



PEER REVIEWED STUDIES,
SELECTED ABSTRACTS & ARTICLES

Insuflow | Port

Insuflow | Port

During every surgery, preventative measures should be taken to reduce tissue desiccation, hypothermia and postoperative pain.

- 01 | Meta-Analysis
- 02 | Effects of CO₂ Gas Properties on Postoperative Pain
- 03 | Effects of CO₂ Gas Properties on Hypothermia
- 04 | Simultaneously Humidifying & Warming CO₂ Gas is the Only Proven Method to Improve Patient Care
- 05 | Effects of CO₂ Gas Properties on Cell Desiccation & Postoperative Complications

Meta-Analysis of the Effect of Warm Humidified Insufflation on Pain After Laparoscopy

Sammour T, Kahokehr A, and Hill A. British Journal of Surgery 2008, 95: 950-956.

RESULTS

Seven RCTs were included. Patients in the warmed humidified group experienced a significant reduction in pain score at 6 h ($P = 0.006$), 1 day ($P = 0.010$) and 3 days ($P < 0.001$) after operation, and in morphine usage on day 2 ($P = 0.040$).

CONCLUSIONS

Warmed humidified insufflation reduces pain after laparoscopy.

Effect of Heated and Humidified Carbon Dioxide on Patients After Laparoscopic Procedures A Meta-Analysis

Sajid M, Mallick A, Rimpel J, Bokari S, Cheek E, Baig M. Surg Laparosc Endosc Percutan Tech 2008; 18: 539-546.

RESULTS

Ten randomized controlled trials on 565 patients were analyzed. In both the fixed and random effect models, postoperative pain was significantly less in heated humidified CO₂ group. Heated humidified CO₂ group was also associated with significantly lower risk of hypothermia and lower analgesic requirement.

CONCLUSIONS

The use of heated humidified CO₂ for pneumoperitoneum in laparoscopic procedures is associated with lesser postoperative pain, lower risk of postoperative hypothermia, and lower analgesic requirements.

Warmed, Humidified CO₂ Insufflation Benefits Intraoperative Core Temperature during Laparoscopic Surgery: A Meta-Analysis

Dean M., Ramsey R., Heriot A., Mackay J., Hiscock R., Lynch C. Asian Journal of Endoscopic Surgery 10 (2017) 128-136

RESULTS

The database search identified 320 studies as potentially relevant, and of these, 13 met the inclusion criteria and were included in the analysis. During laparoscopic surgery, use of warmed, humidified CO₂ is associated with significant increase in intraoperative core temperature (mean temperature change, 0.3°C), when compared with cold, dry CO₂ insufflation.

CONCLUSIONS

Warmed, humidified CO₂ insufflation during laparoscopic abdominal surgery has been demonstrated to improve intraoperative maintenance of normothermia when compared with cold, dry CO₂.

Improved Outcomes for Lap-Banding Using the Insuflow® Device Compared with Heated-Only Gas

Benavides R, Wong A, Nguyen H. JLS (2009) 13:302-305

BACKGROUND

Preconditioning gas by humidification and warming the pneumoperitoneum improves laparoscopic outcomes. This prevents peritoneal desiccation and detrimental events related to traditional cold-dry gas. Few comparisons have been done comparing traditional cold-dry, heated-only, and humidified-warmed carbon dioxide.

METHODS

A prospective, controlled, randomized, double-blind study of laparoscopic gastric banding included 113 patients and compared traditional dry-cold (n=35) versus dry-heated (n=40), versus humidified-warm gas (n=38). Pain medications were standardized for all groups. Endpoints were recovery room length of stay, pain location, pain intensity, and total pain medications used postoperatively for up to 10 days.

RESULTS

The humidified-warmed group had statistically significant differences from the other 2 groups with improvement in all end points. The dry-heated group had significantly more pain medication use and increased shoulder and chest pain than the other 2 groups had.

CONCLUSION

Using warm-humidified gas for laparoscopic gastric banding reduces shoulder pain, shortens recovery room length of stay, and decreases pain medication requirements for up to 10 days postoperatively. Dry-heated gas may cause additional complications as is indicated by the increase in pain medication use and pain intensity.

01

Heated and Humidified Insufflation During Laparoscopic Gastric Bypass Surgery: Effect on Temperature, Postoperative Pain, and Recovery Outcomes

Hamza M, Schneider B, White P, Recart A, Villegas L, Ogunnaike B, Provost D, Jones D. J Laparoendosc Adv Surg Tech 2005, 15(1) :6-12

PATIENTS & METHODS

Fifty morbidly obese patients undergoing laparoscopic Roux-en-Y gastric bypass procedures using a standardized anesthetic technique were randomly assigned to either a control (sham) group receiving room temperature insufflation gases with an inactive Insuflow® (Lexion Medical, St. Paul, MN) device, or an active (Insuflow®) group receiving warmed and humidified intraperitoneal gases. Esophageal and/or tympanic membrane temperature was measured perioperatively. Postoperative pain was assessed at 15 minute intervals using an 11-point verbal rating scale, with 0 = none to 10 = maximal. In addition, postoperative opioid requirements, incidence of nausea and vomiting, as well as the quality of recovery, were recorded.

RESULTS

Use of the active Insuflow® device was associated with significantly higher mean \pm standard deviation (SD) intraoperative core body temperatures (35.5 ± 0.5 vs. $35.0 \pm 0.4^\circ\text{C}$). Postoperative shivering (0 vs. 19%) and the requirement for morphine in the postanesthesia care unit (5 ± 4 vs. 10 ± 5 mg) were both significantly lower in the Insuflow® vs. control groups. Patients in the Insuflow® group also reported a higher quality of recovery 48 hours after surgery (15 vs. 13, $P < 0.05$).

02

The Effect of Warm Humidified CO₂ on the Dissipation of Residual Gas Following Laparoscopy in Piglets

Glew P, Campher M, Pearson K, Schofield J, Davey A. J Am Assoc Gynecol Laparosc 2004, 11(2) :204-210

Piglets were randomly divided into two groups of five and underwent abdominal insufflation with either cold, dry CO₂ or warm, humidified CO₂.

RESULTS

Following insufflation, anteroposterior and lateral gas-bubble radiographic images were obtained at 5, 15, 30, 45, and 60 minutes, and the area of each gas-bubble profile calculated. Blood samples were obtained at 0, 2, 4, and 5 hours, and they were analyzed for IL-1 β and TNF α . Peritoneal tissue samples were obtained on euthanasia at 5 hours for histological analysis. The results indicate that following pneumoperitoneum, residual CO₂ dissipates more rapidly when the gas is heated and humidified compared with when it is cool and dry. This is associated with a reduction in the duration of the inflammatory response as measured by TNF α production, although no histologic differences in the peritoneal tissue were observed.

CONCLUSION

Heating and humidifying CO₂ leads to faster dissipation of residual gas associated with a reduced duration of inflammation, which may contribute toward a reduction in postlaparoscopic pain.

03

Double-Blind, Prospective, Randomized Study of Warmed, Humidified Carbon Dioxide Insufflation vs Standard Carbon Dioxide for Patients Undergoing Laparoscopic Cholecystectomy

Farley D, Greenlee S, Larson D, Harrington J. Arch. Surg. 2004; 139:739-744

DESIGN

A double-blind, prospective, randomized study comparing patients undergoing laparoscopic cholecystectomy with standard CO₂ insufflation vs those receiving warmed, humidified CO₂ (Insuflow[®] Filter Heater Hydrator; Lexion Medical, St Paul, Minn) was performed. Main variables included patient core temperature, postoperative pain, analgesic requirements, and camera lens fogging.

RESULTS

One hundred one blinded patients (69 women, 32 men) undergoing laparoscopic cholecystectomy were randomized into 2 groups - 52 receiving standard CO₂ insufflation (group A) and 49 receiving warmed, humidified CO₂ (group B). Mean patient intraoperative core temperature change (group A decreased by 0.03°C, group B increased by 0.29°C, $P = .01$) and mean abdominal pain (Likert scale, 0-10) at 14 days postoperatively (group A, 1.0; group B, 0.3; $P = .02$) were different. Other variables (camera lens fogging, early postoperative pain, narcotic requirements, recovery room stay, and return to normal activities) between groups were similar.

