do drop into the mild hypothermic range at 60 minutes (35.9°C) and to 35.7°C at the end of surgery, so even such a small increase in temperature does render the patient normothermic. Significant heterogeneity was noted between the studies, but variations in absolute temperature differences were small and the direction of effect was largely consistent. Variation in the background interventions used in these studies is a possible cause of the heterogeneity, but we were unable to explore this because of the relatively small number of studies identified.

Shivering is a clinically significant problem - it is uncomfortable for the patient, and the increase in metabolic demand may cause cardiovascular complications. We were able to demonstrate a significant reduction in shivering; however, we were unable to make any judgement on the severity of shivering, as no two studies used the same scale to assess shivering. We considered the data as indicating presence or absence of shivering, even though some studies used more complex rating scales; for this reason, the quality of data is rated as moderate.

The effect of warmed fluids on bleeding complications was unclear, as this outcome was not reported by all studies. Individual trials reporting this outcome used different measures of bleeding complications and were highly heterogeneous, which prevented meaningful analysis and interpretation.

Warmed irrigation fluids

No statistically significant difference in body temperature was noted between warmed and room temperature fluid groups. The body cavity that is irrigated, along with temperature, volume and duration of irrigation, is likely to affect the core temperature; however we had insufficient data to perform a meaningful analysis that would address these factors.

Summary

Overall, these results suggest that warmed intravenous fluids do keep patients significantly warmer than room temperature fluids, but the actual difference in temperature conferred by these methods is only about a half degree Celsius, and so the clinical significance of such a small difference is unclear. A 'ceiling' effect may occur when multiple methods are used to keep patients warm, for example, the use of three warming methods may not result in patients being three times as warm as with a single warming intervention. This 'ceiling' effect may mean that the addition of warmed fluids to one or more other warming methods may not actually have a meaningful impact on core temperature. We are unable to comment further on combinations of warming methods, as we included studies that used several different background warming methods but analysed groups for which the only difference between groups was warming of fluids. We excluded from our analyses many studies that compared multiple warming interventions.

Similar results were found for risk of shivering and for core temperature. Participants in the room temperature fluids groups had greater risk of shivering than those in the warmed fluids groups, although this finding was not statistically significant.

Warmed fluids given at around body temperature have very few clinically relevant side effects, and none were reported. Overwarming and thermal discomfort are potential problems but were not reported, so no further analyses could be performed.

Overall completeness and applicability of evidence

Participant populations were fairly representative of people undergoing a range of elective surgical procedures with various anaesthetic techniques and co-interventions aimed at reducing hypothermia. Thus the evidence does seem directly applicable to current practice. However, we could not use several trials (Cooper 1994; Demir 2002; Pit 1996), as they did not report relevant outcomes, and no data were available on any of our prespecified primary outcomes or on most of our secondary outcomes.

Quality of the evidence

Reporting of trial design was largely incomplete, leading to difficulty in interpreting the risk of bias. It would be difficult to blind participants and practitioners to the intervention used, but it is not clear how great an effect this may have had on temperature readings made by healthcare professionals. Attrition was generally low, as would be expected in short-term studies. As we were unable to then make a clear assessment of risk of bias, the quality of data was considered moderate for all core temperature outcomes.

Reporting of shivering varied, and several different shivering scales were used, so even though we analysed shivering as present or absent, we ranked data quality as moderate or low. Bleeding complications were inconsistently reported, and heterogeneity was significant, so the quality of the data was considered very low and results were not pooled.

Potential biases in the review process

After the data were reviewed, several decisions were made regarding handling of the data and investigation of heterogeneity, and this may introduce bias. As no data were reported in the trials, we changed our primary outcome to mean core temperature (Differences between protocol and review). Therefore we have been cautious about interpretation of the data.

Agreements and disagreements with other studies or reviews

The National Institute for Health and Care Excellence (NICE) guideline on perioperative hypothermia recommends fluid warming for volumes greater than 500 mL and for surgery durations longer than 30 minutes, but the preferred method of warming and the temperature to which fluid should be warmed are not stated (NICE 2008). Our findings do not contradict this. The NICE guideline was based on modelling of the effects of temperature differences on patient-important outcomes and on an economic analysis, and we have not attempted to replicate this.

AUTHORS' CONCLUSIONS

Implications for practice

Warm intravenous and/or irrigation fluids have a beneficial effect on the patient's core temperature during surgery, but it is unclear whether the benefit offered is clinically important. When warmed fluids are used in addition to other methods of patient warming, the additional benefit conferred by warm fluid is unclear.

Implications for research

Any further trials in this area should be conducted at a high level of quality and should collect outcome data that easily translate into important patient-relevant outcomes. As several other competing interventions are available, the design of further trials should be based on an overview of all relevant comparisons.

ACKNOWLEDGEMENTS

This review builds on the work undertaken as part of the NICE clinical guideline on inadvertent perioperative hypothermia, and we would like to acknowledge the work of the NICE group.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Andrzejowski 2010

Methods	Single-centre study from the UK
Participants	82 patients randomly assigned (6 later excluded) undergoing general anaesthesia for day case surgery anticipated to last < 30 minutes; approx 34% male; mean age approx 40 years Exclusion criteria: laparoscopic surgery, surgery with irrigation fluids, estimated blood loss > 200 mL, use of ACE inhibitors or calcium channel antagonists
Interventions	Room temperature IV fluids (n = 25) In-line warming (n = 25) Warming cabinet IV fluids (n = 26)
Outcomes	Oesophageal temperature recorded every 10 minutes

Andrzejowski 2010 *(Continued)*

Notes	For analysis, in-line warming and prewarmed fluids were combined. After enrolment, 2 participants were excluded as the result of surgical cancellation, 2 as they were given regional anaesthesia and 2 as data sheets were missing Each participant received 1 litre of fluids, and mean anaesthetic duration for the room temp group was 31 minutes, for the in-line warming group 37 minutes and for the warming cabinet group 35 minutes

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'Randomly assigned by a computer'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Single-blind study
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Low risk	6 participants excluded
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Camus 1996

Methods	Single-centre study in France
Participants	ASA I or II individuals undergoing major abdominal surgery lasting at least 3 hours under general anaesthesia; 18 patients
Interventions	Room temperature IV fluids (n = 9) Warmed IV fluids using hotline to 37°C (n = 9) Both groups also had an electric warming blanket
Outcomes	Core temperature (location measured is not stated) measured every 30 minutes for the first 2 hours, then hourly thereafter; shivering measured by a clinical observer as present or absent
Notes	Volume of fluid infused: control group 3.5 ± 0.3 litres over 380 ± 3 minutes, warmed group 3.6 ± 0.3 litres over 340 ± 24 minutes None were obese or febrile or had a history of endocrine disease

Camus 1996 *(Continued)*

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Randomly assigned'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Chung 2012

Methods	Single-centre study from Korea
Participants	45 healthy pregnant ladies undergoing elective caesarean section at between 38 and 42 weeks of gestation
Interventions	Group 1 received warmed intravenous fluids (n = 15), mean volume infused 1210 ± 120 mL Group 2 received forced air warming (n = 15), mean volume infused 1197 ± 215 mL Group 3 received usual care only (n = 15), mean volume infused 1140 ± 140 mL
Outcomes	Core temperature (tympanic) measured every 15 minutes but reported only at 45 minutes; shivering measured using a scale of 0 to 4
Notes	Exclusions: gestational hypertension, weight < 50 kg, weight > 100 kg, fever, placenta praevia, multiple pregnancy, recent drugs/medication

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Randomly assigned'

Chung 2012 *(Continued)*

Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Cooper 1994

Methods	Single-centre study from Australia
Participants	14 women aged 31 to 49 undergoing routine hysteroscopic surgery
Interventions	Room temperature irrigation fluid (n = not stated) Body temperature irrigation fluid (n = not stated)
Outcomes	Oesophageal temperature measured intraoperatively every 10 minutes
Notes	No exclusion criteria were described; the data were provided in the form of a graph, but what the error bars represented was not clear, so data were not useable Neither volumes irrigated nor surgical duration was stated

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'Patients were randomized'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described

