Measurement of CO_2 Hypothermia During Laparoscopy and Pelviscopy: How Cold It Gets and How to Prevent It

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Abstract

Study Objective. *To evaluate intraabdominal CO_2 temperature during a variety of standard operative laparoscopy procedures with different insufflators (BEI Medical, Snowden & Pencer, Storz Laparoflator, Storz Endoflator, Wolf) and devices to maintain body temperature (Bair Hugger, fluid warmer, Blanketrol blankets).*
Design. *Prospective, nonrandomized study (Canadian Task Force classification II-1).*
Setting. *Community hospital in rural Alabama.*
Patients. *Sixty-two consecutive patients (53 women, 9 men; average age 56.8 yrs, range 21–94 yrs).*
Interventions. *Patients underwent standard laparoscopic and pelviscopic procedures during which intraoperative temperature changes in the insufflation system, abdomen, and rectum were measured.*
Measurements and Main Results. *Carbon dioxide was at room temperature in the insufflation hose (~23° C). During insufflation, intraabdominal gas temperature decreased to as much as 27.7° C (average 32.7° C) depending on length of operation (23 min–5 hrs 8 min), amount of gas used (12.8–801 L), gas flow (up to 20 L/min), and leakage rate. Preoperative and postoperative temperature comparisons showed no decline in rectal temperature (average +0.18° C) because warming equipment was sufficient.*
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.*

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Insufflation is an integral part of laparoscopy. With more sophisticated procedures, prolonged pneumoperitoneum, and up to several hundred liters CO_2 used[1] (our maximum was 801 L for a Nissen

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fundoplication combined with cholecystectomy), it is important to consider the effect of laparopelviscopic hypothermia and how to prevent it.

It was shown in 1870 that intraabdominal insufflation of CO_2 gas led to hypothermia in a rabbit model,[2] and a simple gas-heating and hydration device for laparoscopy was used decades ago (Figure 1).[3] But only within the past few years has growing attention been given to the issue.[4,5] The importance of laparoscopic hypothermia is a subject of controversy,[4-10] but warming CO_2 reduces pain.[3,11,12]

In general, two methods are used to prevent laparoscopic hypothermia. One is to heat CO_2 to body temperature, as is done with the Snowden & Pencer insufflator (Tucker, GA) or the NuMo insufflator (Surgical Innovations Ltd., Leeds, U.K.). The second method is to use devices to warm the body surface, such as water mattresses, warm-air fans, fluid warmers, and warming blankets.

We compared the techniques: one insufflator with versus four without internal gas heating, and a combination of warming devices, which were introduced at our medical center 3 years ago. We also evaluated the clinical effects of intraabdominal gas and rectal temperatures during different laparopelviscopic procedures.

Methods

Institutional review board approval for this study was obtained, and written consent was obtained from all patients.

A computer-based intraoperative data-acquisition model was developed (Figure 2). A Pentium 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 different electronic temperature meters [THERM 2283-2 for NTC probes and THERM 2280-1 for K probes (NiCr-Ni); Ahlborn, Holzkirchen, Germany]. Measurement accuracy was ±0.1° C. With different probes (401 AC and 402 AC for intraabdominal CO_2 and rectal temperatures; YSI, Inc., Yellow Springs, OH; T-430-2R for insufflation system temperature; Ahlborn) temperature changes were evaluated during a variety of standard laparopelviscopic procedures in 62 patients (53 women, 9 men, average age 56.8 yrs, range 21–94 yrs).

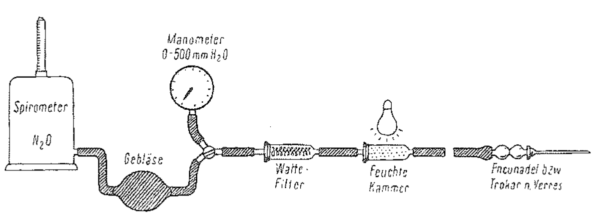

FIGURE 1. First gas-heating and hydration device. Feuchte Kammer ("wet chamber") consists of wet filter paper and light bulb used by Siede and Schneider before 1962.[3]

