SCIENTIFIC PAPER

Carbon Dioxide Gas Heating Inside Laparoscopic Insufflators Has No Effect

Volker R. Jacobs, MD, PhD, Marion Kiechle, MD, PhD, John E. Morrison, Jr., MD

ABSTRACT

Background and Objectives: Within recent years, the insufflation technique for laparoscopy has become more important with high flow insufflators (≥30 L/min) and high gas turn over (≥800 L/procedure). Increased amounts of carbon dioxide (CO_2) gas used can lead to laparoscopic hypothermia. We studied the insufflator with versus insufflators without internal gas heating (inside insufflator) as a sufficient method of hypothermia prevention at different flow rates.

Methods: With a computer-based data acquisition model, different standard insufflators with internal gas heating (Snowden Pencer) vs. without (Storz Endoflator, Storz Laparoflator, Richard Wolf, and BEI Medical) were compared regarding CO_2 gas temperature at different points in the insufflation system (insufflator exit, insufflation hose end).

Results: Gas temperature of the Snowden Pencer insufflator, which is flow-rate dependent, increases at the exit (max. 35.4°C). However, gas temperature is back to room temperature (-0.22 to +1.10°C) at the end of the insufflation hose (10 ft or 3 m) for all 5 insufflators studied. Even at high gas flow rates (≤20 L/min), CO_2 gas is at room temperature when it reaches the patient.

Discussion: No difference was noted regarding gas temperature between the insufflators compared. Insufflator internal gas heating, such as the Snowden Pencer insufflator, can not have a clinically significant effect because it is too far away from the patient to raise the gas temperature in the abdomen. Purchasers are misled because the gas-heating device has no measurable benefit for the patient.

Key Words: Laparoscopy, Insufflator, Hypothermia, Carbon dioxide insufflation.

Frauenklinik (OB/GYN), Technical University Munich, Germany (Drs Jacobs, Kiechle).

Department of Surgery, Fayette Medical Center, Alabama, USA (Dr Morrison).

This article is dedicated to honoring the memory to Prof. Dr. med. Kurt Semm (1927–2003) who invented and promoted technical developments and clinical applications of pelviscopy and laparoscopy to its current heights.

We had no financial interest and no financial support for this study.

Presented as an oral presentation at the Sixth International Meeting of Laparoendoscopic Surgeons, SLS Annual Meeting, Endo Expo '97, Orlando, Florida, USA, December 3–6, 1997.

Address reprint requests to: Volker R. Jacobs, MD, PhD, Frauenklinik (OB/GYN), Technical University, Ismaninger Str. 22, 81675 Munich, Germany. Telephone: ++49 89 4140 5425, Fax: ++49 89 4140 4831, E-mail: volkerjacobs@hotmail.com

INTRODUCTION

Although it had already been shown in 1870 that intraabdominal insufflation of CO_2 gas can lead to hypothermia in a rabbit model[1] and a simple gas heating and hydration device for laparoscopy was used 4 decades ago **(Figure 1)**,[2] only within recent years has growing attention been given to the problem. With increasing amounts of up to several hundred liters of CO_2 gas being used,[3] —our experience was a maximum of 801 L in 1 procedure—and high gas flow rates of ≥30 L/min, the effect and prevention of laparopelviscopic hypothermia needs to be addressed.[4]

Intraoperative systemic hypothermia is linked to a higher intra- and postoperative complication rate (discomfort, pain, coagulopathy, morbid cardiac events, and other things). CO_2 gas warming has been proven to reduce pain;[2,5,6] therefore, a closer look at the prevention methods offered is necessary.

In general, 2 different methods are currently in use to prevent laparopelviscopic hypothermia: changing the gas state (heating, hydration, eg, Insuflow; Lexion Medical Inc., St. Paul, MN) before it reaches the patient, or prevention of systemic hypothermia with patient surface warming equipment (eg, a warm air fan like Bair Hugger, Arizant Healthcare Inc., Eden Prairie, MN; a water mattress like Blanketrol, Cincinnati Sub-Zero Products Inc., Cincinnati, OH, or fluid warmer, warming blankets, and others).

