Heated CO₂ with or without humidification for minimally invasive abdominal surgery (Review)

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[Intervention Review]

Heated \mathbf{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 CO₂ 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 (CO₂) 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 CO₂ 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 I, 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 nonrelevant 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 \pm 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) CO2 with standard cold CO2 were included. All other studies including non-randomized trials and those comparing heated dry CO2 versus heated humidified CO2 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, highsensitivity 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 tempera-

tures 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 post-operative 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: | Pain Score, outcome: |.| Day | pain score.



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

	Н	eated		Un	heated	:	9	Std. Mean Difference	Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	IV, Random, 95% Cl
1.1.1 Heated, humid	ified vs c	old							
Champion 2006	-0.4	0.4	25	0.4	0.5	25	6.0%	-1.74 [-2.40, -1.08]	
Davis 2006	0.4	0.52	11	0.4	0.66	11	5.5%	0.00 [-0.84, 0.84]	_
Farley 2004	0.29	0.52	49	-0.03	0.66	52	6.5%	0.53 [0.14, 0.93]	
Hamza 2005	-0.7	0.52	23	-1.7	0.66	21	5.9%	1.66 [0.97, 2.36]	
Kissler 2004	-0.5	0.52	17	-0.4	0.66	19	6.0%	-0.16 [-0.82, 0.49]	
Manwaring 2008	-0.2	0.52	30	-0.13	0.61	30	6.3%	-0.12 [-0.63, 0.38]	-+
Mouton 1999	-0.25	0.52	16	-0.3	0.66	16	5.9%	0.08 [-0.61, 0.78]	+-
Nguyen 2002	0.4	0.52	10	0.3	0.66	10	5.4%	0.16 [-0.72, 1.04]	_
Ott 1998	-0.3	0.52	25	-1.64	0.66	25	5.8%	2.22 [1.50, 2.94]	
Sammour2010	0.64	0.48	35	0.48	0.66	39	6.4%	0.27 [-0.19, 0.73]	+
Savel 2005	0.4	0.52	15	-0.3	0.66	15	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; C	hi = 9	0.56, d	f = 10 (F	° < 0.0	0001);	²= 89%		
Test for overall effec	t: Z = 1.28	i (P = (0.21)						
1.1.2 Heated vs cold	1								
Davis 2006	0.2	0.21	11	0.4	0.23	11	5.4%	-0.87 [-1.76, 0.01]	
Kissler 2004	-0.6	0.21	17	-0.4	0.23	19	5.9%	-0.89 [-1.57, -0.20]	
Nelskyla 1999	-0.2	0.21	18	0	0.2	19	5.9%	-0.95 [-1.64, -0.27]	
Puttick 1999	-0.24	0.21	15	-0.42	0.23	15	5.8%	0.80 (0.05, 1.54)	⊢ ⊷
Saad 2000	0	0.21	10	-0.1	0.23	10	5.4%	0.43 [-0.45, 1.32]	- -
Wills 2001	0.2	0.21	19	0	0.23	21	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; C	hi = 2	9.60, d	f=5(P	< 0.00	01); I ² =	83%		
Test for overall effec	t: Z = 0.26	i (P = (0.80)	×.					
Total (95% CI)			346			358	100.0%	0.20 [-0.24, 0.65]	•
Heterogeneity: Tau ²	= 0.75; C	hi ² = 1	25.48	df = 16	(P < 0.)	00001)	: ² = 87%		
Test for overall effect	t Z = 0.89) (P = (1.37)			,			-4 -2 0 2 4
corror overall effec	. 2 - 0.02	- (r - (F	Favours experimental Favours control

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

	Heated Unheated							Std. Mean Difference	Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	IV, Random, 95% Cl
1.2.1 Heated, humidi	ïed vs c	old							
Champion 2006	-0.4	0.4	25	0.4	0.5	25	11.2%	-1.74 [-2.40, -1.08]	
Davis 2006	0.4	0.52	11	0.4	0.66	11	10.3%	0.00 [-0.84, 0.84]	-+-
Farley 2004	0.29	0.52	49	-0.03	0.66	52	12.3%	0.53 [0.14, 0.93]	-
Hamza 2005	-0.7	0.52	23	-1.7	0.66	21	11.0%	1.66 [0.97, 2.36]	
Manwaring 2008	-0.2	0.52	30	-0.13	0.61	30	11.9%	-0.12 [-0.63, 0.38]	-+
Nguyen 2002	0.4	0.52	10	0.3	0.66	10	10.1%	0.16 [-0.72, 1.04]	- -
Sammour2010	0.64	0.48	35	0.48	0.66	39	12.1%	0.27 [-0.19, 0.73]	t -
Subtotal (95% CI)			183			188	78.8%	0.11 [-0.56, 0.78]	•
Heterogeneity: Tau ² =									
Test for overall effect:	Z = 0.33	8 (P = 0	0.74)						
1.2.2 Heated vs cold									
Davis 2006	0.2	0.21	11	0.4	0.23	11	10.0%	-0.87 [-1.76, 0.01]	
Wills 2001	0.2	0.21	19	0	0.23	21	11.2%	0.89 [0.23, 1.54]	
Subtotal (95% CI)			30			32	21.2%	0.03 [-1.69, 1.76]	
Heterogeneity: Tau ² =	1.39; C	hi = 9	.88, df=	= 1 (P =	0.002)); I² = 9I)%		
Test for overall effect:	Z = 0.04	4 (P = 0	0.97)						
									L
Total (95% CI)			213			220	100.0%	0.10 [-0.48, 0.68]	•
Heterogeneity: Tau ² =	0.68; C	hi² = 6	4.83, di	f = 8 (P ·	< 0.00	001); P	= 88%	-	
Test for overall effect:	Z = 0.34	l (P = 0	0.74)					For	-4 -2 U Z 4
Test for subgroup diff	erences	: Chi ^z	= 0.10,	df = 1 (i	P = 0.7	'5), I ^z =	0%	Fa	vours experimentar Favours control

Heated				Un	heated	i i		Std. Mean Difference	Std. Mean Difference			
Study or Subgroup	Mean SD Total Mean SD Tota				Total	Weight	IV, Random, 95% Cl	IV, Random, 95% Cl				
Farley 2004	0.29	0.52	49	-0.03	0.66	52	19.9%	0.53 [0.14, 0.93]				
Hamza 2005	-0.7	0.52	23	-1.7	0.66	21	15.5%	1.66 [0.97, 2.36]				
Manwaring 2008	-0.2	0.52	30	-0.13	0.61	30	18.3%	-0.12 [-0.63, 0.38]	│ -♣-			
Nguyen 2002	0.4	0.52	10	0.3	0.66	10	13.0%	0.16 [-0.72, 1.04]	I →-			
Sammour2010	0.64	0.48	35	0.48	0.66	39	19.0%	0.27 [-0.19, 0.73]				
Savel 2005	0.4	0.52	15	-0.3	0.66	15	14.3%	1.15 [0.37, 1.93]	I -			
Total (95% CI)			162			167	100.0%	0.58 [0.10, 1.06]	•			
Heterogeneity: Tau ² =	= 0.26; C	hi = 2	0.71, di	f = 5 (P :	= 0.00	09); I² =	76%					
Test for overall effect	: Z = 2.36	6 (P = (0.02)						Favours experimental Favours control			

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, I² = 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, I² = 0%).