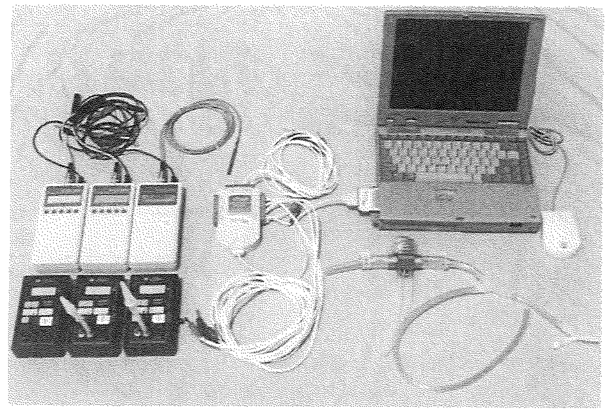

FIGURE 2. Measurement devices (clockwise): Toshiba Notebook, Laminar Flow Element, Digima Premo meters, Therm meters, data acquisition board, and PCMCIA card.

Insufflators from 10 to 20 L/minute (BEI, Snowden & Pencer, Storz, Wolf) were included (Table 1, Figure 3). Devices to maintain body temperature were Bair Hugger (warm-air fan blowing into a plastic cover) set at 38° C and fluid warmer (for infusion fluids) set at 37.8° C (both Augustine Medical, Inc., Eden Prairie, MN), Blanketrol (warming water mattress) set at 37.8° C (Cincinnati Sub Zero Products, Inc., Cincinnati, OH), and warming blankets for body and head. Gas flow (L/min) was measured with a laminar flow element (LFE type 1 for ≤60 L/min) and electronic differential meter Digima premo 720 (both Special Instruments, Nördlingen, Germany). The equipment was connected as shown in Figure 4. Throughout all operations, temperature was measured in the insufflation system, abdomen, and rectum (Table 2).

The measurement scheme was graphically created with an adjustable, multipurpose measurement program (Visual Designer 3.0; Intelligent Instrumentation) and transferred into the final program. Results were displayed with a scientific graphic program (Origin 4.1; Microcal Inc., Northampton, MA). The cost of this model was below US $12,000.

TABLE 1. Insufflators Evaluated.

Manufacturer	Type	Model No.	Maximum Flow (L/min)	Gas Heating	Hose No.
Snowden & Pencer (DSP), Tucker, GA	Computerized high-flow insufflator	89-8600	15	Yes	89-9062
BEI Medical Systems, Chatsworth, CA	High-flow electronic insufflator	92000V	20	No	91310
Karl Storz Endoscopy, Culver City, CA	Electronic endoflator	26012 CH	20	No	26012C.1
Karl Storz Endoscopy, Culver City, CA	Laparoflator	26012C	10	No	26012C.1
Richard Wolf Medical Inst. Corp., Vernon Hills, IL	High-flow CO_2 pneu insufflator	2231	15	No	2460.811

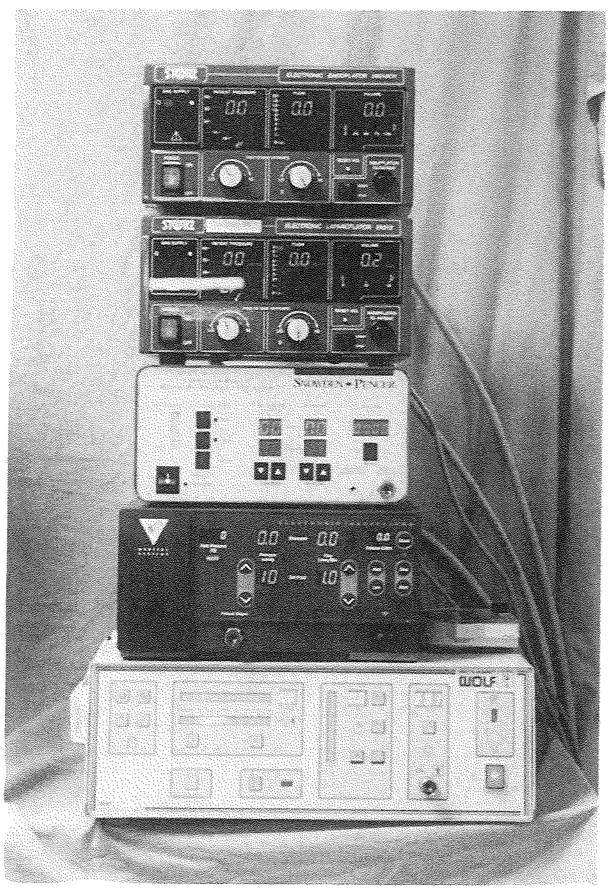

FIGURE 3. Insufflators (from top to bottom): Storz Endoflator, Storz Laparoflator, Snowden & Pencer, BEI Medical, Wolf.

