Heated CO_2 with or without humidification for minimally invasive abdominal surgery (Review)

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[Intervention Review]

Heated CO_2 with or without humidification for minimally invasive abdominal surgery

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ABSTRACT

Background

Intraoperative hypothermia during both open and laparoscopic abdominal surgery may be associated with adverse events. For laparoscopic abdominal surgery, the use of heated insufflation systems for establishing pneumoperitoneum has been described to prevent hypothermia. Humidification of the insufflated gas is also possible. Past studies have shown inconclusive results with regards to maintenance of core temperature and reduction of postoperative pain and recovery times.

Objectives

To determine the effect of heated gas insufflation on patient outcomes following minimally invasive abdominal surgery.

Search methods

The Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library*), MEDLINE (PubMed), EMBASE, International Pharmaceutical Abstracts (IPA), Web of Science, Scopus, www.clinicaltrials.gov and the National Research Register were searched (1956 to 14 June 2010). Grey literature and cross-references were also searched. Searches were limited to human studies without language restriction.

Selection criteria

All included studies were randomized trials comparing heated (with or without humidification) gas insufflation with cold gas insufflation in adult and pediatric populations undergoing minimally invasive abdominal procedures. Study quality was assessed in regards to relevance, design, sequence generation, allocation concealment, blinding, possibility of incomplete data and selective reporting. The selection of studies for the review was done independently by two authors, with any disagreement resolved in consensus with a third co-author.

Data collection and analysis

Screening of eligible studies, data extraction and methodological quality assessment of the trials were performed by the authors. Data from eligible studies were collected using data sheets. Results were presented using mean differences for continuous outcomes and relative risks with 95% confidence intervals for dichotomous outcomes. The estimated effects were calculated using the latest version of RevMan software. Publication bias was taken into consideration and funnel plots were compiled.

Main results

Sixteen studies were included in the analysis. During laparoscopic abdominal surgery, no effect on postoperative pain nor changes in core temperature, morphine consumption, length of hospitalisation, lens fogging, length of operation or recovery room stay were associated with heated compared to cold gas insufflation with or without humidification.

Authors' conclusions

The study offers evidence that during laparoscopic abdominal surgery, heated gas insufflation, with or without humidification, has minimal benefit on patient outcomes.

PLAIN LANGUAGE SUMMARY

Heated CO_2 with or without humidification for minimally invasive abdominal surgery has minimal benefit on patient outcomes

This review compared the effect of using heated, with or without humidification, or cold carbon dioxide (CO_2) gas to expand the abdomen during laparoscopic surgery. Sixteen randomized controlled trials were included in the analysis. The overall effect of heating the CO_2 was measured by performing a meta-analysis. We found that the use of heated CO_2 gas with humidity had no effect on core temperature, lens fogging during the operation, the total duration of the operation, pain control, morphine consumption, recovery room stay after the operation or the length of hospitalisation. However, if heated non-humidified gas was used, morphine usage on the first and second day after surgery was increased compared to the group in which cold gas was used to expand the abdomen. In conclusion, there was no evidence to support the use of heated CO_2 gas in laparoscopic abdominal surgery, with or without humidification.

BACKGROUND

Intraoperative hypothermia can occur with open or minimally invasive surgery. General anesthesia is associated with impaired thermoregulation (Putzu 2007; Qadan 2009) and insufflation of carbon dioxide (CO_2) at ambient temperature during laparoscopic abdominal surgery may contribute to worsened hypothermia due to prolonged procedure times. Perioperative hypothermia has been associated with myocardial ischemia and stimulation of cardiac dysrhythmias such as ventricular tachycardia (Frank 1993; Frank 1997; Putzu 2007). Generalized immunosuppression and increased surgical site infections have also been described in conjunction with hypothermia. Through peripheral vasoconstriction, infections are thought to arise because of a reduction in oxygen delivery to the healing tissues (Beilin 1998; Qadan 2009). Increased blood loss has been associated with intraoperative hypothermia, resulting in greater transfusion requirements (Putzu 2007; Rajagopalan 2008), which may in turn further worsen hypothermia. Certain patient populations, including the elderly, may have a higher risk for hypothermia (Macario 2002).

A European survey of 8083 surgical cases determined that only 19.4% of the patients received intraoperative temperature monitoring (TEMMP). Interventions to prevent hypothermia include passive techniques such as blankets and covers. Active warming methods include heated forced air systems, heated mattresses and blankets, warmed humidified ventilator circuits and warmed intravenous and irrigation fluids. These methods have been suggested to limit perioperative complications from hypothermia (Putzu 2007; Winkler 2000; Wong 2007). Warm and humidified CO_2 insufflation during minimally invasive surgery has been suggested as another active method to prevent hypothermia. The CO_2 is heated by using a tube with an inline heating coil and water reservoir. The gas may be heated to 36 °C and humidified to 95% using such systems.

Several studies have been performed to analyze the impact of using warmed CO_2, with or without humidification, for abdominal insufflation in laparoscopic surgery on patient-centered clinical outcomes. It has been suggested that warming up CO_2 prior to insufflation may prevent hypothermia and peritoneal inflammation (Demco 2001). Other studies concluded that warmed insufflation decreases postoperative pain (Champion 2006; Farley 2004; Hamza 2005; Mouton 1999; Ott 1998) and improves recovery times. These studies typically involved small and specific patient populations. In contradiction, a number of studies exist that show no important clinical benefits of using heated insufflation (Davis 2006; Nguyen 2002) and one in particular showed increased postoperative pain in the heated group (Kissler 2004). This systematic review of the existing literature clarifies the role of warmed CO_2

on core temperature during laparoscopic abdominal surgery and its impact on relevant clinical outcomes.

OBJECTIVES

Primary objective: to determine if the use of heated (with or without humidification) gas insufflation maintains normothermia better than cold gas insufflation in laparoscopic abdominal surgery.

Secondary objectives: to determine if the use of heated (with or without humidification) gas insufflation improves postoperative pain scores, analgesic requirements, recovery room stay and length of hospitalisation as well as lens fogging and length of operation in comparison to cold gas insufflation.

METHODS

Criteria for considering studies for this review

Types of studies

Randomized controlled trials

Types of participants

Adult and pediatric patients undergoing laparoscopic abdominal surgery

Types of interventions

Heated, with or without humidification, gas insufflation versus cold gas insufflation

Types of outcome measures

- Primary outcome: change in core temperature
- Secondary outcomes: the following clinical effects on the patient

- pain score;
- analgesia requirements;
- recovery room stay, hospital stay;
- length of surgery; and also
- lens fogging.

Search methods for identification of studies

We performed electronic searches of the following databases using strategies developed in collaboration with the Cochrane Colorerectal Cancer Group (CCCG) Trial Search Co-ordinator.

MEDLINE (PubMed) (1956 to 14th June 2010)

- MeSH terms
  - Surgical Procedures, Minimally Invasive.
  - Laparoscopy
  - Pneumoperitoneum
  - Video-Assisted Surgery
  - Carbon Dioxide
  - Nitrous Oxide
  - Argon
  - Helium
  - Temperature

- Keywords
  - Gas or gases or carbon dioxide or CO_2 or nitrous oxide or N_2O or helium or argon or laughing gas
  - Minimally invasive surgery or procedure
  - Endoscopy
  - Laparoscopy
  - Peritoneoscopy
  - Heat or temperature or warm or isothermic

Cochrane Central Register of Controlled Trials (CENTRAL) (The Cochrane Library 2009, Issue 1, January 12)

- Keywords
  - Gas or gases or carbon dioxide or CO_2 or nitrous oxide or N_2O or helium or argon or laughing gas
  - Minimally invasive surgery
  - Laparoscopic or laparoscopy
  - Endoscopic or endoscopy
  - Heated or warm or temperature

EMBASE (1980 to June 2010)

- Emtree headings
  - Minimally invasive surgery
  - Endoscopy
  - Laparoscopy
  - Pneumoperitoneum
  - Gas
  - Carbon Dioxide
  - Nitrous Oxide
  - Argon
  - Helium
  - Temperature
  - exp Temperature related phenomena

- Keywords
  - As Medline

We performed keyword searches from the following websites

- International Pharmaceutical Abstracts
- Web of Science
- Scopus
- ClinicalTrials.gov
- National Research Register

A total of 1483 citations were identified and, after removing non-relevant studies, 525 abstracts were reviewed. Trials that involved non-abdominal procedures, uncommon laparoscopic procedures, non-human subjects and those not using cold gas as a control were excluded. Duplicated studies and non-randomized controlled trials were also excluded. Finally, in agreement with the authors (DB, GH and XS), 16 studies were selected. There were no language restrictions.

Data collection and analysis

Inclusion of studies

All included studies were randomized controlled trials that compared heated gas insufflation (with or without humidification) with cold gas insufflation for laparoscopic abdominal surgery. Studies were assessed for quality of sequence generation, allocation concealment, blinding, the possibility of incomplete data and selective reporting (Table 1). Study selection was performed by two authors, with any subsequent disagreement resolved through discussion with a third co-author. Studies were further assessed to determine whether: 1) the method of allocation was concealed and random; 2) an intention-to-treat analysis was performed, and clearly stated; and 3) loss to follow up was considered.

Data extraction

Data from the included studies were collected using data sheets. Missing data were obtained, if possible, either from the original authors or from similar reviews written by others (Sajid 2008; Sammour 2008). Two studies (Saad 2000; Wills 2001) that did not use standard visual analog scales had their 0 to 100 scores converted to a score from 0 to 10.

Data analysis

The effect of intervention was calculated for each trial. Categorical data were expressed as relatives risk (RR) with 95% confidence intervals (CI) and the continuous data were expressed as mean ± standard deviation (SD). Meta-analysis was used to combine the outcomes and the effect of intervention was determined. The included studies were tested for heterogeneity. When significant heterogeneity was found among studies, subgroup analysis was performed to explore the source. The estimated effect of intervention was calculated using the latest version of RevMan software provided by the Cochrane website. The random-effects method was applied in our analysis, assuming that the true effect estimates varied among studies. Publication bias was taken into consideration and funnel plots were compiled for the studies to reveal this. When the original data only provided the mean, the largest SD in the group was used.

RESULTS

Description of studies

See: Characteristics of included studies; Characteristics of excluded studies.

Sixteen randomized controlled trials comparing heated (with or without humidification) CO_2 with standard cold CO_2 were included. All other studies including non-randomized trials and those comparing heated dry CO_2 versus heated humidified CO_2 were excluded. Studies examining outcomes that were dissimilar to those relevant to this review and those studies where a response from the authors was not received were excluded from the analysis. Surgical procedures included in the studies were: gastric bypass (n = 157), gynecologic surgery (n = 202), cholecystectomy (n = 242), Nissen fundoplication (n = 99), and colonic surgery (n = 74). Outcome data were available for 774 participants of which 274 were in the heated, humidified gas group; 121 were in the heated only gas group; and 379 were in the cold gas group. Five studies had relatively long operative times (> 90 minutes). A warming blanket (Bair Hugger) was used for simultaneous active warming in seven out of 16 studies and a humidifier company supported 10 of the 16 trials. Nine studies were deemed to have a low risk of bias in the presentation of their results. Only five of the 16 studies demonstrated a benefit with the use of heated gas insufflation.

Champion 2006 (Champion 2006): this trial of heated humidified versus cold dry CO_2 insufflation for laparoscopic gastric bypass examined 50 consecutive obese patients with homogeneous baseline characteristics (gender, age, preoperative weight, body mass index (BMI) and c-reactive protein (CRP)) between groups. The ambient insufflation gas was at a temperature of 35 °C and 95% relative humidity. The sole difference identified in the heated group was a lower postoperative subjective shoulder pain score at 18 hours. There were no differences between groups in intraoperative core temperature, operating room temperature, litres of insufflation, operating time, number of lens cleanings, recovery room temperature, narcotic usage, length of hospitalisation, high-sensitivity CRP at 24 hours or abdominal pain scores.

Davis 2006 (Davis 2006): with adequate allocation concealment, this study examined 44 laparoscopic Roux-en-Y gastric bypass patients in Ohio State University. There were four study groups with

11 patients in each and similar baseline characteristics across the groups. The groups included the following insufflation techniques: 1) cold dry, 2) cold humidified (97% relative humidity), 3) heated dry (37 °C), and 4) heated humidified (37 °C and 97% relative humidity) CO_2. There were no differences in patient core temperature, intra-abdominal humidity, postoperative narcotic usage, pain scale scores, recovery room time, length of hospitalisation, lens fogging or macrophage activity between groups, though patients in the heated humidified insufflation group demonstrated increased macrophage activity in biopsies.

Farley 2004 (Farley 2004): with adequate allocation concealment, 101 laparoscopic cholecyctectomy patients were randomized to either cold or heated and humidified CO_2 insufflation. The experimental group showed higher intraoperative core temperatures and decreased postoperative pain scores at day 14; the authors questioned the clinical relevance of the latter outcome. No differences were identified in the rate of lens fogging, narcotic requirements, length of hospitalisation or time of return to baseline activity levels.

Hamza 2005 (Hamza 2005): 50 patients undergoing laparoscopic Roux-en-Y gastric bypass surgery were randomized with no information on allocation concealment to cold or heated and humidified CO_2 insufflation. The heated group showed a higher intraoperative core temperature, a reduction in the recovery room and narcotic requirements, and a higher quality of recovery at 48 hours postoperatively. There were no differences in postoperative tympanic membrane temperatures, pain scores, shivering, overall morphine usage, nausea scores, Aldrete recovery assessment scores, length of hospital stay or lens fogging.

Kissler 2004 (Kissler 2004): 90 consecutive women scheduled for gynecologic laparoscopic surgery were recruited into this study with randomization to heated humidified, heated non-humidified, and cold gas insufflation groups, each with 30 patients. The trial was stopped following enrollment of 53 patients due to a tendency for less pain and higher postoperative satisfaction in the cold insufflation control group.

Manwaring 2008 (Manwaring 2008): 60 gynecology patients were randomized to heated humidified or cold insufflation groups. Heated and humidified gas insufflation was not associated with any significant benefits as no difference was found in esophageal temperature, pain scores or narcotic usage.

Mouton 1999 (Mouton 1999): 16 cholecystectomy patients were randomized to heated and humidified insufflation and 16 were randomized to cold gas insufflation. Though no difference was found in core temperature during the relatively brief operations, there was significantly less pain compared to the experimental heated and humidified insufflation patients at 6 hours and on the first to third days postoperatively. Pain was also less on the 14th postoperative day.

Nelskyla 1999 (Nelskyla 1999): 37 laparoscopic hysterectomy patients were randomized to heated or unheated gas insufflation groups. Tympanic and nasopharyngeal intraoperative temperatures were not different between the groups.

Nguyen 2002 (Nguyen 2002): 20 laparoscopic Nissen fundoplication patients were randomized without information on the allocation method to heated and humidified or cold and dry gas insufflation groups. There were no differences in core temperature, pain scores, narcotic consumption, urine output or lens fogging.

Ott 1998 (Ott 1998): without stating the number of patients in each group, 72 patients undergoing laparoscopic gynecologic surgery were randomized to heated and humidified or cold and dry gas insufflation. The experimental heated group showed improved intraoperative normothermia and postoperative pain and reduced recovery room stay.

Puttick 1999 (Puttick 1999): 30 laparoscopic cholecystectomy patients were randomized to heated or cold gas insufflation. The authors concluded that intraoperative cooling can be prevented by heating the insufflated gas.

Saad 2000 (Saad 2000): 20 laparoscopic cholecystectomy patients were randomized to heated or cold gas insufflation with no effects when comparing core temperature or postoperative pain.

Sammour 2010 (Sammour2010): 82 patients undergoing laparoscopic colon surgery were randomized to heated humidified or cold gas insufflation groups, each with 41 patients. No significant effects were found, including no effect on the early postoperative inflammatory cytokine response.

Savel 2005 (Savel 2005): 30 patients undergoing laparoscopic Roux-en-Y gastric bypass were randomized to cold or heated and humidified gas insufflation groups. Length of hospitalisation and operative time were reduced in the experimental group but differences in pain sensation were not found.

Slim 1999 (Slim 1999): 100 patients undergoing laparoscopic cholecystectomy, fundoplication, or Heller's myotomy were enrolled and randomized to cold or heated insufflation. Shoulder and subcostal pain sensation was increased in the heated insufflation group and no difference was found on core temperature or narcotic consumption.

Wills 2001 (Wills 2001): 40 patients were randomized to heated or cold gas insufflation during laparoscopic fundoplication. An increased core temperature was associated with the heated insufflation group, though the control group patients suffered less postoperative pain and required fewer narcotics.

Risk of bias in included studies

The Cochrane Collaboration's tool for assessing risk of bias was used. Sixteen trials met all the criteria and were included in our study. Given that not all studies had adequate sequence generation, proper allocation concealment or blinding, complete outcome data and descriptions of withdrawals, a sensitivity analysis was performed. Nine trials were classified as having low risk of bias. Conclusions were not altered following sensitivity analysis except in recovery room stay. There was less publication bias where rele-

vant outcomes and funnel plots were symmetric (Figure 1; Figure 2; Figure 3; Figure 4; Figure 5; Figure 6; Figure 7; Figure 8).

Figure 1. Funnel plot of comparison: 2 Core temperature, outcome: 2.1 Change in core temperature.