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

	H	eated		Un	heated	i i	9	Std. Mean Difference	std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% (CI IV, Random, 95% CI
2.1.1 Heated, humidi	fied vs c	old (al	bdomin	al)					
Champion 2006	5.1	2.1	25	4.8	1.8	25	7.8%	0.15 [-0.40, 0.71	1]
Davis 2006	4.9	2.8	11	5.5	2.4	11	5.2%	-0.22 [-1.06, 0.6)	2]
Hamza 2005	5	2.8	23	5	2.4	21	7.4%	0.00 [-0.59, 0.59	9] —
Manwaring 2008	4.1	2.5	30	3.5	2.4	30	8.4%	0.24 [-0.27, 0.79	5] +
Mouton 1999	2.5	2.8	16	5.2	2.4	16	6.0%	-1.01 [-1.75, -0.2]	[7
Nguyen 2002	4.5	2.8	10	5.4	1.6	10	4.9%	-0.38 [-1.26, 0.51	1]
Sammour2010	3.9	1.95	35	2.85	2.17	39	8.9%	0.50 (0.04, 0.9)	I I
Savel 2005	2.5	2.2	15	3.8	1.7	15	6.0%	-0.64 [-1.38, 0.09	3]
Subtotal (95% CI)			165			167	54.7%	-0.10 [-0.45, 0.25	5] 🔶
Heterogeneity: Tau ² =	0.14; Cl	hi² = 1	6.67, df	= 7 (P =	= 0.02)); I² = 58	3%		
Test for overall effect:	Z = 0.57	(P=0).57)						
2.1.2 Heated, humidi	fied vs c	old (sl	noulder)					
Champion 2006	0	2.6	25	0.2	0.6	25	7.9%	-0.10 [-0.66, 0.49	5]
Manwaring 2008	3	2.6	30	2.1	2.9	30	8.4%	0.32 [-0.19, 0.83	3] +
Ott 1998	1.9	2.8	31	3.7	2.9	30	8.3%	-0.62 [-1.14, -0.11	1]
Subtotal (95% CI)			86			85	24.5%	-0.13 [-0.69, 0.42	2] 🔶
Heterogeneity: Tau ² =	0.16; Cl	hi = 6	.57, df=	= 2 (P =	0.04);	I ² = 70°	%		
Test for overall effect:	Z = 0.48	(P = 0).63)						
2.1.3 Heated vs cold									
Puttick 1999	5.3	2	15	4.6	1.6	15	6.1%	0.38 [-0.35, 1.10) -
Saad 2000	1.1	0.9	10	1.3	1.4	10	4.9%	-0.16 [-1.04, 0.7)	2]
Slim 1999	2.8	2	49	2	1.1	51	9.7%	0.49 [0.10, 0.89	3]
Subtotal (95% CI)			74			76	20.8 %	0.38 [0.06, 0.71	I] ◆
Heterogeneity: Tau ² =	: 0.00; Cl	hi² = 1	.78, df=	= 2 (P =	0.41);	l ² = 0%			
Test for overall effect:	Z = 2.30	(P=0).02)						
Total (95% CI)			325			328	100.0%	-0.02 [-0.27, 0.22	2] 🔶
Heterogeneity: Tau ² =	0.12; Cl	hi = 3	0.66, df	'= 13 (P	^o = 0.0	04); I² =	58%		
Test for overall effect:	Z = 0.17	(P=0).86)						-4 -2 U 2 4
									r avours experimental in avours control

Figure I3. Forest pl	lot of comparison: I Pain se	core, outcome: 1.3 Day	I pain score for low	risk of bias study.
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Std. Mean Difference
IV, Random, 95% Cl
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urs experimental Favours control

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

	Heated			Uni	neated	i i	9	Std. Mean Difference	Std. Mean Difference			
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% (CI IV, Random, 95% CI			
2.2.1 Heated, humidi	ïed vs c	old (al	bdomin	al)								
Champion 2006	4.6	2.2	25	4	2.2	25	10.0%	0.27 [-0.29, 0.8]	3]			
Davis 2006	3.5	2.2	11	4	2.2	11	7.2%	-0.22 [-1.06, 0.6:	2]			
Hamza 2005	4	2.2	23	4	2.2	21	9.6%	0.00 (-0.59, 0.5)	a] —			
Mouton 1999	0.8	2.2	16	3.8	2.2	16	7.8%	-1.33 [-2.10, -0.5	5]			
Sammour2010	2.7	1.44	35	3.1	1.99	39	11.1%	-0.23 [-0.68, 0.2]	3] ————			
Savel 2005	2.3	3	15	1.6	1.6	15	8.3%	0.28 [-0.44, 1.0])] -			
Subtotal (95% CI)			125			127	53.9%	-0.17 [-0.59, 0.24	1] 🔶			
Heterogeneitly: Tau ² = 0.16; Chi ² = 12.82, df = 5 (P = 0.03); l ² = 61%												
Test for overall effect:	Z = 0.81	(P = 0).42)									
2.2.2 Heated, humidi	ïed vs c	old (sl	noulder	r)								
Champion 2006	0.2	0.6	25	0.1	0.5	25	10.0%	0.18 [-0.38, 0.73	3]			
Ott 1998	0.9	2.2	31	2.9	2.2	30	10.3%	-0.90 [-1.43, -0.3]	7] —			
Subtotal (95% CI)			56			55	20.3%	-0.36 [-1.42, 0.69				
Heterogeneity: Tau ² =	0.50; Cl	hi = 7	.56, df=	= 1 (P =	0.006)); I^z = 8 7	7%					
Test for overall effect:	Z = 0.68) (P = 0).50)									
2.2.3 Heated vs cold												
Davis 2006	4.6	2.2	11	4	2.2	11	7.2%	0.26 [-0.58, 1.1)	D]			
Saad 2000	0.3	1.1	10	0.7	1.6	10	6.8%	-0.28 [-1.16, 0.6)] — 			
Slim 1999	2	2.2	49	1.1	2.2	51	11.8%	0.41 [0.01, 0.8	D]			
Subtotal (95% CI)			70			72	25.8%	0.29 [-0.05, 0.62	2] 🔶			
Heterogeneity: Tau ² =	0.00; Cl	hi² = 1	.93, df=	= 2 (P =	0.38);	I ² = 0%						
Test for overall effect:	Z = 1.69) (P = 0).09)									
Total (95% CI)			251			254	100.0%	-0.12 [-0.44, 0.20	11 (
Heterogeneity: Tau ² =	0.18; Cl	hi = 2	9.65, dt	í = 10 (P	= 0.0	010); I²	= 66%					
Test for overall effect:	Z = 0.74	(P = 0).46)						Favours experimental Favours control			
									r areare experimental in around control			

