Surg Endosc (1999) 13: 1110–1114

Surgical Endoscopy
Ultrasound and
Interventional Techniques

Effect of CO_2 gas warming on pain after laparoscopic surgery

A randomized double-blind controlled trial

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Received: 25 September 1998/Accepted: 13 January 1999

Abstract
Background: Previous studies have suggested that gas temperature has an influence on postlaparoscopy pain. This trial therefore was conducted to study the effect of gas warming on pain after upper abdominal laparoscopic surgery.
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).
Conclusions: Gas warming does not reduce, and probably increases, postoperative shoulder tip and subcostal pains.

Key words: Laparoscopic surgery — Pneumoperitoneum — Postoperative pain — Randomized controlled trial

Although postoperative pain is significantly reduced by the laparoscopic approach as compared with the open techniques [2, 17], many patients still experience postlaparoscopy pain, which is sometimes considerable. After laparoscopic cholecystectomy, patients report two types of pain: a right subcostal pain and mainly a shoulder tip pain [12, 19].

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When reported, the incidence of shoulder tip pain after laparoscopic cholecystectomy was between 12% and 45% [3, 16, 17, 27]. Shoulder tip or subdiaphragmatic pains also have been reported in two-thirds of patients undergoing a laparoscopic appendendicectomy [24].

The residual CO_2 gas in the abdominal cavity now is recognized as the main cause of shoulder tip and subdiaphragmatic pains for several reasons: These symptoms have been reported even after pelvic procedures [5]; there is a significant correlation between CO_2 bubble volume under the right hemidiaphragm and postoperative pain score [10]; and the active evacuation of residual gas significantly reduced the demand for postoperative analgesia in a randomized trial [6]. Moreover, one randomized trial from Germany [15] suggested that the temperature of CO_2 gas has a significant influence on shoulder tip pain after gynecologic laparoscopies. That is, the warm gas reduces postoperative pain. Therefore, we conducted a randomized controlled double-blind trial with the aim of testing the hypothesis that CO_2 gas warming might reduce pain after upper abdominal laparoscopic surgery.

Patients and methods

Inclusion and exclusion criteria

This study was approved beforehand by our local ethic committee, and all patients signed an informed consent. The patients referred to us for an elective laparoscopic upper abdominal surgery including cholecystectomy for symptomatic and uncomplicated gallstone disease, posterior fundoplication for gastroesophageal reflux disease, and Heller's myotomy for achalasia were recruited into the trial. The operative techniques were standardized, and details of these procedures have been reported previously [29–31].

For the cholecystectomy, three trocars were inserted: two 10-mm ports, one at the umbilicus and the other at the left upper quadrant; and one 5-mm port at the right lower quadrant. The specimens were retrieved through the umbilicus. For the fundoplication and the myotomy, five trocars were inserted: two 10-mm ports, one above the umbilicus and the other at the left upper quadrant; and three 5-mm ports, one at the right upper quadrant, one at the epigastrium and the last 3 cm on the left of the midline.

Exclusion criteria eliminated patients who were surgically treated on an emergency basis, those who were unable to evaluate postoperative pain (because of linguistic, visual, or neurologic problems), and those who were unfit to undergo a general anesthesia or laparoscopy. The operations were performed by five surgeons who previously had done at least 40 cholecystectomies or 20 fundoplications. The nature and purpose of the trial were explained to all patients before the operation.

Intraoperative protocol

Randomization, to either warm or cold CO_2 gas using tables of random numbers and sealed envelops, was done in the operating theater after general anesthesia had begun. Preoperative and intraoperative data were collected prospectively by a nurse who did not participate in the postoperative care. The data were reported in a folder kept separately from both patient and postoperative care team.

Anesthesia protocol used thiopental for induction and fentanyl, isoflurance, atracurium, and nitrous oxide for maintenance of anesthesia. During laparoscopy, all patients were placed in a 20° reverse Trendelenburg position. Pneumoperitoneum was delivered via a CO_2 insufflator (Thermoflator® 264320 Karl Storz, Tuttlingen, Germany), and the intra-abdominal pressure was maintained automatically at 14 mmHg. The patients were allocated randomly to receive either warm (warm gas group) or cold (cold gas group) CO_2 gas by the same insufflator.