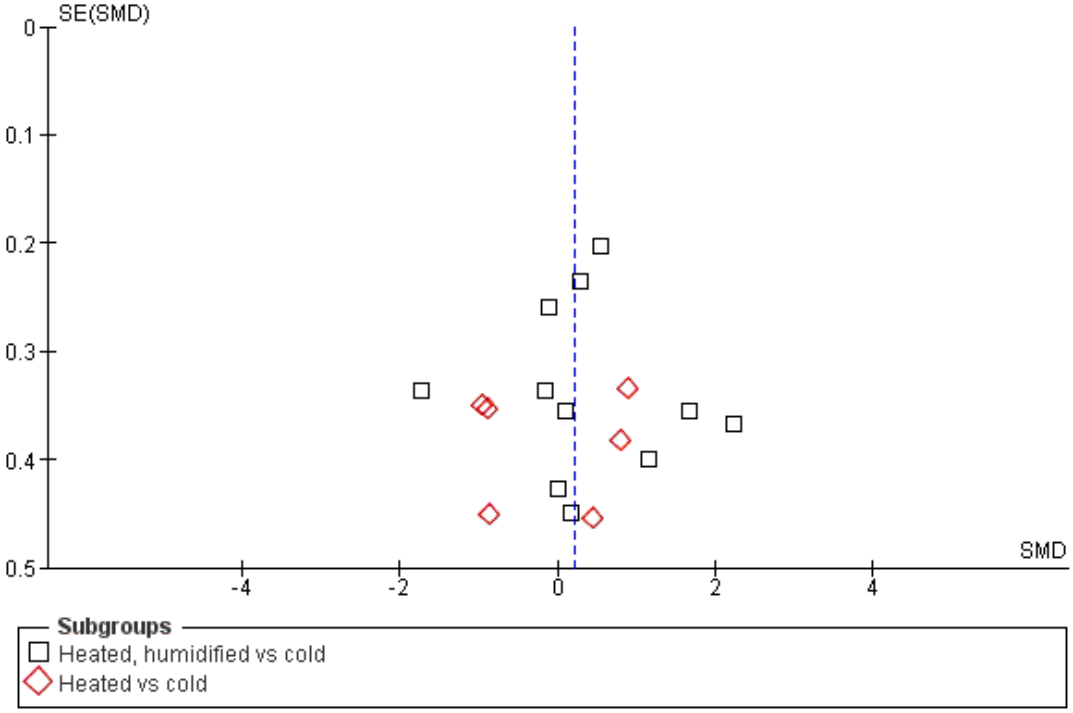


Figure 2. Funnel plot of comparison: 1 Pain Score, outcome: 1.1 Day 1 pain score.

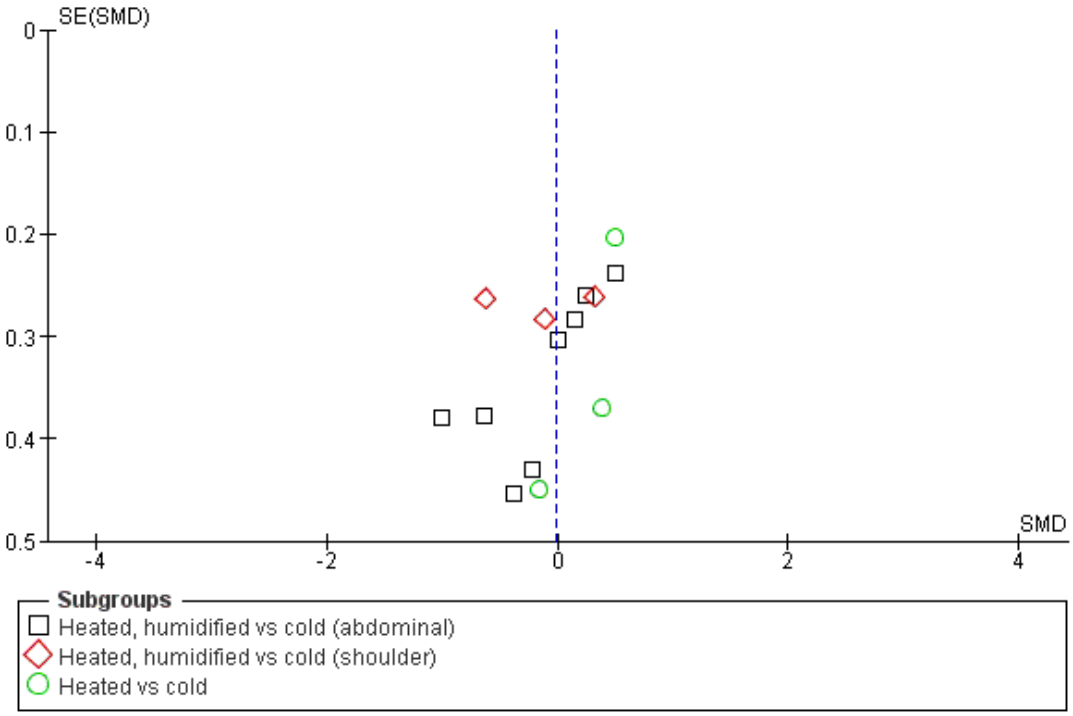


Figure 3. Funnel plot of comparison: 3 Morphine consumption, outcome: 3.2 Day 1 morphine.

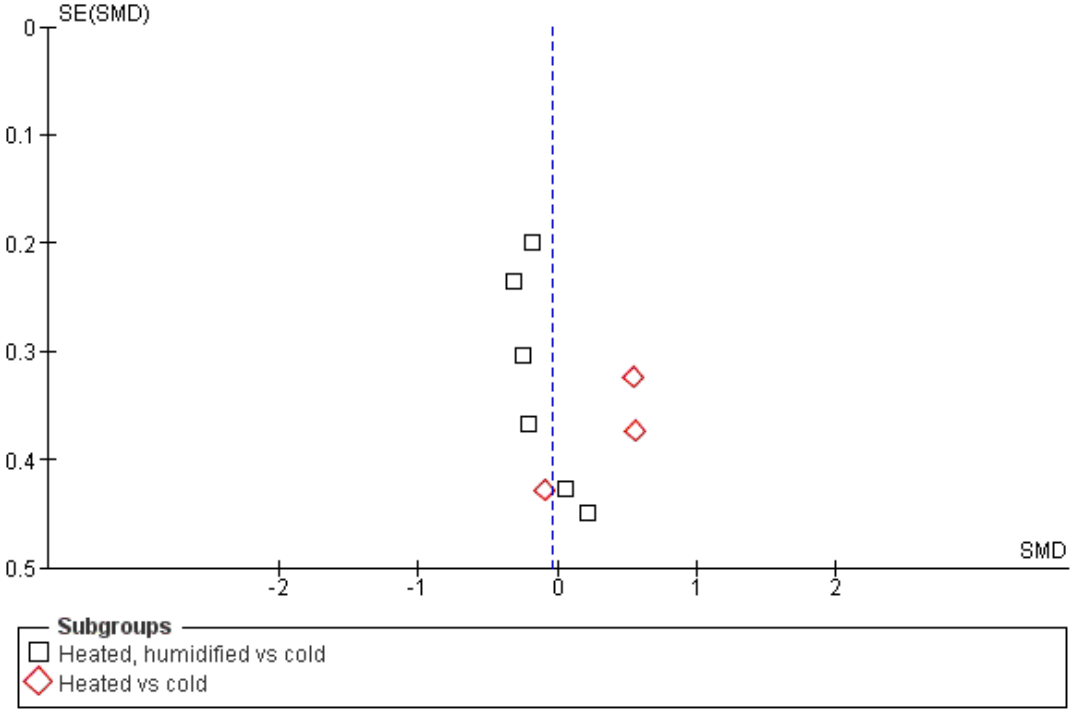


Figure 4. Funnel plot of comparison: 4 Hospital stay, outcome: 4.1 Hospital stay.

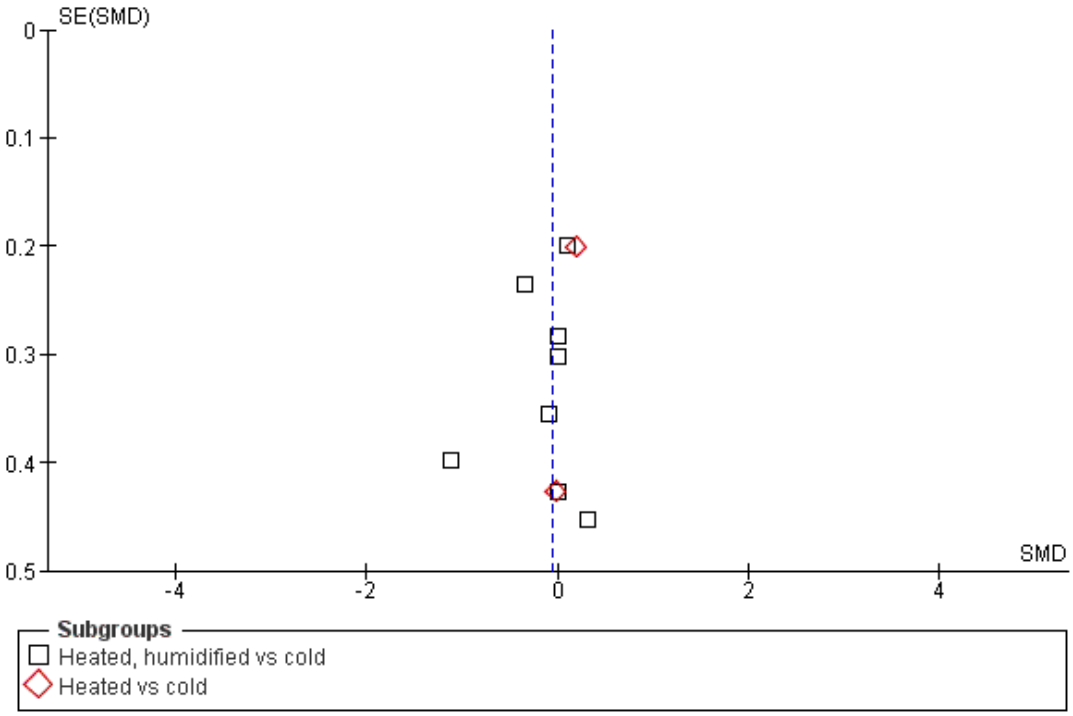


Figure 5. Funnel plot of comparison: 5 Recovery room stay, outcome: 5.1 Recovery time.

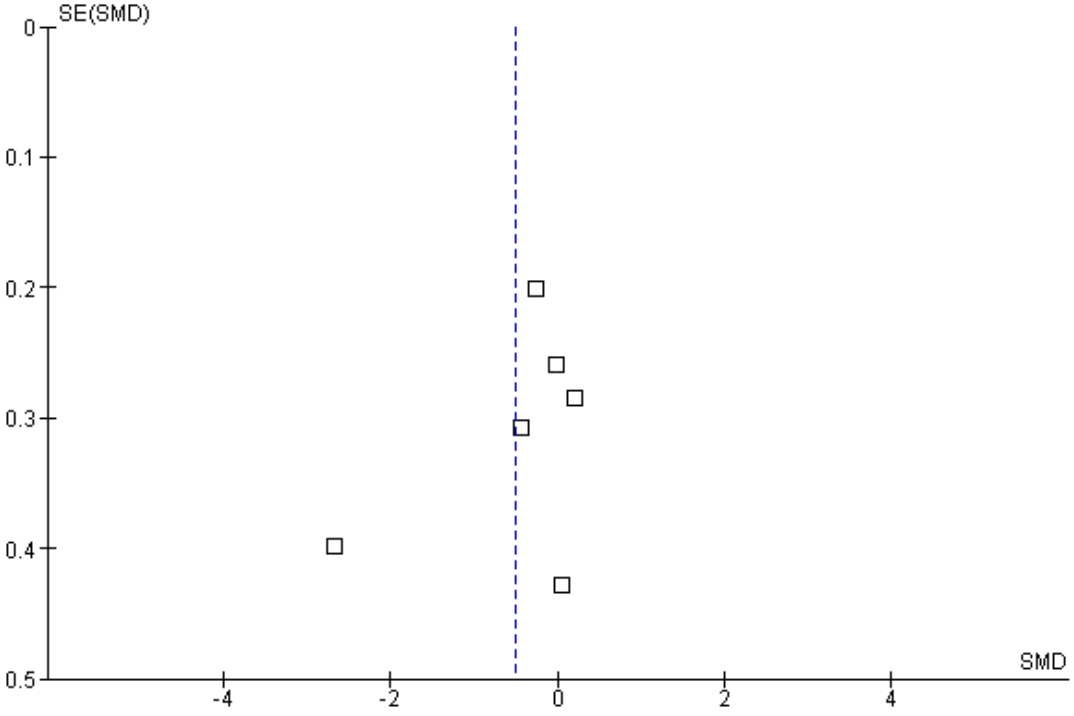


Figure 6. Funnel plot of comparison: 5 Recovery room stay, outcome: 5.2 Recovery time for low risk of bias studies.

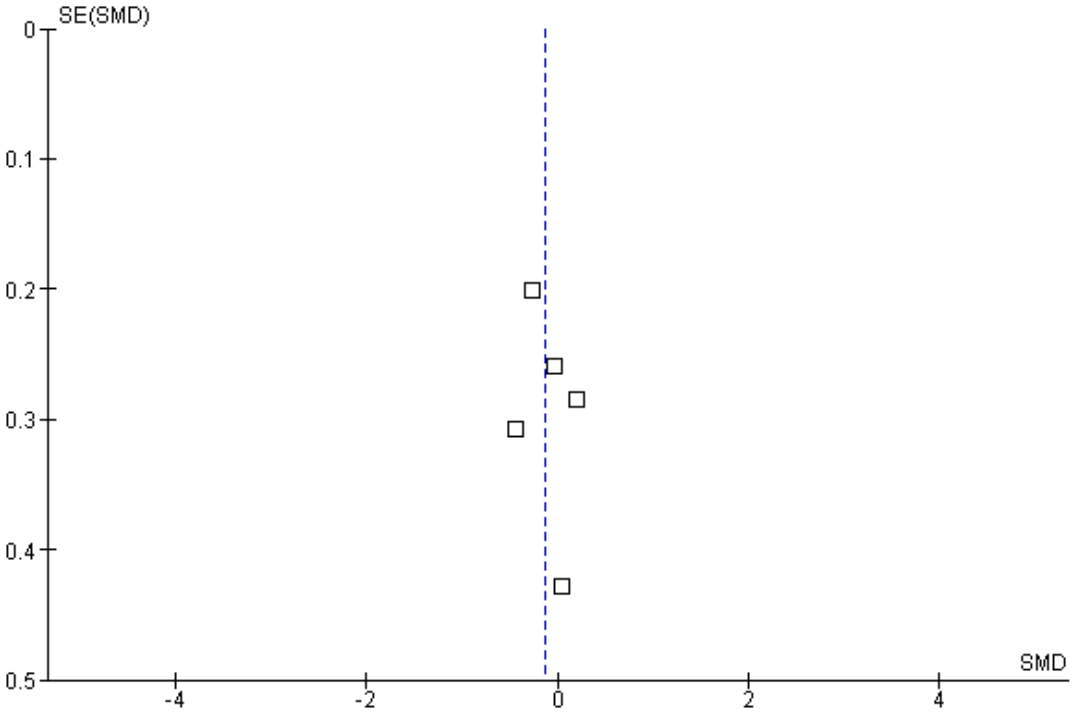


Figure 7. Funnel plot of comparison: 5 Lens fogging, outcome: 5.1 Lens fogging.

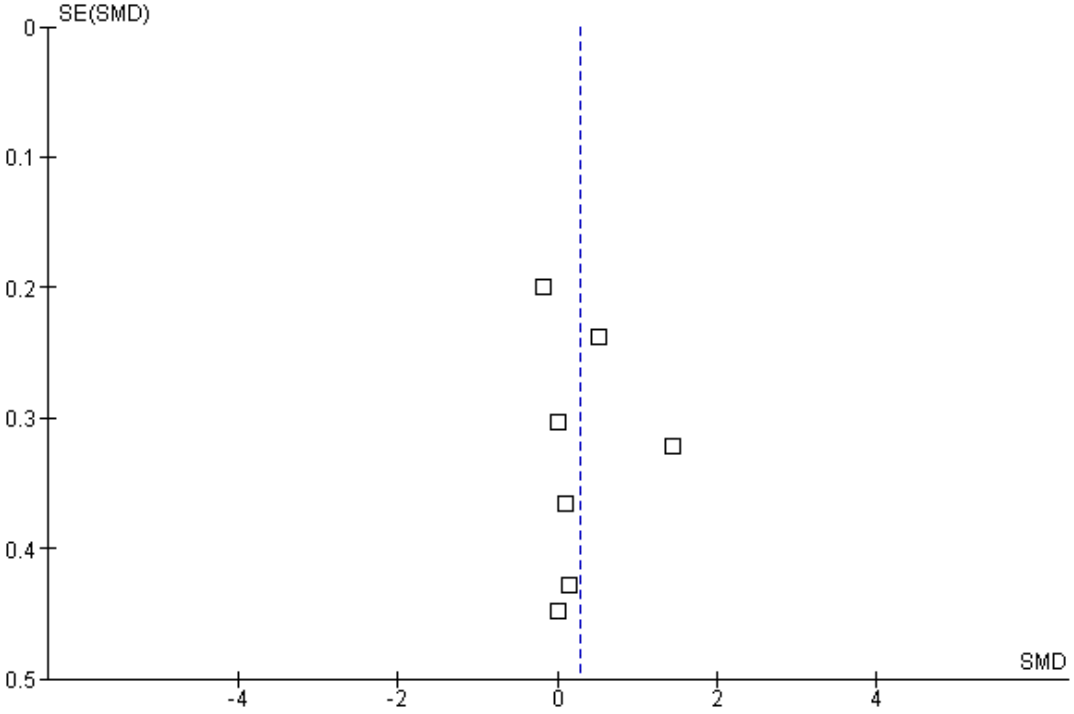
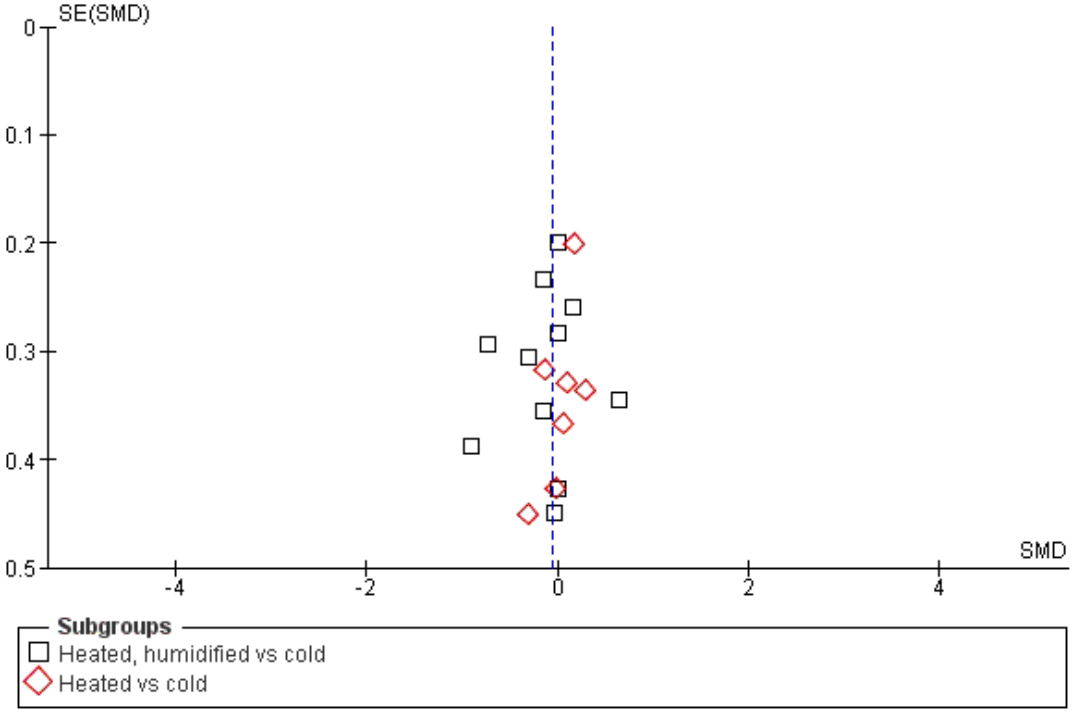


Figure 8. Funnel plot of comparison: 6 Operative time, outcome: 6.1 Operative time.