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

	He	eated		Un	heate	d	:	Std. Mean Difference	Std. Mean Difference				
Study or Subgroup	Mean	SD	Total	Mean	SD	CI IV, Random, 95% CI							
Champion 2006	4.6	2.2	25	4	2.2	25	26.3%	0.27 [-0.29, 0.83	3]				
Davis 2006	3.5	2.2	11	4	2.2	11	11.6%	-0.22 [-1.06, 0.62	2]				
Hamza 2005	4	2.2	23	4	2.2	21	23.3%	0.00 (-0.59, 0.59	9] —				
Sammour2010	2.7	1.44	35	3.1	1.99	39	38.9%	-0.23 [-0.68, 0.23	3] —				
Total (95% CI)			94			96	100.0%	-0.04 [-0.33, 0.24	4] 🔶				
Heterogeneity: Tau ² =	: 0.00; Cl 7 = 0.29	hi ^z = 2 I (P = 1		-4 -2 0 2	4								
. correction on out	- 0.20	· · · - ·							Favours experimental Favours control	I.			

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).



	Heated Unheated							Std. Mean Difference	Std. Mean Difference		
Study or Subgroup	p Mean SD Total			Mean SD Total			Weight	IV, Random, 95% Cl	IV, Random, 95% Cl		
Farley 2004	3.5	5.5	49	2.7	4.3	52	49.2%	0.16 [-0.23, 0.55]			
Sammour2010	15.7	13.6	35	15.8	20.9	39	36.1%	-0.01 [-0.46, 0.45]			
Savel 2005	19	6	15	20	11	15	14.7%	-0.11 [-0.83, 0.61]			
Total (95% CI)			99			106	100.0%	0.06 [-0.21, 0.34]	◆		
Heterogeneity: Tau ² =	0.00; C	hi² = 0	.55, df :	= 2 (P =	0.76);	l ² = 0%					
Test for overall effect:	Z = 0.44	(P = 0	0.66)			Fa	avours experimental Favours control				

Figure I	7.	Forest	plot of	compariso	n: 3 Mor	phine c	onsumption	, outcome	: 3.2 Day	y I mor	phine.
••••										-	

	Heated U					ł	9	Std. Mean Difference	Std. Mean Difference	
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	IV, Random, 95% Cl	
3.2.1 Heated, humidit	fied vs c	old								
Davis 2006	33	28.6	11	31	49.4	11	6.3%	0.05 [-0.79, 0.88]		
Farley 2004	23.2	27.1	49	29.2	35.4	52	24.1%	-0.19 [-0.58, 0.20]		
Hamza 2005	32	20	23	37	18	21	11.9%	-0.26 [-0.85, 0.34]		
Nguyen 2002	32	19	10	27	26	10	5.7%	0.21 [-0.67, 1.09]		
Sammour2010	33.2	28.6	35	46.2	49.4	39	18.6%	-0.31 [-0.77, 0.14]		
Savel 2005	36	17	15	41	27	15	8.4%	-0.22 [-0.93, 0.50]		
Subtotal (95% CI)			143			148	75.0%	-0.19 [-0.42, 0.04]	•	
Heterogeneity: Tau ² = 0.00; Chi ² = 1.44, df = 5 (P = 0.92); l ² = 0%										
Test for overall effect:	Z = 1.60) (P = ().11)							
3.2.2 Heated vs cold										
Davis 2006	27	24.7	11	31	49.4	11	6.3%	-0.10 [-0.93, 0.74]		
Puttick 1999	52.3	24.7	15	36.8	29.2	15	8.1%	0.56 [-0.17, 1.29]	_ 	
Wills 2001	46	23.8	19	32.9	23.5	21	10.6%	0.54 [-0.09, 1.18]		
Subtotal (95% CI)			45			47	25.0%	0.39 [-0.03, 0.80]	-	
Heterogeneity: Tau ² =	: 0.00; C	hi² = 1	.74, df=	= 2 (P =	0.42);	I ² = 0%				
Test for overall effect:	Z = 1.84	(P = ().07)							
T / 1/05// 00			100			105	100.00			
l otal (95% CI)			188			195	100.0%	-0.04 [-0.26, 0.18]	🕈	
Heterogeneity: Tau ² =	: 0.01; C	hi = 8	.85, df=	= 8 (P =	0.36);	$I^{2} = 10^{\circ}$	%		-2 -1 0 1 2	
Test for overall effect:	Z = 0.37	' (P = ().71)					Fa	vours experimental Favours control	

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

	Heated Unheated					i i		Std. Mean Difference	Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% C	I IV, Random, 95% Cl
3.3.1 Heated, humidi	fied vs o	:old							
Champion 2006	3.7	2.1	25	4.6	1.8	25	15.4%	-0.45 [-1.01, 0.11]
Davis 2006	31	25	11	25	34.7	11	9.8%	0.19 [-0.65, 1.03]
Hamza 2005	15	12	23	21	18	21	14.5%	-0.39 [-0.99, 0.21]
Sammour2010	18.9	19.7	35	30.1	34.7	39	18.3%	-0.39 [-0.85, 0.07]
Savel 2005	43	25	15	44	27	15	11.9%	-0.04 [-0.75, 0.68	1
Subtotal (95% CI)			109			111	70.0%	-0.30 [-0.56, -0.03] ♦
Heterogeneity: Tau ² = 0.00; Chi ² = 2.34, df = 4 (P = 0.67); l ² = 0%									
Test for overall effect:	Z = 2.17	7 (P = 0	0.03)						
3.3.2 Heated vs cold									
Davis 2006	33	25	11	25	34.7	11	9.7%	0.25 (-0.59, 1.09]
Slim 1999	31	24	49	21	20	51	20.3%	0.45 (0.05, 0.85]
Subtotal (95% CI)			60			62	30.0 %	0.41 [0.06, 0.77] ◆
Heterogeneity: Tau ² =	: 0.00; C	hi² = 0	.17, df:	= 1 (P =	0.68);	$l^2 = 0\%$			
Test for overall effect:	Z= 2.28	6 (P = 0	0.02)						
Total (95% CI)			169			173	100.0 %	-0.07 [-0.39, 0.25	1 🔶
Heterogeneity: Tau ² =	: 0.09; C	hi ² = 1	2.17, d	f=6(P:	= 0.06)); I ² = 51	1%		
Test for overall effect:	Z= 0.41	(P = ().68)						-4 -2 U Z 4
		•							Favours experimental Favours control

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).