TABLE 2. Laparopelviscopic Procedures Performed in 62 Patients

Procedure	No. of Cases
Cholecystectomy (cholangiography)	24 (5)
Suspension (LVSCS, Burch)	16 (9, 7)
Nissen fundoplication	11
Hernia (ventral, inguinal)	9 (5, 4)
Hysterectomy (CISH)	8
Adhesiolysis	5
Colectomy	2
Appendectomy	1
Others (ovarian cysts, oophorectomy, etc.)	11
Total	87

LVSCS = laparoscopic vaginal-sacral-colposuspension; CISH = classic intrafascial supracervical hysterectomy.

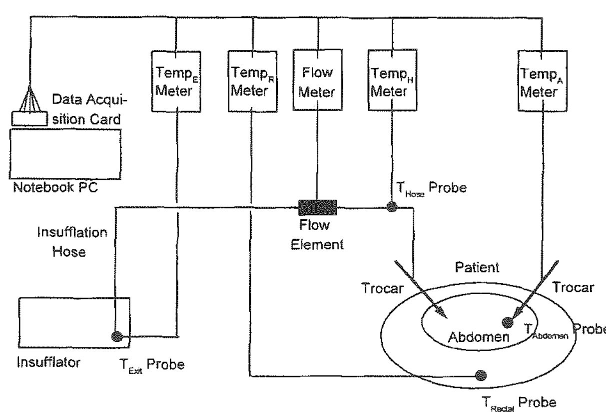

FIGURE 4. Measurement scheme: for operating room temperature in rectum, hose, abdomen, flow; for laboratory temperature at insufflator exit, in hose, flow.

CO_2 Use

The amount of CO_2 used depends on many factors, such as type of operation (e.g., double procedures in one session), size of insufflated area (abdomen, preperitoneal space), instruments (gas sealed), extended suturing (causing high and prolonged leakage). The average gas use per case was 169.1 L (range 12.8–801 L; Table 3).

CO_2 Temperature

The CO_2 was at room temperature (~23° C) at the insufflation hose end where it reaches the patient. Changes in operating room temperature, which often depend on type and regulation of air conditioning, are reflected in CO_2 temperature in the insufflation hose.

Intraoperatively, CO_2 temperature in the abdomen could drop to 27.7° C (maximum –8.3° C, average 32.7° C) and occurred with all insufflators (Figure 5). This occurred most often 45 to 60 minutes, especially in long operations with high gas flow rates (>10 L/min; Figure 6). That is when the patient's rewarming capacity and compensation mechanisms were slowly exhausted.

Even under high flow, large amounts of gas, and long periods of insufflation, the maximum decrease of intraoperative body temperature was only -1.01° C because we used sufficient temperature-maintaining equipment. All insufflators showed a trend of slight increase in rectal temperature from start to end of insufflation of +0.18° C on average. (minimum +0.04° C Storz Endoflator, maximum +0.34° C Wolf insufflator). The intraoperative range of rectal temperature change from insufflation start to end was -1.01 to +1.63° C (Tables 4–6). Statistical analysis (box plots) shows correlation of intraabdominal temperature drop and CO_2 used. With increasing amounts of CO_2, an intraabdominal gas temperature drop becomes more likely (Figure 6).

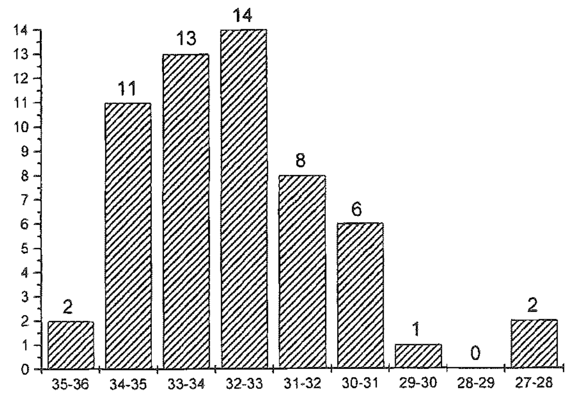

FIGURE 5. Intraoperative intraabdominal temperature minimum.