Effects of interventions

Change in core temperature (Analyses 1.1 to 1.3)

All studies reported intraoperative core temperature. Heated gas (with or without humidification) had no effect on core temperature intraoperatively compared to control (P = 0.21) (Figure 9). Subgroup sensitivity analysis with respect to procedure, operation time, location of temperature probe, CO_2 temperature and study quality were performed (Figure 10: sensitivity analysis of study quality); however, conclusions were unchanged and outcomes still exhibited significant heterogeneity. When studies using active warming with external warming blankets were assessed, the core temperature was significantly higher in the heated and humidified group (SMD 0.58, 95% CI 0.10 to 1.06, P = 0.02) but the studies were not homogenous. If the only study with high risk of bias was excluded, the difference in effect was diminished (SMD 0.48, 95% CI -0.03 to 1.00, P = 0.07) and heterogeneity was still present (Figure 11).

Figure 9. Forest plot of comparison: 2 Core Temperature, outcome: 2.1 Change in Core Temperature.

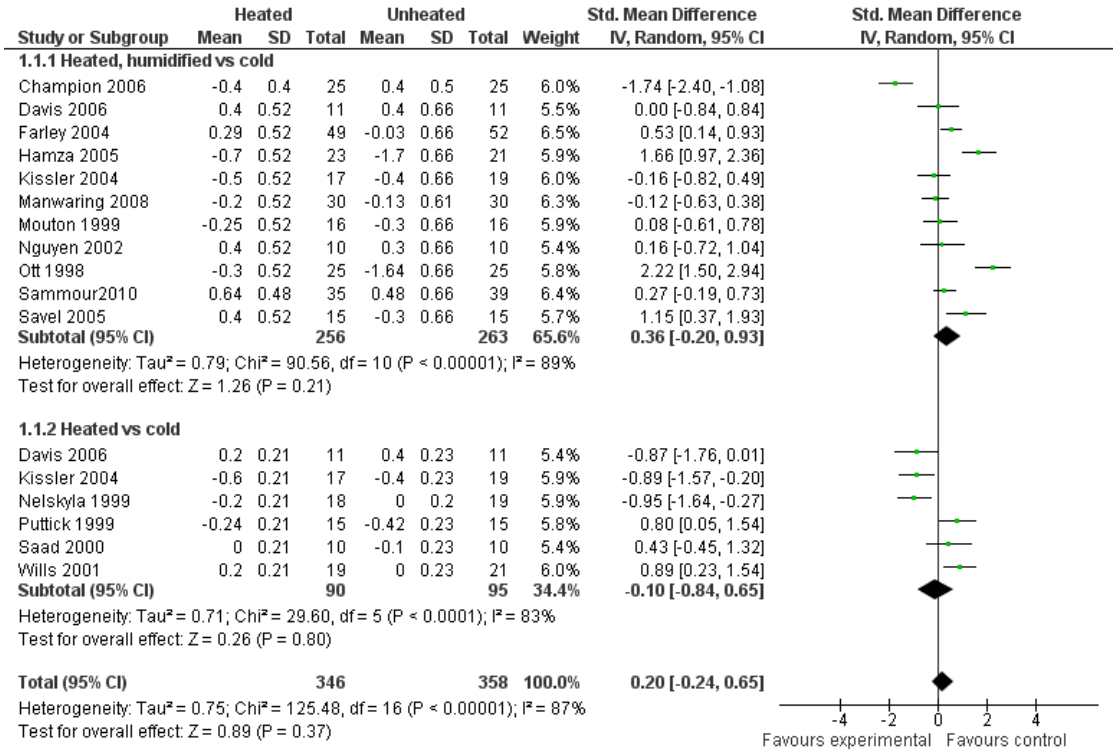


Figure 10. Forest plot of comparison: 2 Core Temperature, outcome: 2.2 Change in Core temperature for low risk of bias studies.

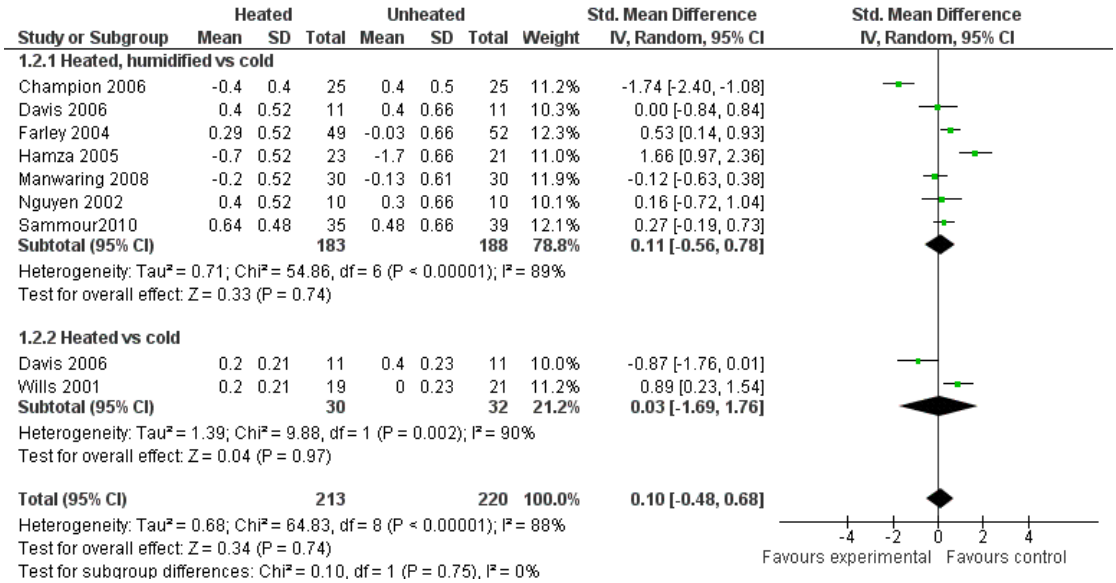
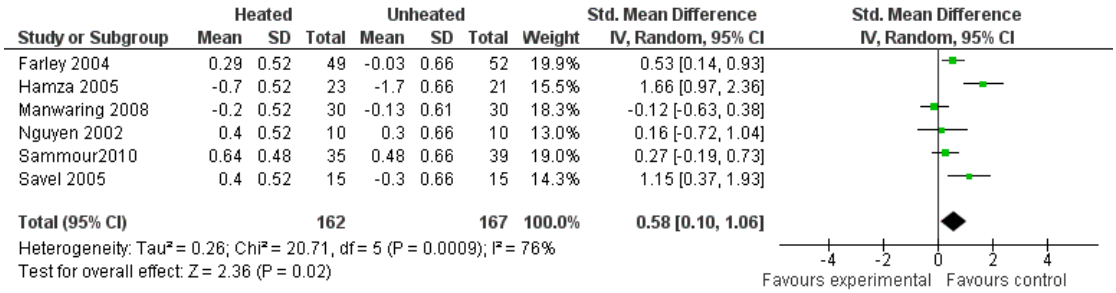


Figure 11. Forest plot of comparison: 2 Core temperature, outcome: 2.3 Change in core temperature with external warming.



Pain scores (Analyses 2.1 to 2.4)

The overall effects of heated and humidified gas on postoperative day-one abdominal and shoulder pain scores were not different (abdominal P = 0.57; shoulder P = 0.63) from using cold gas (Figure 12). Given the significant heterogeneity shown across studies (abdominal P = 0.02, I^2 = 58%; shoulder P = 0.04, I^2 = 70%), sensitivity analysis was performed and only studies with low risk of bias were included. The pain scores were still not different with respect to either abdominal or shoulder pain (P > 0.05) and the test of heterogeneity was no longer significant (abdominal P = 0.46, I^2 = 0%; shoulder P = 0.27, I^2 = 19%) (Figure 13). As for the heated non-humidified versus cold gas comparison, a lower pain score was found in the cold gas group (SMD 0.38, 95% CI 0.06 to 0.71, P = 0.02) and the three studies had homogenous outcomes (P = 0.41, I^2 = 0%) (Figure 12). For pain on the second postoperative day, heated and humidified gas did not improve abdominal or shoulder pain (abdominal P = 0.42; shoulder P = 0.50) and, again, the studies were heterogenous (Figure 14). When the two studies with high risk of bias were excluded, the conclusion was unchanged (Figure 15). With heated non-humidified gas, the postoperative day-two pain score was similar to the cold gas control (P = 0.38) with no significant heterogeneity across groups (P = 0.38, I^2 = 0%).

Figure 12. Forest plot of comparison: 1 Pain Score, outcome: 1.1 Day 1 pain score.

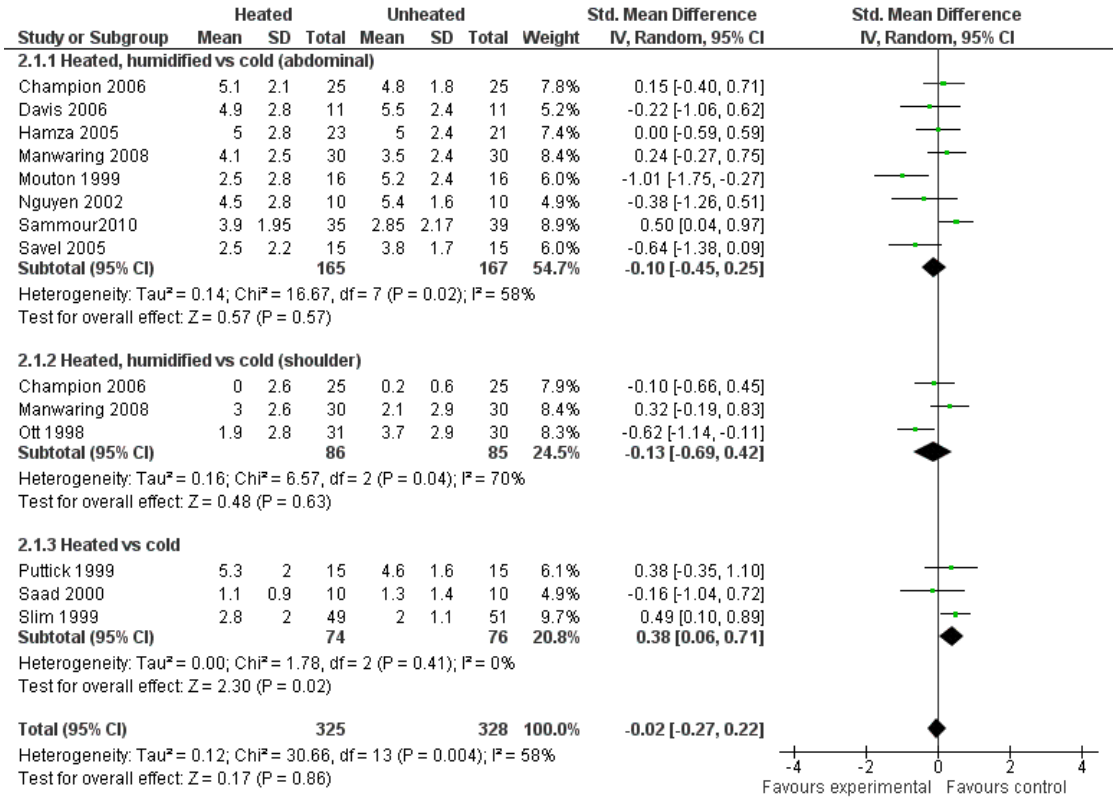


Figure 13. Forest plot of comparison: 1 Pain score, outcome: 1.3 Day 1 pain score for low risk of bias study.

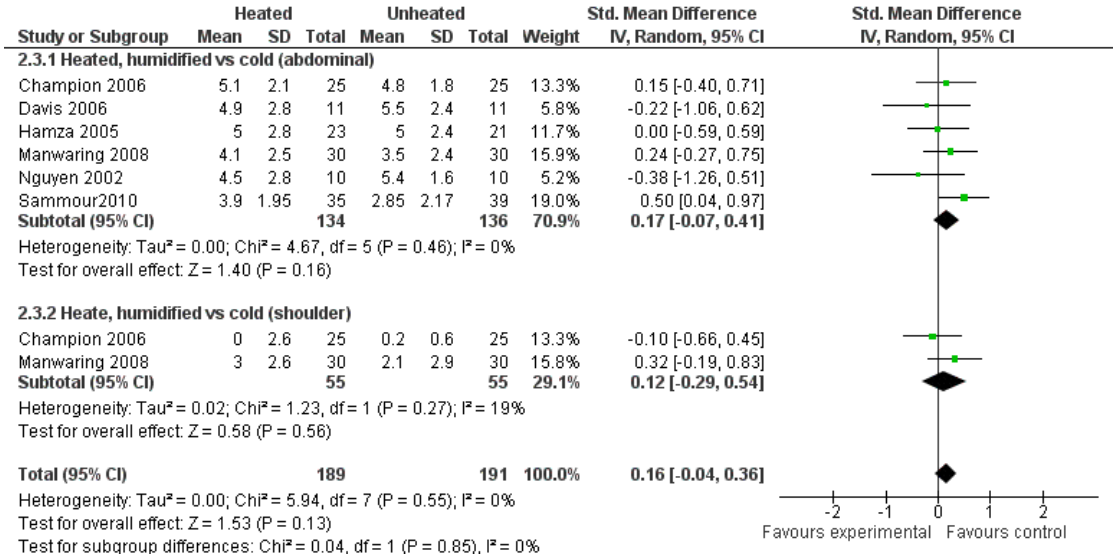


Figure 14. Forest plot of comparison: 1 Pain score, outcome: 1.2 Day 2 pain score.

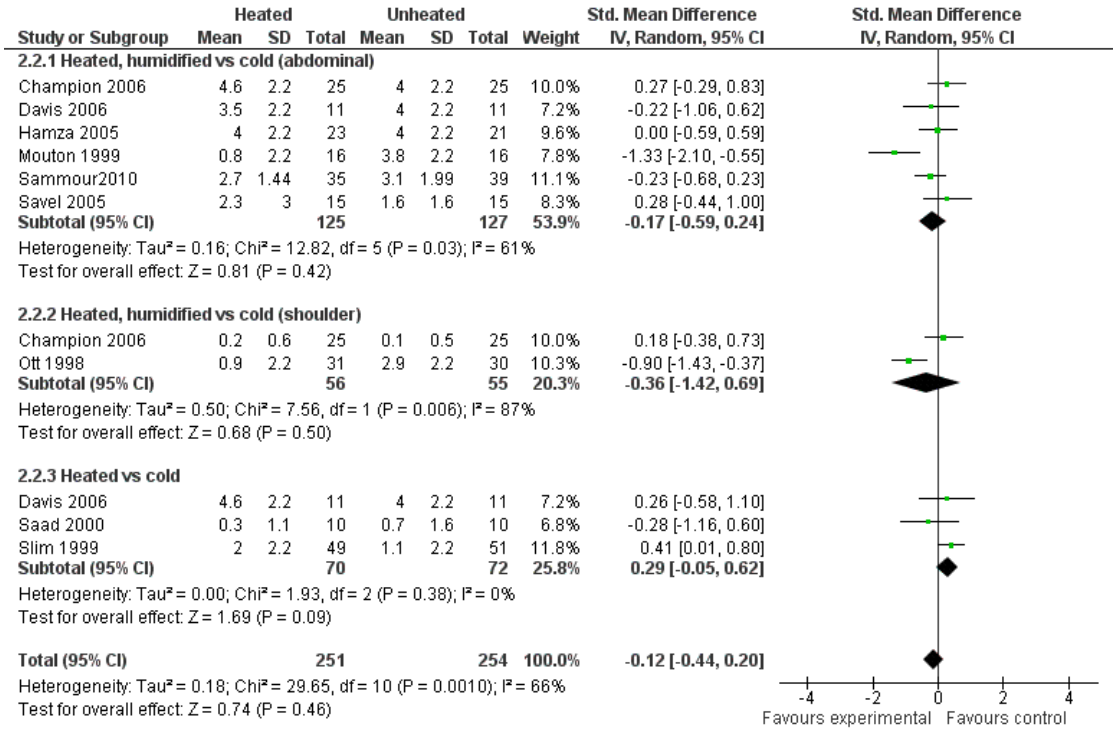
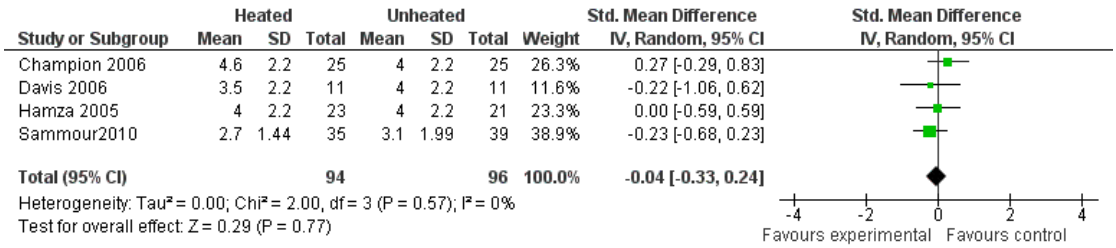


Figure 15. Forest plot of comparison: 1 Pain score, outcome: 1.4 Day 2 pain score of low risk of bias studies.



