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The clinical impact of warmed insufflation carbon dioxide gas for laparoscopic cholecystectomy

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Abstract
Background: Reports suggest that the insufflation of cold gas to produce a pneumoperitoneum for laparoscopic surgery can lead to an intraoperative decrease in core body temperature and increased postoperative pain.
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.

Key words: Cholecystectomy — Hypothermia — Laparoscopy — Pneumoperitoneum

Hypothermia is a common problem during and after open abdominal surgery. It is associated with negative events such as cardiac arrhythmias, changes in blood coagulation, and depressed respiratory function [10]. The introduction of laparoscopic techniques for a variety of abdominal surgical procedures eliminated one factor greatly contributing to hypothermia: the open laparotomy wound with large exposed abdominal surfaces. However, it has been reported that laparoscopy can induce hypothermia from insufflation of cold carbon dioxide (CO_2) gas used to create a pneumoperitoneum. These reports describe a decrease in core body temperature and intra-abdominal temperature in patients who underwent laparoscopy [6, 7, 8]. Furthermore, cold gas insufflation may cause greater postoperative pain for the patient [4, 9]. Therefore, warm gas insufflators have been introduced by industrial firms to counteract the described negative effects of cold gas insufflation.

For physical reasons, we were sceptical that warmed gas could increase body temperature or prevent heat loss during the operation because the specific heat coefficient of blood, similar to that of water, is much higher than that of gas. This means that insufflated cold gas is easily warmed by the body, but that the body temperature can hardly be maintained by insufflated warm gas.

The aim of our approach was to evaluate any clinical important impact of a warm gas pneumoperitoneum during the most often performed and well-established laparoscopy routine procedure: the cholecystectomy. In a controlled randomized trial, warm and cold gas insufflation for creating a pneumoperitoneum were compared using the end points of body temperature changes and postoperative pain intensity.

Patients and methods

In a prospective randomized trial, 20 consecutive patients with symptomatic cholecystolithiasis were divided in two groups (10 patients per group) before laparoscopic cholecystectomy was performed. The power of the study was calculated under the assumption that loss of 1°C in body core or intra-abdominal temperature could make a difference in clinical outcome. To create a pneumoperitoneum, warmed CO_2 gas (37°C) was administered to the treatment group (group W) for abdominal insufflation (Flow Therme, WISAP, Sauerlach, Germany), whereas the control group (group C) received the usual cold CO_2 insufflation (21°C) (Electronic Laparoflater, Karl Storz, Tuttlingen, Germany).

Operative procedures

For laparoscopic cholecystectomy the four-trocar technique was used throughout, and the gallblader was extracted through the incision in the

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Table 1. Basic data of the study groups

	Group W warm CO_2	Group C cold CO_2
Male	3	5
Female	7	5
ASA I	4	5
ASA II	6	5
Age (years)	62 ± 8	51 ± 12
Weight (kg)	75 ± 13	83 ± 19
Height (cm)	161 ± 8	169 ± 10
Operation time (min)	56 ± 14	61 ± 17
Gas consumption (l)	131 ± 60	135 ± 51
Preoperative body temperature (°C)	36.0 ± 45	36.2 ± 160
Rinse solution consumption (ml)	318 ± 45	310 ± 160

right lower abdomen. All operations were performed with the patient under general anesthesia, using thiopental induction, relaxation with succinylcholine, and endotracheal intubation. Anesthesia was maintained with halothane and nitrous oxide inhalation in oxygen. The details of the operation are described elsewhere [11].

The pneumoperitoneum was induced by insufflation of CO_2 gas via a Veress needle placed in the left upper abdomen. The gas flow was limited to 5 l/min, and the intra-abdominal pressure limit was maintained at 15 mmHg in both groups. During the operation, insufflated gas consumption and the amount of used rinse solution (Ringer's lactate solution, 21°C) were recorded.