· 8···································	Figure 19. Forest plot of comparison: 4 Hospital stay, outcome: 4.1 Hospital st	ay.
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	He	Heated U			Unheated			Std. Mean Difference	Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	IV, Random, 95% Cl
4.1.1 Heated, humidi	fied vs c	old							
Champion 2006	2.3	0.5	25	2.3	0.5	25	10.9%	0.00 [-0.55, 0.55]	-
Davis 2006	2.4	3.1	11	2.4	8.9	11	5.5%	0.00 [-0.84, 0.84]	_ _
Farley 2004	1.29	0.9	49	1.2	1	52	17.7%	0.09 [-0.30, 0.48]	
Hamza 2005	2	3.1	23	2	8.9	21	9.8%	0.00 [-0.59, 0.59]	-+-
Mouton 1999	1.5	3.1	16	2.1	8.9	16	7.6%	-0.09 [-0.78, 0.61]	
Nguyen 2002	1.3	0.5	10	1.1	0.7	10	5.0%	0.31 [-0.57, 1.20]	
Sammour2010	6.4	3.1	35	8.8	8.9	39	14.3%	-0.35 [-0.81, 0.11]	
Savel 2005	3.2	0.4	15	4	0.9	15	6.2%	-1.12 [-1.90, -0.34]	_ - _
Subtotal (95% CI)			184			189	76.9%	-0.13 [-0.38, 0.13]	•
Heterogeneity: Tau² = 0.04; Chi² = 9.78, df = 7 (P = 0.20); l² = 28%									
Test for overall effect:	Z = 0.97	? (P =	0.33)						
4.1.2 Heated vs cold									
Davis 2006	2.3	3.1	11	2.4	8.9	11	5.5%	-0.01 [-0.85, 0.82]	
Slim 1999	2.9	1.3	49	2.7	0.8	51	17.6%	0.18 [-0.21, 0.58]	- <u>+</u> -
Subtotal (95% CI)			60			62	23.1%	0.15 [-0.21, 0.50]	◆
Heterogeneity: Tau² =	= 0.00; C	hi² =	0.18, d	f=1(P:	= 0.6	7); I² = ()%		
Test for overall effect:	Z = 0.82	2 (P =	0.41)						
Total (95% CI)			244			251	100.0%	-0.06 [-0.27, 0.15]	T
Heterogeneity: Tau² =	= 0.02; C	hi² =	11.51,	df = 9 (F	? = 0.:	24); I ^z =	22%		-4 -2 0 2 4
Test for overall effect:	Z = 0.58	3 (P =	0.56)					Fa	avours experimental Favours control

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.

	н	eated		un	heated	1		Std. Mean Difference	Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	IV, Random, 95% Cl
Champion 2006	58.8	11.3	25	56.5	11.1	25	17.1%	0.20 [-0.35, 0.76]	
Davis 2006	144.8	30	11	142.5	69	11	14.9%	0.04 [-0.79, 0.88]	_ + _
Farley 2004	74	29	49	82	29	52	18.2%	-0.27 [-0.67, 0.12]	
Hamza 2005	83	30	23	107	69	21	16.8%	-0.45 [-1.05, 0.15]	
Manwaring 2008	62	19.9	30	62.6	17.6	30	17.5%	-0.03 [-0.54, 0.47]	-+-
Ott 1998	45	30	25	190	69	25	15.4%	-2.68 [-3.46, -1.90]	
Total (95% CI)			163			164	100.0 %	-0.50 [-1.18, 0.17]	•
Heterogeneity: Tau² =	= 0.61; C	hi² = 4	0.82, ď	f= 5 (P	< 0.001	001); I ^z	= 88%	-	
Test for overall effect:	Z=1.47	' (P = (0.14)					Fav	rours experimental Favours control

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

	Heated unheated				1		Std. Mean Difference	Std. Mean Difference	
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	IV, Random, 95% Cl
Champion 2006	58.8	11.3	25	56.5	11.1	25	18.1%	0.20 [-0.35, 0.76]	
Davis 2006	144.8	30	11	142.5	69	11	8.0%	0.04 [-0.79, 0.88]	_ + _
Farley 2004	74	29	49	82	29	52	36.4%	-0.27 [-0.67, 0.12]	
Hamza 2005	83	30	23	107	69	21	15.6%	-0.45 [-1.05, 0.15]	
Manwaring 2008	62	19.9	30	62.6	17.6	30	21.9%	-0.03 [-0.54, 0.47]	-+-
Total (95% CI)			138			139	100.0%	-0.14 [-0.37, 0.10]	•
Heterogeneity: Tau ² =	Heterogeneity: Tau ² = 0.00; Chi ² = 3.29, df = 4 (P = 0.51); l ² = 0%								
Test for overall effect	: Z = 1.13) (P = (0.26)					Fav	-4 -2 U 2 4 ours experimental Favours control

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	t of com	parison: 5	Lens fogging,	outcome: 5.1	Lens 1	fogging
o · · ·							00 0

	н	eated		Un	heated	i i		Std. Mean Difference	Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	IV, Random, 95% Cl
Champion 2006	6	2.3	25	2	3.1	25	14.4%	1.44 [0.81, 2.07]	
Davis 2006	1.7	2.3	11	1.3	3.1	11	11.6%	0.14 [-0.70, 0.98]	_ - _
Farley 2004	1.1	2.3	49	1.6	3.1	52	17.8%	-0.18 [-0.57, 0.21]	-
Hamza 2005	2	2.3	23	2	3.1	21	15.0%	0.00 [-0.59, 0.59]	-+-
Nguyen 2002	1.6	2	10	1.6	3.1	10	11.1%	0.00 [-0.88, 0.88]	_
Sammour2010	4.2	2.3	35	3.1	2	39	16.8%	0.51 [0.04, 0.97]	
Savel 2005	1.29	0.91	15	1.2	1.04	15	13.2%	0.09 [-0.63, 0.81]	+
Total (95% CI)			168			173	100.0 %	0.29 [-0.14, 0.72]	•
Heterogeneity: Tau ² =	Heterogeneity: Tau ² = 0.23; Chi ² = 20.96, df = 6 (P = 0.002); l ² = 7							_	
Test for overall effect:	Z=1.33) (P = (0.18)					Favo	ours experimental Favours control

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.