Morphine consumption (Analysis 3.1 to 3.3)

Heterogeneity was not significant across studies. Three studies comparing heated and humidified with cold gas insufflation reported morphine consumption up to six hours after operation with no statistical difference between groups (P = 0.51) (Figure 16). Morphine use on the first postoperative day was not different between the control and heated gas groups with or without humidification (P = 0.11 and 0.07, respectively) (Figure 17). For the second postoperative day, morphine consumption was lower in the heated with humidification gas group (SMD -0.30, 95% CI -0.56 to -0.03, P = 0.03) and higher in the heated without humidification group (SMD 0.41, 95% CI 0.06 to 0.77, P = 0.02), each in comparison to a cold gas control (Figure 18).

Figure 16. Forest plot of comparison: 3 Morphine consumption, outcome: 3.1 Up to 6 hour.

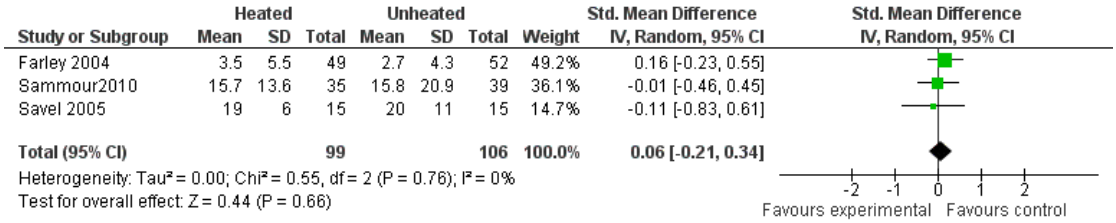


Figure 17. Forest plot of comparison: 3 Morphine consumption, outcome: 3.2 Day 1 morphine.

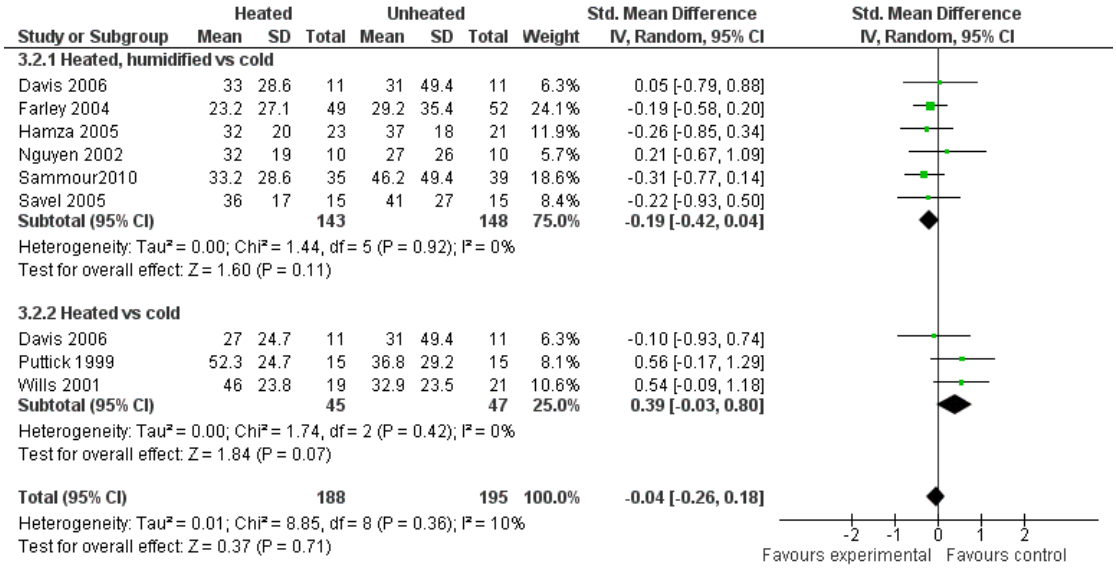
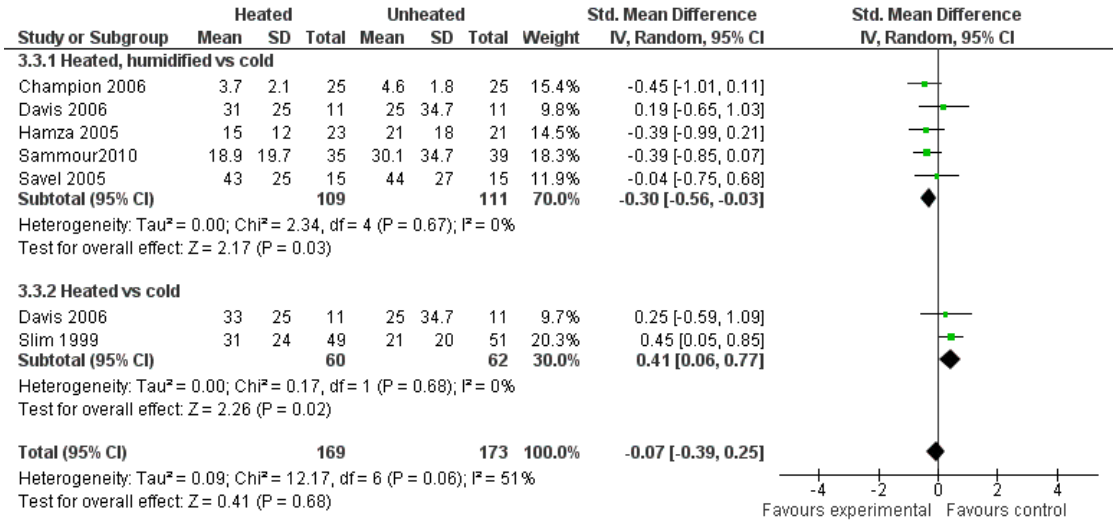


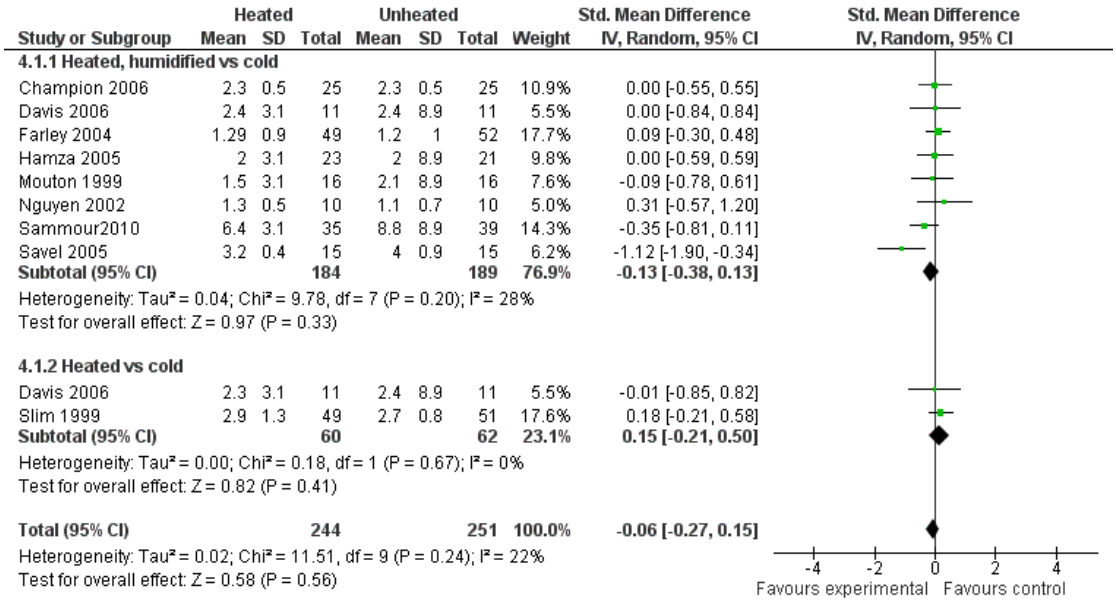
Figure 18. Forest plot of comparison: 3 Morphine consumption, outcome: 3.3 Day 2 morphine.



Hospitalisation (Analysis 4.1)

There was no heterogeneity (P = 0.24, I^2 = 22%) across studies. Hospitalisation was not different between the heated (with or without humidification) and cold gas insufflation groups (P = 0.56) (Figure 19).

Figure 19. Forest plot of comparison: 4 Hospital stay, outcome: 4.1 Hospital stay.



Recovery room stay (Analysis 5.1 to 5.2)

Recovery room time was documented in six studies and there was heterogeneity among them. No beneficial effect on recovery time (P = 0.14) was found with heated insufflation (Figure 20). With exclusion of one study with high risk of bias, though the studies were homogenous the effect of the intervention was not significant (P = 0.26) (Figure 21).

Figure 20. Forest plot of comparison: 7 Recovery room stay, outcome: 7.1 Recovery time.

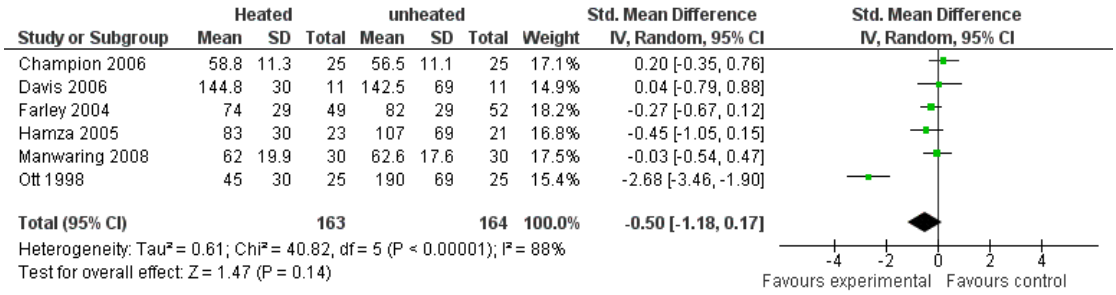
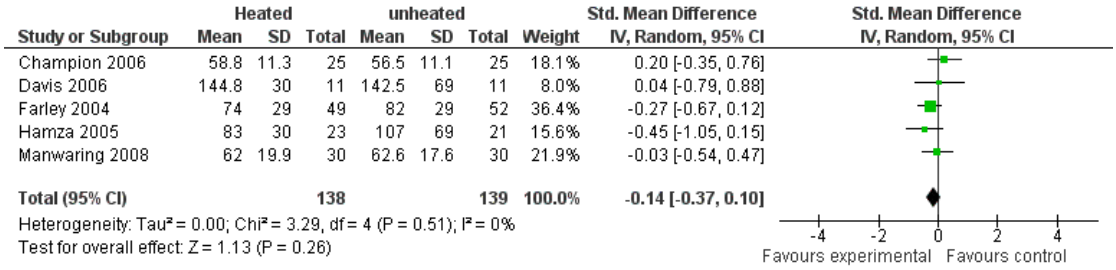


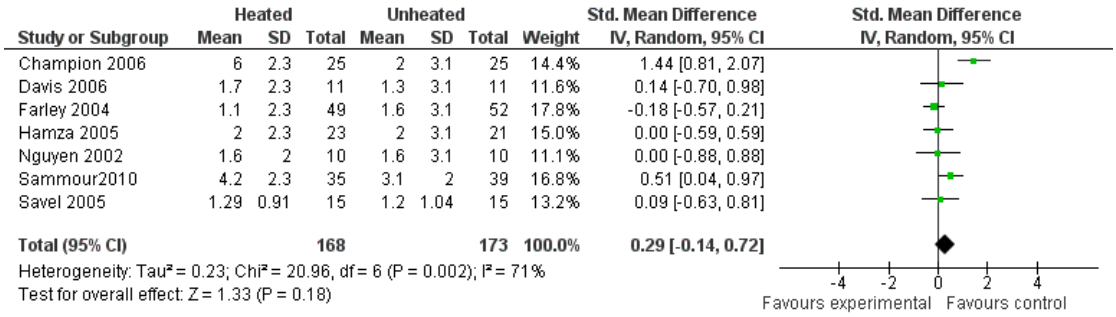
Figure 21. Forest plot of comparison: 7 Recovery room stay, outcome: 7.2 Recovery time for low risk of bias studies.



Lens fogging (Analysis 6.1)

Evidence of heterogeneity (P = 0.002, I^2 = 71%) was present and no significant difference in the lens fogging scores was shown (P = 0.18) (Figure 22). Subgroup analysis neither changed the heterogeneity nor the significance of the result.

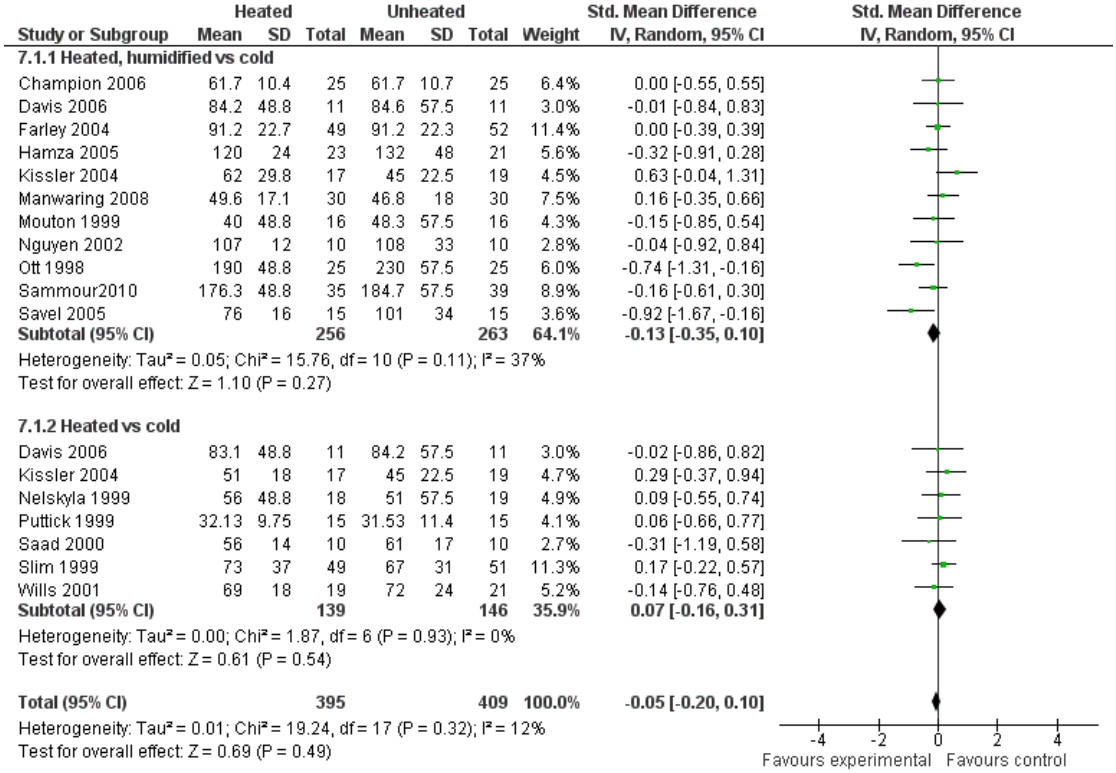
Figure 22. Forest plot of comparison: 5 Lens fogging, outcome: 5.1 Lens fogging.



Operative time (Analysis 7.1)

Sixteen studies reported their mean operative time and SD and no evidence of heterogeneity (P = 0.93, I^2 = 0%) was found. The mean operative time was similar across groups (P = 0.49) (Figure 23).

Figure 23. Forest plot of comparison: 6 Operative time, outcome: 6.1 Operative time.



DISCUSSION

Controversy exists on the use of heated insufflation measures in laparoscopic surgery. Laparoscopic procedures already demand higher operating expenses than conventional open techniques and the addition of further complex equipment only increases this limitation. In 2002, the European Association for Endoscopic Surgery published consensus guidelines for laparoscopic pneumoperitoneum and stated that "the clinical benefits of warmed humidified insufflation gas are minor and contradictory" (Neudecker2002). Evidence based on the 16 randomized controlled trials in this systematic review failed to illustrate definitive evidence for the use of such systems during laparoscopic abdominal surgery. Heated and humidified gas insufflation showed benefit only with respect to postoperative day-two narcotic requirements, though there were significant improvements in core body temperature with heated insufflation in patients alternating external warming devices. On the other hand, non-humidified heated insufflation was worse than cold gas insufflation in regards to postoperative day-two narcotic requirements. Interestingly, patients in this group had higher pain scores than the cold gas control group on the first postoperative day.

Among the nine low risk of bias studies included in the review only one study demonstrated improved maintenance of normothermia, as well as a reduction in analgesic use in the early postoperative period (Hamza 2005). In this study, external warming blankets were used solely as a 'rescue' treatment, potentially confounding the effect of the experimental intervention. The heterogeneity in core temperature outcomes across studies may be secondary to minor protocol differences between studies. Different insufflation gas temperatures (35 ^{o}C to 37 ^{o}C), humidity ranges (88% to 100%), gas volumes and location of the temperature probe may all have attributed to this variability in effects.

The results of this review should be interpreted cautiously due to some limitations. Though the studies were all randomized controlled trials and applicable to the research question, some lacked design information making evaluation of study quality difficult. Many of the studies included small sample sizes, which made individual inferences difficult regarding the attribution of effects to random error or the heated insufflation intervention. The standard deviations used for meta-analysis were not all drawn from the included studies, secondary to missing data, thereby potentially distorting the true effects and potentially increasing the error. Finally, some heterogeneity across studies could not be explained through subgroup analysis and therefore may have weakened the conclusions.

Two previously published meta-analysis revealed different conclusions than the current study (Sajid 2008; Sammour 2008). Both provided evidence for a reduction in postoperative pain and the study by Sajid et al also demonstrated decreased postoperative hypothermia and narcotic requirements. The current review incorporates a greater number of studies in the analysis, including two recent trials showing equivocal results with heated insufflation compared to cold gas insufflation (Manwaring 2008; Sammour2010). Finally, one study included in the previous reviews compared heated insufflation with humidification to heated insufflation without humidification, a comparison not in keeping with the aims of the current review.

AUTHORS' CONCLUSIONS

Implications for practice

Based on our review, there is no evidence to confirm that heated CO_2 insufflation, either with or without humidification, improves maintenance of core temperature in patients undergoing laparoscopic abdominal surgery. In addition, heated insufflation did not reduce postoperative pain or analgesic requirements overall. If the maintenance of normothermia can be achieved through the use of warmed irrigation and external warming devices, perhaps less consideration can be given to the use of heated insufflation systems which add expenses to procedures already more costly than open surgical approaches.