TABLE 3. CO_2 Use

Procedure	Average (L)	Range (L)	No. of Cases
CISH + LVSCS + Burch	349.8	177–623	4
LVSCS + Burch	128.9	85–207	5
Cholecystectomy	48.9	23–130	14
Nissen fundoplication	309.2	164–486	7
CO_2 gas use/ operation (L)	169.1	12.8–801	55

CISH = classic intrafascial supracervical hysterectomy; LVSCS = laparoscopic vaginal-sacral-colposuspension.

TABLE 4. Body Core Temperature

Temperature	Average (° C)	Range (° C)
At start of operation	36.17	35.02–38.13
At end of operation	36.35	34.55–37.63
Change (start to end)	+0.18	-1.01 to +1.63

TABLE 5. Rectal Temperature Change

Change	No.
Increase	31
Decrease	22
Unchanged	2

TABLE 6. Body Temperature Changes with Insufflators

Insufflator	Change (start–end, ° C)	Range (° C)	No.
BEI	+0.20	–0.70 to +1.06	13
Wolf	+0.34	–0.37 to +1.24	10
Storz Endoflator	+0.04	–0.80 to +1.16	15
Storz Laparoflator	+0.28	–1.01 to +1.63	10
Snowden & Pence	+0.15	–0.22 to +1.16	14
All	+0.18	–1.01 to +1.63	62

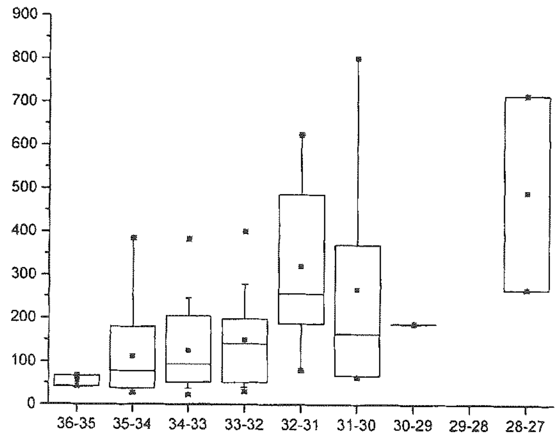

FIGURE 6. Statistical analysis (box plot) of intraabdominal CO_2 temperature drop with CO_2 use.

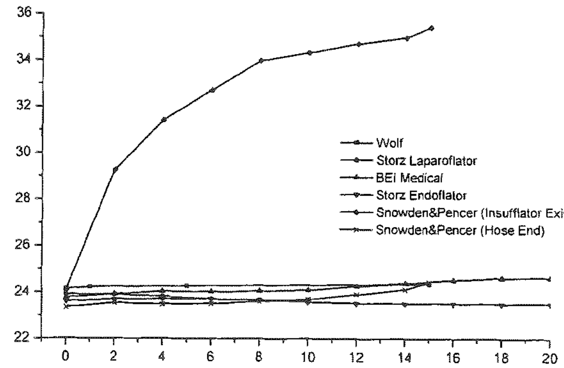

FIGURE 7. Flow-dependent CO_2 temperature at insufflator exit (Snowden & Pencer insufflator top curve) and for all insufflators with Snowden & Pencer at insufflation hose end (bottom).

An unexpected result was that the Snowden & Pencer insufflator showed no increased intraabdominal gas temperature compared with insufflators without gas-heating devices. To study the missing clinical effect of this insufflator, we evaluated gas temperature in the laboratory. Measurements of CO_2 temperature of insufflators with internal gas heating (Snowden & Pencer) and without (all others) at increasing flow rates (F = 2, 4, 6, etc., L/min) taken at the hose end (10 ft, 3 m), showed that for all insufflators, gas temperature equaled room temperature. Although a flow-dependent increased gas temperature was measured at Snowden & Pencer's insufflator exit (Figure 7, top curve), it was back to room temperature at the hose end, as for all other insufflators (bottom curves). Snowden & Pencer's insufflator with internal gas heating was not efficient enough to heat CO_2 above room temperature at the hose end to increase intraabdominal gas temperature.