Temperature measurements

The temperature changes during laparoscopy were recorded with the Sirecust 404 monitor (Siemens, Erlangen, Germany). After induction of anesthesia and endotracheal intubation, a thermotip catheter was placed in the esophagus to monitor body core temperature. A second thermotip catheter was brought into the abdominal cavity through a trocar and placed on the surface of the intra-abdominal peritoneum to determine intraperitoneal temperature. The environment temperature in the operation room was kept at 21°C.

Assessment of pain

Postoperative pain was measured using a visual analog scale (VAS) that consisted of a 100-mm line anchored by two extremes of pain: from 0 (no pain) on the one end to 100 (worst pain imaginable) on the other [3] The patient's pain was assessed 6 h after the operation and on the first and second postoperative day (10 a.m., patient lying on bed without movement). Pain measurements were performed by ward nurses who did not know which treatment the patient had received.

The consumption of analgesics was recorded by counting the number of consumed ibuprofen 500-mg tablets (nonsteroidal anti-inflammatory drug; Imbun, Merckle, Blaubeuren, Germany). All patients were given a box containing six ibuprofen tablets every morning, then left to decide whether to take them.

Statistics

Statistical analysis was performed by Student's *t*-test. The level of significance was set to $p \leq 0.05$.

Results

The two groups did not significantly differ with respect to the patient's demographic data, operating time, volume of gas used during laparoscopy, volume of irrigation solution used, and preoperative body temperature (Table 1).

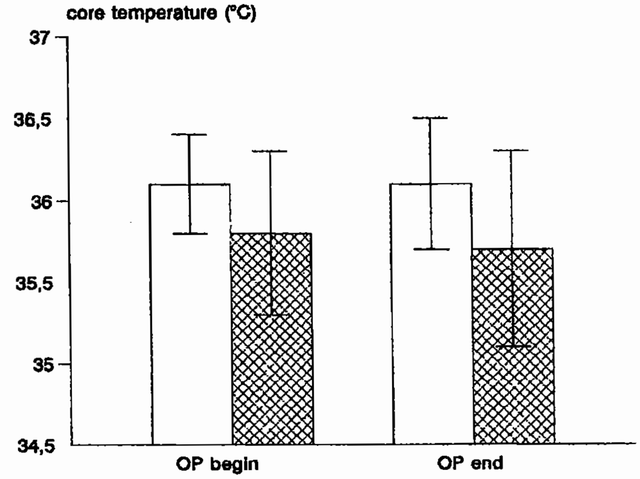

Fig. 1. Body core temperature (mean ± SD) at the beginning and end of laparoscopic cholecystectomy. white columns, warm gas; hatched columns, cold gas.

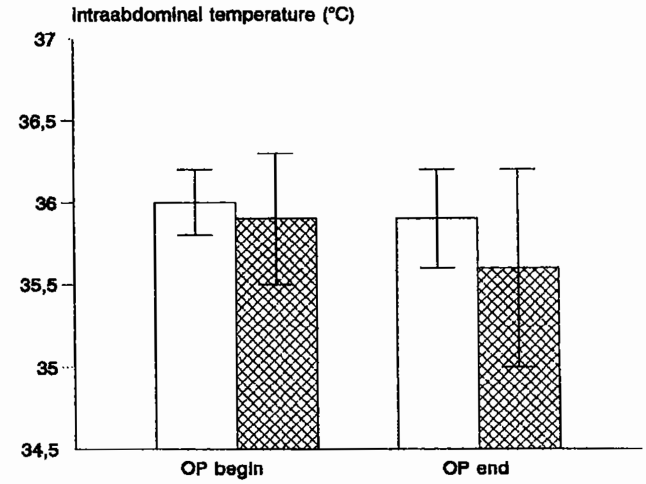

Fig. 2. Intra-abdominal temperature (mean ± SD) at the beginning and end of laparoscopic cholecystectomy. white columns, warm gas; hatched columns, cold gas.