Cooper 1994 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

De Mattia 2013

Methods	Single-centre study in Brazil
Participants	60 ASA I to III adults undergoing elective abdominal surgery with anaesthetic duration longer than 1 hour, with body temperature 36°C to 37.1°C upon entry to the OR Patients with a predisposition to temperature changes were excluded, including those with thyroid and neurological disorders, extreme weight, ASA IV to VI and axillary body temperature under 36°C or over 37.1°C upon entry to the OR
Interventions	Warmed intravenous infusion (n = 30) Routine care (n = 30)
Outcomes	Temperature at time of exit from the OR
Notes	All participants received passive warming via a cover sheet

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Random sampling technique: 'A draw was held to determine the group of the first patient of the sample, whether it was the experimental group or the control group, who was selected for the experimental group, and from this, the second patient was selected for the control group, and so forth, successively intercalated until 30 patients were selected for each group'
Allocation concealment (selection bias)	Unclear risk	Not stated
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not stated
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this

De Mattia 2013 *(Continued)*

Other bias	Low risk	None

Demir 2002

Methods	Single-centre study in Turkey
Participants	27 patients undergoing elective major abdominal surgery who did had no metastatic malignancy or secondary disease. All patients underwent a thoracic epidural
Interventions	No extra warming other than routine anaesthetic care (n = 9); rate and volume not stated Mixed amino acid solution (n = 9), infused at 143 mL/h; duration not stated but recordings until 4 hours All IV fluids warmed to 37°C until the end of anaesthesia (n = 9)
Outcomes	Rectal temperature as measured every 30 minutes during surgery
Notes	No useable data were provided: We tried to contact the study author but received no reply

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Randomly assigned'
Allocation concealment (selection bias)	Unclear risk	Not stated
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not stated
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not stated
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Hasankhani 2007

Methods	Single-centre study in Iran
Participants	ASA I orthopaedic patients with surgeries lasting longer than 60 minutes

Hasankhani 2007 *(Continued)*

	Exclusion criteria: preoperative calcium channel antagonists, temperature > 38°C or < 35.5°C, endocrine disease, obesity, pregnancy, anaemia, age < 18 or > 55 years
Interventions	Room temperature intravenous fluids (n = 30): volume infused 918 ± 118 mL, duration of surgery 70 ± 4 minutes Warmed intravenous fluids (n = 30): volume infused 984 ± 173 mL, duration of surgery 73 ± 6 minutes
Outcomes	Oesophageal temperature as measured every 15 minutes intraoperatively; shivering; time spent in postanaesthesia care unit
Notes	Shivering was measured using a 5-point scale

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Randomly assigned (by the toss of a coin)'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Low risk	'Recording nurse was unaware of which patients were in which group'
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Jaffe 2001

Methods	Single-centre study in USA
Participants	56 male patients (mean age 71.2 ± 8.2 years) undergoing transurethral resection of the prostate (TURP)
Interventions	Room temperature irrigation fluids (n = 27): volume irrigated 17,333 ± 1226 mL, time in OR 102.2 ± 30.6 minutes Warmed irrigation fluids (n = 29): volume irrigated 17,596 +/- 1013 mL, time in OR 96.8 ± 27.9 minutes
Outcomes	Core (tympanic) body temperature at the beginning and at the conclusion of TURP; shivering
Notes	Consecutive patients; no exclusion criteria were documented

Jaffe 2001 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'Randomly assigned'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Jeong 2008

Methods	Single-centre study in Korea
Participants	40 patients undergoing off-pump coronary artery bypass surgery; 29 male, 11 female, average age 62 years Exclusion criteria: patients requiring inotropes or intra-aortic balloon pump, preoperative temperature < 36°C or > 37°C, anticipated need for cardiopulmonary bypass, skin disease, hypersensitivity to skin adhesives
Interventions	Intravenous fluids warmed to 41°C (n = 20): mean volume infused crystalloid 2301.5 ± 1006.7, blood 400.5 ± 622.8 mL, anaesthesia time 280 ± 59 minutes No warmed fluids (n = 20): mean volume infused crystalloid 2191.2 ± 622.3 mL, blood 365.0 ± 437.1 mL, anaesthesia time 278 ± 53 minutes Both groups lay on a warming water mattress, and operating room temperature was maintained at 25°C
Outcomes	Hourly bladder temperature recorded intraoperatively; temperature at 4 hours postoperatively; blood loss; length of ICU stay; length of hospital stay
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement

Jeong 2008 *(Continued)*

Random sequence generation (selection bias)	Low risk	'Randomly allocated'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Jorgenson 2000

Methods	Study conducted in Denmark (presumed single centre)
Participants	120 healthy term parturients consenting to spinal anaesthesia for elective caesarean section; patients with pre-eclampsia, arterial hypertension or multiple pregnancy were excluded
Interventions	Warmed saline heated to 37°C (n = 57) Cold saline at 21°C (n = 56) Each participant was infused with 20 mL/kg 15 minutes before spinal, then 10 mL/kg in the 20 minutes after spinal injection
Outcomes	Decrease in core temperature (location measured not specified); discomfort; incidence of shivering; blood pressure; heart rate
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomization was achieved with computer-generated codes
Allocation concealment (selection bias)	Low risk	Codes were placed in sealed envelopes, which were opened after the participant arrived to the theatre
Blinding of participants and personnel (performance bias)	Unclear risk	Not described

Jorgenson 2000 *(Continued)*

All outcomes		
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	7 participants were withdrawn from the study: 1 because of violation of selection criteria, 2 because of failed spinal anaesthesia and 5 because of protocol violations
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Kelly 2000

Methods	Single-centre study in USA
Participants	24 ASA I and II patients aged 18 to 65 years undergoing spinal anaesthesia for arthroscopic knee surgery; 17 male, 3 female Exclusion criteria: patients who could not have a spinal, co-existing disease that may affect temperature, recent use of antipyretics 4 participants were excluded from the final analysis
Interventions	Room temperature irrigation fluids (n = 12): surgical duration 45.6 ± 20.1 minutes, volume irrigated 11.7 ± 10.7 litres Irrigation fluids warmed to 40°C (n = 12): surgical duration 44.3 ± 22.6 minutes, volume irrigated 11.8 ± 11.0 litres Both groups were covered with cloth sheets and drapes and were given room temperature intravenous fluids
Outcomes	Tympanic temperature as measured every 15 minutes intraoperatively and for 1 hour postoperatively
Notes	Data were recorded as percentage change in temperature, so were not included in the analyses

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'Random numbers table'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias)	Unclear risk	Not described

Kelly 2000 *(Continued)*

All outcomes		
Incomplete outcome data (attrition bias) All outcomes	High risk	1 participant in the treatment group and 1 in the control group were excluded from the final analysis, as they required warming. 2 additional participants in the treatment group were excluded as they required tourniquet inflation
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Kim 2009

Methods	Single-centre study in Korea
Participants	50 patients undergoing elective arthroscopic shoulder surgery 4 patients were excluded because of incomplete data; no other exclusion criteria were described
Interventions	Room temperature irrigation fluid (n = 23): volume irrigated 10.3 ± 4.3 litres, surgical time 91.1 ± 32.4 minutes Warmed irrigation fluid to 37°C to 39°C (n = 23): volume irrigated 9.8 ± 3.2 litres, surgical time 94.5 ± 21.9 minutes
Outcomes	Core temperature (oesophageal) measured every 20 minutes; shivering; fall in haemoglobin
Notes	No shivering score was used

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Randomly assigned
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Shivering detected by an independent observer
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	4 excluded because of incomplete data
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

McCarroll 1986

Methods	Single-centre study in Canada
Participants	40 patients undergoing elective caesarean section
Interventions	Room temperature intravenous fluids (n = 20) Warmed intravenous fluids (n = 20) Volumes infused and surgical duration not stated
Outcomes	Core (tympanic) temperature every 10 minutes
Notes	No inclusion or exclusion criteria were described Shivering was scored as 0 to 3

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	Randomly assigned
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Person who assessed shivering was blinded
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Moore 1997