According to Storz, with the use of warm gas, the temperature is supposed to be raised to approximately 37°C. The temperature of the gas going into the abdomen was measured in fact at 36.2°C (heat loss over the tube of 0.8°C). At the end of the procedure, the subdiaphragmatic area gas temperature was measured by a thermometric probe (Dräger® 8500356 Drägerwerk, Lübeck, Germany) before evacuation of pneumoperitoneium. The probe was introduced through a 5-mm trocar, and its tip had no contact with the abdominal viscera. Then the gas was evacuated according to our routine practice of pressing the abdominal wall while the trocar valve is opened until gas can no longer be heard escaping. We did not use subdiaphragmatic instillation nor trocar wound infiltration with anesthetics. No drain was left in place. After fundoplication, a nasogastric suction tube was maintained 24 h.

The parameters recorded pre- and intraoperatively were patient characteristics (age, gender, body mass index (BMI), and socioprofessional context), the American Society of Anesthesiologists (ASA) score [21], the type and duration of the procedure, the surgeon, the total gas consumption, and the subdiaphragmatic area temperature.

Postoperative protocol

Postoperative analgesia began in the postanesthesia care unit with morphine, 5 or 10 mg depending on the titration of morphine. Afterward, all patients were instructed to request morphine (subdermally) when they complained of pain. No other analgesic was administered.

Shoulder tip pain was considered to be the primary end point. The other types of pain, nausea, vomiting, postoperative ileus, length of hospital stay, and potential postoperative complications, were the secondary end points.

Assessment of pain was done by the staff nurse before a morphine dose was administered. Neither the patients nor the nurse knew the temperature of the gas used (double blinding). Neither the surgeon nor the anesthesiologist collected the postoperative data. The site of pain was recorded: shoulder tip, subcostal, trocar wound, or visceral (deep, difficult to localize inside the abdomen) pain. The degree of pain was assessed at 6 h, 24 h, and 48 h postoperatively by a 100-mm visual analog pain scale (0 = no pain to 100 = unbearable pain) and a 4-point verbal rating scale (0 = none, 1 = slight, 2 = moderate, 4 = severe) at rest, during movement, and while coughing. The amount of analgesics used during hospital stay also was recorded as the third criterion for assessment of pain.

The patients in whom the laparoscopy was converted to laparotomy and the patients who sustained a postoperative surgical complication (bile leakage, peritonitis, intra-abdominal hemorrhage) were secondarily removed from the study.

Sample size calculation and statistical analysis

By taking into account the incidence and intensity of shoulder tip pain after laparoscopic cholecystectomy, which was considered as the primary end point, the prospective calculation of the sample size, aiming to detect at least one standard deviation of difference, with a statistical power of 0.99 and a significance level (two-tailed) of 0.01, showed that at least 49 patients should be included in each group.

Data were expressed as mean (±SD) values. Qualitative data were tested with chi-square (χ^2) analysis. Crossing qualitative and numerical data were tested with Student's *t* test and analysis of variance (ANOVA). When data distributions were not Gaussian or variances were different, the data were tested with Mann-Whitney *U* test or Kruskall-Wallis H test. When patients were their own controls, we used matched-pairs Student's *t* test. Correlations between the criteria of pain assessment were studied by Pearson correlation coefficient or Spearman rank coefficient, and *p* values less than 0.05 were considered significant.

Results

Intake

Between June 1997 and February 1998, 108 patients, who met the inclusion criteria, were recruited into the study and randomized to receive either warm or cold CO_2 gas. Eight patients were excluded secondarily from the study (5 in the warm gas group and 3 in the cold gas group). The reasons for exclusion were conversion to laparotomy (4 patients), postoperative subdiaphragmatic biliary collections (2 patients), technical problems with the insufflator (1 patient), and subsequent refusal of the protocol (1 patient). Eventually, 100 patients were included for comparison of postoperative pain: 49 randomized to receive warm gas and 51 to receive cold gas.