CONCLUSION

The statistically significant findings in this double-blinded, prospective, randomized study of patients undergoing LC with warmed, humidified CO₂ vs standard CO₂ were 4-fold: patients were warmer intraoperatively using the Insuflow[®] device, they harbored slightly less shoulder pain at PACU entry, they had less abdominal pain at 2 weeks postoperatively, and they used less pain medication at 2 weeks postoperatively. None of the other main variables studied showed a statistically significant difference between groups A and B.

04

Warm and Humidified Carbon Dioxide During Laparoscopic Roux-en-y Gastric Bypass Surgery for Morbid Obesity Decreases Post-Operative Pain and Analgesic Requirement

Bala S, Arabov E, Fazilov R, Lazzaro R, Macura J, Cunningham J. Murray Friedman Resident Research Award, 2004 Department of Surgery, Division of Bariatric Surgery, Maimonides Medical Center, Brooklyn, NY

CONCLUSION

Patients who received warm and humidified carbon dioxide during laparoscopic Roux-en-y gastric bypass surgery for morbid obesity required significantly less post operative analgesia than those who did not.

05

Complications of Microlaparoscopy and Awake Laparoscopy

Demco L. JSLS (2003) 7:141-145

ABSTRACT

Complications of laparoscopy are categorized into trocar insertion complications, complications resulting from image quality, and complications resulting from instrumentation. Microlaparoscopy also has similar complications and additional complications when being performed in the awake patient. Each of these complications is reviewed as they apply to microlaparoscopy. The results reveal that the seriousness of the complication is directly dependent on the size of the perforation. Therefore, surgeons' reluctance to downsize the instruments used is increasing the laparoscopy complication rate. Using smaller-diameter trocars and instruments reduces laparoscopic complication rates.

06

Decreased Incidence of Hypothermia and Peritoneal Irritation in Laparoscopic Donor Nephrectomy Using a Filter-Hydrator-Heating Device (Insuflow®)

Kandaswamy R, Gillingham K, Harmon J, Asolati M. Presented at SAGES 2003 Poster Program, Los Angeles, CA

METHODS

Insuflow® was used in 10 laparoscopic kidney donors during a 2 month period. The data was compared with 10 contemporaneous donors without Insuflow® use. Results were calculated using Wilcoxon two-sided tests for calculating differences in means. Surface and IV fluid warming devices were used in all patients. Temperature monitoring was done by esophageal probe.

RESULTS

The Insuflow® group was younger (36.8 vs. 44.5 years) ($p=0.09$). Other demographics were comparable. The volume of CO₂ used (591 vs. 487 liters) volume of irrigation (400 vs. 450 liters), or room temperature (67.7 vs. 67.9 degrees F), duration of surgery (250 vs. 227 minutes) were not different. Length of hospital stay (3.3 vs. 3.8 days) and postoperative analgesic use measured in morphine equivalents (62 mg vs. 69 mg) were no different between groups. However, Insuflow® patients spent less time in the recovery room (94 vs. 140 minutes) ($p=0.02$), had decreased incidence of shoulder pain (0% vs. 40%) ($p=0.09$) and shivering (0% vs. 40%) ($p=0.09$). At the end of the procedure, seventy percent (70%) of non-Insuflow® patients were hypothermic (<36 degrees C) compared to none (0%) of the Insuflow® group.

CONCLUSIONS

The Insuflow® device decreases the incidence of hypothermia and shivering and may be associated with decreased peritoneal desiccation leading to decreased incidence of shoulder tip pain.

07

A Randomized Controlled Trial Assessing the Benefit of Humidified Insufflation Gas During Laparoscopic Surgery

Mouton W, Bessell J, Millard S, Baxter P, Maddern G. Surg Endosc (1999) 13:106-108

SUMMARY

No adverse effects from the humidification of insufflated gas were observed. There was no significant difference in core body temperature between the two groups for this brief operation. Pain, as assessed by the Analogue Pain Score (APS) was significantly less for the group with humidified gas insufflation than for the control group at 6 h postoperatively as well as on the 1st, 2nd and 3rd postoperative day and at follow-up 10 days after the operation. In the humidified group, the mean time to return to normal activities was significantly less - 5.9 days, as compared to 10.9 days in the control group.

CONCLUSION

The use of humidified insufflation gas reduces postoperative pain following laparoscopic cholecystectomy, but except for these relatively brief procedures, the heat-preserving effect of humidified gas insufflation is not significant.

08

Optimal Warming Technique for Major Laparoscopic Surgery: Forced Air Warming or Warmed and Humidified Insufflation Gas

Hamza M, Ogunnaike B, Provost D, White P. *Anesth Analg* 96: S121

CONCLUSION

The Insuflow[®] device may be a useful alternative to forced air warming devices during major laparoscopic surgery. Although less effective in maintaining core body temperature than the external forced air warming device, the Insuflow[®] improved pain control and reduced the need for opioid analgesics and antiemetics in the postoperative period.

09

Awake Microlaparoscopy with the Insuflow[®] Device

Almeida O. *JSLs* (2002) 6:199-201

RESULTS

The incidence of transient shoulder pain in the Insuflow[®] group was 5% compared with 40% in the dry carbon dioxide group. No patient in the Insuflow[®] group complained of shivering, whereas 55% in the control group had shivering. Fogging of the microlaparoscope lens was decreased in the Insuflow[®] group.

CONCLUSION

Heating and humidifying the carbon dioxide gas produced fewer patient complaints of shoulder pain and shivering and decreased fogging of the microlaparoscope lens compared with procedures done with dry carbon dioxide during awake microlaparoscopic procedures.

10

Effect of Heating and Humidifying Gas on Patients Undergoing Awake Laparoscopy

Demco L. *J Am Assoc Gynecol Laparosc* 8(2):247-251, 2001

RESULTS

Heating and humidifying CO₂ decreased the frequency of shoulder pain and increased tolerance of the procedure. Thirty percent of patients required no intravenous sedation and did not experience shoulder pain when 3 L of gas or 15 mm Hg pressure was achieved. When shoulder pain did occur with heated and humidified gas, it was brief.

CONCLUSION

Heating and humidifying CO₂ increases tolerance of awake laparoscopy and decreases the frequency and duration of shoulder pain.

11

Pain After Laparoscopy

Mouton W, Bessell J, Otten K, Maddern G. Surg Endosc (1999) 13:445-448

BACKGROUND

In the context of the much-heralded advantages of laparoscopic surgery, it can be easy to overlook postlaparoscopy pain as a serious problem, yet as many as 80% of patients will require opioid analgesia. It generally is accepted that pain after laparoscopy is multifactorial, and the surgeon is in a unique position to influence many of the putative causes by relatively minor changes in technique.

CONCLUSIONS

On the basis of the factors implicated in postlaparoscopy pain, the following recommendations can be made in an attempt to reduce such pain: empathetically consider each patients' unique sociocultural and individual pain experience; inject port sites with local anesthesia at the start of the operation; keep intra-abdominal pressure during pneumoperitoneum below 15 mmHg, avoiding pressure peaks and prolonged insufflation; use humidified gas at body temperature if available; use nonsteroidal anti-inflammatory drugs at the time of induction; attempt to evacuate all intraperitoneal gas at the end of the operation, and use drains only when required, rather than as a routine.

12

Reduction of Laparoscopic-Induced Hypothermia, Postoperative Pain and Recovery Room Length of Stay by Pre-Conditioning Gas with the Insuflow® Device: A Prospective Randomized Controlled Multi-Center Study

Ott D, Reich H, Love B, McCorvey R, Toledo A, Liu C, Syed R, Kumar K. JSLS. 1998; 2:321-329.