Methods	Single-centre study in USA
Participants	N = 35; gynaecological laparoscopy (excluding laparoscopic hysterectomy); mean age 32 years Pregnant women and those weighing < 40 kg or > 100 kg were excluded
Interventions	Ambient temperature irrigation fluids (n = 16): mean irrigation volume 1481 ± 231 mL, surgery time 96 ± 8 minutes

Moore 1997 *(Continued)*

	Irrigation fluids warmed to 39°C (n = 13): mean irrigation volume 1264 ± 231 mL, surgery time 90 ± 10 minutes Both groups were lying on a heating blanket at 37.8°C, and the upper body was covered with blankets
Outcomes	Oesophageal temperature as measured every 15 minutes
Notes	6 were excluded post randomization as they did not require irrigation; 1 was excluded as temperature was < 34°C

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Random numbers table'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Blinding was attempted (nurses selected appropriate fluid temperature without the knowledge of the operating surgeon), but fluid temperature was obvious by the temperature of the handheld probe
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	6 women did not require irrigation and were analysed separately
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Muth 1996

Methods	Single-centre study in Germany
Participants	50 patients of average age 65 years undergoing elective repair of abdominal aortic aneurysm Inclusion/exclusion criteria were not described
Interventions	No warmed intravenous fluids (n = 25): total volume fluid replacement 3449 ± 1380 mL, surgical duration 173 ± 8 minutes Intravenous fluids warmed via countercurrent-like heat exchangers (hotline) (n = 25): total volume fluid replacement 3499 ± 1623 mL, surgical duration 171 ± 59 minutes
Outcomes	Oesophageal temperature at end of surgery
Notes	

Muth 1996 *(Continued)*

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Random allocation according to patients' day of surgery (odd or even numbers)'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Oshvandi 2011

Methods	Single-centre study in Iran
Participants	62 women undergoing elective caesarean section under general anaesthesia at 37 to 42 weeks of gestation. Average maternal age about 28 years Exclusion criteria: steroids, sedatives, magnesium sulphate, antihypertensive drugs, endocrine or vascular disease, hypertension, fever, ruptured membranes, polyhydramnios or oligohydramnios
Interventions	IV fluid was Ringer's lactate at 25.5°C (n = 31) IV fluid was Ringer's lactate at 37°C (n = 31)
Outcomes	Tympanic temperature as measured by infrared thermometer, measured before anaesthesia and at 15-minute intervals
Notes	Appears to describe postrandomization exclusion criteria: surgery lasting longer than 1 hour, intraoperative hypotension requiring extra IV fluid, but it is not clear whether any participants were excluded on the basis of these criteria

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Unclear risk	"The subjects were randomly assigned to study and control groups"

Oshvandi 2011 *(Continued)*

Allocation concealment (selection bias)	Unclear risk	"The subjects were randomly assigned to study and control groups"
Blinding of participants and personnel (performance bias) All outcomes	Low risk	".....the subjects were blinded to the study.." and, as the outcome was measured while participants were under general anaesthesia, it is unlikely that the measurement was affected. Personnel were probably aware of the group, but it seems unlikely that this would have introduced bias
Blinding of outcome assessment (detection bias) All outcomes	Low risk	"...the research coworkers.......were blinded to the study..."; seems to suggest adequate blinding, although it is not explicit that these staff members were measuring the temperature
Incomplete outcome data (attrition bias) All outcomes	Low risk	No apparent loss to follow-up
Selective reporting (reporting bias)	Unclear risk	No clear evidence that other outcomes were collected
Other bias	Unclear risk	No evidence

Pit 1996

Methods	Single-centre Dutch study
Participants	59 men (mean age 72 years) undergoing transurethral resection of the prostate under spinal anaesthesia
Interventions	Room temperature irrigation fluid (n = 31): resection time 30 minutes Isothermic irrigation fluid (n = 28): resection time 28 minutes
Outcomes	Rectal temperature, preoperative and postoperative haemoglobin concentrations and subjective participant assessment
Notes	No exclusion criteria were described. The data were not useable, as differences between lowest temperature and starting temperature were recorded rather than serial temperature measurements, postoperative haemoglobin rather than estimated blood loss and subjective feeling of cold rather than shivering Volumes irrigated were not stated As a result of the proximity of the rectum and prostate, core temperature measurements at the rectum may be inaccurate

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'Randomized selection'
Allocation concealment (selection bias)	Unclear risk	Not described

Pit 1996 *(Continued)*

Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	'The patient was not aware of the temperature treatment he had received until the second post-operative day'; it was not described whether the investigator was blinded
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Not described
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Shao 2012

Methods	Single-centre RCT in China
Participants	160 ASA I or II patients aged 18 to 60 years, scheduled for elective abdominal surgery Exclusions: abnormal temperature, systemic metabolic disease, infection, interruption of surgery for frozen section
Interventions	A total of 32 intervention groups were described, each with 5 patients who had a unique combination of the following 5 interventions: 1. Heating of IV fluids to 37°C. 2. Body wrap. 3. Warmed, moist dressings at 37°C. 4. Warmed irrigation fluids at 37°C. 5. Heating blankets (Astropad Plus).
Outcomes	Nasopharyngeal and rectal temperature at end of surgery
Notes	Data provided for each of the 32 groups. We combined these to compare groups when the only difference was warmed intravenous fluids or surgical rinse

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Not described
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	'Double blind was carried out by having one researcher seal each envelope containing warming instructions and then have the envelope opened by a second researcher, with the operation and warming method conducted according to the instructions'

Shao 2012 *(Continued)*

Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Smith 1998a

Methods	Single-centre study in USA
Participants	61 patients: 15 male, 41 female; ASA I to III; major gynaecological, orthopaedic or general surgery scheduled to last longer than 90 minutes under general anaesthesia Exclusion criteria: emergency surgery, preoperative calcium channel blockers
Interventions	Room temperature intravenous fluids (n = 30): fluid replacement crystalloid 1773 ± 253 mL, colloid 1000 ± 500 mL, red cells 2 units; anaesthesia time 162 ± 16 minutes Warmed intravenous fluids (hotline) (n = 31): fluid replacement crystalloid 2973 ± 307 mL, colloid 594 ± 131 mL, red cells 1.5 ± 0.5 units; anaesthesia time 243 ± 23 minutes
Outcomes	Oesophageal temperature; estimated blood loss; length of stay in recovery; shivering requiring meperidine; extra warming required in recovery; hypoxia (oxygen saturations < 91%); incidences of mild and moderate hypothermia
Notes	Both groups received forced air warming

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Random numbers table'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Low risk	'A nurse who was unaware of patient group'
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No loss to follow-up

Smith 1998a *(Continued)*

Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Smith 1998b

Methods	Single-centre study in the USA
Participants	38 female patients undergoing general anaesthesia for elective gynaecological surgery; mean age 33 years Exclusion criteria: head injury, otitis, preoperative temperature > 38°C or < 35.5°C, patients taking calcium channel blockers
Interventions	Room temperature intravenous fluids (n = 20): mean volume infused 1390 ± 220 mL, anaesthesia time 112 ± 16 minutes Intravenous fluids warmed to 38°C to 39°C using hotline set to 42°C, with 8 cm extension flowing at 13 to 25 mL/min (n = 18): mean volume infused 1270 ± 100 mL, total anaesthesia time 100 ± 16 minutes Both groups were covered with 2 cotton blankets
Outcomes	Tympanic temperature was recorded every 15 minutes intraoperatively and at 30 and 60 minutes after arrival to the PACU; shivering; pain requiring opioids; use of radiant heat lamps; hypoxia (sats < 91%)
Notes	Shivering was measured as none, mild or severe

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Randomized'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Postoperative data were recorded by a PACU nurse who was unaware of study groups
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Woolnough 2009