Another method offered is an insufflator built-in CO_2 gas heating device that heats up CO_2 gas to body temperature, eg, inside insufflators like the Snowden Pencer (Snowden Pencer, Tucker, GA) or in the NuMo insufflator (distributed by EndoVentions International Inc., Des Plaines, IL).

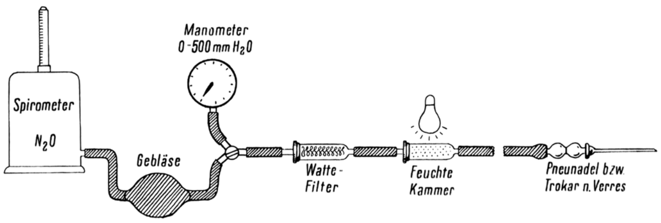

Figure 1. A simple gas heating and hydration device for laparoscopy named "Feuchte Kammer" (wet chamber) with wet filter paper inside and warming light bulb above used by Siede and Schneider from Darmstadt, Germany, before 1962.[2]

It is clinically obvious that the patient benefits from hypothermia prevention methods, but which technique shall the physician rely on? The physician is finally responsible for all equipment used on or around the patient, so from this background arise 2 questions: How efficient is insufflator internal gas heating, and do high gas flow rates affect the CO_2 gas temperature? In the following, we compare both types of insufflators—one with vs. 4 without internal gas heating—at increasing flow rates in a laboratory measurement model.

METHODS

A notebook PC (TECRA 510 CDT; Toshiba Inc., Irvine, CA) and a PCMCIA data acquisition board (PCI-460-P1; Intelligent Instrumentation Inc., Tucson, AZ) were connected to electronic temperature meters (THERM 2280-1 with T-430-2R (K probes, NiCr-Ni); Ahlborn, Holzkirchen, Germany). Measurement accuracy was $\leq \pm 0.1$°C. At 2 different points in the insufflation system (at the insufflator exit and at end of insufflation hose), CO_2 gas temperature was measured with different standard insufflators with a maximum flow rate of 10 L/min to 20 L/min (BEI, Snowden Pencer, 2 x Storz, Richard Wolf) **(Figure 2)**. Gas flow was measured with a laminar flow element LFE type 1 ($\leq$60 L/min) and an electronic differential meter Digima premo 720 (both Special Instruments, Noerdlingen, Germany). The measurement scheme **(Figure 3)** was graphically created with an adjustable, multipurpose measurement program (Visual Designer 3.0; Intelligent Instrumentation Inc., Tucson, AZ) and transferred into the final program. Results are displayed with a scientific graphic program (Origin 4.1; Microcal Inc., Northampton, MA).

RESULTS

The results of laboratory measurements are described under 3 aspects:

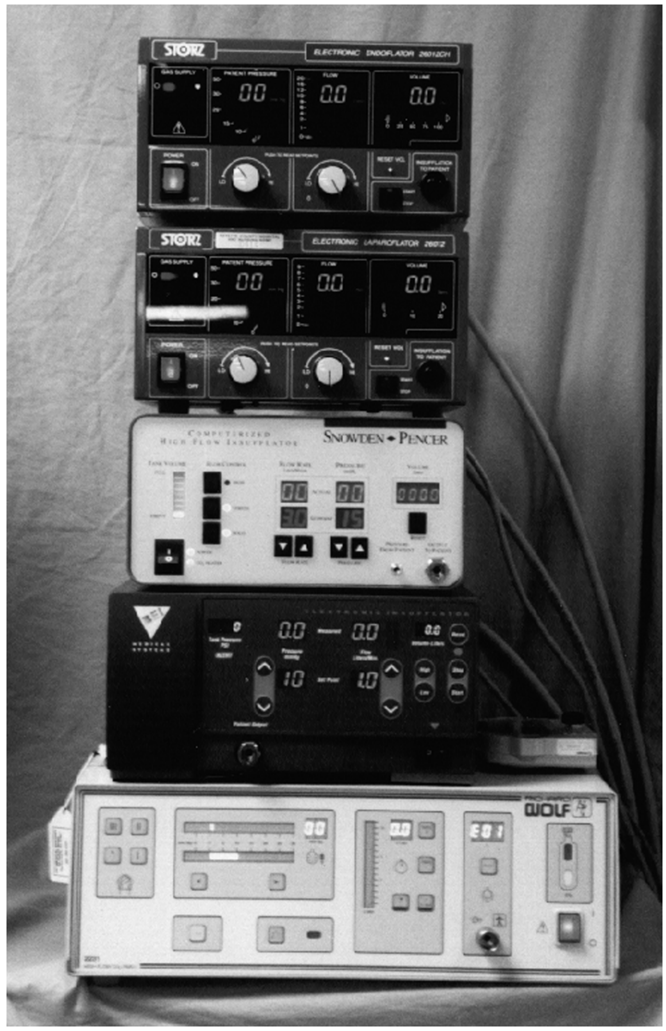

Figure 2. Insufflators evaluated (top to bottom): Storz Endoflator; Storz Laparoflator; Snowden Pencer; BEI Medical; Richard Wolf.

(1) Gas temperature at the exit of the insufflator (patient distal): The Snowden Pencer insufflator showed a gas flow rate-dependent increase in CO_2 gas temperature at the exit of the insufflator up to a maximum of 35.4°C, which is reached only at the maximum gas flow rate of 15 L/min. At lower flow rates, the CO_2 gas temperature is less, eg, 29.3°C at 2 L/min and 31.4 at 4 L/min. The measurements showed that body temperature of 37.0°C is neither reached nor exceeded (Figure 4).

(2) Gas temperature at the end of the insufflation hose (patient proximal): CO_2 gas temperature is around OR room temperature (~ 24°C) at the insufflation hose end when it reaches the patient. At the specific maximum gas flow rate, the range of temperature change from initial

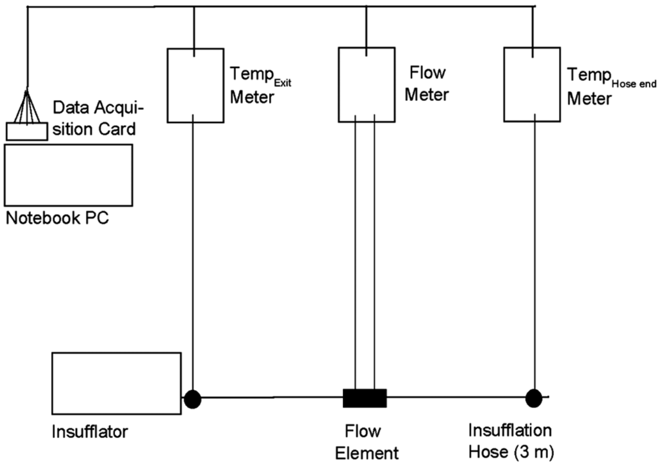

Figure 3. Measurement scheme for gas temperature evaluation of laparoscopic insufflators.

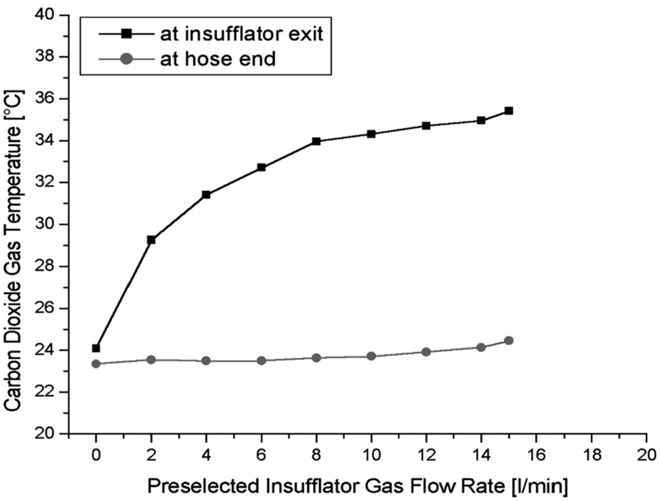

Figure 4. Gas flow-dependent CO_2 temperature of the Snowden Pencer insufflator at insufflator exit (top curve) and at insufflation hose end (bottom curve).