Temperature measurements

The changes in body core temperature and intra-abdominal temperature during the operation are shown in the Figs. 1 and 2. In group W, the body core temperature was 36.1 ± 0.3°C after creation of the pneumoperitoneum (operation beginning) and remained stable to 36.1 ± 0.4°C until desufflation (operation end). In group C, the temperature was 35.8 ± 0.5°C after gas insufflation and decreased to 35.7 ± 0.6°C by the end of the operation. No significant difference was found between the groups. The same was true concerning intra-abdominal temperature. There were only minimal changes from 36 ± 0.2°C to 35.9 ± 0.3°C (group W) and from 35.9 ± 0.4°C to 35.6 ± 0.6°C (group C) during the operation.

Evaluation of pain intensity and consumption of analgesics

Figure 3 shows the patients' postoperative pain intensity. In group W, the mean visual analog scale points were 22 ± 18

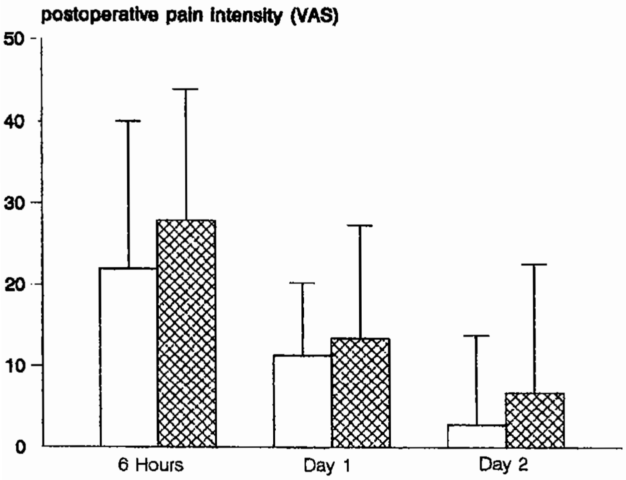

Fig. 3. Pain intensity (mean ± SD) at 6 h, day 1 and day 2 after laparoscopic cholecystectomy. white columns, warm gas; hatched columns, cold gas.

after 6 h, 11.3 ± 9 on the first, and 2.8 ± 11 on the second postoperative day. In group C, 27.9 ± 16 points were measured after 6 h, 13.4 ± 14 points on the first, and 6.7 ± 16 points on the second day after surgery. There was no difference between the groups.

Correspondingly, the postoperative consumption of ibuprofen tablets did not show a group-specific difference. At 6 h after the operation, the mean number of consumed tablets was 2.8 in both groups. During the first postoperative day, patients in group W took 1.2, and patients in group C took 1.5 tablets. On the second postoperative day, tablet consumption was 1.1 in group W and 0.9 in group C.

Discussion

The possible induction of hypothermia by laparoscopic insufflation of cold CO_2 gas has led to the development and industrial production of warm gas insufflators. Purchasers hoped that patients who received a pneumoperitoneum with warmed gas would not suffer intraoperative heat losses, and that the postoperative intensity of pain might be reduced [7, 8, 9].

We tested this hypothesis in a randomized controlled trial evaluating the clinical effect of a warmed gas pneumoperitoneum applied during cholecystectomy, the leading operation among those performed by minimally invasive gastrointestinal surgery. An improved clinical outcome with the insufflation of warm gas would represent a benefit for many patients, and an economic advantage would have a high socioeconomic impact.

However, our trial did not show any significant differences between the groups, either in body core or intraperitoneal temperature during the operation nor in the intensity of patients' pain or the amount of analgesics consumed in the postoperative course. Furthermore, there was no difference in the amount of gas used for the operation as reported by other authors [1, 9].

Our results do not confirm previous reports on hypothermia induced by laparoscopy. Semm et al. [9] found that cold gas insufflation could decrease the intra-abdominal temperature to 28°C during a laparoscopic operation. He could prevent this effect and reduce postoperative pain by using warmed insufflation gas. The authors did not find a significant difference between cold gas and warm gas insufflation in rectal temperature changes. These oberservations may be explained by the fact that the temperature of the gaseous phase was determined in the abdominal cavity. That is, the authors measured a mixed temperature of newly insufflated gas and that of gas already warmed by its stay in the abdominal cavity. Furthermore, the authors did not perform a defined surgical procedure. Perhaps the differences in postoperative pain were influenced primarily by the type of operation and the differences in their duration.