Methods	Single-centre study from UK
Participants	75 female patients undergoing elective caesarean section for a singleton pregnancy greater than 37 weeks of gestation under combined spinal-epidural anaesthesia Exclusion criteria: pyrexia, pre-eclampsia, drug therapy other than antacids or vitamins, patients at increased risk of intraoperative bleeding
Interventions	Group 1 (n = 25) room temperature intravenous fluids: 2.0 ± 0.4 litres infused Group 2 (n = 25) prewarmed intravenous fluids: 2.1 ± 0.4 litres infused Group 3 (n = 23) in-line warming: 2.4 ± 1.4 litres infused
Outcomes	Tympanic temperature measured every 15 minutes; blood loss; shivering; subjective feelings of hot or cold Shivering assessed using a 3-point scale: 0 = no shivering; 1 = mild, intermittent shivering; 2 = intense, continuous shivering
Notes	Both groups of warmed fluids combined for analysis

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'Computer generated random numbers and sealed envelopes'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Low risk	To maintain blinding, all groups had fluids delivered via a hotline fluid warmer, which was switched on only for group 3. The investigator was not allowed to touch any fluid bags or to give any IV drugs
Blinding of outcome assessment (detection bias) All outcomes	Low risk	A blinded investigator recorded temperature and assessed the degree of shivering
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Xu 2010

Methods	Single-centre study from China

Xu 2010 *(Continued)*

Participants	ASA I or II adult patients requiring general anaesthesia for abdominal surgery; 30 patients aged 18 to 65, 19 female, 11 male Exclusion criteria: thyroid disease, dysautonomia, malignant hyperthermia
Interventions	Room temperature intravenous fluids (n = 15): volume infused 2.1 ± 0.4 litres over 174 ± 14 minutes Intravenous fluids warmed to 37°C with hotline (n = 15): volume infused 2.0 ± 0.3 litres over 164 ± 11 minutes Both groups had unwarmed cotton blankets; operating temperature was maintained at 24°C and humidity at 30%
Outcomes	Tympanic temperature was recorded every 30 minutes, as was the incidence of shivering
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	'Random digits table'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Observer evaluating shivering was blinded to the study; low risk for shivering, unclear for temperature
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Yamakage 2004

Methods	Single-centre study in Japan
Participants	20 patients (3 female, 17 male), ASA I or II undergoing urological surgery under general anaesthesia plus epidural Exclusion criteria: thyroid disease, dysautonomia, Raynaud's disease, malignant hyperthermia
Interventions	Unwarmed intravenous HES 1000 mL (n = 10)

Yamakage 2004 *(Continued)*

	Prewarmed HES 1000 mL (n = 10)
Outcomes	Temperature measured every 5 minutes up to 60 minutes
Notes	All participants received 10 mL/kg unwarmed Ringer's lactate before removal of 800 to 1200 mL blood for haemodilution autotransfusion; subsequent 1000 mL hydroxy ethyl starch (HES) was then given at room temperature or prewarmed

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	'Randomly allocated by an envelope technique'
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not described
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not described
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

Yokoyama 2009

Methods	Single-centre study in Japan
Participants	30 female patients undergoing elective caesarean section under combined spinal-epidural block
Interventions	Warmed intravenous fluids (n = 15): volume infused 1980 ± 400 mL Room temperature fluids (n = 15): volume infused 1800 ± 240 mL
Outcomes	Core temperature (tympanic) at key points in the procedure and at the end of the procedure, use of vasopressors, blood loss, fetal pH, Apgar scores
Notes	Estimation of blood loss was not used, as the value also includes the volume of amniotic fluid Surgical duration approximately 45 minutes

Risk of bias

Bias	**Authors' judgement**	**Support for judgement**

Yokoyama 2009 *(Continued)*

Random sequence generation (selection bias)	Low risk	Computer-generated randomization
Allocation concealment (selection bias)	Unclear risk	Not described
Blinding of participants and personnel (performance bias) All outcomes	Low risk	'Double blinded study'; administration of Iv fluids was started by nurses who were not involved in the investigation
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Temperature and blood loss were measured by nurses who were not involved in the investigation
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	No evidence of this
Other bias	Low risk	None

ACE inhibitor = angiotensin-converting enzyme inhibitor.
ASA = American Society of Anesthesiologists.
C = Celsius.
HES = hydroxy ethyl starch.
ICU = intensive care unit.
IV = intravenous.
N = numbers.
OR = operating room.
PACU = postanaesthesia care unit.
RCT = randomized controlled trial.
TURP = transurethral resection of the prostate.

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Board 2008	Not randomized - first 12 patients were control group followed by next 12 assigned to warmed irrigation fluids
Carli 1986	Several interventions vs none
Carli 1989	Multiple interventions
Cavallini 2005	Multiple interventions - control group with standard surgical drapes vs fluid warming and forced air warming concurrently
Chan 1989	Multi-intervention
Dai 2010	Multiple interventions
Dyer 1986	Sublingual temperature, not core temperature

Study	Reason for exclusion
Ellis-Stoll 1996	Compared 2 methods of warming fluids - prewarmed vs in-line warming
Evans 1994	Multiple interventions
Gerig 1979	No information on formation of comparison groups
Heathcote1986	Not randomized
Kiessling 2006	Active warming vs warmed fluids and thermal insulation
Monga 1996	Oral temperature, not central
Neoh 1989	Axilliary temperature, not core temperature
Okeke 2007	Oral temperature, not central
Park 2007	Not an RCT, before-and-after study
Park 2009	Retrospective study
Patel 1996	Compares 2 different fluid warming methods
Patel 1997	Multiple interventions - control group with reflective blankets and warmed fluids vs forced air warming with room temperature fluids
Szlyk-Augustyn 2002	Multiple interventions
Xu 2004	Multiple interventions
Yamauchi 1998	All patients were on cardiopulmonary bypass

RCT = randomized controlled trial.

DATA AND ANALYSES

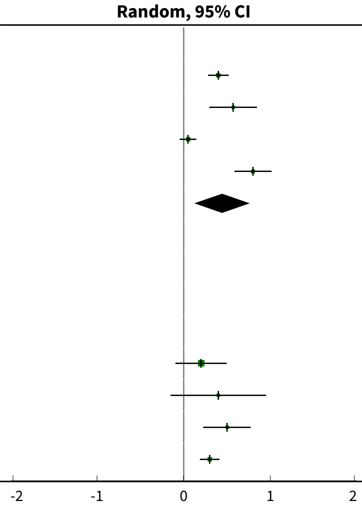
Comparison 1. Warmed vs room temperature intravenous fluids

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Temperature at 30 minutes after induction	9	374	Mean Difference (IV, Random, 95% CI)	0.41 [0.24, 0.57]
1.1 Elective caesarean section	4	207	Mean Difference (IV, Random, 95% CI)	0.44 [0.12, 0.76]
1.2 All other surgery	5	167	Mean Difference (IV, Random, 95% CI)	0.39 [0.26, 0.51]
2 Temperature at 60 minutes after induction	8	312	Mean Difference (IV, Random, 95% CI)	0.51 [0.33, 0.69]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2.1 Elective caesarean section	2	105	Mean Difference (IV, Random, 95% CI)	0.60 [0.01, 1.19]
2.2 All other surgery	6	207	Mean Difference (IV, Random, 95% CI)	0.47 [0.30, 0.64]
3 Temperature at 90 minutes after induction	3	109	Mean Difference (IV, Random, 95% CI)	0.54 [0.04, 1.04]
4 Temperature at 120 minutes after induction	4	149	Mean Difference (IV, Random, 95% CI)	0.74 [0.31, 1.17]
5 Temperature at end of procedure/arrival to PACU (simple design)	11	682	Mean Difference (IV, Random, 95% CI)	0.63 [0.28, 0.98]
5.1 Elective caesarean section	3	205	Mean Difference (IV, Random, 95% CI)	0.56 [0.08, 1.04]
5.2 All other surgery	8	477	Mean Difference (IV, Random, 95% CI)	0.66 [0.19, 1.12]
6 Event rate of shivering	9	428	Risk Ratio (M-H, Random, 95% CI)	0.39 [0.23, 0.67]
6.1 Elective caesarean section	3	145	Risk Ratio (M-H, Random, 95% CI)	0.61 [0.36, 1.02]
6.2 All other surgery	6	283	Risk Ratio (M-H, Random, 95% CI)	0.29 [0.14, 0.62]
7 Estimated blood loss	4		Mean Difference (IV, Random, 95% CI)	Totals not selected

Analysis 1.1. Comparison 1 Warmed vs room temperature intravenous fluids, Outcome 1 Temperature at 30 minutes after induction.