room temperature is only -0.24°C to +1.10°C for all insufflators. Although the Snowden Pencer insufflator shows the largest increase of +1.10°C above room temperature, an absolute value of 24.45°C is far from reaching body temperature (Figure 5). Minimal changes in operating room temperature caused by the air conditioning system can also be reflected in the CO_2 gas temperature in the insufflation hose.

(3) CO_2 temperature at high gas flow rates at the insufflation hose end (patient proximal): Despite increasing gas flow rates, the temperature measurement curves are almost linear for all insufflators **(Figure 5)**. Even at high gas

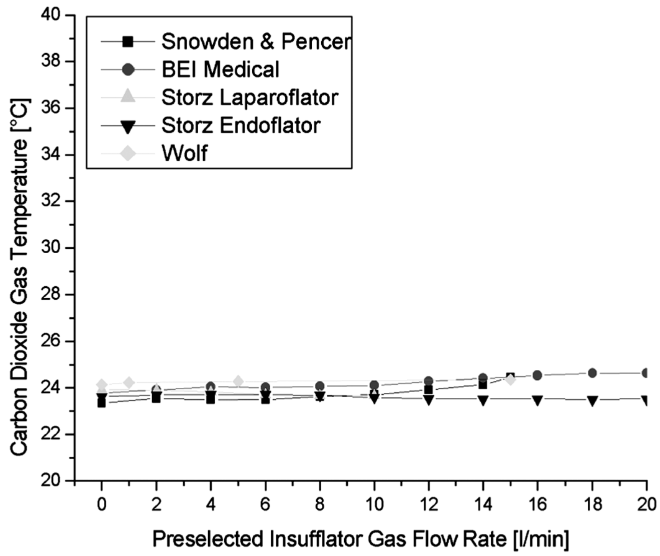

Figure 5. Gas flow-dependent CO_2 temperature for all insufflators at the insufflation hose end.

flow rates with up to 20 L/min, the insufflation gas stays at room temperature at the hose end for all insufflators. Although only minor flow-dependent temperature changes are measurable, all insufflators have a gas temperature trend. Three insufflators show a CO_2 gas temperature increase (Snowden Pencer +1.10°C, BEI Medical +0.86°C, and Richard Wolf +0.22°C), and 2 show a minor decrease in gas temperature (Storz Laparoflator -0.24°C and Storz Endoflator -0.09°C) **(Figure 5)**. However, these effects are not clinically relevant.

DISCUSSION

Laparoscopic hypothermia and possible prevention methods have been discussed controversially within recent years. Ott[7,8] found a linear decrease in body temperature with the insufflated amount of gas (0.3°C/50 l). Semm[3,5] recommended CO_2 hydration and gas heating and developed a device for such (Flow Therme; WISAP, Sauerlach, Germany). However, with the use of gas heating devices, patients have less pain.[2,5,6,9]

Maintaining patients' body temperature is meanwhile often recommended as standard patient care because a decrease of intraoperative body temperature is related to a variety of complications, from discomfort for the patient like postoperative tremor[10] to higher complication rates, such as coagulopathy,[11] morbid cardiac events,[12] and postoperative wound infections.[13] However, during a comprehensive clinical evaluation, we did not notice any severe laparoscopic hypothermia-related intra- or postoperative complications at our institution.[4]

Measurements of the CO_2 gas temperature of the Snowden Pencer insufflators with internal gas heating versus those without (all other insufflators) at increasing flow rates measured at insufflation hose end (10 ft or 3 m) showed a flow-dependent increased gas temperature at the Snowden Pencer insufflator exit (**Figure 4**, top curve). But the temperature is back to room temperature at the hose end (**Figure 4**, bottom curve) like for all other insufflators **(Figure 5)**. The Snowden Pencer insufflator with internal gas heating proved to be not efficient enough to heat up CO_2 gas to body temperature.