Although heat loss and decreased body temperature during laparoscopic operations can occur, the induction of a pneumoperitoneum with cold gas cannot explain it. For physical reasons, it is unlikely that the warming of the insufflation gas could have a major effect on the body temperature. The specific heat coefficient of CO_2 gas (0.84 J/g × grad) is very low compared with the specific heat coefficient of water (4.19 J/g × grad). In the more or less closed abdominal cavity, this high heat storage capacity of the body (high water content) would result in warming of the insufflated gas by the body and not in warming of the body by the insufflated gas (warm water heater effect). On the other hand, it might be possible that the consumption of energy for warming of the insufflation gas could result in heat loss and decrease of the body temperature. Therefore, the mass of the CO_2 gas insufflated during the operation and the intraperitoneal blood perfusion mass must be compared.

Theoretically, the mixed temperature of gas and fluids can be calculated by a physical formula (Table 2). The mass of the insufflation gas, as measured during the operation, averaged 4.2 g/min. The mass of the intraperitoneal blood perfusion cannot be measured, but should at least be more than the mesenterial blood perfusion mass (portal vein flow, 1100 g/min). In the theoretical model, we used water instead of the mesenterial blood for the calculation.

Under these assumptions, the maximal theoretical expected temperature difference between the use of cold gas and warm gas would be only 0.01 °C/min which is only 0.6°C during an operation time of 60 min. This theoretical calculation model does not reflect the time factor in the dynamic process of gas insufflation, which means that only the new insufflated gas must be warmed, and that it is mixed with the already warmed gas in the abdominal cavity. Therefore, in a real setting, this time factor and the certainly greater intraperitoneal blood perfusion mass would further reduce the temperature difference between the use of cold and warm insufflation gases. Our results can be explained by this physical rationale.

In a randomized study using pigs, Bessel et al. [2] got similar results. Over a 3-h period of high-flow gas insufflation during laparoscopy, the authors found that the provision of warmed rather than cold gas does not affect core temperature.

Other factors such as humidity of the insufflated gas, general anesthesia, operating theater temperature, and surgical skin disinfection solution may cause any measured decrease of core and intraperitoneal temperature during laparoscopy. Also, the use of cold solutions for infusion and

Table 2. Calculation formula for mixed gas and water temperatures

Mixed temperature $= [C_{gas} \times M_{gas} \times T_{gas} + C_{water} \times M_{water} \times T_{water}] / [C_{gas} \times M_{gas} + C_{water} \times M_{water}]$

Specific heat coefficient	Mass/min	Temperature[a]
$C_{gas} = 0.84$ J/g × grad	$M_{gas} = 4.2$ g/min	$T_{gas} = 21°C/37°C$
$C_{water} = 4.19$ J/g × grad	$M_{water} = 1100$ g/min	$T_{water} = 37°C$

[a] Maximal possible temperature difference between cold and warm gas: 0.01°C/min

irrigation and the number of skin incisions may contribute to a heat loss.

Some of these variables were considered in a recent study by Bäcklund et al. [1]. These authors also tried to calculate the exchange of heat by physical models. In a randomized trial with 13 versus 13 patients undergoing different types of prolonged gastrointestinal surgery, they found significant differences in core temperature and urine output to the advantage of the warm gas. The differences in body temperature were significant but very small, in the order of 0.4°C, which may not be clinically relevant. Indeed, the authors did not find a difference in pain and consumption of analgesics. More striking was the higher urine excretion by the patients receiving warm gas and the need of mannitol in the other group.

The contradictions between the different studies point to type and duration of the surgical procedures as important factors. According to our data, warming the insufflation gas during the highly standardized laparoscopic cholecystectomy with a duration of only 1 h to counteract intraoperative heat loss seems ineffective. More extended surgical procedures may result in more distinct differences, as shown in a recent publication by Luck et al. [5]. Because of the higher specific heat coefficient of water and blood, heating of the body mass by warmed solutions for infusion and irrigation and the use of a warming mat is probably more appropriate for preventing or reducing intraoperative hypothermia.

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