	Heated Unheated					1		Std. Mean Difference	Std. Mean Difference	
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% Cl	IV, Random, 95% Cl	
7.1.1 Heated, humidi	fied vs c	old								
Champion 2006	61.7	10.4	25	61.7	10.7	25	6.4%	0.00 [-0.55, 0.55]	+	
Davis 2006	84.2	48.8	11	84.6	57.5	11	3.0%	-0.01 [-0.84, 0.83]		
Farley 2004	91.2	22.7	49	91.2	22.3	52	11.4%	0.00 [-0.39, 0.39]	+	
Hamza 2005	120	24	23	132	48	21	5.6%	-0.32 [-0.91, 0.28]		
Kissler 2004	62	29.8	17	45	22.5	19	4.5%	0.63 [-0.04, 1.31]	⊢	
Manwaring 2008	49.6	17.1	30	46.8	18	30	7.5%	0.16 [-0.35, 0.66]		
Mouton 1999	40	48.8	16	48.3	57.5	16	4.3%	-0.15 [-0.85, 0.54]		
Nguyen 2002	107	12	10	108	33	10	2.8%	-0.04 [-0.92, 0.84]		
Ott 1998	190	48.8	25	230	57.5	25	6.0%	-0.74 [-1.31, -0.16]		
Sammour2010	176.3	48.8	35	184.7	57.5	39	8.9%	-0.16 [-0.61, 0.30]		
Savel 2005	76	16	15	101	34	15	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); l ² = 37%										
Test for overall effect	:Z=1.10) (P = (0.27)							
7.1.2 Heated vs cold										
Davis 2006	83.1	48.8	11	84.2	57.5	11	3.0%	-0.02 [-0.86, 0.82]		
Kissler 2004	51	18	17	45	22.5	19	4.7%	0.29 [-0.37, 0.94]		
Nelskyla 1999	56	48.8	18	51	57.5	19	4.9%	0.09 [-0.55, 0.74]		
Puttick 1999	32.13	9.75	15	31.53	11.4	15	4.1%	0.06 [-0.66, 0.77]		
Saad 2000	56	14	10	61	17	10	2.7%	-0.31 [-1.19, 0.58]		
Slim 1999	73	37	49	67	31	51	11.3%	0.17 [-0.22, 0.57]		
Wills 2001	69	18	19	72	24	21	5.2%	-0.14 [-0.76, 0.48]		
Subtotal (95% CI)			139			146	35.9%	0.07 [-0.16, 0.31]	♦	
Heterogeneity: Tau ² =	= 0.00; C	hi² = 1	.87, df:	= 6 (P =	0.93);	l ² = 0%				
Test for overall effect	: Z = 0.61	(P = 0	0.54)							
Total (95% CI)			395			409	100.0%	-0.05 [-0.20, 0.10]	•	
Heterogeneity: Tau ² :	= 0.01; C	hi ² = 1	9.24, d	f = 17 (F	e = 0.30	2); I 2 = 1	12%			
Test for overall effect	: Z = 0.69	9 (P = 0	0.49)					E.	-4 -Z U Z 4	
								E ·	avours experimental in ravours control	

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.

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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	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

RCT
40 laparoscopic cholecystectomy patients
Heated, humidified CO ₂ versus cold CO ₂
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	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	d CO ₂ versus cold CO ₂	
Outcomes	Core temperature, pair	n 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 cholec	ystectomy patients	
Interventions	Warmed CO ₂ versus c	old 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 co	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 colonio	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	

Methods	RCT - blinded			
Participants	30 laparoscopic gastric	bypass patients		
Interventions	Heated humidified CC	D_2 versus cold CO_2		
Outcomes	Postoperative pain scor	re, 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 risk of bia	y was apparently free of other problems that could put it at high as
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Slim 1999

Methods	RCT- double blinded				
Participants	100 laparoscopic choled	cystectomy, fundoplication or Heller's myotomy patients			
Interventions	Heated CO ₂ versus unl	neated CO ₂			
Outcomes	Postoperative pain, core length of postoperative	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 fundop	lication, 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]

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	5	220	Std. Mean Difference (IV, Random, 95% CI)	-0.30 [-0.56, -0.03]
cold				
3.2 Heated vs cold	2	122	Std. Mean Difference (IV, Random, 95% CI)	0.41 [0.06, 0.77]

Comparison 3. Morphine consumption

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 No. of No. of utcome or subgroup title studies 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 I.I. Comparison I Core temperature, Outcome I Change in Core Temperature.

Review: Heated CO $_2$ with or without humidification for minimally invasive abdominal surgery

Comparison: I Core temperature

Outcome: I Change in Core Temperature

Study or subgroup	Heated		Unheated		Std. Mean Difference	Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)	IV,Random,95% Cl		IV,Random,95% CI
l Heated, humidified vs c	old						
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]

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Favours experimental Favours control

(Continued . . .)

Heated CO $_2$ with or without humidification for minimally invasive abdominal surgery (Review) Copyright © 2011 The Cochrane Collaboration. Published by John Wiley & Sons, Ltd.

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Study or subgroup	Heated		Unheated		Std. Mean Difference	Weight	(Continued) Std. Mean Difference	
	Ν	Mean(SD)	Ν	Mean(SD)	IV,Random,95% Cl		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<0.0	00001 ; $ ^2 = 8$	39%				
Test for overall effect: $Z = I$.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: $Z = 0$	0.26 (P = 0.	80)						
Total (95% CI)	346		358		+	100.0 %	0.20 [-0.24, 0.65]	
Heterogeneity: $Tau^2 = 0.75$;	; $Chi^2 = 12$	5.48, df = 16 (P<0	.00001); I ² =	=87%				
Test for overall effect: $Z = 0$).89 (P = 0.	37)						

-4 -2 0 2 4 Favours experimental Favours control

Analysis I.2. Comparison I 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: I Core temperature

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

Study or subgroup	Heated		Unheated		Std. Mean Difference	Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)	IV,Random,95% Cl		IV,Random,95% CI
I Heated, humidified vs c	old						
Champion 2006	25	-0.4 (0.4)	25	0.4 (0.5)		11.2 %	-1.74 [-2.40, -1.08]
Davis 2006	11	0.4 (0.52)	11	0.4 (0.66)	-	10.3 %	0.0 [-0.84, 0.84]
Farley 2004	49	0.29 (0.52)	52	-0.03 (0.66)	-#-	12.3 %	0.53 [0.14, 0.93]
Hamza 2005	23	-0.7 (0.52)	21	-1.7 (0.66)		11.0 %	1.66 [0.97, 2.36]
Manwaring 2008	30	-0.2 (0.52)	30	-0.13 (0.61)	-	11.9 %	-0.12 [-0.63, 0.38]
Nguyen 2002	10	0.4 (0.52)	10	0.3 (0.66)		10.1 %	0.16 [-0.72, 1.04]
Sammour2010	35	0.64 (0.48)	39	0.48 (0.66)		12.1 %	0.27 [-0.19, 0.73]
Subtotal (95% CI)	183		188		•	7 8.8 %	0.11 [-0.56, 0.78]
Heterogeneity: $Tau^2 = 0.7$	71; Chi ² = 54	.86, df = 6 (P<0.00	0001); I ² =89	%			
Test for overall effect: Z =	= 0.33 (P = 0.	74)					
2 Heated vs cold		02 (021)		0.4.(0.22)		10.0.0/	
Davis 2006	11	0.2 (0.21)	11	0.4 (0.23)	-	10.0 %	-0.87 [-1.76, 0.01]
Wills 2001	19	0.2 (0.21)	21	0 (0.23)		11.2 %	0.89 [0.23, 1.54]
Subtotal (95% CI)	30		32			21.2 %	0.03 [-1.69, 1.76]
Heterogeneity: $Iau^2 = I.$	39; Chi ² = 9.8 = 0.04 (P = 0)	88, df = 1 (P = 0.00 97)	JZ); I ² =90%				
Total (95% CI)	213	,,,,	220		•	100.0 %	0.10 [-0.48, 0.68]
Heterogeneity: $Tau^2 = 0.6$	68; Chi ² = 64	.83, df = 8 (P<0.00)001); l ² =88	%		10000 /0	0110 [0110, 0100]
Test for overall effect: Z =	= 0.34 (P = 0.	74)	,				
Test for subgroup differen	nces: $Chi^2 = 0$	10, df = 1 (P = 0.1)	75), l ² =0.0%	5			
				-	4 -2 0 2 4		
				Favours	experimental Favours contro	bl	