Implications for research

Good quality studies of how heated and humidified CO_2 affects patient outcomes have been completed. However, the studies have relatively small sample sizes. In order to further clarify the effect of heated insufflation on patient outcomes, at least one large multi-center randomized control trial with adequate power should be performed. Though some change in core temperature may be noted during intraoperative monitoring, one must question the clinical relevance of such findings and, therefore, more useful outcomes such as postoperative pain may be used to adequately power the study.

ACKNOWLEDGEMENTS

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REFERENCES

References to studies included in this review

Champion 2006 *{published data only}*
Champion JK, Williams M. Prospective randomized trial of heated humidified versus cold dry carbon dioxide insufflation during laparoscopic gastric bypass. *Surgery for Obesity and Related Diseases* 2006;**2**(4):445-9; discussion 449-450.

Davis 2006 *{published data only}*
Davis SS, Mikami DJ, Newlin M, Needleman BJ, Barett MS, Fries R, et al.Heating and humidifying of carbon dioxide during pneumoperitoneum is not indicated: a prospective randomized trial. *Surgical Endoscopy* 2006;**20**(1):153–8.

Farley 2004 *{published data only}*
Farley DR, Greenlee SM, Larson DR, Harrington JR. Double-blind, prospective, randomized study of warmed, humidified carbon dioxide insufflation vs standard carbon dioxide for patients undergoing laparoscopic cholecystectomy. *Archives of Surgery (Chicago, Ill: 1960)* 2004;**139**(7):739–4.

Hamza 2005 *{published data only}*
Hamza MA, Schneider BE, White PF, Recart A, Villegas L, Ogunnaike B, et al.Heated and humidified insufflation during laparoscopic gastric bypass surgery: effect on temperature, postoperative pain, and recovery outcomes. *Journal of Laparoendoscopic & Advanced Surgical Techniques. Part A* 2005;**15**(1):6–12.

Kissler 2004 *{published data only}*
Kissler S, Haas M, Strohmeier R, Schmitt H, Rody A, Kaufmann M, et al.Effect of humidified and heated CO2 during gynecologic laparoscopic surgery on analgesic requirements and postoperative pain. *The Journal of the American Association of Gynecologic Laparoscopists* 2004;**11**(4):473–7.

Manwaring 2008 *{published data only}*
Manwaring JM, Readman E, Maher PJ. The effect of heated humidified carbon dioxide on postoperative pain, core temperature, and recovery times in patients having laparoscopic surgery: A randomized controlled trial. *Journal of Minimally Invasive Gynecology* 2008 March–April;**15**(2):161–5. [DOI: 10.1016/j.jmig.2007.09.007]

Mouton 1999 *{published data only}*
Mouton WG, Bessell JR, Millard SH, Baxter PS, Maddern GJ. A randomized controlled trial assessing the benefit of humidified insufflation gas during laparoscopic surgery. *Surgical Endoscopy* 1999;**13**(2):106–8.

Nelskyla 1999 *{published data only}*
Nelskyla K, Yli-Hankala A, Sjoberg J, Korhonen I, Korttila K. Warming of insufflation gas during laparoscopic hysterectomy: effect on body temperature and the autonomic nervous system. *Acta Anaesthesiological Scandinavica* 1999;**43**(10):974–8.

Nguyen 2002 *{published data only}*
Nguyen NT, Furdui G, Fleming NW, Lee SJ, Goldman CD, Singh A, et al.Effect of heated and humidified carbon dioxide gas on core temperature and postoperative pain: a randomized trial. *Surgical Endoscopy* 2002;**16**(7):1050–4.

Ott 1998 *{published data only}*
Ott DE, Reich H, Love B, McCorvey R, Toledo A, Liu CY, et al.Reduction of laparoscopic-induced hypothermia, postoperative pain and recovery room length of stay by pre-conditioning gas with the Insuflow device: a prospective randomized controlled multi-center study. *Journal of the Society of Laparoendoscopic Surgeons* 1998;**2**(4):321–9.

Puttick 1999 *{published data only}*
Puttick MI, Scott-Coombes DM, Dye J, Nduka CC, Menzies-Gow NM, Mansfield AO, et al.Comparison of immunologic and physiologic effects of CO_2 pneumoperitoneum at room and body temperatures. *Surgical Endoscopy* 1999;**13**(6):572–5.

Saad 2000 *{published data only}*
Saad S, Minor I, Mohri T, Nagelschmidt M. The clinical impact of warmed insufflation carbon dioxide gas for laparoscopic cholecystectomy. *Surgical Endoscopy* 2000;**14**(9):787–90.

Sammour2010 *{published data only}*
Sammour T, Kahokehr A, Hayes J, Hulme-Moir M, Hill AG. Warming and humidification of insufflation carbon dioxide in laparoscopic colonic surgery. *Annals of Surgery* 2010;**251**(6):1024–33. [DOI: 10.1097/SLA.0b013e3181d77a25]

Savel 2005 *{published data only}*
Savel RH, Balasubramanya S, Lasheen S, Gaprindashvili T, Arabov E, Fazylov RM, et al.Beneficial effects of humidified, warmed carbon dioxide insufflation during laparoscopic bariatric surgery: a randomized clinical trial. *Obesity Surgery* 2005;**15**(1):64–9.

Slim 1999 *{published data only}*
Slim K, Bousquet J, Kwiatkowski F, Lescure G, Pezet D, Chipponi J. Effect of CO(2) gas warming on pain after laparoscopic surgery: a randomized double-blind controlled trial. *Surgical Endoscopy* 1999;**13**(11):1110–4.

Wills 2001 *{published data only}*
Wills VL, Hunt DR, Armstrong A. A randomized controlled trial assessing the effect of heated carbon dioxide for insufflation on pain and recovery after laparoscopic fundoplication. *Surgical Endoscopy* 2001;**15**(2):166–70.

References to studies excluded from this review

Backlund 1998 *{published data only}*
Backlund M, Kellokumpu I, Scheinin T, von Smitten K, Tikkanen I, Lindgren L. Effect of temperature of insufflated CO_2 during and after prolonged laparoscopic surgery. *Surgical Endoscopy* 1998;**12**(9):1126–30.

Barragan 2005 *{published data only}*

Barragan AB, Frezza EE. Impact of a warm gas insufflation on operating-room ergonometrics during laparoscopic gastric bypass: a pilot study. *Obesity Surgery* 2005;**15**(1): 70–2.

Beste 2006 *{published data only}*

Beste TM, Daucher JA, Holbert D. Humidified compared with dry, heated carbon dioxide at laparoscopy to reduce pain. *Obstetrics and Gynecology* 2006;**107**(2 pt 1):263–8.

Demco 2001 *{published data only}*

Demco L. Effect of heating and humidifying gas on patients undergoing awake laparoscopy. *The Journal of the American Association of Gynecologic Laparoscopists* 2001;**8**(2):247–51.

Monagle 1993 *{published data only}*

Monagle J, Bradfield S, Nottle P. Carbon dioxide, temperature and laparoscopic cholecystectomy. *The Australian and New Zealand Journal of Surgery* 1993;**63**(3): 186–9.

Mouton 2001 *{published data only}*

Mouton WG, Naef M, Bessell JR, Otten KT, Wagner HE, Maddern GJ. A randomized controlled trial to determine the effect of humidified carbon dioxide (CO_2) insufflation on postoperative pain following thoracoscopic procedures. *Surgical Endoscopy* 2001;**15**(6):579–81.

Ott 1991 *{published data only}*

Ott DE. Correction of laparoscopic insufflation hypothermia. *Journal of Laparoendoscopic Surgery* 1991;**1** (4):183–6.

Yeh 2007 *{published data only}*

Yeh CH, Kwok SY, Chan MK, Tjandra JJ. Prospective, case-matched study of heated and humidified carbon dioxide insufflation in laparoscopic colorectal surgery. *Colorectal Disease* 2007;**9**(8):695–700.

Additional references

Beilin 1998

B Beilin, Y Shavit, J Razumovsky, Y Wolloch, A Zeidel, H Bessler. Effects of mild perioperative hypothermia on cellular immune responses [Effects of mild perioperative hypothermia on cellular immune responses]. *Anesthesiology* 1998;**89**(5):1133–40. [: 9822001]

Demco 2001

Demco L. Effect of heating and humidifying gas on patients undergoing awake laparoscopy. *The Journal of the American Association of Gynecologic Laparoscopists* 2001;**8**(2):247–51. [: 11342732]

Frank 1993

Frank SM, Beattie C, Christopherson R, Norris EJ, Perler BA, Williams GM, Gottlieb SO. Unintentional hypothermia is associated with postoperative myocardial ischemia. The Perioperative Ischemia Randomized Anesthesia Trial Study Group. *Anesthesiology* 1993;**78**(3): 468–76. [: 8457047]

Frank 1997

Frank SM, Fleisher LA, Breslow MJ, Higgins MS, Olson KF, Kelly S, Beattie C. Perioperative maintenance of normothermia reduces the incidence of morbid cardiac events. A randomized clinical trial. *JAMA* 1997;**277**(14): 1127–34. [PUBMED: 9087467]

Macario 2002

Macario A. What are the most important risk factors for a patient's developing intraoperative hypothermia?. *Anesthesia and Analgesia* 2002;**94**(1):215–20. [: 11772832]

Neudecker2002

Neudecker J, Sauerland S, Neugebauer E, Bergamaschi R, Bonjer HJ, Cuschieri A, et al.The European Association for Endoscopic Surgery clinical practice guideline on the pneumoperitoneum for laparoscopic surgery. *Surgical Endoscopy* 2002;**16**(7):1121–43. [PUBMED: 12015619]

Putzu 2007

Putzu M. Casati A. Berti M. Pagliarini G. Fanelli G. Clinical complications, monitoring and management of perioperative mild hypothermia: anesthesiological features. *Acta Bio-Medica de l Ateneo Parmense* 2007;**78**(3):163–9. [PUBMED: 18330074]

Qadan 2009

Qadan M, Gardner SA, Vitale DS, Lominadze D, Joshua IG, Polk HC Jr. Hypothermia and surgery: immunologic mechanisms for current practice. *Annals of Surgery* 2009; **250**(1):134–40. [PUBMED: 19561472]

Rajagopalan 2008

Rajagopalan S, Mascha E, Na J, Sessler DI. The effects of mild perioperative hypothermia on blood loss and transfusion requirement. *Anesthesiology* 2008;**108**(1):71–7.

Sajid 2008

Sajid MS, Mallick AS, Rimpel J, Bokari SA, Cheek E, Baig MK. Effect of heated and humidified carbon dioxide on patients after laparoscopic procedures: a meta-analysis. *Surgical Laparoscopy, Endoscopy & Percutaneous Techniques* 2008;**18**(6):539–46. [DOI: 10.1097/SLE.0b013e3181886ff4; : 00129689–200812000–00001; : Sajid:2008p530; PUBMED: 19098656]

Sammour 2008

Sammour T, Kahokehr A, Hill AG. Meta-analysis of the effect of warm humidified insufflation on pain after laparoscopy. *The British Journal of Surgery* 2008;**95**(8): 950–6. [DOI: 10.1002/bjs.6304; : Sammour:2008p528; PUBMED: 18618870]

Winkler 2000

Winkler M, Akca O, Birkenberg B, Hetz H, Scheck T, Arkiliç CF, et al.Aggressive warming reduces blood loss during hip arthroplasty. *Anesthesia and Analgesia* 2000;**91**: 978–84.

Wong 2007

Wong PF, Kumar S, Bohra A, Whetter D, Leaper DJ. Randomized clinical trial of perioperative systemic warming in major elective abdominal surgery. *The British Journal*

of Surgery 2007;**94**(4):421–6. [MEDLINE: 10.1002/bjs.5631; : 17380549]

* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

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

Champion 2006

Methods	RCT
Participants	50 consecutive morbidly obese patients undergoing laparoscopic antecolic proximal Roux-en-Y gastric bypass surgery
Interventions	Heated and humidified CO_2 versus cold and dry CO_2
Outcomes	Intraoperative core temperature, room temperature, liters of CO_2 insufflation, operating time, number of lens cleanings, recovery room temperature, narcotics usage, length of hospitalisation, high-sensitivity CRP at 24 hours, abdominal and shoulder pain scores
Notes	

Risk of bias

Item	Authors' judgement	Description
Adequate sequence generation?	Yes	A blind drawing by an impartial third party.
Allocation concealment?	Unclear	A drawing was held to determine which type insufflation was to be used on the first case, after which the insufflation method was alternated for the next 49 cases consecutively, with no interruption or exclusions
Blinding? All outcomes	Yes	The nurses who recorded the pain score were blinded.
Free of selective reporting?	Yes	
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

Davis 2006

Methods	RCT - blinded
Participants	44 laparoscopic gastric bypass patients
Interventions	Cold CO_2 versus cold humidified CO_2 versus heated CO_2 versus heated humidified CO_2
Outcomes	Core temperature, humidity, intraoperative urine output, lens fogging, recovery room time, length of hospital stay, postoperative pain, total morphine sulfate equivalent
Notes	

Davis 2006 (*Continued*)

Risk of bias		
Item	**Authors' judgement**	**Description**
Adequate sequence generation?	Yes	Block fashion randomization.
Allocation concealment?	Yes	Results in sealed envelopes.
Blinding? All outcomes	Yes	A study nurse completed randomization on the morning of procedure
Free of selective reporting?	Yes	
Free of other bias?	Unclear	11 patients in each group, small sample size.

Farley 2004

Methods	RCT - double blinded	
Participants	101 laparoscopic cholecystectomy patients	
Interventions	Heated, humidified CO_2 versus cold CO_2	
Outcomes	Core temperature, lens fogging, postoperative pain, total morphine equivalents, hospital stay, return to baseline activity level	
Notes		
Risk of bias		
Item	**Authors' judgement**	**Description**
Adequate sequence generation?	Yes	Computer model randomization.
Allocation concealment?	Yes	Randomization was done by surgical scrub nurse at the time of anesthetic induction
Blinding? All outcomes	Yes	Patients, surgeons, operative and floor nurses, study coordinators were masked
Free of selective reporting?	Yes	
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

Hamza 2005

Methods	RCT - double blinded
Participants	44 laparoscopic gastric bypass patients
Interventions	Heated and humidified CO_2 versus cold CO_2
Outcomes	Core temperature, postoperatively tympanic temperature, pain score, shivering, morphine, nausea score, Aldrete recovery assessment score, hospital stay, lens fogging
Notes	Warm blankets were used to cover the upper chest and arms in all control group patients for ethical considerations

Risk of bias

Item	Authors' judgement	Description
Adequate sequence generation?	Yes	Computer-generated randomization.
Allocation concealment?	Yes	An OR nurse was responsible for connecting the device.
Blinding? All outcomes	Yes	Patients, surgeons, anesthesiologist, data-collecting personnel, recovery nurses were blinded
Free of selective reporting?	Yes	
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

Kissler 2004

Methods	Double blinded RCT
Participants	90 laparoscopic gynecologic patients
Interventions	Humidified heated CO_2 versus heated dry CO_2 versus cold dry CO_2
Outcomes	Analgesic requirements and postoperative pain
Notes	The trial was stopped following enrolment of 53 patients because of a tendency toward less pain and higher postoperative satisfaction in control group

Risk of bias

Item	Authors' judgement	Description
Adequate sequence generation?	Yes	Computer-generated randomization.
Allocation concealment?	Unclear	No description.

Kissler 2004 (*Continued*)

Blinding? All outcomes	Yes	Patients, data analyst and interviewer were blinded.
Free of selective reporting?	Unclear	Out of 90 participants, data only available on 53 patients.
Free of other bias?	Unclear	Trial was stopped early for there was a tendency toward less pain and higher postoperative satisfaction in patients in the control group

Manwaring 2008

Methods	RCT
Participants	60 gynecologic laparoscopic patients
Interventions	Heated humidified CO_2 versus cold dry CO_2
Outcomes	Core temperature, analgesic usage, postoperative pain, postoperative nausea and recovery room time
Notes	

Risk of bias

Item	**Authors' judgement**	**Description**
Adequate sequence generation?	Yes	Random number generator.
Allocation concealment?	Yes	Sealed in sequential opaque envelopes.
Blinding? All outcomes	Yes	All nursing staff were blinded.
Free of selective reporting?	Yes	
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

Mouton 1999

Methods	RCT
Participants	40 laparoscopic cholecystectomy patients
Interventions	Heated, humidified CO_2 versus cold CO_2
Outcomes	Core temperature change, postoperative pain score, morphine usage

Mouton 1999 (*Continued*)

Notes	

Risk of bias

Item	Authors' judgement	Description
Adequate sequence generation?	Unclear	No description.
Allocation concealment?	Unclear	No description.
Blinding? All outcomes	Unclear	No description.
Free of selective reporting?	Yes	Data were available on 32 out of 40 patients and the reason was given by the author
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

Nelskyla 1999

Methods	RCT - double blinded
Participants	40 laparoscopic hysterectomy women
Interventions	Heated CO_2 versus cold CO_2
Outcomes	Tympanic temperature, heart rate variability
Notes	Data on 37 women were analyzed

Risk of bias

Item	Authors' judgement	Description
Adequate sequence generation?	Unclear	No description.
Allocation concealment?	Unclear	No description.
Blinding? All outcomes	Yes	Patient and staff in the postoperation care unit were blinded
Free of selective reporting?	Yes	
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

Nguyen 2002

Methods	RCT	
Participants	20 laparoscopic Nissen fundoplication patients	
Interventions	Heated and humidified CO_2 versus cold CO_2	
Outcomes	Core temperature, pain score, morphine consumption, urine output, lens fogging	
Notes		
Risk of bias		
Item	**Authors' judgement**	**Description**
Adequate sequence generation?	Yes	Sealed envelopes.
Allocation concealment?	Yes	Intraoperative randomization.
Blinding? All outcomes	Unclear	No description about masking the procedure or the acknowledge of the data collector
Free of selective reporting?	Yes	
Free of other bias?	Unclear	Small sample size (n=10).

Ott 1998

Methods	Multi-center study	
Participants	72 laparoscopic surgery patients	
Interventions	Heated and humidified CO_2 versus cold CO_2	
Outcomes	Postoperative pain and recovery room length of stay	
Notes		
Risk of bias		
Item	**Authors' judgement**	**Description**
Adequate sequence generation?	Unclear	No description.
Allocation concealment?	Unclear	No description.
Blinding? All outcomes	Unclear	No description.