RESULTS

The Insuflow® group had significantly less intra-operative hypothermia, reduced length of recovery room stay and reduced postoperative pain. Pre-conditioning of laparoscopic gas by filtering heating and hydrating was well tolerated with no adverse effects. The safety profile of the Insuflow® pre-conditioned gas showed significant benefits compared to currently used raw gas.

CONCLUSIONS

Pre-conditioning laparoscopic gas by filtering heating and hydrating with the Insuflow® device was significantly more effective than the currently used standard raw gas and was safe in reducing or eliminating laparoscopic-induced hypothermia, shortening recovery room length of stay and reducing postoperative pain.

13

Warmed Humidified Carbon Dioxide Insufflation Versus Standard Carbon Dioxide in Laparoscopic Cholecystectomy: A Double-Blinded Randomized Controlled Trial

Klugsberger B, Schreiner M, Rothe A, Haas D, Oppelt P, Shamiyeh A. Surg Endosc (2014) 28: 2656-2660.

CONCLUSIONS

14

The use of warmed and humidified carbon dioxide during laparoscopic cholecystectomy reduces postoperative pain at the day of operation.

The Pneumoperitoneum

Ott D. The Practical Manual for Laparoscopic and Hysteroscopic Gynecological Surgery. The Kiel School of Medicine, Kiel, Germany 2012.

RESULTS

Rapid gas insufflation does cause a peritoneal stretch reflex and should be avoided, but the cause of shoulder pain is mostly related to desiccation effects resulting from acute inflammatory peritoneal reaction caused by unconditioned dry gas. Patients have less peritoneal trauma and disruption when humidified gas is used having less pain and requiring fewer or lower doses of postoperative analgesics or anti-emetics. These benefits coupled with maintenance of body temperature and prevention of hypothermia account for shortened recovery.

SUMMARY

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It has been shown clinically that pre-conditioning CO₂ to 35°C and 95% relative humidity reduces peritoneal desiccation and cell damage, inflammation, inflammatory stress and decreases pain. Post-laparoscopy pain is a serious problem. The following factors have been implicated in post-laparoscopy pain, (lack of) humidity of insufflated gas. On the basis of the factors implicated in post-laparoscopy pain, the following recommendation can be made in an attempt to reduce such pain, use humidified gas at body temperature.

Insufflation with Humidified and Heated Carbon Dioxide in Short-Term Laparoscopy: A Double-Blinded Randomized Controlled Trial

Herrmann A, Leon De Wilde R. BioMed Research International (2015) 2015: 412618.

METHODS

A doubled-blinded, randomized, controlled trial was conducted to compare warm, humidified CO₂ and cold-dry CO₂. Patients with benign uterine diseases were randomized to either treatment (n = 48) or control (n = 49) group during laparoscopically assisted vaginal hysterectomy.

CONCLUSIONS

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Warm, humidified insufflation gas significantly reduces postoperative shoulder-tip pain as well as morphine demand.

Impact of Temperature and Humidity of Carbon Dioxide Pneumoperitoneum on Body Temperature and Peritoneal Morphology

Hazebroek E, Schreve M, Visser P, De Bruin R, Marquet R, Bonjer H. *Journal of Laparoendoscopic & Advanced Surgical Techniques*, Vol. 12, No. 5, 2002, 355-364

RESULTS

During the 120-minute study period, core temperature and intraperitoneal temperature were significantly reduced in group I (cold, dry CO₂), Group II (cold, humidified CO₂), and Group III (warm, dry CO₂). In the animals that underwent warm, humidified insufflation (group IV) and the gasless controls (group V), intraoperative hypothermia did not develop. At SEM (scanning electron microscopy), retraction and bulging of mesothelial cells and exposure of the basal lamina were seen in the four insufflation groups (groups I-IV) and the gasless controls (group V).

CONCLUSION

Insufflation with cold, dry CO₂ may lower the body temperature during laparoscopic surgery. Hypothermia can be prevented by both heating and humidifying the insufflation gas. Changes of the peritoneal surface occur after CO₂ insufflation, despite heating or humidifying, and also after gasless surgery.

17

Mild Intraoperative Hypothermia Prolongs Postanesthetic Recovery

Lenhardt R, Marker E, Goll V, Tschernich H, Kurz A, Sessler D, Narzt E, Lackner F. *Anesthesiology* 1997 Dec; 87(6):1318-1323

BACKGROUND

Intraoperative hypothermia is common and persists for several hours after surgery. Hypothermia may prolong immediate recovery by augmenting anesthetic potency, delaying drug metabolism, producing hemodynamic instability, or depressing cognitive function. Accordingly, the authors tested the hypothesis that intraoperative hypothermia prolongs postoperative recovery.

CONCLUSION

Maintaining core normothermia decreases the duration of postanesthetic recovery and may, therefore, reduce costs of care.

18

Model to Determine Resistance and Leakage-Dependent Flow on Flow Performance of Laparoscopic Insufflators to Predict Gas Flow Rate of Cannulas

Jacobs R, Morrison J, Mundhenke C, Golombeck K, Jonat W, Harder D. *J. Am Assoc Gynecol Laparosc*, Vol .7 (3):331-337, 2000

DISCUSSION

Although high CO₂ flow is often intended in laparoscopy to improve insufflation, a side effect cannot be overlooked. If gas is directed at high flow through a small diameter against tissue, it can dry out the tissue, causing laparoscopic hypothermia and potential tissue damage. Although significant damage is unlikely with today's cannulas and how and where they are placed, hypothermia can and should be prevented with adequate gas hydration and warming devices.

19

Severe Local Hypothermia from Laparoscopic Gas Evaporative Jet Cooling: A Mechanism to Explain Clinical Observations

Gray R, Ott D, Henderson A, Cochran S, Roth E. *JLS* (1999) 3:171-177

RESULTS

Cooling rates of 10 to 25 degrees centigrade per second for high flow rates were found based on gas flow rate and effective size of gas delivery site. These rapid temperature drops extended beyond a 2 cm² diameter.

CONCLUSION

Evaporative cooling accounts for significant hypothermia. The cooling is dependent on the lack of water vapor in the gases currently used during laparoscopy. Cooling rates are independent of height from tissue and geometry of delivery port. Heating and hydrating the gas to a physiologic condition eliminates hypothermia and tissue dessication.

20

Correction of Laparoscopic Insufflation Hypothermia

Ott D. *Journal of Laparoendoscopic Surgery*, 1991 Jun; 1(4) :183-186

ABSTRACT

Operative laparoscopy is experiencing an increase in its use and indications. This expansion exposes patients to increased operation time, larger volumes of carbon dioxide for maintenance of a pneumoperitoneum, and higher gas flow rates for intraperitoneal delivery. Patients with medical complications, advancing age, and potentially contaminated procedures are now considered acceptable candidates for operative endoscopic techniques via laparoscopy. A previously observed but unquantified amount of hypothermia was measured and evaluated by changes in core temperatures after known quantities of carbon dioxide were delivered intraabdominally over measured periods of time and with controlled flow rates. A decrease of 0.3°C in the core temperature was observed for each 50 L of carbon dioxide delivered.

21

Humidification During Laparoscopic Surgery: Overview of the Clinical Benefits of Using Humidified Gas During Laparoscopy Surgery

Binda M. Arch Gynecol Obstet (2015) 292(5): 955-971

RESULTS

Insufflating dry and cold CO₂ into the abdomen causes peritoneal damage, postoperative pain, hypothermia and postoperative adhesions. Using humidified and warm gas prevents pain after surgery. With regard to hypothermia due to desiccation, it can be fully prevented using humidified and warm gas. Results relating to the patient recovery are still controversial.

22

Influence of Gas Temperature During Laparoscopic Procedures

Bessell J, Maddern G. The Pathophysiology of Pneumoperitoneum, Springer, 1998, Rosenthal R, Friedman R, Phillips E, editors. Chapter 3, 18-27

ABSTRACT

Therapeutic laparoscopy has been rapidly accepted worldwide and currently accounts for an increasing proportion of intraabdominal procedures, yet the influence of laparoscopic surgery on perioperative temperature homeostasis has received little attention. Evidence is emerging to suggest that the nature of insufflated gas plays a substantial role in the development or prevention of hypothermia during laparoscopy.