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

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

Comparison: I Core temperature

Outcome: 3 Change core temperature with external warming

Study or subgroup	Heated		Unheated		Std. Mean Difference	Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)	IV,Random,95% CI		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 diffe	rences: Not	applicable					
					<u></u>		
					-4 -2 0 2 4		

Favours experimental Favours control

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

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

Comparison: 2 Pain score

Outcome: I Day I pain score

Study or subgroup	Heated		Unheated		Std. Mean Difference	Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)	IV,Random,95% Cl		IV,Random,95% Cl
I Heated, humidified vs co	old (abdomin	al)					
Champion 2006	25	5.1 (2.1)	25	4.8 (1.8)		7.8 %	0.15 [-0.40, 0.71]
Davis 2006	11	4.9 (2.8)	11	5.5 (2.4)		5.2 %	-0.22 [-1.06, 0.62]
Hamza 2005	23	5 (2.8)	21	5 (2.4)	+	7.4 %	0.0 [-0.59, 0.59]
Manwaring 2008	30	4.1 (2.5)	30	3.5 (2.4)		8.4 %	0.24 [-0.27, 0.75]
Mouton 1999	16	2.5 (2.8)	16	5.2 (2.4)		6.0 %	-1.01 [-1.75, -0.27]
Nguyen 2002	10	4.5 (2.8)	10	5.4 (1.6)		4.9 %	-0.38 [-1.26, 0.51]
Sammour2010	35	3.9 (1.95)	39	2.85 (2.17)	-=-	8.9 %	0.50 [0.04, 0.97]
Savel 2005	15	2.5 (2.2)	15	3.8 (1.7)		6.0 %	-0.64 [-1.38, 0.09]
Subtotal (95% CI)	165		167		•	54.7 %	-0.10 [-0.45, 0.25]
Heterogeneity: Tau ² = 0.1 Test for overall effect: Z =	4; Chi ² = 16. 0.57 (P = 0.	67, df = 7 (P = 0.0 57)	02); I ² =58%				
2 Heated, humidified vs co	old (shoulder))					
Champion 2006	25	0 (2.6)	25	0.2 (0.6)		7.9 %	-0.10 [-0.66, 0.45]
Manwaring 2008	30	3 (2.6)	30	2.1 (2.9)		8.4 %	0.32 [-0.19, 0.83]
Ott 1998	31	1.9 (2.8)	30	3.7 (2.9)		8.3 %	-0.62 [-1.14, -0.11]
Subtotal (95% CI)	86		85		•	24.5 %	-0.13 [-0.69, 0.42]
Heterogeneity: $Tau^2 = 0.1$	6; Chi ² = 6.5	7, df = 2 (P = 0.0^{4}	4); I ² =70%				
3 Heated vs cold	0.10 (1 – 0.1	55)					
Puttick 1999	15	5.3 (2)	15	4.6 (1.6)		6.1 %	0.38 [-0.35, 1.10]
Saad 2000	10	1.1 (0.9)	10	1.3 (1.4)		4.9 %	-0.16 [-1.04, 0.72]
Slim 1999	49	2.8 (2)	51	2 (1.1)	-#-	9.7 %	0.49 [0.10, 0.89]
Subtotal (95% CI)	74		76		•	20.8 %	0.38 [0.06, 0.71]
Heterogeneity: $Tau^2 = 0.0$; Chi ² = 1.78	, df = 2 (P = 0.41)	; l ² =0.0%				
Test for overall effect: $Z =$	2.30 (P = 0.0	021)	220			100.0.0/	
Iotal (95% CI) Heterogeneity $T_{2}u^{2} = 0.1$	325 2: Chi ² - 30	66 df - 13 (P - 0	328 1004): 12 - 58	29/	Ť	100.0 %	-0.02 [-0.2/, 0.22]
Test for overall effect: $Z =$	0.17 (P = 0.1)	86)		576			
					4 -2 0 2 4		
				Favours e	experimental Favours contro	bl	

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

Study or subgroup	Heated	Maan (SD)	Unheated	Maan(SD)	Std. Mean Difference	Weight	Std. Mean Difference
	IN	Mean(SD)	IN	riean(SD)	IV,Random,#37% CI		IV,Rahuom,73% Ci
I Heated, humidified vs c	old (abdomin	al)	25	4 (2.2)			
Champion 2006	25	4.6 (2.2)	25	4 (2.2)	Ē	10.0 %	0.27 [-0.29, 0.83]
Davis 2006	11	3.5 (2.2)	11	4 (2.2)		7.2 %	-0.22 [-1.06, 0.62]
Hamza 2005	23	4 (2.2)	21	4 (2.2)	-	9.6 %	0.0 [-0.59, 0.59]
Mouton 1999	16	0.8 (2.2)	16	3.8 (2.2)		7.8 %	-1.33 [-2.10, -0.55]
Sammour2010	35	2.7 (1.44)	39	3.1 (1.99)		11.1 %	-0.23 [-0.68, 0.23]
Savel 2005	15	2.3 (3)	15	1.6 (1.6)		8.3 %	0.28 [-0.44, 1.00]
Subtotal (95% CI)	125		127		•	53.9 %	-0.17 [-0.59, 0.24]
Heterogeneity: Tau ² = 0.1 Test for overall effect: Z = 2 Heated, humidified vs c	$ 6; Chi^2 = 2.$ = 0.81 (P = 0.4 old (shoulder)	82, df = 5 (P = 0.0 42)	03); I ² =61%				
Champion 2006	25	0.2 (0.6)	25	0.1 (0.5)	-	10.0 %	0.18 [-0.38, 0.73]
Ott 1998	31	0.9 (2.2)	30	2.9 (2.2)	-	10.3 %	-0.90 [-1.43, -0.37]
Subtotal (95% CI)	56		55		-	20.3 %	-0.36 [-1.42, 0.69]
Test for overall effect: Z = 3 Heated vs cold	= 0.68 (P = 0.1	50)	i), i —07 //o	4 (2 2)		70%	02/1.050 1.001
Davis 2006	11	4.0 (2.2)	11	4 (2.2)		1.2 %	0.26 [-0.36, 1.10]
Saad 2000	10	0.3 (1.1)	10	0.7 (1.6)		6.8 %	-0.28 [-1.16, 0.60]
Slim 1999	49	2 (2.2)	51	1.1 (2.2)	-	11.8 %	0.41 [0.01, 0.80]
Subtotal (95% CI)	70	I(- 2 (D - 0 20)	72		•	25.8 %	0.29 [-0.05, 0.62]
Test for overall effect: Z =	; Cni~ = 1.93 = 1.69 (P = 0.0	, at — 2 (P — 0.38, 091)	l; I² −0.0%				
Total (95% CI) Heterogeneity: Tau ² = 0.1 Test for overall effect: Z =	251 18; Chi ² = 29. = 0.74 (P = 0.4	65, df = 10 (P = 0 16)	254 0.00098); I ² =	-66%	•	100.0 %	-0.12 [-0.44, 0.20]
				 Favours e	xperimental Favours contro	bl	