Ott 1998 (*Continued*)

Free of selective reporting?	Unclear	Data were available on 55 out of 72 patients and no reason was given
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

Puttick 1999

Methods	RCT
Participants	30 laparoscopic cholecystectomy patients
Interventions	Warmed CO_2 versus cold CO_2
Outcomes	Core temperature, intraperitoneal cytokines, pain score
Notes	

Risk of bias

Item	**Authors' judgement**	**Description**
Adequate sequence generation?	Unclear	No description.
Allocation concealment?	Unclear	No description.
Blinding? All outcomes	Unclear	No description.
Free of selective reporting?	Yes	
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

Saad 2000

Methods	RCT
Participants	20 laparoscopic cholecystectomy patients
Interventions	Heated CO_2 versus cold CO_2
Outcomes	Core temperature, intra-abdominal temperature, postoperative pain, analgesics consumption
Notes	

Risk of bias

Saad 2000 (*Continued*)

Item	Authors' judgement	Description
Adequate sequence generation?	Unclear	No description.
Allocation concealment?	Unclear	No description.
Blinding? All outcomes	Yes	Ward nurses were blinded.
Free of selective reporting?	Yes	
Free of other bias?	Unclear	10 patients in each group.

Sammour2010

Methods	Multi-center RCT
Participants	82 laparoscopic colonic surgery patients
Interventions	Heated humidified CO_2 versus cold CO_2
Outcomes	Postoperative pain, intraoperative core temperature, camera fogging, Morphine equivalent usage, postoperative parameters
Notes	

Risk of bias

Item	Authors' judgement	Description
Adequate sequence generation?	Yes	Computer generated.
Allocation concealment?	Yes	Allocations were concealed in opaque numbered envelopes.
Blinding? All outcomes	Yes	Patients, investigators, surgeon and medical care staff were all blinded
Free of selective reporting?	Yes	
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

Savel 2005

Methods	RCT - blinded
Participants	30 laparoscopic gastric bypass patients
Interventions	Heated humidified CO_2 versus cold CO_2
Outcomes	Postoperative pain score, morphine consumption, OR time, core temperature, hospital stay
Notes	

Risk of bias

Item	Authors' judgement	Description
Adequate sequence generation?	Unclear	No description.
Allocation concealment?	Unclear	Patients randomized at the time of enrollment.
Blinding? All outcomes	Yes	All clinicians other than one of the author were blinded.
Free of selective reporting?	Yes	
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

Slim 1999

Methods	RCT- double blinded
Participants	100 laparoscopic cholecystectomy, fundoplication or Heller's myotomy patients
Interventions	Heated CO_2 versus unheated CO_2
Outcomes	Postoperative pain, core temperature, morphine consumption, nausea and vomiting, hospital stay, length of postoperative Ileus
Notes	

Risk of bias

Item	Authors' judgement	Description
Adequate sequence generation?	Yes	Random number table in sealed envelopes.
Allocation concealment?	Yes	Sealed envelopes opened in the operating room.

Slim 1999 (*Continued*)

Blinding? All outcomes	Yes	Data were collected by a nurse who didn't participate in the postoperative care. Patient and Clinician were blinded too
Free of selective reporting?	Yes	
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

Wills 2001

Methods	RCT - blinded
Participants	40 laparoscopic fundoplication, Heller myotomy, cholecystectomy patients
Interventions	Heated CO_2 versus cold CO_2
Outcomes	Core temperature, postoperative pain, analgesic requirement, postoperative recovery
Notes	

Risk of bias

Item	**Authors' judgement**	**Description**
Adequate sequence generation?	Yes	Random number table.
Allocation concealment?	Yes	Sequentially numbered opaque, sealed envelopes.
Blinding? All outcomes	Yes	Surgeons, anesthetist, data analyst, patients and ward nurses were blinded
Free of selective reporting?	Yes	
Free of other bias?	Yes	The study was apparently free of other problems that could put it at high risk of bias

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

Study	Reason for exclusion
Backlund 1998	Not a RCT
Barragan 2005	Not a RCT
Beste 2006	Intervention was heated dry CO_2 versus heated humidified CO_2

(*Continued*)

Demco 2001	Only reported the percentage of patients who felt shoulder pain after insufflating a certain amount of CO_2 and didn't quantify the outcomes
Monagle 1993	Not a RCT
Mouton 2001	Not a laparoscopic abdominal procedure (thoracoscopic)
Ott 1991	Not a RCT
Yeh 2007	Not a RCT

DATA AND ANALYSES

Comparison 1. Core temperature

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Change in Core Temperature	15	704	Std. Mean Difference (IV, Random, 95% CI)	0.20 [-0.24, 0.65]
1.1 Heated, humidified vs cold	11	519	Std. Mean Difference (IV, Random, 95% CI)	0.36 [-0.20, 0.93]
1.2 Heated vs cold	6	185	Std. Mean Difference (IV, Random, 95% CI)	-0.10 [-0.84, 0.65]
2 Change in Core temperature for low risk of bias studies	8	433	Std. Mean Difference (IV, Random, 95% CI)	0.10 [-0.48, 0.68]
2.1 Heated, humidified vs cold	7	371	Std. Mean Difference (IV, Random, 95% CI)	0.11 [-0.56, 0.78]
2.2 Heated vs cold	2	62	Std. Mean Difference (IV, Random, 95% CI)	0.03 [-1.69, 1.76]
3 Change core temperature with external warming	6	329	Std. Mean Difference (IV, Random, 95% CI)	0.58 [0.10, 1.06]

Comparison 2. Pain score

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Day 1 pain score	12	653	Std. Mean Difference (IV, Random, 95% CI)	-0.02 [-0.27, 0.22]
1.1 Heated, humidified vs cold (abdominal)	8	332	Std. Mean Difference (IV, Random, 95% CI)	-0.10 [-0.45, 0.25]
1.2 Heated, humidified vs cold (shoulder)	3	171	Std. Mean Difference (IV, Random, 95% CI)	-0.13 [-0.69, 0.42]
1.3 Heated vs cold	3	150	Std. Mean Difference (IV, Random, 95% CI)	0.38 [0.06, 0.71]
2 Day 2 pain score	9	505	Std. Mean Difference (IV, Random, 95% CI)	-0.12 [-0.44, 0.20]
2.1 Heated, humidified vs cold (abdominal)	6	252	Std. Mean Difference (IV, Random, 95% CI)	-0.17 [-0.59, 0.24]
2.2 Heated, humidified vs cold (shoulder)	2	111	Std. Mean Difference (IV, Random, 95% CI)	-0.36 [-1.42, 0.69]
2.3 Heated vs cold	3	142	Std. Mean Difference (IV, Random, 95% CI)	0.29 [-0.05, 0.62]
3 Day 1 pain score for low risk of bias studies	6	380	Std. Mean Difference (IV, Random, 95% CI)	0.16 [-0.04, 0.36]
3.1 Heated, humidified vs cold (abdominal)	6	270	Std. Mean Difference (IV, Random, 95% CI)	0.17 [-0.07, 0.41]
3.2 Heate, humidified vs cold (shoulder)	2	110	Std. Mean Difference (IV, Random, 95% CI)	0.12 [-0.29, 0.54]
4 Day 2 pain score of low risk of bias studies	4	190	Std. Mean Difference (IV, Random, 95% CI)	-0.04 [-0.33, 0.24]

Comparison 3. Morphine consumption

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Up to 6 hour	3	205	Std. Mean Difference (IV, Random, 95% CI)	0.06 [-0.21, 0.34]
2 Day 1 morphine	8	383	Std. Mean Difference (IV, Random, 95% CI)	-0.04 [-0.26, 0.18]
2.1 Heated, humidified vs cold	6	291	Std. Mean Difference (IV, Random, 95% CI)	-0.19 [-0.42, 0.04]
2.2 Heated vs cold	3	92	Std. Mean Difference (IV, Random, 95% CI)	0.39 [-0.03, 0.80]
3 Day 2 morphine	6	342	Std. Mean Difference (IV, Random, 95% CI)	-0.07 [-0.39, 0.25]
3.1 Heated, humidified vs cold	5	220	Std. Mean Difference (IV, Random, 95% CI)	-0.30 [-0.56, -0.03]
3.2 Heated vs cold	2	122	Std. Mean Difference (IV, Random, 95% CI)	0.41 [0.06, 0.77]

Comparison 4. Hospital stay

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Hospital Stay	9	495	Std. Mean Difference (IV, Random, 95% CI)	-0.06 [-0.27, 0.15]
1.1 Heated, humidified vs cold	8	373	Std. Mean Difference (IV, Random, 95% CI)	-0.13 [-0.38, 0.13]
1.2 Heated vs cold	2	122	Std. Mean Difference (IV, Random, 95% CI)	0.15 [-0.21, 0.50]

Comparison 5. Recovery room stay

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Recovery time	6	327	Std. Mean Difference (IV, Random, 95% CI)	-0.50 [-1.18, 0.17]
2 Recovery time for low risk of bias studies	5	277	Std. Mean Difference (IV, Random, 95% CI)	-0.14 [-0.37, 0.10]

Comparison 6. Lens fogging

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Times cleaned	7	341	Std. Mean Difference (IV, Random, 95% CI)	0.29 [-0.14, 0.72]

Comparison 7. Operative time

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Operative Time	16	804	Std. Mean Difference (IV, Random, 95% CI)	-0.05 [-0.20, 0.10]
1.1 Heated, humidified vs cold	11	519	Std. Mean Difference (IV, Random, 95% CI)	-0.13 [-0.35, 0.10]
1.2 Heated vs cold	7	285	Std. Mean Difference (IV, Random, 95% CI)	0.07 [-0.16, 0.31]

Analysis 1.1. Comparison 1 Core temperature, Outcome 1 Change in Core Temperature.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 1 Core temperature

Outcome: 1 Change in Core Temperature

Study or subgroup	Heated N	Mean(SD)	Unheated N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Heated, humidified vs cold							
Champion 2006	25	-0.4 (0.4)	25	0.4 (0.5)		6.0 %	-1.74 [-2.40, -1.08]
Davis 2006	11	0.4 (0.52)	11	0.4 (0.66)		5.5 %	0.0 [-0.84, 0.84]
Farley 2004	49	0.29 (0.52)	52	-0.03 (0.66)		6.5 %	0.53 [0.14, 0.93]
Hamza 2005	23	-0.7 (0.52)	21	-1.7 (0.66)		5.9 %	1.66 [0.97, 2.36]
Kissler 2004	17	-0.5 (0.52)	19	-0.4 (0.66)		6.0 %	-0.16 [-0.82, 0.49]
Manwaring 2008	30	-0.2 (0.52)	30	-0.13 (0.61)		6.3 %	-0.12 [-0.63, 0.38]
Mouton 1999	16	-0.25 (0.52)	16	-0.3 (0.66)		5.9 %	0.08 [-0.61, 0.78]
Nguyen 2002	10	0.4 (0.52)	10	0.3 (0.66)		5.4 %	0.16 [-0.72, 1.04]
Ott 1998	25	-0.3 (0.52)	25	-1.64 (0.66)		5.8 %	2.22 [1.50, 2.94]

(*Continued* . . .)

(. . . *Continued*)

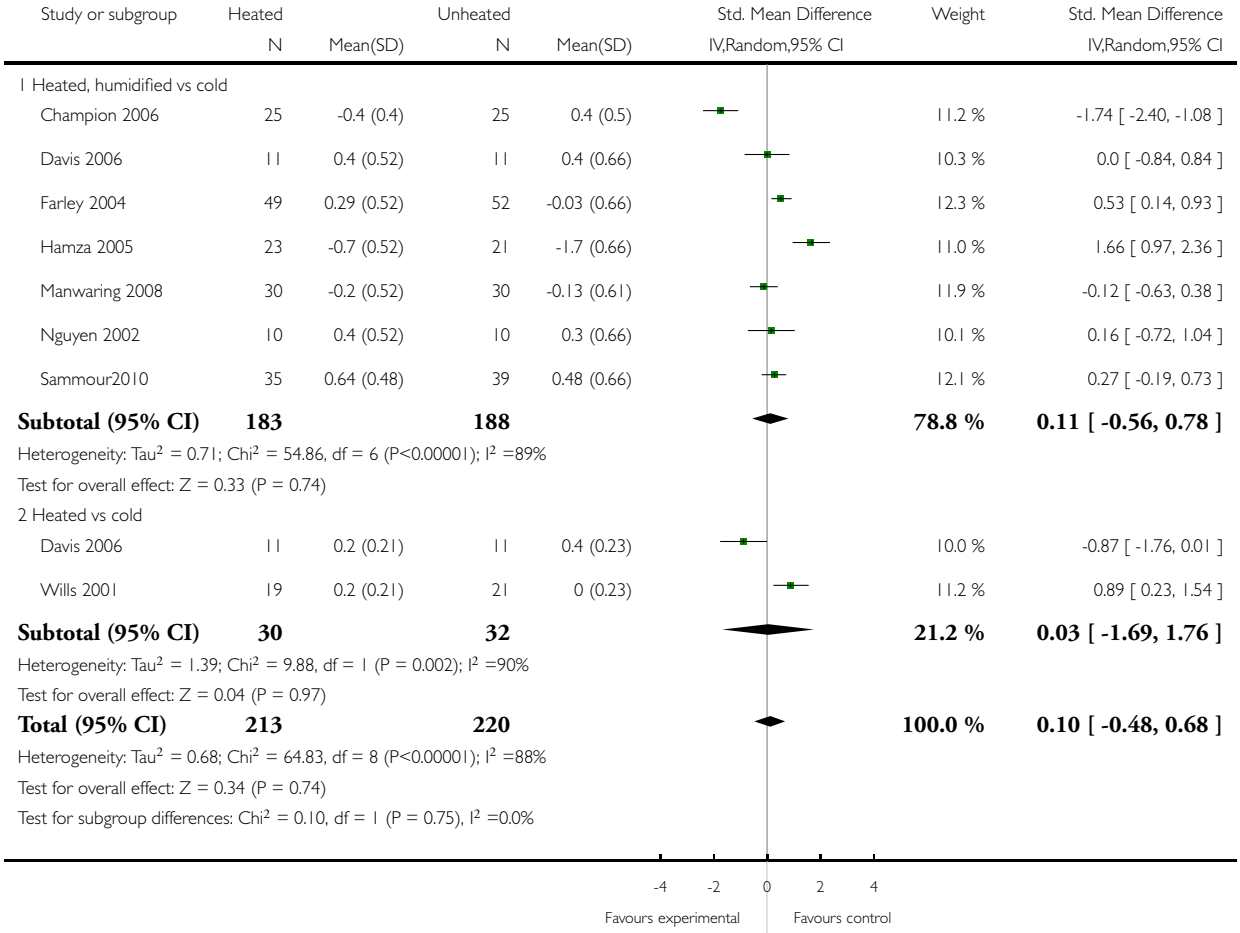
Study or subgroup	Heated N	Mean(SD)	Unheated N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
Sammour2010	35	0.64 (0.48)	39	0.48 (0.66)		6.4 %	0.27 [-0.19, 0.73]
Savel 2005	15	0.4 (0.52)	15	-0.3 (0.66)		5.7 %	1.15 [0.37, 1.93]
Subtotal (95% CI)	**256**		**263**			**65.6 %**	**0.36 [-0.20, 0.93]**
Heterogeneity: $Tau^2 = 0.79$; $Chi^2 = 90.56$, df = 10 (P<0.00001); $I^2 = 89\%$							
Test for overall effect: Z = 1.26 (P = 0.21)							
2 Heated vs cold							
Davis 2006	11	0.2 (0.21)	11	0.4 (0.23)		5.4 %	-0.87 [-1.76, 0.01]
Kissler 2004	17	-0.6 (0.21)	19	-0.4 (0.23)		5.9 %	-0.89 [-1.57, -0.20]
Nelskyla 1999	18	-0.2 (0.21)	19	0 (0.2)		5.9 %	-0.95 [-1.64, -0.27]
Puttick 1999	15	-0.24 (0.21)	15	-0.42 (0.23)		5.8 %	0.80 [0.05, 1.54]
Saad 2000	10	0 (0.21)	10	-0.1 (0.23)		5.4 %	0.43 [-0.45, 1.32]
Wills 2001	19	0.2 (0.21)	21	0 (0.23)		6.0 %	0.89 [0.23, 1.54]
Subtotal (95% CI)	**90**		**95**			**34.4 %**	**-0.10 [-0.84, 0.65]**
Heterogeneity: $Tau^2 = 0.71$; $Chi^2 = 29.60$, df = 5 (P = 0.00002); $I^2 = 83\%$							
Test for overall effect: Z = 0.26 (P = 0.80)							
Total (95% CI)	**346**		**358**			**100.0 %**	**0.20 [-0.24, 0.65]**
Heterogeneity: $Tau^2 = 0.75$; $Chi^2 = 125.48$, df = 16 (P<0.00001); $I^2 = 87\%$							
Test for overall effect: Z = 0.89 (P = 0.37)							

Analysis 1.2. Comparison 1 Core temperature, Outcome 2 Change in Core temperature for low risk of bias studies.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 1 Core temperature

Outcome: 2 Change in Core temperature for low risk of bias studies



Analysis 1.3. Comparison 1 Core temperature, Outcome 3 Change core temperature with external warming.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 1 Core temperature

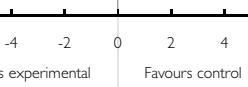
Outcome: 3 Change core temperature with external warming

Study or subgroup	Heated N	Mean(SD)	Unheated N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
Farley 2004	49	0.29 (0.52)	52	-0.03 (0.66)		19.9 %	0.53 [0.14, 0.93]
Hamza 2005	23	-0.7 (0.52)	21	-1.7 (0.66)		15.5 %	1.66 [0.97, 2.36]
Manwaring 2008	30	-0.2 (0.52)	30	-0.13 (0.61)		18.3 %	-0.12 [-0.63, 0.38]
Nguyen 2002	10	0.4 (0.52)	10	0.3 (0.66)		13.0 %	0.16 [-0.72, 1.04]
Sammour2010	35	0.64 (0.48)	39	0.48 (0.66)		19.0 %	0.27 [-0.19, 0.73]
Savel 2005	15	0.4 (0.52)	15	-0.3 (0.66)		14.3 %	1.15 [0.37, 1.93]
Total (95% CI)	**162**		**167**			**100.0 %**	**0.58 [0.10, 1.06]**

Heterogeneity: $Tau^2 = 0.26$; $Chi^2 = 20.71$, df = 5 (P = 0.00092); $I^2 = 76\%$

Test for overall effect: Z = 2.36 (P = 0.018)