EFFECTS

The importance of perioperative hypothermia becomes apparent when the numerous deleterious effects it may cause are considered. Conditions such as increased susceptibility to dermal infection [24], induction of a hypokalemic state [4,11], impaired myocardial function [12], respiratory depression, negative nitrogen balance [5], thrombocytopenia, and depletion of clotting factors [7] have been reported.

The net effect of these complications is reflected in the mortality rate of patients thus affected. One study reported a 24% mortality in postoperative patients who remained hypothermic for 2 hours, compared with 4% of their normothermic counterparts [25]. There is a financial penalty as well since hypothermic patients are reported to spend up to 1 hours longer in the recovery ward [6], and a mean increase in length of hospital stay of 2.6 days was recently demonstrated for patients with postoperative temperatures less than 35.5°C [10].

23

Effects of Mild Perioperative Hypothermia on Cellular Immune Responses

Beilin B, Shavit Y, Razumovsky J, Wolloch Y, Zeidel A, Bessler H. Anesthesiology 1998 Nov; 89 (5):1133-40

CONCLUSION

Mild perioperative hypothermia suppressed mitogen-induced activation of lymphocytes and reduced the production of certain cytokines, IL-1 β and IL-2, and in this way may contribute to the immune alterations observed in the perioperative period.

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Hypothermic Effect of Laparoscopic on Intestinal Motility

Ott D. Presented at SLS Annual Meeting, Orlando, FL, 1996

SUMMARY

During laparoscopy, due to gas insufflation or irrigation, there is resultant local hypothermia of the intestines. The temperature of gas that is insufflated is 20° Centigrade. Irrigation provides a prolonged heat sink. Irrigation liquid conducts heat 32 times more efficiently than gas at the same temperature. The temperature reduction reduces intestinal motility and metabolic activity and may compromise or detrimentally effect laparoscopic bowel surgery. These occurrences lead to iatrogenic ileus and increased patient postoperative bowel discomfort. Intraabdominal thermocouple evaluation of surface and pneumoperitoneal temperatures was performed during forty (40) procedures. Evaluation of intestinal motility was performed by performing electromyographic analysis during laparoscopic procedures. Findings demonstrate that smooth muscle contractions are decreased during laparoscopy due to hypothermic temperature changes.

25

Perioperative Problems: Threats to Thermal Balance in the Elderly

Holtzclaw J. *Semin Perioper Nurs.* 1997 Jan; 6(1):42-48

ABSTRACT

The perioperative period is a time of thermal instability for older surgical patients. Beyond the elder person's vulnerability to intraoperative heat loss and hypothermia, the surgical procedure initiates host responses that affect body temperature. Technology and drug therapies often deliberately or inadvertently alter thermal balance. Alterations range from mild hypothermia to shaking febrile chills. A reasoned approach to preventing or caring for each of these alterations is based on an understanding of the dynamics of heat loss or heat gain. Early recognition of problems and appropriate action by perioperative nurses may forestall more serious consequences.

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Help! This Postanesthesia Care Unit Patient is Hypothermic

Villamiel L. *J Post Anesth Nurs.* 1990 Apr; 5(2):75-79

Hypothermia is a common intraoperative and immediate postoperative complication. Hypothermia causes morbidity from shivering, hypotension, cyanosis and respiratory diseases. In severe cases, bradycardia, premature ventricular contractions and even ventricular fibrillation may occur. The various causes of excessive heat loss, both intraoperatively and during the postanesthesia period, the methods of prevention and rewarming measures are important factors in administering patient care.

27

Laparoscopic vs Open Nephrectomy in 210 Consecutive Patients

Kandaswamy R. Surgical Endoscopy (2004) 18:1684

It has been shown that the use of heated humidified gas for laparoscopy is beneficial in terms of reduced hypothermia, reduced postoperative pain scores, shortened recovery time, reduced pain medication use and less peritoneal damage. Although the length of hospital stay and analgesic requirements were not different between the groups, we found that the Insuflow[®] patients had a decreased incidence of shoulder pain and rigor. At the end of the procedure 70% of the control group were hypothermic (<36°) as compared with none in the Insuflow[®] group.

28

Twenty-Five Simple Ways to Increase Insufflation Performance and Patient Safety in Laparoscopy

Jacobs V, Morrison J, Kiechle M. The Journal of the American Association of Gynecologic Laparoscopists, August 2004, Vol. 11, No.3:410-423

SUMMARY

#19. Heat and Hydrate Insufflation Gas

Prevention of laparoscopic hypothermia is possible with different devices, such as the disposable Insuflow[®] (Lexion Medical, St. Paul, MN) or reusable devices made by insufflator manufacturers. Besides avoiding negative effects for the patient and reducing postoperative pain and ICU time, physicians also experience less fogging and the necessity for repeated optic cleaning. Heating and hydration of the insufflation gas should be done close to the patient to be most effective. However, it is clear that heating or hydration of the gas alone doesn't prevent laparoscopic hypothermia. Insufflators that contain a gas-heating unit inside have no effect at all as demonstrated by the fact that the heated gas at the insufflator exit is equal to room temperature within 50-100cm of insufflation hose length.

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Method of Water Nebulization Used to Prevent Heat Loss During Laparoscopic Surgery Matters

Presthus J, Jacobs V, Redan J. Surgical Endoscopy (2009) 23:1678-1679

SUMMARY

There is a device that is efficacious and shows clinical utility in humans by preventing laparoscopic hypothermia; the Insuflow[®] device.

30

Effect of CO₂ Gas Warming on Pain After Laparoscopic Surgery A Randomized Double Blind Controlled Trial

Slim K, Bousquet J, Kwiatkowski F, Lescure G, Pezet D, Chipponi J. Surg Endosc. 1999, 13:1110-4

METHODS

Patients who underwent laparoscopic cholecystectomy, fundoplication, or Heller's myotomy were included and randomly allocated to receive either warm or cold gas. Primary end point was shoulder tip pain, and secondary end points were subcostal, trocar wound, and visceral pains, as well as other postoperative events. Criteria of pain assessment were the visual analog scale, verbal rating scale, and amount of analgesics.

RESULTS

A total of 100 patients were suitable for postoperative evaluation. The groups were well matched. Shoulder tip and subcostal pains were significantly more intense after gas warming ($p < 0.05$). The three assessment criteria showed the same differences. No difference was observed concerning trocar wound and visceral pains and the other secondary end points. Subdiaphragmatic temperature was not significantly different (34.4° with warming vs. 34° without warming).

CONCLUSION

Gas warming does not reduce, and probably increases, postoperative shoulder tip and subcostal pains.

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A Randomized Controlled Trial Assessing the Effect of Heated Carbon Dioxide for Insufflation on Pain and Recovery After Laparoscopic Fundoplication

Wills V, Hunt D, Armstrong A. Surg Endosc. 2001, 15:166-170

RESULTS

For this study, 40 patients were randomized to heated CO₂ (n = 19) and standard CO₂ (control) (n = 21) groups. The heated CO₂ group increased core body temperature from 36.1°C, ($p = 0.008$), whereas the control group maintained core temperature at 35.8°C. The control group had lower analgesic requirements and pain scores, significant at 12 h (VAS: 20 vs 36 mm; $p = 0.04$). There was no difference between the groups in terms of late recovery. The heated CO₂ group showed a significant correlation between operative duration and requirement for postoperative morphine ($p = 0.01$).

CONCLUSION

Heated gas provides no benefits for patients and may be associated with increased early pain. The elevation of core body temperature observed with heated CO₂ is of little clinical significance.