Baseline equivalence

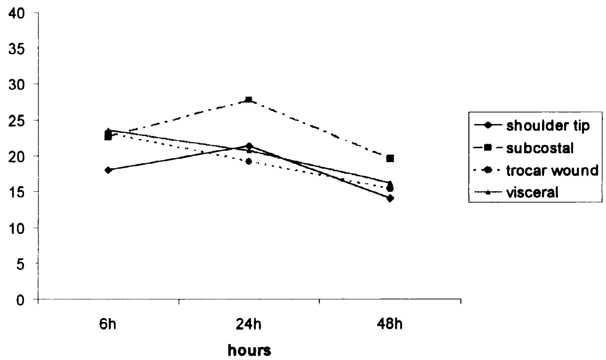
The two groups were well matched for age, gender, BMI, socioprofessional context, ASA score, type and duration of the procedure, and total gas consumption (Table 1). However, one surgeon had performed significantly more procedures with warm gas (11 vs. 3).

Comparison of endpoints

Subdiaphragmatic temperature was 34.4°C in the warm group and 34°C in the cold group, and this difference was not significant ($p = 0.09$). Regarding the methods of postoperative pain assessment, there was an excellent correlation between the three methods used: the visual analog pain scale, the 4-point verbal rating scale, and the amount of analgesics for all pains at each time point ($p < 0.000001$ in all cases).

Figures 1 and 2 show the mean visual scores of the different types of pain in each group. Shoulder tip pain, considered to be the primary end point was significantly less intense than subcostal pain, whether the gas was warm ($p < 0.03$) or cold ($p < 0.01$). When the evolution of pain in the two groups was compared, shoulder tip pain (using the visual analog scale) was significantly more intense in the warm gas group ($p < 0.05$). Subcostal pain also was significantly more intense in this group ($p < 0.05$). However, no statistically significant (NS) difference was found between the two groups for either trocar wound pain (p = NS) or visceral pain (p = NS).

Figures 3 and 4 show the mean visual scores of shoulder



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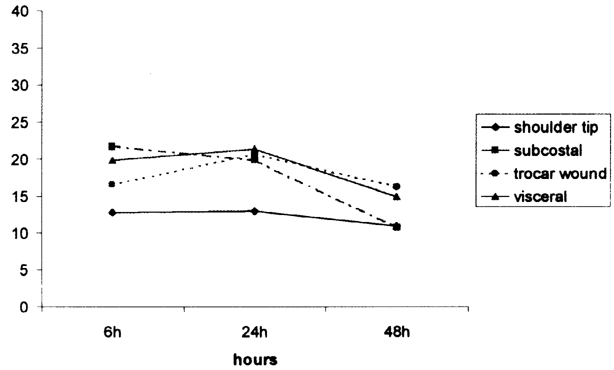

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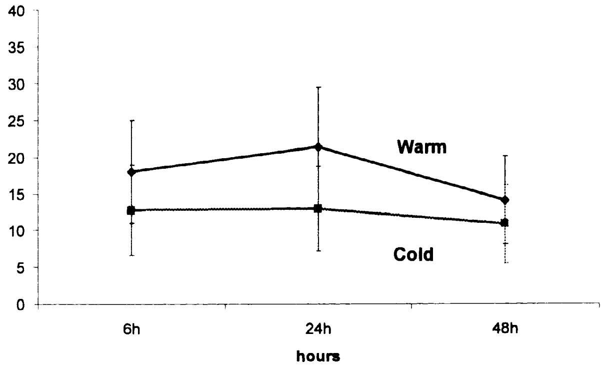

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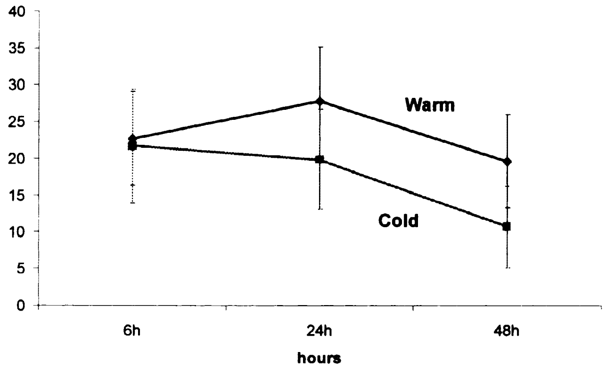

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Fig. 1. Mean visual scores for the four types of pain (shoulder tip, subcostal, trocar wound, and visceral pain) at 6, 24, and 48 h postoperatively in the group with warm gas. Subcostal pain was significantly more intense than shoulder tip pain ($p < 0.001$). VAS, visual analog scale of pain.