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

Study or subgroup	Heated		Unheated		Std. Mean Difference	Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)	IV,Random,95% CI		IV,Random,95% CI
l Heated, humidified vs co	old (abdomina	ıl)					
Champion 2006	25	5.1 (2.1)	25	4.8 (1.8)		13.3 %	0.15 [-0.40, 0.71]
Davis 2006	11	4.9 (2.8)		5.5 (2.4)		5.8 %	-0.22 [-1.06, 0.62]
Hamza 2005	23	5 (2.8)	21	5 (2.4)		11.7 %	0.0 [-0.59, 0.59]
Manwaring 2008	30	4.1 (2.5)	30	3.5 (2.4)		15.9 %	0.24 [-0.27, 0.75]
Nguyen 2002	10	4.5 (2.8)	10	5.4 (1.6)		5.2 %	-0.38 [-1.26, 0.51]
Sammour2010	35	3.9 (1.95)	39	2.85 (2.17)		19.0 %	0.50 [0.04, 0.97]
Subtotal (95% CI)	134		136		•	7 0.9 %	0.17 [-0.07, 0.41]
Heterogeneity: $Tau^2 = 0.0$; Chi ² = 4.67,	df = 5 (P = 0.46)	; I ² =0.0%				
Test for overall effect: Z =	1.40 (P = 0.1	6)					
2 Heate, humidified vs col	ld (shoulder)						
Champion 2006	25	0 (2.6)	25	0.2 (0.6)		3.3 %	-0.10 [-0.66, 0.45]
Manwaring 2008	30	3 (2.6)	30	2.1 (2.9)		15.8 %	0.32 [-0.19, 0.83]
Subtotal (95% CI)	55		55		-	29.1 %	0.12 [-0.29, 0.54]
Heterogeneity: $Tau^2 = 0.0$	12; Chi ² = 1.2	3, df = 1 (P = 0.27	7); 2 = 9%				
Test for overall effect: Z =	0.58 (P = 0.5	6)					
Total (95% CI)	189		191		•	100.0 %	0.16 [-0.04, 0.36]
Heterogeneity: $Tau^2 = 0.0$; Chi ² = 5.94,	df = 7 (P = 0.55)	; I ² =0.0%				
Test for overall effect: $Z =$	1.53 (P = 0.1	3)					
Test for subgroup differen	ces: Chi ² = 0.	04, df = 1 (P = 0.3)	85), I ² =0.0%				
				-2	-1012		
				Favours e	xperimental Favours contro		

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

Study or subgroup	Heated		Unheated			Std. N	1ean Difference	. Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)		IV,Rano	iom,95% Cl		IV,Random,95% CI
Champion 2006	25	4.6 (2.2)	25	4 (2.2)				26.3 %	0.27 [-0.29, 0.83]
Davis 2006	11	3.5 (2.2)	11	4 (2.2)		_	-	11.6 %	-0.22 [-1.06, 0.62]
Hamza 2005	23	4 (2.2)	21	4 (2.2)		-	-	23.3 %	0.0 [-0.59, 0.59]
Sammour2010	35	2.7 (1.44)	39	3.1 (1.99)		4	-	38.9 %	-0.23 [-0.68, 0.23]
Total (95% CI) Heterogeneity: Tau ² = Test for overall effect:	94 = 0.0; Chi ² = 2 Z = 0.29 (P =	2.00, df = 3 (P = 0 = 0.77)	96 0.57); I ² =0.0%				•	100.0 %	-0.04 [-0.33, 0.24]
Test for subgroup diffe	erences: Not a	applicable							
				Favours	-4 s exper	-2 rimental	0 2 Favours con	4 trol	

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: I Up to 6 hour

Study or subgroup	Heated		Unheated			Std. N	1ean Differe	nce	Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)		IV,Rano	dom,95% Cl			IV,Random,95% Cl
Farley 2004	49	3.5 (5.5)	52	2.7 (4.3)					49.2 %	0.16 [-0.23, 0.55]
Sammour2010	35	5.7 (3.6)	39	15.8 (20.9)		_	•		36.1 %	-0.01 [-0.46, 0.45]
Savel 2005	15	19 (6)	15	20 (11)					14.7 %	-0.11 [-0.83, 0.61]
Total (95% CI)	99		106				•		100.0 %	0.06 [-0.21, 0.34]
Heterogeneity: Tau ² =	0.0; Chi ² =	0.55, df = 2 (P =	0.76); l ² =0.0%							
Test for overall effect: 2	Z = 0.44 (P	= 0.66)								
					-2	-	0 I	2		
				Favour	s exper	rimental	Favours	control		

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

Review: Heated CO $_2$ with or without humidification for minimally invasive abdominal surgery

Comparison: 3 Morphine consumption

Outcome: 2 Day I morphine

Study or subgroup	Heated N	Mean(SD)	Unheated N	Mean(SD)	Std. Mean Difference IV,Random,95% Cl	Weight	Std. Mean Difference IV,Random,95% Cl
L Heated, humidified vs.co	bld						
Davis 2006		33 (28.6)		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		•	7 5.0 %	-0.19 [-0.42, 0.04]
Heterogeneity: $Tau^2 = 0.0$ Test for overall effect: $Z = 2$ Heated vs cold	$Chi^2 = 1.44$ 1.60 (P = 0.	, df = 5 (P = 0.9	92); I ² =0.0%				
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) Heterogeneity: $Tau^2 = 0.0$	45 ; Chi ² = 1.74	$f_{\rm r}, df = 2 (P = 0.4)$	47 42); I ² =0.0%		•	25.0 %	0.39 [-0.03, 0.80]
Total (95% CI) Heterogeneity: Tau ² = 0.0 Test for overall effect: $Z =$	188 188 1 ; Chi ² = 8.8 6 0.37 (P = 0.	066) 15, df = 8 (P = 0 71)	195 0.36); I ² = I 0%		•	100.0 %	-0.04 [-0.26, 0.18]
				Favours	-2 -1 0 I 2 s experimental Favours contro	1	