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The Clinical Impact of Warmed Insufflation Carbon Dioxide Gas for Laparoscopic Cholecystectomy

Saad S, Minor I, Mohri T, Nagelschmidt M. *Surg Endosc.* 2000, 14:787-790

METHODS

In a randomized controlled trial with 20 patients undergoing laparoscopic cholecystectomy, the effect of insufflation using carbon dioxide gas warmed to 37°C (group W) was compared with insufflation using room-temperature cold (21°C) gas (group C). Intraoperative body core and intra-abdominal temperatures were determined at the beginning and end of surgery. Postoperative pain intensity was evaluated using a visual analog scale and recording the consumption of analgesics.

RESULTS

There were no significant group-specific differences during the operation, neither in body temperature (group W: 36.1 ± 0.4°C vs group C: 35.7 ± 0.6°C) nor in intra-abdominal temperature (group W: 35.9 ± 0.3°C vs group C: 35.6 ± 0.6°C) Postoperatively, the two groups did not differ in pain susceptibility and need of analgesics.

CONCLUSION

The use of carbon dioxide gas warmed to body temperature to produce a pneumoperitoneum during short-term laparoscopic surgery has no clinically important effect.

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Hypothermia A Potential Risk of CO₂ Insufflation?

MacFadyen B. *Surg Endosc.* (1999) 13:99-100

It appears that heated humidified gas is a key factor in preventing heat loss as opposed to dry heated CO₂, since there is an expected temperature decrease from the heat required for water evaporation.

Although the postoperative pain problem is often multifactorial, it appears that using humidified heated carbon dioxide can reduce this pain.

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Hypothermia Induced by Laparoscopic Insufflation A Randomized Study in a Pig Model

Bessell J, Karatassas A, Patterson J, Jamieson G, Maddern G. *Surg Endosc* (1995) 9(7):791-796

Insufflation of CO₂ gas at high-flow rates over a prolonged period of time results in a significant fall in core temperature. The provision of warmed rather than cold insufflated gas confers no protection against changes in core temperature during laparoscopic surgery due to the small amount of heat required to warm the gas to body temperature. A much greater effect is the latent heat required to saturate the insufflated gas. Most of the hypothermic effect is due to this, and could be minimized by humidifying the flow.

35

Intraoperative Evaluation of Laparoscopic Insufflation Technique for Quality Control in the OR

Jacobs V, Morrison J, Mundhenke C, Golombeck K, Jonat W. *JSLs* (2000) 4:189-195

DISCUSSION

The significance of a decrease of intraabdominal gas temperature and its potential correction is controversial. Internal heating of gas in the insufflator is inefficient because CO₂ gas at the end of the insufflation hose is at room temperature. Maintaining body temperature with standard warming equipment, such as Bair Hugger®, Blanketrol®, heating blankets, and fluid warmer, etcetera, is possible and efficient, but take care of the problem (hypothermia) after it occurs. Prolonged CO₂ pneumoperitoneum should be avoided in patients who could be affected by high-flow of CO₂ gas and drop of abdominal temperature. Recent studies seem to have solved the problem with Insuflow®, a patient close-gas heating and hydration device.

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Measurement of CO₂ Hypothermia During Laparoscopy and Pelviscopy: How Cold it Gets and How to Prevent it

Jacobs V, Morrison J, Mettler L, Mundhenke C, Jonat W. *J Am Assoc Gynecol Laparosc* 6(3):289-295, 1999

CONCLUSION

The decrease in intraoperative intraabdominal gas temperature is remarkable and can potentially harm the patient. It can be limited by restricting gas flow and leakage. In operations longer than 1 hour, substantial core body temperature drop should be prevented with appropriate heating and hydration devices. An insufflator with internal gas heating (Snowden & Pencer) had no significant clinical effect.

DISCUSSION

New devices for gas heating and hydration that are situated close to the patient (e.g. Insuflow®) might be a solution because hydration seems to be even more important than heating the gas.

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Humidified Compared with Dry, Heated Carbon Dioxide at Laparoscopy to Reduce Pain

Beste T, Daucher J, Holbert D. Obstet Gynecol (2006);(2)(1)107:263-8

SUMMARY

A blinded randomized controlled study of seventy seven (77) patients consisting of humidified heated Insuflow[®], n=41) gas versus heated only (Linvatec, n=36) gas. Standardized pain control and verbal analog scale scores were assessed up to 48 hours. Statistical analysis was by Mann Whitney-U test.

RESULTS

The 89 patients available in the intent-to-treat model revealed a decrease in total morphine equivalents and a decrease in pain scores at 1, 2, and 24 hours in the study group (directional *P* values < .05). Subgroup analysis in patients without chronic pelvic pain revealed lower mean pain scores at 1, 2, 24, and 48 hours and decreases in postoperative and total morphine equivalents (directional *P* values < .05) in the study group.

CONCLUSION

At laparoscopy, heated, 95% humidified CO₂ effectively decreases postoperative pain and narcotics usage compared with heated, dry CO₂.

38

A Simple Solution to Lens Fogging during Robotic and Laparoscopic Surgery

Nezhat C, Morozov V. JSLS, (2008)12:431

SUMMARY

One of the fundamental principles of safe and successful endoscopic procedures is an ability to maintain a clear operating field. The Insuflow[®] device warms and humidifies CO₂ gas that bathes both lenses and significantly decreases the amount of fogging when attached to a robotic camera cannula.

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Unique Laparoscopic Access Port for Improving Gas Delivery, Quality and Surgical Outcomes

Ott D. Journal of Medical Devices, September 2014 Vol. 8

SUMMARY

A method to preserve normal homeostatic body cavity conditions exists to humidify and warm the gas (the Insuflow®). The newly designed access cannula (Synergy®) improves gas delivery circumstances and is the focus of this paper.

The results are saved time since less is spent in pneumoperitoneum filling once access is established, less time refilling and allows the system to overcome loss of gas, whether intentional (suction for fluids or smoke or specimen removal) or unintentional via cannula or incision leaks. This reduces surgical costs, operative time and anesthesia exposure by 3-5 min saving of an estimated \$500 million per year.

Maintenance of Cell Viability at Laparoscopy by Hydration of CO₂

Garner R, Wright E, Ott D. *J Am Assoc Gynecol Laparosc* 7 (3S):519, 2000

RESULTS

The study involved indirect CO₂ exposure of a peritoneal-like cell proxy to 1.3 L/minute gas flow of currently used laparoscopic gas compared to flow with 75% or 95% humidified gas. Cell viability was measured by flow cytometry counting analyzing incorporation of fluorescent dye into fragmented DNA of dead or dying cells. Viability of cells exposed to unconditioned CO₂ showed significant percentage of death attributable to desiccation at 4- to 5-minute exposure. Cells exposed to CO₂ containing 75% or 95% humidity shows sustained viability even after 20 minutes exposure.

CONCLUSION

These data demonstrate the importance of modifying CO₂ by heating and hydration to reduce cellular stress, reduce desiccation, and prevent cell death.

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Reduction of the Inflammatory Response Using Wet CO₂ During Laparoscopy

Ott D. *J Am Assoc Gynecol Laparosc* 2002; 9 (3) 51

MEASUREMENTS AND MAIN RESULTS

Twenty-seven patients were randomized to have insufflation with cold, dry CO₂ and 25 with warm, wet CO₂ at laparoscopy performed for benign reasons. Preoperative IL-6 and CRP values were not different between groups (Mann-Whitney U test). Comparison of wet CO₂ and dry CO₂ showed IL-6 6±3 versus 24±9 pg/ml x hour x 10 (p<0.002) and CRP 5±2 versus 23±6 mg/dl x hour x 10 (p<0.003).

CONCLUSION

Changes in IL-6 and CRP are directly related to dry gas volume used. The decreased inflammatory response to warm, wet gas is an indication of reduced peritoneal trauma. Peritoneal trauma is due to desiccation caused by cold, dry gas. Warming and wetting CO₂ eliminates inflammation caused by tissue drying and desiccation.