Study or subgroup	Warmed N	Warmed Mean(SD)	Room temperature N	Room temperature Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
1.1.1 Elective caesarean section							
McCarroll 1986	20	36.9 (0)	20	36.5 (0.3)		13.26%	0.4[0.28,0.52]
Oshvandi 2011	31	36 (0.5)	31	35.4 (0.6)		10.1%	0.57[0.29,0.85]
Woolnough 2009	50	36.6 (0.2)	25	36.5 (0.2)		13.6%	0.05[-0.05,0.15]
Yokoyama 2009	15	36.6 (0.3)	15	35.8 (0.3)		11.41%	0.8[0.59,1.01]
Subtotal ***	**116**		**91**			**48.37%**	**0.44[0.12,0.76]**
Heterogeneity: Tau²=0.1; Chi²=52.7, df=3(P<0.0001); I²=94.31%							
Test for overall effect: Z=2.71(P=0.01)							
1.1.2 All other surgery							
Camus 1996	9	36.7 (0.3)	9	36.5 (0.3)		9.67%	0.2[-0.1,0.5]
Smith 1998a	31	36 (1.1)	30	35.6 (1.1)		5.36%	0.4[-0.15,0.95]
Smith 1998b	18	36.3 (0.4)	20	35.8 (0.4)		10.13%	0.5[0.23,0.77]
Xu 2010	15	36.8 (0.1)	15	36.5 (0.2)		13.35%	0.3[0.19,0.41]



Study or subgroup	Warmed		Room temperature		Mean Difference	Weight	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Random, 95% CI		Random, 95% CI
Yamakage 2004	10	-0.2 (0.1)	10	-0.7 (0.2)		13.12%	0.5[0.37,0.63]
Subtotal ***	**83**		**84**			**51.63%**	**0.39[0.26,0.51]**
Heterogeneity: Tau²=0.01; Chi²=7.46, df=4(P=0.11); I²=46.39%							
Test for overall effect: Z=6.01(P<0.0001)							
Total ***	**199**		**175**			**100%**	**0.41[0.24,0.57]**
Heterogeneity: Tau²=0.05; Chi²=64.58, df=8(P<0.0001); I²=87.61%							
Test for overall effect: Z=4.92(P<0.0001)							
Test for subgroup differences: Chi²=0.1, df=1 (P=0.75), I²=0%							

Favours room temperature -2 -1 0 1 2 Favours warmed fluids

Analysis 1.2. Comparison 1 Warmed vs room temperature intravenous fluids, Outcome 2 Temperature at 60 minutes after induction.

Study or subgroup	Warmed		Room temperature		Mean Difference	Weight	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Random, 95% CI		Random, 95% CI
1.2.1 Elective caesarean section							
Woolnough 2009	50	36.6 (0.3)	25	36.3 (0.3)		15.07%	0.3[0.16,0.44]
Yokoyama 2009	15	36.4 (0.2)	15	35.5 (0.3)		14.24%	0.9[0.72,1.08]
Subtotal ***	**65**		**40**			**29.3%**	**0.6[0.01,1.19]**
Heterogeneity: Tau²=0.17; Chi²=25.59, df=1(P<0.0001); I²=96.09%							
Test for overall effect: Z=1.99(P=0.05)							
1.2.2 All other surgery							
Camus 1996	9	36.4 (0.3)	9	36.2 (0.3)		11.5%	0.2[-0.1,0.5]
Jeong 2008	20	36.1 (0.4)	20	35.7 (0.6)		11.01%	0.4[0.08,0.72]
Smith 1998a	31	36 (1.1)	30	35.6 (1.1)		6.49%	0.4[-0.15,0.95]
Smith 1998b	18	36.5 (0.4)	20	35.6 (0.5)		11.96%	0.9[0.62,1.18]
Xu 2010	15	36.5 (0.1)	15	36.1 (0.2)		15.65%	0.4[0.29,0.51]
Yamakage 2004	10	-0.3 (0.1)	10	-0.8 (0.3)		14.1%	0.5[0.31,0.69]
Subtotal ***	**103**		**104**			**70.7%**	**0.47[0.3,0.64]**
Heterogeneity: Tau²=0.03; Chi²=14.06, df=5(P=0.02); I²=64.43%							
Test for overall effect: Z=5.5(P<0.0001)							
Total ***	**168**		**144**			**100%**	**0.51[0.33,0.69]**
Heterogeneity: Tau²=0.05; Chi²=40.94, df=7(P<0.0001); I²=82.9%							
Test for overall effect: Z=5.52(P<0.0001)							
Test for subgroup differences: Chi²=0.16, df=1 (P=0.69), I²=0%							

Favours room temperature -5 -2.5 0 2.5 5 Favours warmed fluids

Analysis 1.3. Comparison 1 Warmed vs room temperature intravenous fluids, Outcome 3 Temperature at 90 minutes after induction.

Study or subgroup	Warmed		Room temperature		Mean Difference	Weight	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Random, 95% CI		Random, 95% CI
Camus 1996	9	36.3 (0.4)	9	36 (0.2)		34.74%	0.25[-0.04,0.54]
Smith 1998a	31	36.3 (1.1)	30	35.9 (1.1)		26.67%	0.4[-0.15,0.95]

Favours room temperature -5 -2.5 0 2.5 5 Favours warmed fluids

Study or subgroup	Warmed		Room temperature		Mean Difference	Weight	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Random, 95% CI		Random, 95% CI
Xu 2010	15	36.8 (0.2)	15	35.9 (0.1)		38.6%	0.9[0.79,1.01]
Total ***	**55**		**54**			**100%**	**0.54[0.04,1.04]**
Heterogeneity: Tau²=0.17; Chi²=18.63, df=2(P<0.0001); I²=89.26%							
Test for overall effect: Z=2.11(P=0.03)							
				Favours room temperature	-5 -2.5 0 2.5 5	Favours warmed fluids	

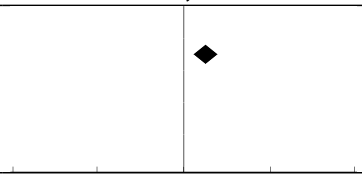
Analysis 1.4. Comparison 1 Warmed vs room temperature intravenous fluids, Outcome 4 Temperature at 120 minutes after induction.

Study or subgroup	Warmed		Room temperature		Mean Difference	Weight	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Random, 95% CI		Random, 95% CI
Camus 1996	9	36.3 (0.6)	9	35.8 (0.3)		24.74%	0.45[0.01,0.89]
Jeong 2008	20	36.2 (0.4)	20	35.5 (0.8)		26.27%	0.7[0.31,1.09]
Smith 1998a	31	36.4 (1.1)	30	36 (1.6)		18.01%	0.4[-0.29,1.09]
Xu 2010	15	36.9 (0.3)	15	35.7 (0.3)		30.98%	1.2[0.99,1.41]
Total ***	**75**		**74**			**100%**	**0.74[0.31,1.17]**
Heterogeneity: Tau²=0.14; Chi²=14.07, df=3(P=0); I²=78.67%							
Test for overall effect: Z=3.36(P=0)							
				Favours room temperature	-5 -2.5 0 2.5 5	Favours warmed fluids	

Analysis 1.5. Comparison 1 Warmed vs room temperature intravenous fluids, Outcome 5 Temperature at end of procedure/arrival to PACU (simple design).