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

Study or subgroup	Heated		Unheated		Std. Mean Difference	Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)	IV,Random,95% Cl		IV,Random,95% CI
I Heated, humidified vs co	old						
Champion 2006	25	3.7 (2.1)	25	4.6 (1.8)	-8-	15.4 %	-0.45 [-1.01, 0.11]
Davis 2006	11	31 (25)	11	25 (34.7)		9.8 %	0.19 [-0.65, 1.03]
Hamza 2005	23	15 (12)	21	21 (18)		14.5 %	-0.39 [-0.99, 0.21]
Sammour2010	35	18.9 (19.7)	39	30.1 (34.7)		18.3 %	-0.39 [-0.85, 0.07]
Savel 2005	15	43 (25)	15	44 (27)	-	11.9 %	-0.04 [-0.75, 0.68]
Subtotal (95% CI)	109		111		•	7 0.0 %	-0.30 [-0.56, -0.03]
Heterogeneity: $Tau^2 = 0.0$; Chi ² = 2.34	, $df = 4 (P = 0.67)$	7); l ² =0.0%				
Test for overall effect: Z =	2.17 (P = 0.	030)					
2 Heated vs cold							
Davis 2006	11	33 (25)	11	25 (34.7)		9.7 %	0.25 [-0.59, 1.09]
Slim 1999	49	31 (24)	51	21 (20)	-	20.3 %	0.45 [0.05, 0.85]
Subtotal (95% CI)	60		62		•	30.0 %	0.41 [0.06, 0.77]
Heterogeneity: $Tau^2 = 0.0$; Chi ² = 0.17	f, df = 1 (P = 0.68)	8); l ² =0.0%				
Test for overall effect: Z =	2.26 (P = 0.	024)					
Total (95% CI)	169		173		+	100.0 %	-0.07 [-0.39, 0.25]
Heterogeneity: $Tau^2 = 0.0$	9; Chi ² = 12	.17, df = 6 (P = 0	0.06); l ² =51%				
Test for overall effect: Z =	0.41 (P = 0.	68)					
					-4 -2 0 2 4		

-4 -2 0 2 4 Favours experimental Favours control

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

Review: Heated CO $_2$ with or without humidification for minimally invasive abdominal surgery

Comparison: 4 Hospital stay

Outcome: I Hospital Stay

Study or subgroup	Heated		Unheated		Std. Mean Difference	Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)	IV,Random,95% CI		IV,Random,95% CI
l Heated, humidified vs c	old						
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 %	0.3 [-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: $Tau^2 = 0.0$	04; Chi ² = 9.7	8, df = 7 (P = 0.20)); I ² =28%				
Test for overall effect: Z =	= 0.97 (P = 0.3	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: $Tau^2 = 0.0$	0; Chi ² = 0.18	df = 1 (P = 0.67)	; I ² =0.0%				
Test for overall effect: Z =	= 0.82 (P = 0.4	41)					
Total (95% CI)	244		251		+	100.0 %	-0.06 [-0.27, 0.15]
Heterogeneity: $Tau^2 = 0.0$	02; Chi ² = 11.	5I, df = 9 (P = 0.2)	24); I ² =22%				
Test for overall effect: Z =	= 0.58 (P = 0.5	56)					
				•			
				-4	-2 0 2 4		
				Favours e	xperimental Favours contro	bl	

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

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

Comparison: 5 Recovery room stay

Outcome: I Recovery time

Study or subgroup	Heated		unheated		Std. Mean Difference	Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)	IV,Random,95% CI		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); l ² = 88% -0.50 [-1.18, 0.17 Test for overall effect: Z = 1.47 (P = 0.14) -0.50 [-1.18, 0.17 Test for subgroup differences: Not applicable -0.50 [-1.18, 0.17							-0.50 [-1.18, 0.17]
					-4 -2 0 2 4		
				Favou	rs experimental Favours contro	1	

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		unheated		Std. Mean Difference	Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)	IV,Random,95% CI		IV,Random,95% CI
Champion 2006	25	58.8 (11.3)	25	56.5 (.)	-	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 =					
Test for overall effect: 2	Z = 1.13 (P =	= 0.26)					
Test for subgroup diffe	rences: Not	applicable					

-4 -2 0 2 4 Favours experimental

Favours control

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

Review: Heated CO $_{2}$ with or without humidification for minimally invasive abdominal surgery

Comparison: 6 Lens fogging

Outcome: I Times cleaned

Study or subgroup	Heated N	Mean(SD)	Unheated N	Mean(SD)	Std. Mean Difference IV,Random,95% Cl	Weight	Std. Mean Difference IV,Random,95% Cl
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) Heterogeneity: Tau ² =	168 0.23; Chi ² =	20.96, df = 6 (P =	173 = 0.002); I ² =7	1%	•	100.0 %	0.29 [-0.14, 0.72]
Test for overall effect: Z	C = 1.33 (P =	= 0.18)					
				Favours	+ -2 U Z 4	d	

Favours experimental

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

Review: Heated CO $_{2}$ with or without humidification for minimally invasive abdominal surgery

Comparison: 7 Operative time

Outcome: I Operative Time

Study or subgroup	Heated		Unheated		Std. Mean Difference	Weight	Std. Mean Difference
	Ν	Mean(SD)	Ν	Mean(SD)	IV,Random,95% CI		IV,Random,95% CI
I Heated, humidified vs co	ld						
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, .3]
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: $Tau^2 = 0.05$	5; Chi ² = 15	5.76, df = 10 (P =	0.11); 12 =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: $Tau^2 = 0.0$;	$Chi^2 = 1.8^{-1}$	7, df = 6 (P = 0.9	3); 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: $Tau^2 = 0.01$	$1; Chi^2 = 19$	P.24, df = 17 (P = 10)	$(0.32); ^2 = ^2$	%			
lest for overall effect: $\angle =$	0.69 (P = 0	.47)					
					-4 -2 0 2 4		

Favours experimental

Favours control

ADDITIONAL TABLES

Table 1. The Cochrane Collaboration's tool for assessing risk of bias	
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Domain	Description	Author's judgment
Sequence generation		Was the allocation sequence adequately generated? YES / NO / UN-CLEAR
Allocation concealment		Was allocation sequence adequately concealed? YES / NO / UNCLEAR
Blinding participants, personnel and out- come assessors		Was the knowledge of the allocated intervention adequately prevented during the study? YES / NO / UNCLEAR
Blinding participants, personnel and out- come 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 / UN-CLEAR
Incomplete outcome data		Were incomplete outcome data adequately addressed? YES / NO / UN-CLEAR
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