Discussion

Laparoscopic hypothermia and its possible prevention have been topics of controversy in past years. The results so far are inconclusive, as are the consequences. Body temperature decreases linearly with the amount of insufflated gas (0.3° C/50 L).[4,5] Carbon dioxide hydration and heating was recommended and led to the development of the WISAP Flow Therme.[1,11] Patients seem to have less pain when gas-heating devices are used.[3,10,11,12] One author calculated that warming insufflation gas suffices, whereas hydration is dispensable.[9] In contrast, others prefer CO_2 hydration without gas heating.[6] A statistical but not a clinically relevant drop in body core temperature was reported.[8] One group concluded that gas heating and hydration for short procedures such as cholecystectomy are not necessary,[13] which was confirmed by our results. Heat loss due to cold CO_2 may be a relatively minor contribution to surgical hypothermia.[7] Hypothermia could not be induced in a pig model despite insufflation of over 1000 L CO_2,[10] which questions the validity of an animal model to evaluate laparoscopic hypothermia.

Given this background, a practical access was chosen for this study and intraoperative measurements were taken. Our results support the possibility of hypothermia with CO_2 temperature decreased to 27.7° C in the abdomen during standard laparoscopic procedures. This is confirmed by similar results of 28° C.[14]

Maintaining the patient's body temperature should be standard care because a decrease of intraoperative body temperature is related to a variety of complications from discomfort such as postoperative tremor[15] to coagulopathy,[16] morbid cardiac events,[17] and postoperative wound infections.[18] However during this evaluation we did not encounter laparoscopic hypothermia-related intraoperative or postoperative complications.

In contrast to an expected rectal temperature decrease of 1 to 3° C,[1,11] our results show an average, slight, insufflator-independent increase of +0.18° C from start to end of insufflation. The reason for that increase was adequate body-warming equipment, which prevented systemic hypothermia even with high-flow insufflators (≤20 L/min) or large amounts of CO_2 (800 L). Critically important is the fact that a loss in body core temperature of as much as 1.01° C occurred with constant and aggressive methods of heat preservation. Without this body-warming equipment the temperature would have dropped even more. Thus the control group would have been without warming equipment, but such equipment is standard at this institution and cannot be circumvented, and lowering the standard is considered unethical.

A closer look at options for preventing intraoperative hypothermia is necessary. Intraoperative results confirmed the laboratory findings that internal devices to heat CO_2 are ineffective because gas temperature in the insufflation hose is back to room temperature by the time it reaches the patient. A report of continuous decrease of CO_2 temperature over the length of the hose to room temperature at the hose end[19] confirms our results. Gas heating can have an effect on intraabdominal gas temperature only if it is heated close to the patient without heat loss. Clinical evaluation and comparison of such gas-heating devices (7070 insufflator, WISAP USA, Market-tiers, Inc., Lenexa, KS), which was not approved to be evaluated in this study, are necessary to determine their efficiency.

We showed that maintaining body temperature with a combination of external devices is effective. Disadvantages are that such equipment is expensive, and it addresses the problem only after it occurs. New devices for gas heating and hydration that are situated close to the patient (e.g., Insuflow; Georgia BioMedical, Inc., Macon, GA) might be a solution[20] because hydration seems to be even more important than heating the gas.[21,22] This is especially the case with extended insufflation times, because our study shows the specific patient gas-rewarming capacity becomes slowly exhausted over time. Nevertheless local effects of cold gas on peritoneum and intestines, as well as other systemic consequences, require further investigation because rapid drying of wet peritoneal surface can also damage peritoneum by desiccation, a precursor to prostaglandin release, and cause adhesion formation.

Conclusion

Insufflators were not significantly different with respect to insufflation gas temperature. Intraabdominal gas temperature can drop with all of them and often depends on interaction between technique and patient. Insufflators with internal gas heating were inefficient because the gas at the end of the hose returned to room temperature. Prolonged CO_2 pneumoperitoneum (≥1 hr) could be problematic in patients who could be affected by high-flow CO_2 (>10 L/min) with large gas turnover and resulting abdominal gas temperature drop. Maintaining body temperature with standard warming equipment (Bair Hugger, fluid warmers, Blanketrol, blankets) is efficient and can prevent systemic hypothermia. Increasing operating room temperature directly increases CO_2 temperature but is uncomfortable for surgeon and operating staff. Limiting CO_2 gas leakage (around cannulas, during suturing, inadequate instrument and cannula sizes, use of seals) and reducing gas flow rates (especially for expected extended periods of insufflation time) can reduce intraabdominal temperature drop but not prevent it.

This experimental study demonstrates the need for intraoperative evaluation of insufflation technique for laparoscopy and documents insufflation-related problems. Although no obvious complication related to insufflation problems occurred during our measurements, some results potentially question patient security. Therefore further investigation of physical effects and its influence on patient's physiology is necessary.

Acknowledgments

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