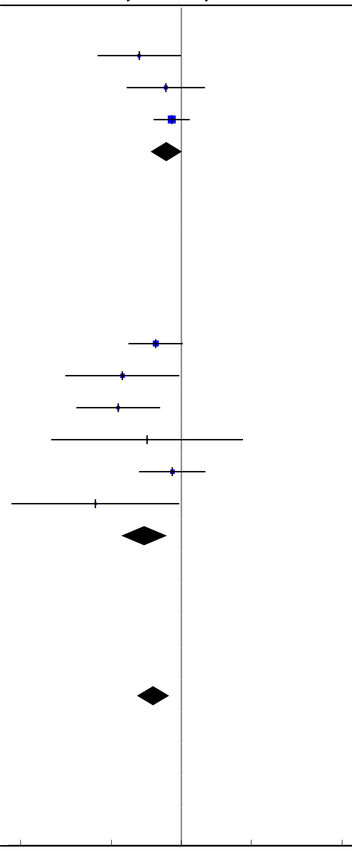
Study or subgroup	Warmed		Room temperature		Mean Difference	Weight	Mean Difference
	N	Mean(SD)	N	Mean(SD)	Random, 95% CI		Random, 95% CI
1.5.1 Elective caesarean section							
Jorgenson 2000	57	-0.8 (0.6)	56	-0.9 (0.8)		9.25%	0.1[-0.16,0.36]
Oshvandi 2011	31	36 (0.5)	31	35.3 (0.6)		9.2%	0.66[0.39,0.93]
Yokoyama 2009	15	36.4 (0.2)	15	35.5 (0.3)		9.51%	0.9[0.72,1.08]
Subtotal ***	**103**		**102**			**27.97%**	**0.56[0.08,1.04]**
Heterogeneity: Tau²=0.16; Chi²=24.25, df=2(P<0.0001); I²=91.75%							
Test for overall effect: Z=2.3(P=0.02)							
1.5.2 All other surgery							
Camus 1996	9	36.7 (0.2)	9	35.8 (0.2)		9.5%	0.9[0.72,1.08]
De Mattia 2013	30	34.3 (1.1)	30	34.4 (1.1)		7.8%	-0.1[-0.66,0.46]
Hasankhani 2007	30	36.4 (0.5)	30	35.9 (0.5)		9.28%	0.5[0.25,0.75]
Muth 1996	25	-0.3 (0.4)	25	-1.5 (0.5)		9.25%	1.15[0.89,1.41]
Shao 2012	80	36.9 (0.5)	80	36.9 (0.5)		9.58%	-0.02[-0.18,0.14]
Smith 1998a	31	36.7 (1.1)	30	36.1 (1.1)		7.82%	0.6[0.05,1.15]
Smith 1998b	20	36.3 (0.4)	18	35.7 (0.5)		9.19%	0.6[0.32,0.88]
Xu 2010	15	37 (0.2)	15	35.5 (0.2)		9.61%	1.5[1.36,1.64]
Subtotal ***	**240**		**237**			**72.03%**	**0.66[0.19,1.12]**
Heterogeneity: Tau²=0.42; Chi²=222.99, df=7(P<0.0001); I²=96.86%							
Test for overall effect: Z=2.79(P=0.01)							
				Favours room temperature	-5 -2.5 0 2.5 5	Favours warmed fluids	

Study or subgroup	Warmed N	Warmed Mean(SD)	Room temperature N	Room temperature Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
Total ***	**343**		**339**			**100%**	**0.63[0.28,0.98]**
Heterogeneity: Tau²=0.32; Chi²=250.7, df=10(P<0.0001); I²=96.01%							
Test for overall effect: Z=3.57(P=0)							
Test for subgroup differences: Chi²=0.08, df=1 (P=0.78), I²=0%							



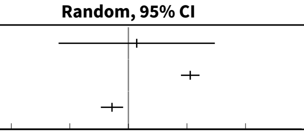
Analysis 1.6. Comparison 1 Warmed vs room temperature intravenous fluids, Outcome 6 Event rate of shivering.

Study or subgroup	Warmed n/N	Room temperature n/N	Risk Ratio M-H, Random, 95% CI	Weight	Risk Ratio M-H, Random, 95% CI
1.6.1 Elective caesarean section					
Chung 2012	2/15	8/15		10.43%	0.25[0.06,0.99]
McCarroll 1986	3/20	5/20		11.37%	0.6[0.17,2.18]
Woolnough 2009	16/50	11/25		23.97%	0.73[0.4,1.32]
Subtotal (95% CI)	**85**	**60**		**45.76%**	**0.61[0.36,1.02]**
Total events: 21 (Warmed), 24 (Room temperature)					
Heterogeneity: Tau²=0.01; Chi²=2.04, df=2(P=0.36); I²=1.85%					
Test for overall effect: Z=1.89(P=0.06)					
1.6.2 All other surgery					
Andrzejowski 2010	7/51	8/25		17.44%	0.43[0.18,1.05]
Camus 1996	1/9	7/9		6.48%	0.14[0.02,0.94]
Hasankhani 2007	2/30	16/30		10.36%	0.13[0.03,0.5]
Smith 1998a	0/31	1/30		2.61%	0.32[0.01,7.63]
Smith 1998b	4/18	6/20		14.02%	0.74[0.25,2.21]
Xu 2010	0/15	8/15		3.33%	0.06[0,0.94]
Subtotal (95% CI)	**154**	**129**		**54.24%**	**0.29[0.14,0.62]**
Total events: 14 (Warmed), 46 (Room temperature)					
Heterogeneity: Tau²=0.27; Chi²=7.35, df=5(P=0.2); I²=31.94%					
Test for overall effect: Z=3.19(P=0)					
Total (95% CI)	**239**	**189**		**100%**	**0.39[0.23,0.67]**
Total events: 35 (Warmed), 70 (Room temperature)					
Heterogeneity: Tau²=0.21; Chi²=12.48, df=8(P=0.13); I²=35.91%					
Test for overall effect: Z=3.45(P=0)					
Test for subgroup differences: Chi²=2.44, df=1 (P=0.12), I²=59.08%					

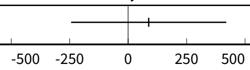


Analysis 1.7. Comparison 1 Warmed vs room temperature intravenous fluids, Outcome 7 Estimated blood loss.

Study or subgroup	Warmed N	Warmed Mean(SD)	Room temperature N	Room temperature Mean(SD)	Mean Difference Random, 95% CI	Mean Difference Random, 95% CI
Jeong 2008	20	400.5 (622.8)	20	365 (437.1)		35.5[-297.96,368.96]
Smith 1998a	31	423 (101)	30	159 (49)		264[224.36,303.64]
Smith 1998b	18	90 (40)	20	160 (100)		-70[-117.56,-22.44]



Study or subgroup	Warmed N	Warmed Mean(SD)	Room temperature N	Room temperature Mean(SD)	Mean Difference Random, 95% CI	Mean Difference Random, 95% CI
Yamakage 2004	10	1342 (412)	10	1254 (342)		88[-243.87,419.87]
				Favours warmed fluids	-500 -250 0 250 500	Favours room temperature

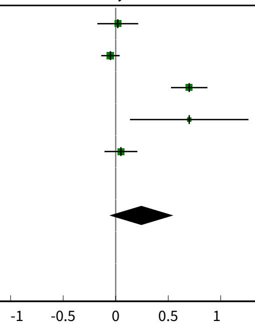


Comparison 2. Warmed vs room temperature irrigation fluids

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Temperature at end of procedure/arrival to PACU (simple design)	5	310	Mean Difference (IV, Random, 95% CI)	0.24 [-0.06, 0.55]
2 Event rate of shivering	2	102	Risk Ratio (M-H, Random, 95% CI)	0.09 [0.01, 1.55]

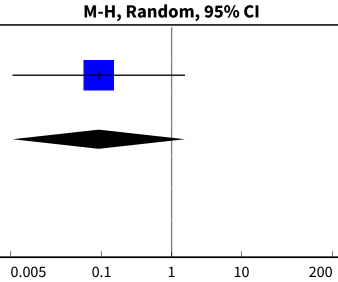
Analysis 2.1. Comparison 2 Warmed vs room temperature irrigation fluids, Outcome 1 Temperature at end of procedure/arrival to PACU (simple design).