Test for subgroup differences: Not applicable

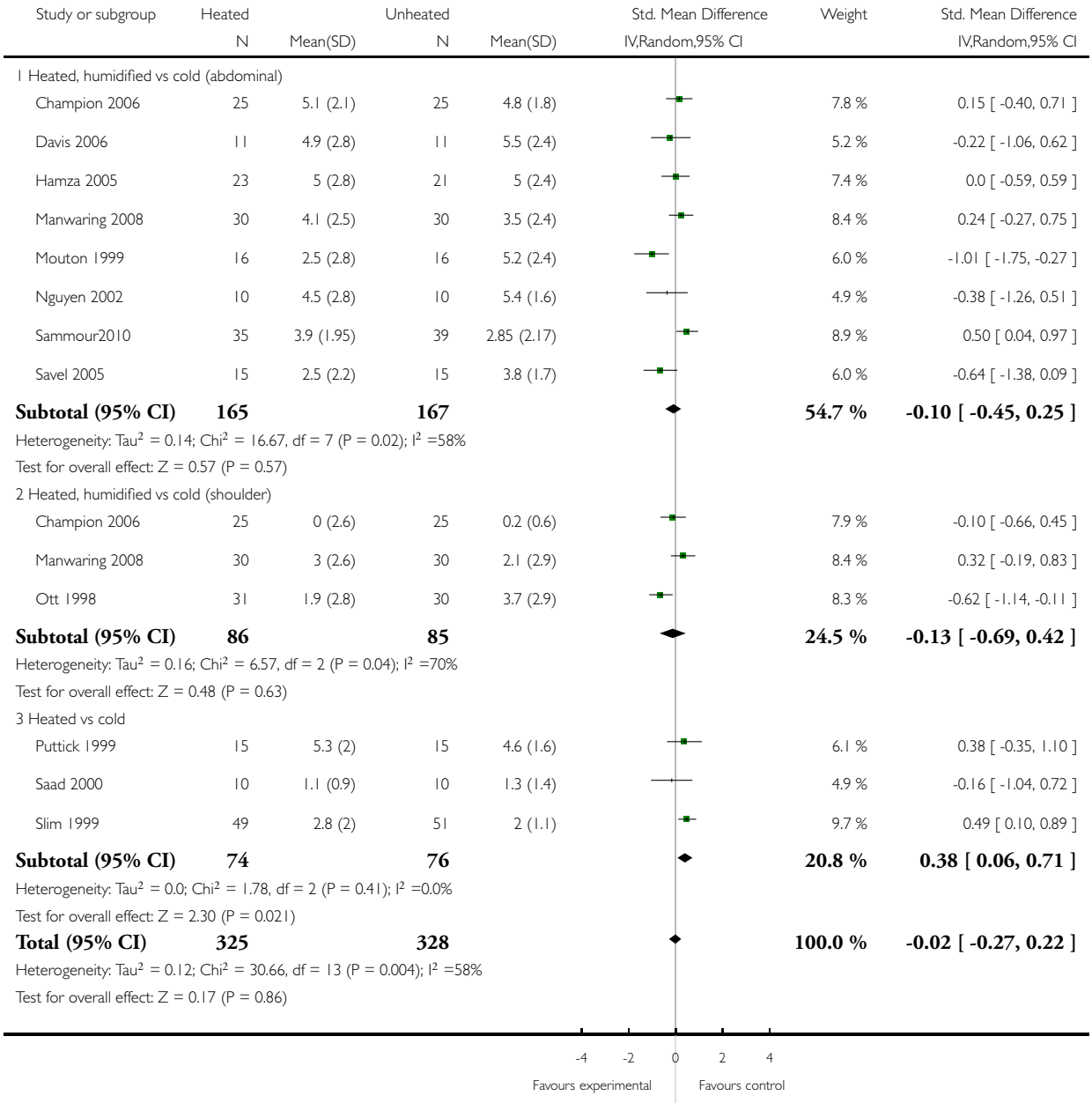


Analysis 2.1. Comparison 2 Pain score, Outcome 1 Day 1 pain score.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 2 Pain score

Outcome: 1 Day 1 pain score

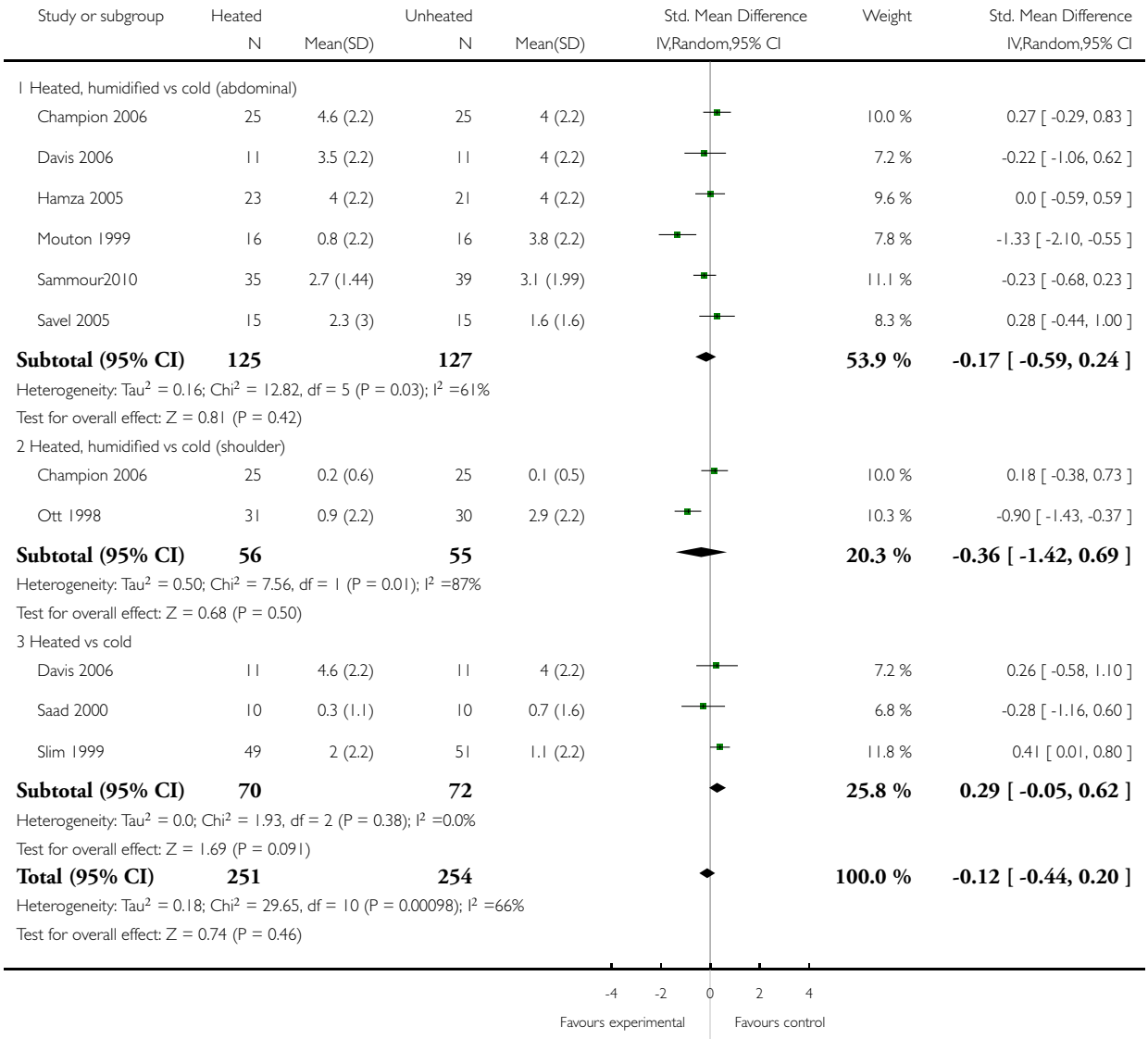


Analysis 2.2. Comparison 2 Pain score, Outcome 2 Day 2 pain score.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 2 Pain score

Outcome: 2 Day 2 pain score

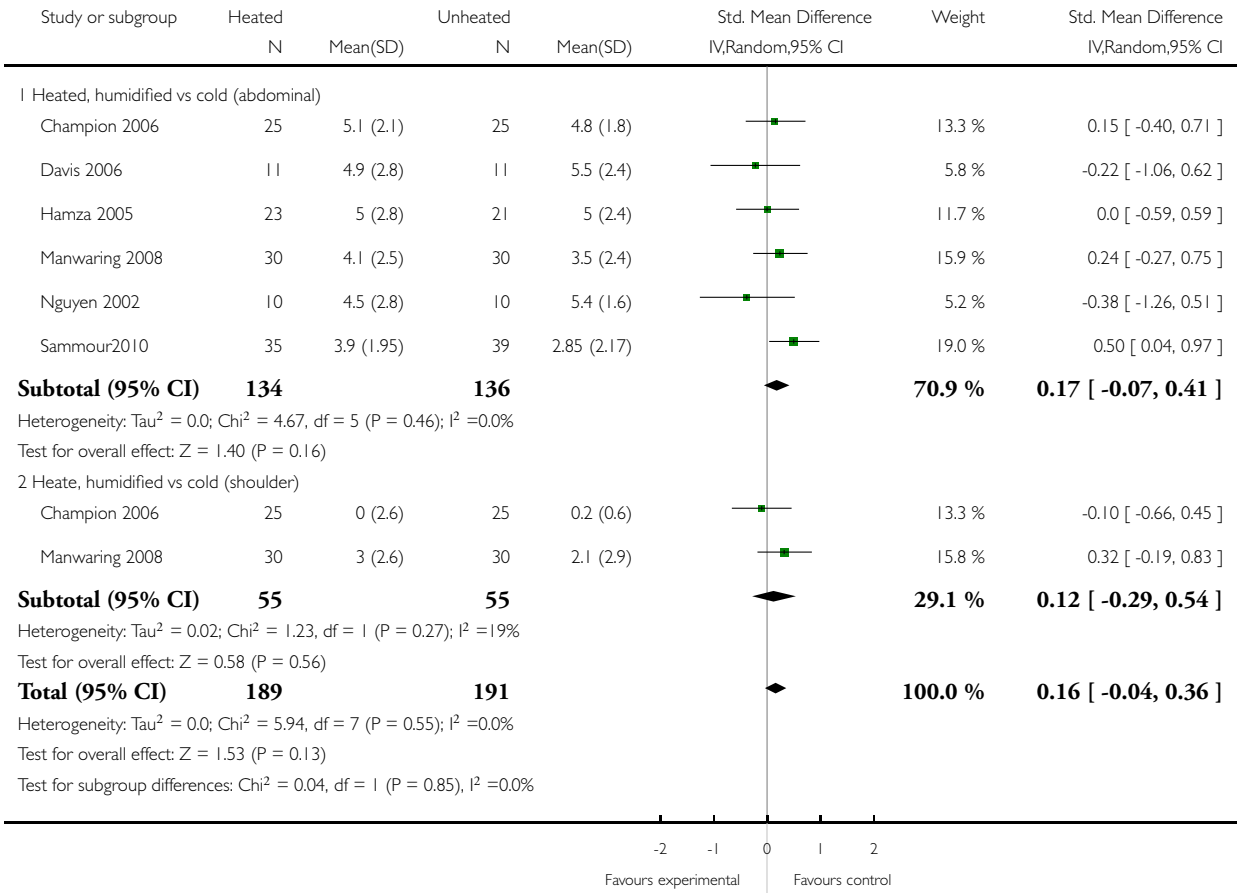


Analysis 2.3. Comparison 2 Pain score, Outcome 3 Day 1 pain score for low risk of bias studies.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 2 Pain score

Outcome: 3 Day 1 pain score for low risk of bias studies

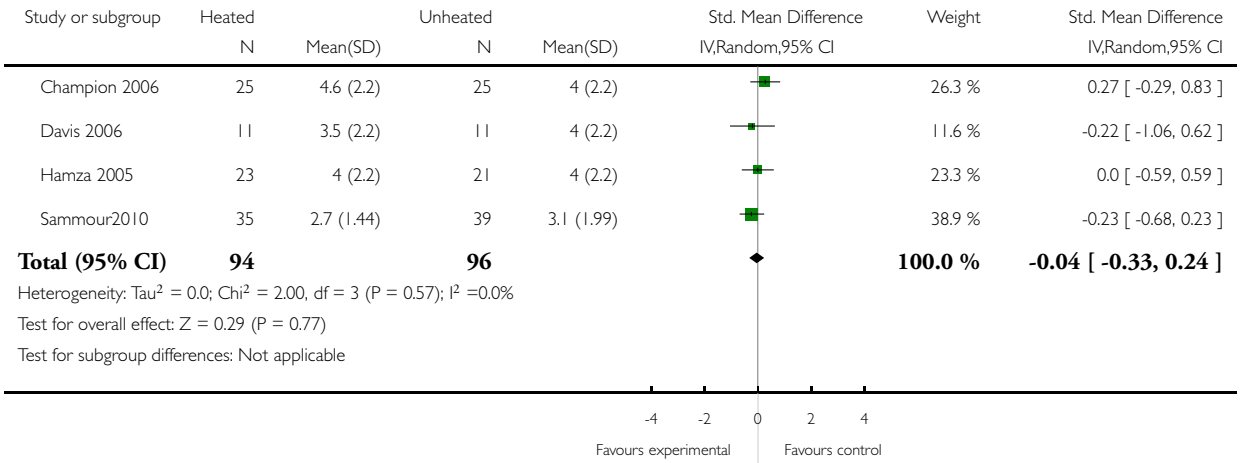


Analysis 2.4. Comparison 2 Pain score, Outcome 4 Day 2 pain score of low risk of bias studies.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 2 Pain score

Outcome: 4 Day 2 pain score of low risk of bias studies

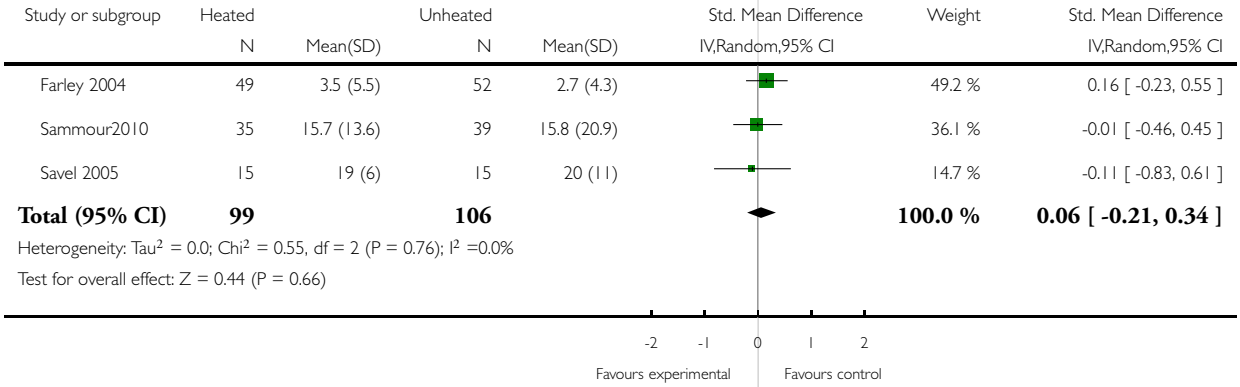


Analysis 3.1. Comparison 3 Morphine consumption, Outcome 1 Up to 6 hour.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 3 Morphine consumption

Outcome: 1 Up to 6 hour



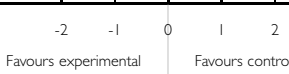
Analysis 3.2. Comparison 3 Morphine consumption, Outcome 2 Day 1 morphine.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 3 Morphine consumption

Outcome: 2 Day 1 morphine

Study or subgroup	Heated N	Mean(SD)	Unheated N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Heated, humidified vs cold							
Davis 2006	11	33 (28.6)	11	31 (49.4)		6.3 %	0.05 [-0.79, 0.88]
Farley 2004	49	23.2 (27.1)	52	29.2 (35.4)		24.1 %	-0.19 [-0.58, 0.20]
Hamza 2005	23	32 (20)	21	37 (18)		11.9 %	-0.26 [-0.85, 0.34]
Nguyen 2002	10	32 (19)	10	27 (26)		5.7 %	0.21 [-0.67, 1.09]
Sammour2010	35	33.2 (28.6)	39	46.2 (49.4)		18.6 %	-0.31 [-0.77, 0.14]
Savel 2005	15	36 (17)	15	41 (27)		8.4 %	-0.22 [-0.93, 0.50]
Subtotal (95% CI)	**143**		**148**			**75.0 %**	**-0.19 [-0.42, 0.04]**
Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 1.44$, df = 5 (P = 0.92); I^2 =0.0%							
Test for overall effect: Z = 1.60 (P = 0.11)							
2 Heated vs cold							
Davis 2006	11	27 (24.7)	11	31 (49.4)		6.3 %	-0.10 [-0.93, 0.74]
Puttick 1999	15	52.3 (24.7)	15	36.8 (29.2)		8.1 %	0.56 [-0.17, 1.29]
Wills 2001	19	46 (23.8)	21	32.9 (23.5)		10.6 %	0.54 [-0.09, 1.18]
Subtotal (95% CI)	**45**		**47**			**25.0 %**	**0.39 [-0.03, 0.80]**
Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 1.74$, df = 2 (P = 0.42); I^2 =0.0%							
Test for overall effect: Z = 1.84 (P = 0.066)							
Total (95% CI)	**188**		**195**			**100.0 %**	**-0.04 [-0.26, 0.18]**
Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 8.85$, df = 8 (P = 0.36); I^2 =10%							
Test for overall effect: Z = 0.37 (P = 0.71)							