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Peritoneal Cell Death Due to Heated-Only CO₂ Insufflation

Johnston G, Ott D. J Am Assoc Gynecol Laparosc 2002; 9 (3) 51

MEASUREMENTS AND MAIN RESULTS

Cell desiccation and viability were evaluated by assessing incorporation of fluorescent dye into cell DNA. Flow of each type gas was directed over peritoneal-like cells at 1.5 and 3 L/minute for durations up to 20 minutes. The cells were then assessed by fluorescent dye uptake to determine viability. Cell viability was measured by lack of incorporation of fluorescent dye into its DNA, with dye incorporation indicating dead or dying cells. Significant cell DNA fragmentation and cell death occurred in the cold dry and warmed-only groups ($p < 0.05$) within 4 to 5 minutes of gas exposure. Warm wet gas maintained cell viability even after 20 minutes of continuous exposure.

CONCLUSION

Rapid evaporation caused by dry gas and gas flow desiccates the cell. It is necessary to warm wet gas to preserve normal tissue moisture, maintain cellular integrity and prevent cell death. Warmed-only CO₂ (warm and still bone-dry) results in loss of peritoneal cell integrity and causes cell death.

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Water Content of Laparoscopic Gas Affects Peritoneal Fluid Function

Ott D. J Am Assoc Gynecol Laparosc 2002; 9 (3) 51

MEASUREMENTS AND MAIN RESULTS

Peritoneal fluid samples were obtained from 20 patients having tubal ligation with no known peritoneal pathology. Samples were exposed to continuous or intermittent flow of bone-dry CO₂ or CO₂ humidified to 95% using the Insuflow[®] device. Samples were evaluated by bubble surfactometric and viscometric analyses to evaluate viscosity and surface tension during dynamic compression and after timed exposure to intermittent or continuous dry or wet CO₂ flow. Peritoneal fluid pH decreased but was statistically the same for both dry and wet gas exposures. During continuous dry gas flow, water concentration decreased dramatically and solute concentration increased. Complete evaporation of the bubble of peritoneal fluid occurred in 45 seconds at a flow rate of 100 ml/minute. Viscosity measured in centipoise increased from 1.43 to 78. Intermittent gas flow showed a similar pattern to evaporation but was shifted to the right. Surface tension decreased as water concentration decreased. With wet gas, water concentration and viscosity were maintained as normal with no loss of surface tension quality.

CONCLUSION

Exposure of the peritoneal cavity and peritoneal tissue during laparoscopy to dry CO₂, whether continuous or intermittent, decreases water content, increases viscosity and deteriorates the surface tension qualities of peritoneal fluid. Wet gas exposure (95%) during laparoscopy, continuous or intermittent, maintains normal water content, viscosity and surface tension characteristics of peritoneal fluid.

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Humidity and Temperature of Insufflation Gas on Intact Peritoneum

Wiseman D. J Am Assoc Gynecol Laparosc 2002; 9 (3) 51

MEASUREMENTS AND MAIN RESULTS

Standard CO₂ was painted onto 2 x 2-cm areas of peritoneum covering either large bowel or parietal peritoneum at a standard pressure (5 psi), distance (2 cm), and time (30 sec) of dogs sacrificed for other reasons. Gas was passed through an Insuflow® (Lexion Medical, St. Paul, MN) device with or without conditioning. During conditioning, gas was humidified and warmed to 37°C. Tissues were dissected, processed for histology and stained with hematoxylin and eosin or trichrome stains. Appearance of the mesothelial layer was determined by light microscopy. Few mesothelial changes were observed in sidewall tissues. For intestinal tissues, damage consisting of mesothelial denudation was evident after cold, dry gas. Mesothelial damage was greatly attenuated when gas was warmed and humidified. Tissue exposed to conditioned CO₂ appeared comparable with control tissue.

CONCLUSION

Mesothelial damage due to dry gas exposure can be detected by simple light microscopy. Visceral peritoneum appears more sensitive to dry gas than parietal peritoneum. Mesothelial damage is attenuated when gas is humidified and warmed.

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Extent of Peritoneal Damage with Dry Gas During Laparoscopy

Ott D. JSLS (2002) 6:246

RESULTS

Gas flows of 1, 3, 6 and 10 liters per minute all caused loss of peritoneal cell surface. The smaller the effective diameter of the gas delivery port, the higher the gas flow and the closer to the tissue surface the deeper and more extensive the damage. Even short gas exposures of 30 to 60 seconds 10 centimeters away from tissue with a 3 liter per minute flow through a 10-mm port containing a laparoscope caused significant damage. The higher the flow rate, the smaller the effective exiting gas port, and the distance from tissue determined the extent of peritoneal damage. Even under the best conditions of increased tissue distance from the gas port, largest effective gas-port diameter and lowest gas flow rates caused tissue compromise in 90-second exposure.

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Humidified Carbon Dioxide Preserves Peritoneal Integrity and Sustains Peritoneal Cell Viability

Ott D. *JSLs* (2002) 6:246

RESULTS

Dry gas exposure showed loss of peritoneal cells in 30-second exposure with submesothelial disruption and loss of integrity with 3-minute exposure at 1 liter per minute flow. No loss of peritoneal cells or lamina disruption was seen when 95% humidity was used. Significant ($P < 0.05$) cell death was seen in the cell culture exposure to dry gas. Significant cell survival was seen when 95% humidity gas was used.

CONCLUSION

Unmodified dry CO₂ gas used during laparoscopy causes cell stress, disrupts peritoneal cells, denudes large areas of peritoneum, causes loss of peritoneal integrity and has a lethal effect on cell viability even with indirect exposure to CO₂ and low flow rates. These findings are directly attributable to the dryness of the gas, which causes rapid cellular desiccation. Humidifying the gas reduces cell stress, sustains peritoneal integrity and maintains cell viability.

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Laparoscopy and Tribology: The Effect of Laparoscopic Gas on Peritoneal Fluid

Ott D. *J Am Assoc Gynecol Laparosc* 2001; 8 (1) 117-123

MEASUREMENTS AND MAIN RESULTS

Peritoneal fluid viscosity was tested by viscometric methods and mathematic modeling. Initial viscosity of peritoneal fluid before gas exposure was 1.425 centipoise (cP). Viscosity measurements were obtained at 20-second intervals for gas flows of 1 and 3 L/minute. Increases in viscosity occur rapidly, and by 200 seconds it was 59 cP and 98 cP for 1 and 3 L flow rates, respectively.

CONCLUSION

Very dry CO₂ for laparoscopy causes peritoneal fluid viscosity to increase dramatically.

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Peritoneal Surgery

Gomel V. Foreward. In DiZerega GS, ed. *Peritoneal Surgery*, New York, NY: Springer; 1999; vii-xi

SUMMARY

This book is a summary of both the science of peritoneal repair and a manual of surgical techniques directed to the reduction of postsurgical adhesion and consequently improved surgical outcome. Postoperative adhesions may cause abdominal and pelvic pain, bowel obstruction and infertility. Desiccation of peritoneal cells, even from exposure to the atmosphere and lights of the operating room, may be sufficient to cause adhesions. Laparoscopic gas can cause peritoneal drying. This concept demands respect for peritoneal surfaces. Every effort must be made not to damage the peritoneum. To avoid desiccation, the peritoneum must be kept moistened at all times. Operating within a closed peritoneal cavity largely prevents desiccation of the peritoneal surface, especially if the insufflation gas has been moistened and warmed to body temperature.

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Desertification of the Peritoneum by Thin-Film Evaporation During Laparoscopy

Ott D. *JSLs* (2003) 7:189-195

RESULTS

High-velocity gas interface conditions during laparoscopic gas insufflation result in peritoneal surface temperature decreases up to 20°C/second due to rapid thin-film evaporation of the peritoneal fluid. Evaporation of the thin film of peritoneal fluid extends quickly to the peritoneal cell membrane, causing peritoneal cell desiccation, internal cytoplasmic stress, and disruption of the cell membrane, resulting in loss of peritoneal surface continuity and integrity. Changing the gas conditions to 35°C and 95% humidity maintains normal peritoneal fluid thin-film characteristics, cellular integrity, and prevents evaporative losses.