Study or subgroup	Warmed irrigation N	Warmed irrigation Mean(SD)	Room temp irrigation N	Room temp irrigation Mean(SD)	Mean Difference Random, 95% CI	Weight	Mean Difference Random, 95% CI
Jaffe 2001	29	36.8 (0.3)	27	36.8 (0.4)		21.12%	0.02[-0.17,0.21]
Kelly 2000	9	-0.8 (0.1)	11	-0.8 (0.1)		22.69%	-0.05[-0.14,0.04]
Kim 2009	23	36.2 (0.3)	23	35.5 (0.3)		21.51%	0.7[0.53,0.87]
Moore 1997	14	-1 (0.7)	14	-1.7 (0.8)		12.89%	0.7[0.14,1.26]
Shao 2012	80	36.9 (0.5)	80	36.9 (0.5)		21.79%	0.05[-0.11,0.21]
Total ***	**155**		**155**			**100%**	**0.24[-0.06,0.55]**
Heterogeneity: Tau²=0.1; Chi²=62.59, df=4(P<0.0001); I²=93.61%							
Test for overall effect: Z=1.58(P=0.12)							
				Favours room temperature	-1 -0.5 0 0.5 1	Favours warmed irrigation	



Analysis 2.2. Comparison 2 Warmed vs room temperature irrigation fluids, Outcome 2 Event rate of shivering.

Study or subgroup	Warmed irrigation n/N	Room temperature n/N	Risk Ratio M-H, Random, 95% CI	Weight	Risk Ratio M-H, Random, 95% CI
Jaffe 2001	0/29	0/27			Not estimable
Kim 2009	0/23	5/23		100%	0.09[0.01,1.55]
Total (95% CI)	**52**	**50**		**100%**	**0.09[0.01,1.55]**
Total events: 0 (Warmed irrigation), 5 (Room temperature)					
Heterogeneity: Not applicable					
Test for overall effect: Z=1.66(P=0.1)					
	Favours warmed irrigation		0.005 0.1 1 10 200	Favours room temperature	



APPENDICES

Appendix 1. Search strategy for CENTRAL

#1 MeSH descriptor Rewarming explode all trees
#2 (intervention* adj3 treat*):ti,ab or vasodilatat* or infrared light* or intravenous nutrient* or warming system* or ((Mattress* or blanket*) near (warm water or Electric)) or (warm* near (air or CO2 or fluid* or an?esthetic* or IV or gas* or device* or patient* or passive* or active* or skin or surg*)) or (warming or blanket*):ti,ab or pharmacological agent* or thermal insulat* or pre?warm* or re?warm*
#3 (#1 OR #2)
#4 MeSH descriptor Hypothermia explode all trees
#5 MeSH descriptor Body Temperature Regulation explode all trees
#6 MeSH descriptor Shivering explode all trees
#7 hypo?therm* or normo?therm* or thermo?regulat* or shiver* or ((thermal or temperature) near (regulat* or manage* or maintain*)) or (low* near temperature*) or thermo?genesis or ((reduc* or prevent*) and temperature and (decrease or decline)) or (heat near (preserv* or loss or retention or retain* or balance)) or (core near (thermal or temperature*))
#8 (#4 OR #5 OR #6 OR #7)
#9 (#3 AND #8)

Appendix 2. Search strategy for MEDLINE (Ovid SP)

1. Rewarming/ or (intervention* adj3 treat*).ti,ab. or vasodilatat*.mp. or infrared light*.mp. or intravenous nutrient*.mp. or warming system*.mp. or ((Mattress* or blanket*) adj3 (warm water or Electric)).mp. or (warm* adj3 (air or CO2 or fluid* or an?esthetic* or IV or gas* or device* or patient* or passive* or active* or skin or surg*)).mp. or (warming or blanket*).ti,ab. or pharmacological agent*.mp. or thermal insulat*.mp. or (pre?warm* or re?warm*).mp.
2. exp Hypothermia/ or exp body temperature regulation/ or exp piloerection/ or exp shivering/ or hypo?therm*.af. or normo?therm*.mp. or thermo?regulat*.mp. or shiver*.mp. or ((thermal or temperature) adj2 (regulat* or manage* or maintain*)).mp. or (low* adj2 temperature*).mp. or thermo?genesis.mp. or ((reduc* or prevent*).af. and (temperature adj3 (decrease or decline)).mp.) or (heat adj2 (preserv* or loss or retention or retain* or balance)).mp. or (core adj2 (thermal or temperature*)).mp.
3. 1 and 2
4. ((randomized controlled trial or controlled clinical trial).pt. or randomized.ab. or placebo.ab. or drug therapy.fs. or randomly.ab. or trial.ab. or groups.ab.) not (animals not (humans and animals)).sh.
5. 3 and 4

Appendix 3. Search strategy for EMBASE (Ovid SP)

1. warming/ or (intervention* adj3 treat*).ti,ab. or vasodilatat*.mp. or infrared light*.mp. or intravenous nutrient*.mp. or warming system*.mp. or ((Mattress* or blanket*) adj3 (warm water or Electric)).mp. or (warm* adj3 (air or CO2 or fluid* or an?esthetic* or IV or gas* or device* or patient* or passive* or active* or skin or surg*)).mp. or (warming or blanket*).ti,ab. or pharmacological agent*.mp. or thermal insulat*.mp. or (pre?warm* or re?warm*).mp.
2. exp HYPOTHERMIA/ or exp thermoregulation/ or reflex/ or exp SHIVERING/ or hypo?therm*.af. or normo?therm*.mp. or thermo?regulat*.mp. or shiver*.mp. or ((thermal or temperature) adj2 (regulat* or manage* or maintain*)).mp. or (low* adj2 temperature*).mp. or thermo?genesis.mp. or ((reduc* or prevent*).af. and (temperature adj3 (decrease or decline)).mp.) or (heat adj2 (preserv* or loss or retention or retain* or balance)).mp. or (core adj2 (thermal or temperature*)).mp.
3. 1 and 2
4. (placebo.sh. or controlled study.ab. or random*.ti,ab. or trial*.ti,ab.) not (animals not (humans and animals)).sh.
5. 3 and 4

Appendix 4. Search strategy for ISI Web of Science

#1 TS=((hypo?therm* or normo?therm* or thermo?regulat* or shiver*) or ((thermal or temperature) SAME (regulat* or manage* or maintain*)) or (low* SAME temperature*) or thermo?genesis or ((reduc* or prevent*) and temperature and (decrease or decline)) or (heat SAME (preserv* or loss or retention or retain* or balance)) or (core SAME (thermal or temperature*)))
#2 TS=((intervention* SAME treat*) or (vasodilatat* or infrared light* or intravenous nutrient* or warming system*) or ((Mattress* or blanket*) SAME (warm water or Electric)) or (warm* and (air or CO2 or fluid* or an?esthetic* or IV or gas* or device* or patient* or passive* or active* or skin or surg*))) or TI=(warming or blanket*) or TI=(pharmacological agent* or thermal insulat* or pre?warm* or re?warm*)
#3 #1 and #2
#4 TS=(random* or (trial* SAME (control* or clinical*)) or placebo* or multicenter* or prospective* or ((blind* or mask*) SAME (single or double or triple or treble)))
#5 #3 and #4

Appendix 5. Search strategy for CINAHL (EBSCOhost)

S1 (MM "Warming Techniques")

S2 vasodilatat* or infrared light* or intravenous nutrient* or warming system*
S3 intervention* N3 treat*
S4 ((Mattress* or blanket*) and (warm water or Electric))
S5 (warm* and (air or CO2 or fluid* or an?esthetic* or IV or gas* or device* or patient* or passive* or active* or skin or surg*))
S6 AB warming or blanket*
S7 AB pharmacological agent*
S8 TI thermal insulat* or AB (pre?warm* or re?warm*)
S9 S1 or S2 or S3 or S4 or S5 or S6 or S7 or S8
S10 (MM "Hypothermia") OR (MM "Body Temperature Regulation") OR (MM "Shivering")
S11 hypo?therm* or normo?therm* or thermo?regulat* or shiver*
S12 AB ((thermal or temperature) and (regulat* or manage* or maintain*))
S13 low* N3 temperature*
S14 (reduc* or prevent*) and temperature and (decrease or decline)
S15 thermogenesis
S16 heat N3 (preserv* or loss or retention or retain* or balance)
S17 core N3 (thermal or temperature*)
S18 S10 or S11 or S12 or S13 or S14 or S15 or S16 or S17
S19 S9 and S18

Appendix 6. Data extraction form

Cochrane Anaesthesia Review Group Study selection, quality assessment & data extraction form	***Code of paper:***	
	Reviewer initials:	*Date:*
Warming of IV and irrigation fluids for preventing inadvertent perioperative hypothermia		

First author	Journal/Conference proceedings, etc.	Year

Study eligibility

RCT/Quasi/CCT (delete as appropriate)	Relevant participants	Relevant interventions	Relevant outcomes
Yes/No/Unclear	Yes/No/Unclear	Yes/No/Unclear	Yes/No*/Unclear

is

*** Issue relates to selective reporting – when study authors may have taken measurements for particular outcomes without reporting these within the paper(s). Review authors should contact trialists for information on possible non-reported outcomes and reasons for exclusion from publication. Study should be listed in 'Studies awaiting assessment' until clarified. If no clarification is received after three attempts, study should then be excluded.**

Do not proceed if any of the above answers is 'No'. If study is to be included in the 'Excluded studies' section of the review, record below the information to be inserted into 'Table of excluded studies'.