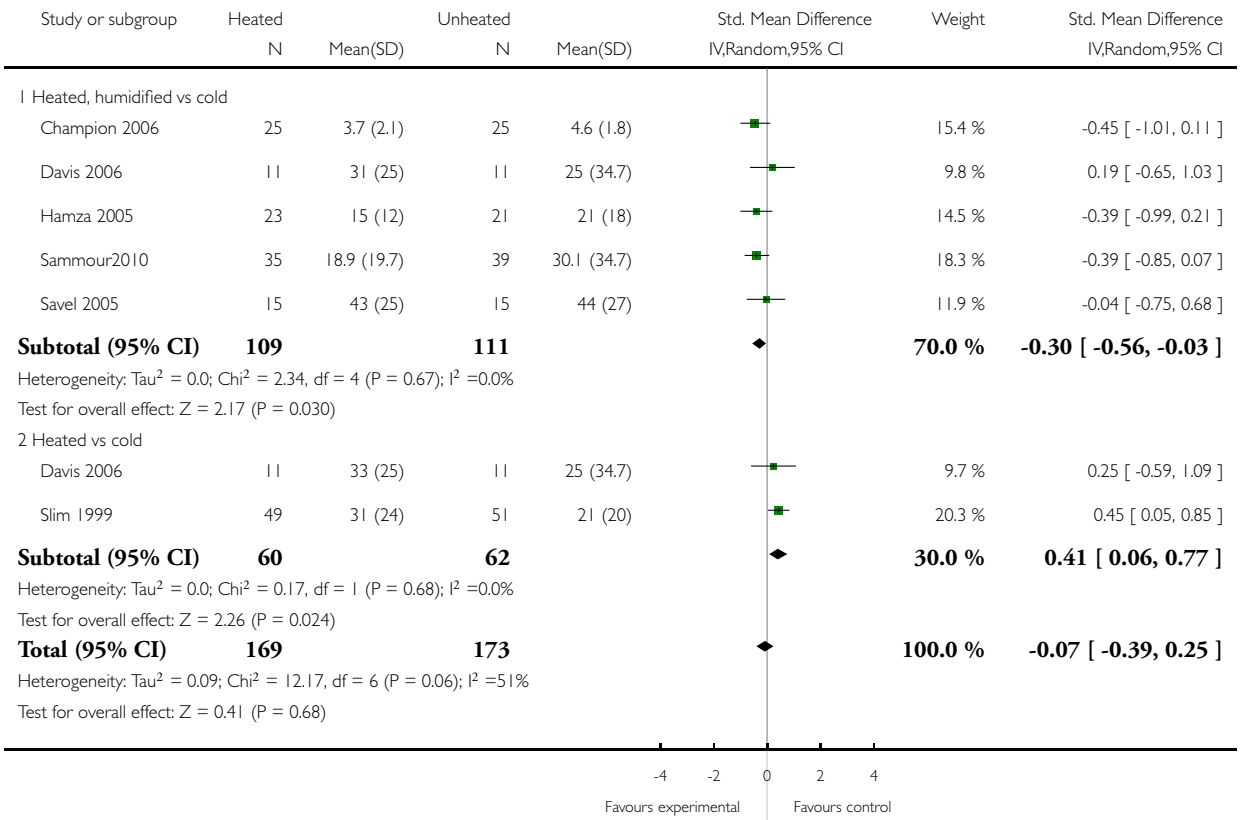


Analysis 3.3. Comparison 3 Morphine consumption, Outcome 3 Day 2 morphine.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 3 Morphine consumption

Outcome: 3 Day 2 morphine



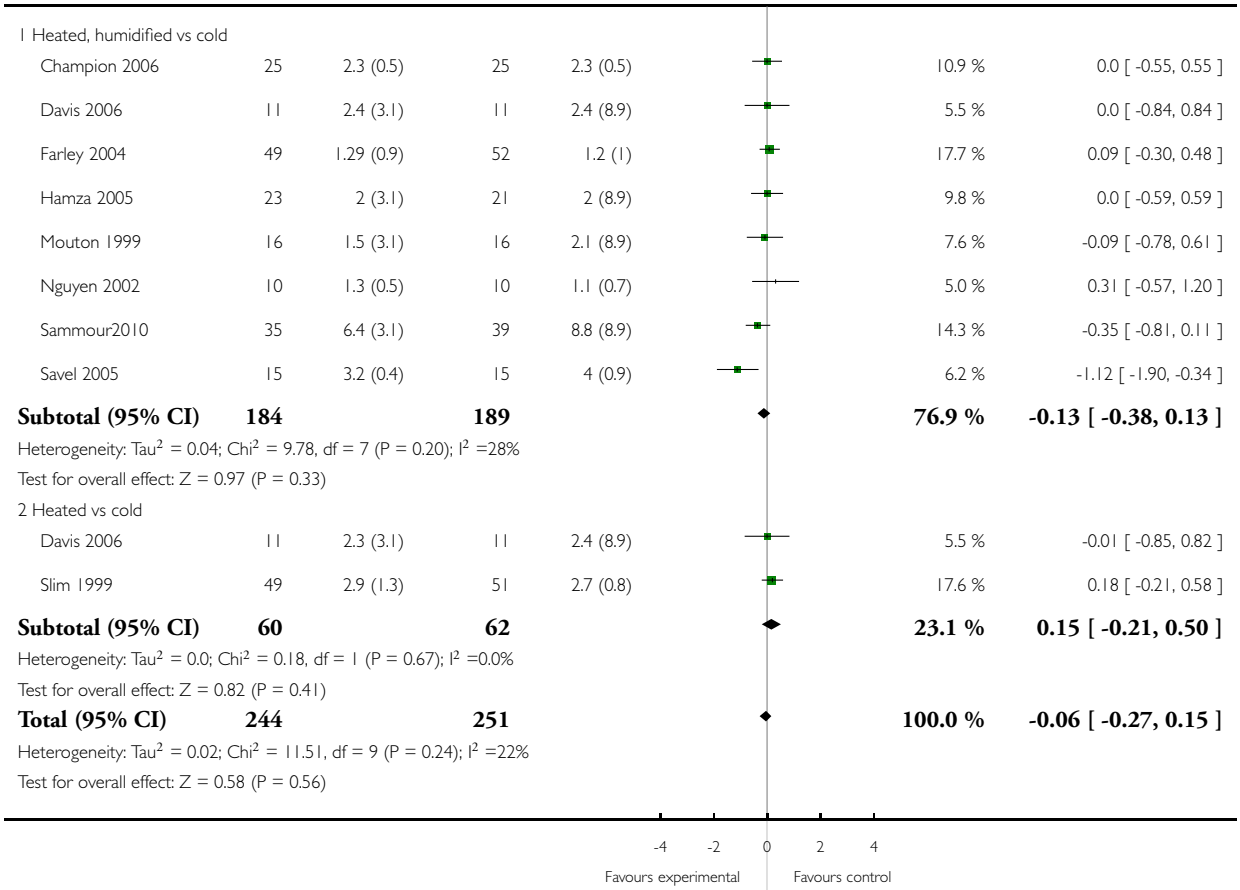
Analysis 4.1. Comparison 4 Hospital stay, Outcome 1 Hospital Stay.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 4 Hospital stay

Outcome: 1 Hospital Stay

Study or subgroup	Heated N	Mean(SD)	Unheated N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Heated, humidified vs cold							
Champion 2006	25	2.3 (0.5)	25	2.3 (0.5)		10.9 %	0.0 [-0.55, 0.55]
Davis 2006	11	2.4 (3.1)	11	2.4 (8.9)		5.5 %	0.0 [-0.84, 0.84]
Farley 2004	49	1.29 (0.9)	52	1.2 (1)		17.7 %	0.09 [-0.30, 0.48]
Hamza 2005	23	2 (3.1)	21	2 (8.9)		9.8 %	0.0 [-0.59, 0.59]
Mouton 1999	16	1.5 (3.1)	16	2.1 (8.9)		7.6 %	-0.09 [-0.78, 0.61]
Nguyen 2002	10	1.3 (0.5)	10	1.1 (0.7)		5.0 %	0.31 [-0.57, 1.20]
Sammour2010	35	6.4 (3.1)	39	8.8 (8.9)		14.3 %	-0.35 [-0.81, 0.11]
Savel 2005	15	3.2 (0.4)	15	4 (0.9)		6.2 %	-1.12 [-1.90, -0.34]
Subtotal (95% CI)	**184**		**189**			**76.9 %**	**-0.13 [-0.38, 0.13]**
Heterogeneity: $Tau^2 = 0.04$; $Chi^2 = 9.78$, df = 7 (P = 0.20); $I^2 = 28\%$							
Test for overall effect: Z = 0.97 (P = 0.33)							
2 Heated vs cold							
Davis 2006	11	2.3 (3.1)	11	2.4 (8.9)		5.5 %	-0.01 [-0.85, 0.82]
Slim 1999	49	2.9 (1.3)	51	2.7 (0.8)		17.6 %	0.18 [-0.21, 0.58]
Subtotal (95% CI)	**60**		**62**			**23.1 %**	**0.15 [-0.21, 0.50]**
Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 0.18$, df = 1 (P = 0.67); $I^2 = 0.0\%$							
Test for overall effect: Z = 0.82 (P = 0.41)							
Total (95% CI)	**244**		**251**			**100.0 %**	**-0.06 [-0.27, 0.15]**
Heterogeneity: $Tau^2 = 0.02$; $Chi^2 = 11.51$, df = 9 (P = 0.24); $I^2 = 22\%$							
Test for overall effect: Z = 0.58 (P = 0.56)							



Analysis 5.1. Comparison 5 Recovery room stay, Outcome 1 Recovery time.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 5 Recovery room stay

Outcome: 1 Recovery time

Study or subgroup	Heated N	Mean(SD)	unheated N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
Champion 2006	25	58.8 (11.3)	25	56.5 (11.1)		17.1 %	0.20 [-0.35, 0.76]
Davis 2006	11	144.8 (30)	11	142.5 (69)		14.9 %	0.04 [-0.79, 0.88]
Farley 2004	49	74 (29)	52	82 (29)		18.2 %	-0.27 [-0.67, 0.12]
Hamza 2005	23	83 (30)	21	107 (69)		16.8 %	-0.45 [-1.05, 0.15]
Manwaring 2008	30	62 (19.9)	30	62.6 (17.6)		17.5 %	-0.03 [-0.54, 0.47]
Ott 1998	25	45 (30)	25	190 (69)		15.4 %	-2.68 [-3.46, -1.90]
Total (95% CI)	**163**		**164**			**100.0 %**	**-0.50 [-1.18, 0.17]**

Heterogeneity: $Tau^2 = 0.61$; $Chi^2 = 40.82$, df = 5 ($P<0.00001$); $I^2 = 88\%$

Test for overall effect: Z = 1.47 (P = 0.14)

Test for subgroup differences: Not applicable

Analysis 5.2. Comparison 5 Recovery room stay, Outcome 2 Recovery time for low risk of bias studies.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 5 Recovery room stay

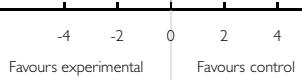
Outcome: 2 Recovery time for low risk of bias studies

Study or subgroup	Heated N	Mean(SD)	unheated N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
Champion 2006	25	58.8 (11.3)	25	56.5 (11.1)		18.1 %	0.20 [-0.35, 0.76]
Davis 2006	11	144.8 (30)	11	142.5 (69)		8.0 %	0.04 [-0.79, 0.88]
Farley 2004	49	74 (29)	52	82 (29)		36.4 %	-0.27 [-0.67, 0.12]
Hamza 2005	23	83 (30)	21	107 (69)		15.6 %	-0.45 [-1.05, 0.15]
Manwaring 2008	30	62 (19.9)	30	62.6 (17.6)		21.9 %	-0.03 [-0.54, 0.47]
Total (95% CI)	**138**		**139**			**100.0 %**	**-0.14 [-0.37, 0.10]**

Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 3.29$, df = 4 (P = 0.51); $I^2 = 0.0\%$

Test for overall effect: Z = 1.13 (P = 0.26)

Test for subgroup differences: Not applicable



Analysis 6.1. Comparison 6 Lens fogging, Outcome 1 Times cleaned.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

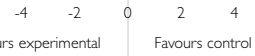
Comparison: 6 Lens fogging

Outcome: 1 Times cleaned

Study or subgroup	Heated N	Mean(SD)	Unheated N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
Champion 2006	25	6 (2.3)	25	2 (3.1)		14.4 %	1.44 [0.81, 2.07]
Davis 2006	11	1.7 (2.3)	11	1.3 (3.1)		11.6 %	0.14 [-0.70, 0.98]
Farley 2004	49	1.1 (2.3)	52	1.6 (3.1)		17.8 %	-0.18 [-0.57, 0.21]
Hamza 2005	23	2 (2.3)	21	2 (3.1)		15.0 %	0.0 [-0.59, 0.59]
Nguyen 2002	10	1.6 (2)	10	1.6 (3.1)		11.1 %	0.0 [-0.88, 0.88]
Sammour2010	35	4.2 (2.3)	39	3.1 (2)		16.8 %	0.51 [0.04, 0.97]
Savel 2005	15	1.29 (0.91)	15	1.2 (1.04)		13.2 %	0.09 [-0.63, 0.81]
Total (95% CI)	**168**		**173**			**100.0 %**	**0.29 [-0.14, 0.72]**

Heterogeneity: $Tau^2 = 0.23$; $Chi^2 = 20.96$, df = 6 (P = 0.002); $I^2 = 71\%$

Test for overall effect: Z = 1.33 (P = 0.18)



Analysis 7.1. Comparison 7 Operative time, Outcome 1 Operative Time.

Review: Heated CO_2 with or without humidification for minimally invasive abdominal surgery

Comparison: 7 Operative time

Outcome: 1 Operative Time

Study or subgroup	Heated N	Mean(SD)	Unheated N	Mean(SD)	Std. Mean Difference IV,Random,95% CI	Weight	Std. Mean Difference IV,Random,95% CI
1 Heated, humidified vs cold							
Champion 2006	25	61.7 (10.4)	25	61.7 (10.7)		6.4 %	0.0 [-0.55, 0.55]
Davis 2006	11	84.2 (48.8)	11	84.6 (57.5)		3.0 %	-0.01 [-0.84, 0.83]
Farley 2004	49	91.2 (22.7)	52	91.2 (22.3)		11.4 %	0.0 [-0.39, 0.39]
Hamza 2005	23	120 (24)	21	132 (48)		5.6 %	-0.32 [-0.91, 0.28]
Kissler 2004	17	62 (29.8)	19	45 (22.5)		4.5 %	0.63 [-0.04, 1.31]
Manwaring 2008	30	49.6 (17.1)	30	46.8 (18)		7.5 %	0.16 [-0.35, 0.66]
Mouton 1999	16	40 (48.8)	16	48.3 (57.5)		4.3 %	-0.15 [-0.85, 0.54]
Nguyen 2002	10	107 (12)	10	108 (33)		2.8 %	-0.04 [-0.92, 0.84]
Ott 1998	25	190 (48.8)	25	230 (57.5)		6.0 %	-0.74 [-1.31, -0.16]
Sammour2010	35	176.3 (48.8)	39	184.7 (57.5)		8.9 %	-0.16 [-0.61, 0.30]
Savel 2005	15	76 (16)	15	101 (34)		3.6 %	-0.92 [-1.67, -0.16]
Subtotal (95% CI)	**256**		**263**			**64.1 %**	**-0.13 [-0.35, 0.10]**
Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 15.76$, df = 10 (P = 0.11); $I^2 = 37\%$							
Test for overall effect: Z = 1.10 (P = 0.27)							
2 Heated vs cold							
Davis 2006	11	83.1 (48.8)	11	84.2 (57.5)		3.0 %	-0.02 [-0.86, 0.82]
Kissler 2004	17	51 (18)	19	45 (22.5)		4.7 %	0.29 [-0.37, 0.94]
Nelskyla 1999	18	56 (48.8)	19	51 (57.5)		4.9 %	0.09 [-0.55, 0.74]
Puttick 1999	15	32.13 (9.75)	15	31.53 (11.4)		4.1 %	0.06 [-0.66, 0.77]
Saad 2000	10	56 (14)	10	61 (17)		2.7 %	-0.31 [-1.19, 0.58]
Slim 1999	49	73 (37)	51	67 (31)		11.3 %	0.17 [-0.22, 0.57]
Wills 2001	19	69 (18)	21	72 (24)		5.2 %	-0.14 [-0.76, 0.48]
Subtotal (95% CI)	**139**		**146**			**35.9 %**	**0.07 [-0.16, 0.31]**
Heterogeneity: $Tau^2 = 0.0$; $Chi^2 = 1.87$, df = 6 (P = 0.93); $I^2 = 0.0\%$							
Test for overall effect: Z = 0.61 (P = 0.54)							
Total (95% CI)	**395**		**409**			**100.0 %**	**-0.05 [-0.20, 0.10]**
Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 19.24$, df = 17 (P = 0.32); $I^2 = 12\%$							
Test for overall effect: Z = 0.69 (P = 0.49)							

ADDITIONAL TABLES

Table 1. The Cochrane Collaboration's tool for assessing risk of bias

Domain	Description	Author's judgment
Sequence generation		Was the allocation sequence adequately generated? YES / NO / UNCLEAR
Allocation concealment		Was allocation sequence adequately concealed? YES / NO / UNCLEAR
Blinding participants, personnel and outcome assessors		Was the knowledge of the allocated intervention adequately prevented during the study? YES / NO / UNCLEAR
Blinding participants, personnel and outcome assessors		Was the knowledge of the allocated intervention adequately prevented during the study? YES / NO / UNCLEAR
Incomplete outcome data		Were incomplete outcome data adequately addressed? YES / NO / UNCLEAR
Incomplete outcome data		Were incomplete outcome data adequately addressed? YES / NO / UNCLEAR
Selective outcome reporting		Are reports of the study free of suggestion of selective outcome reporting? YES / NO / UNCLEAR

HISTORY

Protocol first published: Issue 2, 2009

Review first published: Issue 1, 2011

Date	Event	Description
26 July 2010	Amended	Final amendment
12 July 2010	Amended	Final draft

CONTRIBUTIONS OF AUTHORS

DWB: protocol development, screening retrieved papers for eligibility criteria, analysing and editing review, providing guidance on methodology and quality control.

NM: analysis and review editing.

XS: literature search, screening search results, retrieving and analysing data, draft preparation.

GH: protocol development, literature search, screening search results, draft preparation.

SK: analysis and review editing, quality control.

DECLARATIONS OF INTEREST

No conflict

SOURCES OF SUPPORT

Internal sources

- University of Alberta Library, Cambodia.

External sources

- Cochrane Library Cancer Group, Canada.

INDEX TERMS

Medical Subject Headings (MeSH)

*Carbon Dioxide; Analgesics, Opioid [administration & dosage]; Body Temperature; Hot Temperature [*therapeutic use]; Humidity; Hypothermia [*prevention & control]; Insufflation [*methods]; Laparoscopy [methods]; Morphine [administration & dosage]; Pain, Postoperative [prevention & control]; Pneumoperitoneum, Artificial [methods]; Randomized Controlled Trials as Topic

MeSH check words

Adult; Female; Humans; Male