50

Safety in Laparoscopy

From the World Congress on Gynecologic Endoscopy and the 1st Annual Meeting of the Israel Society of Gynecological Endoscopy, 2000

During an interview with Dr. Larry Demco, Dr. Duncan Turner stated that “one of the problems that we run into with patients is that they get cold during surgery, and the dryness of the gas has been shown to be damaging to the peritoneum. There are new methods now of very simply and very economically warming and humidifying the CO₂ as it goes into the abdominal cavity. And as you know in your experience with an awake patient, when we are doing pain mapping under local anesthesia or minimal anesthesia, these patients can tolerate a much greater distension of the abdomen if the carbon dioxide is warmed and moistened.” He continued by commenting, “I think that this is a very good example of the decreased damage and trauma to the tissue.”

51

Comparison of Immunologic and Physiologic Effects of CO₂ Pneumoperitoneum at Room and Body Temperatures

Puttick M, Scott-Coombes D, Dye J, Nduka C, Menzies-Gow N, Mansfield A, Darzi A. Surg Endosc. 1999; 13 (6):572-5

CONCLUSIONS:

The authors conclude that intraoperative cooling can be prevented by warming the insufflation gas even in short laparoscopic procedures. In addition, warming the insufflation gas leads to a reduced postoperative intraperitoneal cytokine response.

52

Adhesions May Cause Pain in Some Women

Worcester S. OB GYN News . June 1, 1999

SUMMARY

In 68 patients who underwent early second-look laparoscopy following an initial laparoscopic procedure, 97% had adhesion reformation. On a more optimistic note, only 12% had de novo adhesions. Dr. Michael Diamond of Wayne State University in Detroit states that "laparoscopic surgery itself is not a panacea for prevention of postoperative adhesions" and further notes that the CO₂ gas used for the procedure appears to cause adhesions.

53

Characteristic Alterations of the Peritoneum after Carbon Dioxide Pneumoperitoneum

Volz J, Köster S, Spacek Z, Paweletz N. Surg Endosc (1999) 13:611-614

RESULTS

Already 2 h after release of the pneumoperitoneum, mesothelial cells were bulging up. The intercellular clefts thereby increased in size, and the underlying basal lamina became visible. This reaction peaked after 12 h. Subsequently, peritoneal macrophages and lymphocytes filled all gaps, thereby recovering the basal lamina.

CONCLUSION

The morphologic integrity of the peritoneum is temporarily disturbed by a CO₂ pneumoperitoneum.

54

Effect of Desiccation and Temperature During Laparoscopy on Adhesion Formation in Mice

Binda M, Molinas C, Hansen P, Koninckx P. Fertil Steril. 2006 Jul;86(1):166-75

CONCLUSION

Adhesions increase with desiccation and decrease when body temperature is reduced. Adhesions are minimized when humidified gas is used. Since desiccation is associated with cooling, its effect is generally underestimated because of the counterbalance with cooling. The concept of combining controlled intraperitoneal cooling with a rigorous prevention of desiccation might be important for clinical adhesion prevention.

55

Electron-Microscopic Alterations of the Peritoneum After Both Cold and Heated Carbon Dioxide Pneumoperitoneum

Erikoglu M, Yol S, Avunduk M, Erdemli E, Can. *A Journal of Surgical Research* 125, 73-77 (2005)

BACKGROUND

Carbon-dioxide (CO₂) is used universally as an insufflation agent to create a laparoscopic pneumoperitoneum. In this study, we aimed to examine the electron and light microscopic alterations of the peritoneum after both cold-dry and heated-humidified CO₂ pneumoperitoneum. Group I - Control Group, Group II - Standard cold dry, and Group III - Heated humidified.

RESULTS

According to light microscopic examination; in group II and III, cellular response (increased lymphocyte) was significantly higher than the control group ($P < 0.01$). Similarly, in group II cellular response was significantly higher than group III. ($P < 0.01$). There was no difference in increased capillarity among all groups. ($P < 0.05$). According to scanning electron microscopic examination, in group I, normal peritoneum was covered by a sheet of flat mesothelial cells densely covered with microvilli. No intercellular clefts and no free basal lamina were detected. In group II, drastic alterations of the surface layer were seen. The mesothelial cells had extreme desquamation, and the basal membrane was clearly visible. In group III, the mesothelial cells had bulged up to the surface layer and retracted. Intercellular clefts become visible, but the basal lamina was not seen.

CONCLUSION

Electron and light microscopic examination revealed that heated-humidified CO₂ results in less peritoneal alteration than cold-dry CO₂. Accordingly, we believe that heated-humidified CO₂ is more suitable for pneumoperitoneum application in laparoscopic surgery especially in selected cases.

Heated and Humidified CO₂ Prevents Hypothermia, Peritoneal Injury, and Intra-Abdominal Adhesions During Prolonged Laparoscopic Insufflations

Peng Y, Zheng M, Ye Q, Chen X, Yu B, Liu B. *Journal of Surgical Research* 151, 40-47 (2009)

BACKGROUND

Insufflation with standard cold-dry CO₂ during laparoscopic surgery has been shown to predispose patients to hypothermia and peritoneal injury. This study aimed to compare the effect of prolonged cold-dry CO₂ insufflation with heated-humidified CO₂ insufflation (3-5 h) on hypothermia, peritoneal damage, and intra-abdominal adhesion formation in a rat model.

MATERIALS AND METHODS

A total of 160 Wistar rats were randomized to undergo no insufflation or insufflation with cold-dry CO₂ (21°C, <1% relative humidity) or heated-humidified CO₂ (37°C, 95% relative humidity) for 3, 4, or 5 h. Core body temperature was measured via rectum before and during insufflations. Peritoneal samples were taken at 6, 24, 48, and 96 h after treatments and analyzed with light microscopy and scanning electron microscopy. Intra-abdominal adhesions were evaluated 2 weeks later.

RESULTS

Core body temperature significantly decreased in the cold-dry group, whereas it was maintained and increased in the heated-humidified group. Scanning electron microscopy and light microscopy studies showed intense peritoneal injury in the cold-dry CO₂ group but significantly less damages in the heated-humidified group. Increased intra-abdominal adhesion formation was observed in the cold-dry CO₂ group, while no adhesions were found in the rats insufflated with heated-humidified CO₂.

CONCLUSION

Heated-humidified CO₂ insufflation results in significantly less hypothermia, less peritoneal damage, and decreased adhesion formation as compared with cold-dry CO₂ insufflation. Heated-humidified CO₂ may be more suitable for insufflation application in prolonged laparoscopic surgery.

Laparoscopy and Adhesion Formation, Adhesions and Laparoscopy

Ott D. Seminars in Reproductive Medicine, Volume 26, Number 4, 2008 322-330

Adhesion formation occurs as a result of peritoneal damage. Peritoneal damage occurs during laparoscopy. Adhesions form as a result of laparoscopy. Why are adhesions important? Adhesions occur in more than 90% of patients having major abdominal surgery and in 55 to 100% of women as a result of pelvic surgery. The most common consequences of peritoneal adhesions are small bowel obstruction, infertility, chronic abdominal and pelvic pain, and difficult reoperative surgery.

The hypothesis that laparoscopy results in less adhesion formation is based on assumptions that with laparoscopy there is less tissue handling, more gentle tissue handling, less bleeding, less desiccation, fewer foreign body contaminants, and less desiccation. Is this really true? The points and counterpoints of the reasoning that laparoscopy is less likely to cause adhesions and that there are less adhesions as a result of laparoscopy are as follows.

The closed peritoneal cavity reduces the risk of tissue desiccation. False, old myth, no it doesn't, not so. During laparotomy, the ambient relative humidity is 40 to 50%. It is reported that cecal drying occurs in 5 minutes that can lead to adhesion formation. The gas used for laparoscopy has only 200 ppm or less water vapor (0.0002% relative humidity) or 5000 times dryer than the Sahara Desert. Gas speed going through trocars can reach 67 miles per hour. The average intra-abdominal volume to reach 12 mm Hg is 3 L and ~60 to 100 L of gas is used per hour, or 20 to 33 complete volume turnover exchanges per hour. This large volume of gas at high velocity in a 3-L space passing over a 60- μ m wet thin film of peritoneal fluid causes large amounts of evaporative heat loss by evaporation and results in peritoneal desiccation. There is a large body of work recognizing peritoneal desiccation as a cause of peritoneal damage and adhesion formation. Solution: Use gas that is conditioned with moisture for the pneumoperitoneum to prevent peritoneal desiccation and its consequences. It has been shown that laparoscopic adhesions are minimized when humidified gas is used and increased with increasing levels of desiccation.