Intraoperative results confirmed the laboratory findings that insufflator internal CO_2 gas heating has no clinical effect, because the gas temperature in the insufflation hose is back to room temperature by the time it reaches the patient.[4] Novak,[14] who showed a continuous decrease in preheated insufflation gas temperature to room temperature over the length of the insufflation hose, from 35° to 40°C at the beginning to ~22°C at the insufflation hose end after only 1.5 m to 2 m length, confirms our results **(Figure 6)**.

So gas heating can only be efficient and have an effect on intraabdominal gas temperature if it is heated close to the patient without loss of heat. A clinical evaluation and comparison of different patient close gas heating devices is necessary to determine their efficiency. Maintaining body temperature with standard warming equipment like Bair Hugger, Blanketrol, fluid warmer, or blankets should be more efficient.[4] The use of body warm saline (~38°C) for repeated intraoperative irrigation of the abdominal cavity is also a useful method to prevent local drying and consecutive damage of the peritoneal surface and can also reduce fogging of the laparoscopic optic. But it was found that warmed irrigation saline can only decrease but not eliminate the drop in core temperature during laparoscopic procedures.[15]

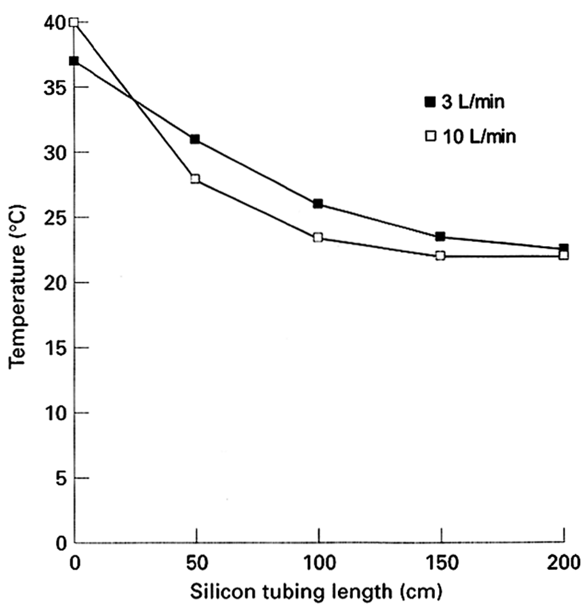

Figure 6. CO_2 gas temperature decrease as a function of insufflation tubing length at different flow rates. Reprinted from Novak P. High-flow insufflation. *Min Invas Technol*. 1997;6:170–178. © Taylor & Francis Group, London, UK.

Another possibility–increasing the OR temperature–would directly increase CO_2 gas temperature. But in a physically hard-working environment often with clothes that are too warm, an increase of OR room temperature is limited. Limitation of CO_2 gas leakage (around trocars, during suturing, inadequate instrument-trocar sizes, use of seals) and reduction of gas flow rates (especially for expected extended periods of insufflation time) can reduce the intraabdominal temperature drop.[4,16,17]

CONCLUSION

Purchasers of insufflators with internal gas heating should be aware that such insufflators do not increase the intraabdominal gas temperature sufficiently. It has been proven that these insufflators have no significant effect and therefore cannot and should not be relied on to prevent laparoscopic hypothermia.

Manufacturers and developing industry are our partners in performing laparoscopy. But physicians have to carefully follow and critically evaluate new technology and instruments for actually available function for a real benefit for the patient.[18] This study proves that quality control studies for all laparoscopic equipment are necessary.[19]

References:

1. Simon R. Genese der Temperaturerniedrigung [Genesis of temperature decrease]. Medical dissertation, Germany, University of Bonn; 1870.