Freehand space for comments on study design and treatment:

Methodological quality

Allocation of intervention	
State here method used to generate allocation and reasons for grading (quote)	Grade (circle)
Page number	Adequate (random)
	Inadequate (e.g. alternate)
	Unclear

Concealment of allocation	
Process used to prevent foreknowledge of group assignment in an RCT, which should be seen as distinct from blinding	
State here method used to conceal allocation and reasons for grading (quote)	Grade (circle)
Page number	Adequate
	Inadequate

(Continued)

		Unclear

Blinding		**Page number**
Person responsible for participant's care	Yes/No	
Participant	Yes/No	
Outcome assessor	Yes/No	
Other (please specify)	Yes/No	
Intention-to-treat An intention-to-treat analysis is one in which all participants in a trial are analysed according to the intervention to which they were allocated, whether or not they received it		
Number of participants entering the trial		
Number excluded		
% excluded (greater than or less than 15%)		
Not analysed as ‘intention-to-treat’		
Unclear		
Were withdrawals described?	Yes/No/Not clear	
Free text:		

Participants and trial characteristics

Participant characteristics		
	Further details	Page number
Age (mean, median, range, etc.)		
Sex of participants (numbers/%, etc.)		

Trial characteristics		
	Further details	Page number
Single centre/Multi-centre		
Country/Countries		
How was participant eligibility defined?		
How many people were randomly assigned?		
How many people were analysed?		
Control group (size and details, e.g. 2 cotton blankets + fluid warmer + HME)		
Intervention group 1 (size and details)		
Intervention group 2 (size and details)		
Intervention group 3 (size and details)		
Time treatment applied (e.g. 30 minutes preoperatively)		
Duration of treatment (mean + SD)		
Total anaesthetic time		
Duration of follow-up		
Time points when measurements were taken during the study		
Time points reported in the study		
Time points you are using in RevMan		
Trial design (e.g. parallel/cross-over*)		
Other		

* If cross-over design, please refer to the Cochrane Editorial Office for further advice on how to analyse these data.

Relevant outcomes		
	Reported in paper (circle)	Page number
Infection and complications of surgical wound	Yes/No	
Major CVS complications (CVS death, MI, CVA)	Yes/No	

(Continued)

Risk of hypothermia (core temperature)	Yes/No
Pressure ulcers	Yes/No
Bleeding complications	Yes/No
Other CVS complications (arrhythmias, hypotension)	Yes/No
Patient-reported outcomes (shivering, discomfort)	Yes/No
All-cause mortality	Yes/No
Adverse effects	Yes/No

Relevant subgroups		Page number
Age > 80	Yes/No	
Pregnancy	Yes/No	
ASA scores	Yes/No	
Urgency	Yes/No	

Subgroups

Number of participants

	Age > 80	Pregnant	Elective	Urgent	ASA I or II	ASA III or IV
Control						
Intervention 1						
Intervention 2						
Intervention 3						

Free text:

(Continued)

For continuous data

Code of paper	Outcomes	Unit of measurement	Control group		Intervention 1 (thermal insulation)		Intervention 2		Intervention 3	
			n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
	Temperature at end of surgery	Degrees C								
	Temperature at	Degrees C								
	Temperature at	Degrees C								
	Number of units of red cells transfused	Units								

For dichotomous data (n = number of participants)

Code of paper	Outcomes	Control group	Intervention 1 (thermal insulation)	Intervention 2	Intervention 3	Free text
		n	n	n	n	
	Wound complications					
	Major CVS complications (CVS death, non-fatal MI, non-fatal CVA and non-fatal arrest)					
	Bleeding complications (coagulopathy)					
	Pressure ulcers					

(Continued)

Other CVS complications (hypotension, bradycardia, hypotension)

Other information that you feel is relevant to the results:
Indicate if any data were obtained from the primary author; if results were estimated from graphs, etc.; or if results were calculated by you using a formula (this should be stated and the formula given). In general if results not reported in paper(s) are obtained, this should be made clear here to be cited in the review.

Freehand space for writing actions such as contact with study authors and changes

References to trial

Check other references identified in searches. If further references describe this trial, link the papers now and list below. All references to a trial should be linked under one *Study ID* in RevMan.

Code each paper	Study author(s)	Journal/Conference proceedings, etc.	Year

References to other trials

Did this report include any references to published reports of potentially eligible trials not already identified for this review?		
First author	Journal/Conference	Year of publication
Did this report include any references to unpublished data from potentially eligible trials not already identified for this review? If yes, list contact names and details		

CONTRIBUTIONS OF AUTHORS

Gillian Campbell (GC), Phil Alderson (PA), Andrew F Smith (AS), Sheryl Warttig (SW).

Conceiving the review: PA.

Co-ordinating the review: GC.

Undertaking manual searches: not applicable.

Screening search results: GC, PA, SW.

Organizing retrieval of papers: GC.

Screening retrieved papers against inclusion criteria: GC, PA, SW.

Appraising quality of papers: GC, PA, SW.

Abstracting data from papers: GC, PA, SW.

Writing to authors of papers for additional information: GC.

Providing additional data about papers: none.

Obtaining and screening data on unpublished studies: none.

Managing data for the review: GC, SW.

Entering data into Review Manager (RevMan 5.3): GC, SW, PA.

Analysing RevMan statistical data: CG, SW.

Performing other statistical analysis not using RevMan: none.

Interpreting data: GC, SW.

Making statistical inferences: GC, SW.

Writing the review: GC, SW.

Securing funding for the review: none.

Performing previous work that provided a foundation for the present study: none.

Serving as guarantor for the review (one author): AS

Taking responsibility for reading and checking the review before submission: GC, SW, PA, AS.

DECLARATIONS OF INTEREST

Gillian Campbell - none known.

Phil Alderson - none known.

Andrew F Smith - none known.

Sheryl Warttig - none known.

SOURCES OF SUPPORT

Internal sources

- Morecambe Bay University Hospital Trust, UK.

  GC is employed by MBUHT

External sources

- National Institute for Health Research, UK.

  Provided a grant for preparation of Cochrane reviews on perioperative care that has supported this work

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

Differences between Campbell 2012b and review

We had wanted to analyse the outcome of hypothermia as a dichotomous one, but the data were not presented in this way. Outcomes for analysis were chosen after review of study data. As no data on hypothermia were available, we made the decision to analyse mean core temperatures at different time points during surgery.

For assessment of heterogeneity, we had set a threshold of $I^2 > 30\%$ as indicating important heterogeneity. We found high levels of I^2 in almost all analyses, but the absolute differences in temperature were very small and the direction of effect largely consistent. No obvious explanation was found for the heterogeneity, and so we decided to proceed with a meta-analysis.

INDEX TERMS

Medical Subject Headings (MeSH)

*Body Temperature; Administration, Intravenous; Anesthesia [adverse effects]; Hot Temperature; Hypothermia [etiology] [*prevention & control]; Infusions, Intravenous [*methods]; Randomized Controlled Trials as Topic; Shivering; Therapeutic Irrigation [*methods]

MeSH check words

Humans