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Conditioning of the Abdominal Cavity Reduces Tumor Implantation in a Laparoscopic Mouse Model

Binda M, Corona R, Amant F, Koninckx P. Surgery Today, 2014 Jul; 44(7) 1328-35.

PURPOSE

The addition of 4% O₂ and 10% N₂O to the CO₂ pneumoperitoneum (PP), together with slight cooling and humidification (conditioning), contributes to reducing adhesions by preventing mesothelial damage. We investigated the effect of the peritoneal damage during laparoscopy on tumor implantation.

CONCLUSION

Tumor implantation was enhanced by peritoneal damage (60 min of dry CO₂ PP and desiccation), but this was prevented by conditioning. If confirmed in humans, conditioning would become important for oncologic surgery.

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Carbon Dioxide Pneumoperitoneum Causes Severe Peritoneal Acidosis, Unaltered by Heating, Humidification, or Bicarbonate in a Porcine Model

Wong Y, Shah P, Birkett D, Brams D. *Surgical Endoscopy*, 2004 October 18(10): 1498-503

BACKGROUND

Carbon dioxide (CO₂) is most common gas used for insufflation in laparoscopy, but its effects on peritoneal physiology are poorly understood. This study looks at the changes in peritoneal and bowel serosal pH during CO₂ pneumoperitoneum, and whether heating and humidification with or without bicarbonate alters the outcomes.

CONCLUSION

CO₂ pneumoperitoneum resulted in severe peritoneal acidosis that was unaltered by heating and humidification with or without bicarbonate. Alteration in peritoneal pH may conceivably be responsible for providing an environment favorable for tumor-cell implantation during laparoscopy.

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Heated and Humidified CO₂ Pneumoperitoneum Inhibits Tumour Cell Proliferation, Migration and Invasion in Colon Cancer

Cai W, Dong F, Wang Z, Yang X, Zheng M, Che X. *International Journal of Hyperthermia* 2014; 30(3): 201-209

BACKGROUND

Peritoneal carcinomatosis (PC) arising from colorectal cancer is associated with poor prognosis and few treatment options are currently available. Laparoscopic CO₂ insufflation stimulates the progression and metastatic potential of gastrointestinal carcinomas. However, heated and humidified CO₂ pneumoperitoneum (HH-CO₂) is a promising treatment for PC, although its effects and mechanism of action in human colon cancer cells remain unclear. This study evaluated the anti-tumour effects of HH-CO₂ on human colon cancer *in vitro*.

CONCLUSIONS

HH-CO₂ induces apoptosis and inhibits proliferation, migration, invasion and adhesion of human colon cancer cells. Our results suggest that HH-CO₂ may serve as a potential candidate for the treatment and/or prevention of peritoneal carcinomatosis from colorectal cancer and warrant further *in vivo* investigation.

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Effects of Insufflation Conditions on Rat Mesothelium

Davey A, Hayward J, Marshall J, Woods A. *International Journal of Inflammation Volume (2013) 2013: 816283*

AIM

The aim of this investigation was to examine the alterations in the peritoneum after standard cold dry CO₂, heated dry CO₂, and humidified heated CO₂ at pressures equivalent to intraperitoneal pressures used in human laparoscopy.

RESULTS

The condition of the gas is also a factor. Generally, CO₂ is administered at room temperature (cold) and at very low relative humidity (dry). Cold gas is associated with hypothermia which is linked to numerous postoperative problems, although some slight cooling in the absence of desiccation may be protective, presumably due to suppression of the immune system and reduction of the metabolic activity of the cells. Using dry gas can damage the mesothelium also due to water evaporating from the peritoneal surface causing desiccation of the cells and further contributing to the hypothermia through the evaporative cooling effect. The insult to the mesothelium through a combination of these mechanisms induces an inflammatory response which further acts to damage the tissue including sloughing of cells, which increases susceptibility to cancer spread and adhesion formation.

Our results strongly suggest that under the conditions of the study, cold/dry CO₂ caused mesothelial damage comparable to that previously reported, with little protection provided by heating the gas. In contrast, heating with humidification protected the mesothelial cells such that there was little deviation from the control animals. This is supported by the findings of other studies albeit under more extreme environmental conditions.

CONCLUSION

The light microscopy results indicate that insufflations with heated, humidified CO₂ are the least likely to induce mesothelial damage.

Postoperative Adhesions as a Consequence of Pelvic Surgery

Bolnick A, Bolnick J, Diamond M. Journal of Minimally Invasive Gynecology (2015) 22 (4): 549-563.

ABSTRACT

Adhesions represent a frequent thought-provoking surgical ramification that greatly affects clinical practice, thereby making adhesion deterrence an important area of public health intervention, research, and the fiscal budget. Postoperative adhesions have been observed in up to 94% of patients after laparotomy. Adhesion-related readmissions, 1 year after surgery, were found to be in 1.3% to 1.5% of the therapeutic and diagnostic laparoscopic procedures. This systematic review looks at gynecologic experience with the management of postoperative adhesions and related complications and recommends intervention when data permits.

LAPAROSCOPY VERSUS LAPAROTOMY

Studies show that, in the presence of a direct surgical trauma, the entire peritoneal environment is quantitatively the most important factor in adhesion formation and hence adhesion prevention after both open and laparoscopic surgery. Mesothelial hypoxia (CO₂ pneumoperitoneum) or hyperoxia (open surgery), desiccation, and surgical manipulation have been identified as factors cumulatively augmenting adhesion development. The clinical ramification is especially relevant for laparoscopic surgery because pneumoperitoneum, being a closed environment, can be easily conditioned.

It has been shown that there is a different morphologic effect of CO₂ pneumoperitoneum compared with laparotomy. Using heated humidified CO₂ in the rodent model decreases the risk of desiccation on the peritoneum during laparoscopy.

Humification During Surgery: Benefits of Using Humified Gas During Laparoscopic and Open Surgery

Binda M. An Atlas of Gynecologic Oncology: Investigation and Surgery. Fourth Edition, Chapter 27, CRC Press, Taylor and Francis Group, October 2018, pp 208-213.

BASICS OF THE PHYSIOLOGY OF THE PNEUMOPERITONEUM:

The pneumoperitoneum is the serous membrane that forms the lining of the abdominal cavity, and it covers most of the intra-abdominal organs. It is composed of a single layer of mesothelium, generally 2.5 - 3 μm thick supported by a thin layer of connective tissue. With the surface area of some 14,000 cm^2 in adults, almost equal to that of the skin, this membrane may be the largest organ in humans. Its primary function is to diminish the friction among the abdominal viscera, enabling their free movement.

CONCLUSION

The peritoneum, one of the largest organs in humans, has a very important function in the abdominal cavity. It diminishes the friction, serves as a barrier to infections, and enables the secretions of cytokines. It is a delicate layer highly susceptible to damage. Of course, it is not designed to cope with the variable conditions such as being in contact with dry and cold CO_2 during laparoscopic surgery. Insufflating dry and cold CO_2 into the abdominal cavity causes peritoneal damage, postoperative pain, hypothermia, and postoperative adhesions. Humidified and warm gas reduces the inflammatory response demonstrating that less trauma is incurred to the peritoneum. It has been clearly confirmed by meta-analysis that warm and humidified gas prevents pain after laparoscopic surgery. In regard to hypothermia due to desiccation, it can be fully prevented using humidified and warm gas.

Using humidified and warm insufflation gas now offers a significant clinical benefit to the patient, creating a more physiologic peritoneal environment and reducing postoperative pain and hypothermia.

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