2. Siede W, Schneider H. Leitfaden und Atlas der Laparoskopie [Guideline and Atlas of Laparoscopy]. Munich, Germany: Lehmann Verlag; 1962.

3. Semm K. Das unterkühlte Pneumoperitoneum [The undercooled pneumoperitoneum]. *Laparo-Endosk Chir*. 1992;1:21–22.

4. Jacobs VR, Morrison JE Jr., Mettler L, Mundhenke C, Jonat W. Measurement of CO_2 hypothermia during laparoscopy and pel-

viscopy: how cold it gets and how to prevent it. *J Am Assoc Gynecol Laparosc*. 1999;6(3):289–295.

5. Semm K, Arp WD, Trappe M, Kube D. Schmerzreduzierung nach pelvi-/laparoskopischen Eingriffen durch Einblasen von körperwarmem CO_2-Gas (Flow-Therme) [Pain reduction after pelvi/-laparoscopic interventions by insufflation of CO_2 gas at body temperature (Flow-Therme)]. *Geburtshilfe Frauenheilkd*. 1994;54:300–304.

6. Korell M, Schmaus F, Strowitzki T, Schneeweiss SG, Hepp H. Pain intensity following laparoscopy. *Surg Laparosc Endosc*. 1996;6:375–379.

7. Ott DE. Laparoscopic hypothermia. *J Laparoendosc Surg*. 1991;1:127–131.

8. Ott DE. Correction of laparoscopic insufflation hypothermia. *J Laparoendosc Surg*. 1991;1:183–186.

9. Ott DE, Reich H, Love B, McCorvey R, Toledo A, Liu CY, Syed R, Kumar K. Reduction of laparoscopic-induced hypothermia, postoperative pain and recovery room length of stay by preconditioning gas with the Insuflow device: a prospective randomized controlled multi-center study. *JSLS*. 1998;2(4):321–329.

10. Ralley F, Wynands JE, Ramsey JG, Carley F, MacSulivan R. The effects of shivering on oxygen consumption and carbon dioxide production in patients rewarming from hypothermic cardiopulmonary bypass. *Can J Anaesth*. 1988;35:332–337.

11. Michelson AD, MacGregor H, Barnard MR, Kestin AS, Rohrer MJ, Valeri CR. Reversible inhibitation of human platelet activation by hypothermia in vivo and in vitro. *Thromb Haemostat*. 1994;71:633–640.

12. Frank SM, Fleisher LA, Breslow MJ, Higgins MS, Olson KF, Kelly S. Beattie C. Perioperative maintenance of normothermia reduces the incidence of morbid cardiac events. *JAMA*. 1997;277: 1127–1134.

13. Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. *N Engl J Med*. 1996;334:1209–1215.

14. Novak P. High-flow insufflation. *Min Invas Technol*. 1997; 6:170–178.

15. Moore SS, Green CR, Wang FL, Pandit SK, Hurd WW. The role of irrigation in the development of hypothermia during laparoscopic surgery. *Am J Obstet Gynecol*. 1997;176(3):598–602.

16. Jacobs VR, Morrison JE Jr. Warmed insufflation carbon dioxide gas for laparoscopic cholecystectomy. *Surg Endosc*. 2001; 15(10):1244–1245.

17. Jacobs VR, Morrison JE Jr. Carbon dioxide gas heating in laparoscopy: is it worth it? Intraoperative evaluation of insufflators with vs. without CO_2 gas heating device [abstract]. *JSLS*. 1997;1(4):369.

18. Jacobs VR, Morrison JE Jr., Kiechle M. Twenty-five simple ways to improve insufflation performance and patient safety in laparoscopy. *J Am Assoc Gynecol Laparosc*. 2004;11(3):410–423.

19. Jacobs VR, Morrison JE Jr., Mundhenke C, Golombeck K, Jonat W. Intraoperative evaluation of laparoscopic insufflation technique for quality control in the OR. *JSLS*. 2000;4(3):189–195.