Fig. 2. Mean visual scores for the four types of pain (shoulder tip, subcostal, trocar wound, and visceral pain) at 6, 24, and 48 h postoperatively in the group with cold gas. Subcostal pain was significantly more intense than shoulder tip pain ($p < 0.001$). VAS, visual analog scale of pain.

Fig. 3. Mean visual scores of shoulder tip pain at 6, 24, and 48 h postoperatively in the two groups. Pain was significantly more intense in the warm group than in the cold group ($p < 0.05$). VAS, visual analog scale of pain.

Fig. 4. Mean visual scores for subcostal pain at 6, 24, and 48 h postoperatively in the two groups. Pain was significantly more intense in the warm group than in the cold group ($p < 0.05$). VAS, visual analog scale of pain.

tip and subcostal pain (at rest, movement, and coughing) for the two groups at 6, 24, and 48 h. Differences between the two groups regarding the verbal rating scale for shoulder tip and subcostal pains were similar to those of visual scale (i.e., more pain in the warm gas group) ($p < 0.001$). Mean (±SD) amount of morphine also was higher in the warm gas group than in the cold gas group: 31 (±24) mg versus 21 (±20) mg ($p < 0.05$).

Importantly, the surgeon who had performed more procedures with warm gas was associated with significantly less shoulder tip pain ($p < 0.02$), similar subcostal pain ($p = 1.68$), and a similar amount of morphine (p = 0.37) as than the other surgeons.

No significant difference was found between the two groups for the other end points: nausea, vomiting, postoperative ileus, length of hospital stay, and potential postoperative complications. Table 2 shows the values of those secondary end points.

Discussion

Contrary to our initial hypothesis, the results of this trial show clearly that CO_2 gas warming does not reduce shoulder tip and subcostal pains after upper abdominal laparoscopic surgery. Moreover, patients undergoing laparoscopy with warm gas had significantly more pain than patients undergoing laparoscopy with cold gas, suggesting that gas warming may increase postoperative pain.

These findings are in contrast to the results of a previous randomized trial in gynecologic laparoscopy [15]. Korell et al. [15] concluded that "the use of warm CO_2 gas leads to significant reduction of pain." The conflicting results between the current trial and theirs deserve comment. They assumed that the warming of gas reduces irritation of the peritoneum, but the current trial showed that warming is not actual in the abdomen because intraperitoneal temperature was not significantly different whether the gas was warmed or not. This demonstrates, on the one hand, how difficult it is to warm an expanding gas and, on the other hand, that cold gas is in fact heated by the peritoneum [9]. For an inflow temperature of 22°C, the outflow temperature after laparoscopy was of 32°C [9]. Furthermore, another study [28] concluded that cold dry CO_2 gas does not induce hypothermia or abnormal decrease of humidity in the intraperitoneal space. The data of the gynecologic surgery trial [15] surprisingly showed that although the pain scores differed, analgesic requirements were similar. On the contrary, in the current study there was an excellent correlation between the three criteria of pain assessment.

Therefore, in the light of the current study results, it can be stated that at least the gas warming does not reduce

Table 1. Baseline characteristics of patients in both groups and statistical analysis

	Warm gas group (n = 49)	Cold gas group (n = 51)	Statistics
Mean (±SD) age (years)	52 (16)	53 (14)	p = 0.63
Gender ratio male:female	1 : 1.4	1 : 1.4	p = 0.98
Mean BMI[a] (±SD)	26.9 (4)	25.7 (4)	p = 0.09
ASA[b] (score 1 and 2)	43	50	p = 0.15
Socioprofessional context			
Employee	23	21	p = 0.50
Unemployed	3	2	
Retired or pensioner	9	10	
Others	14	18	
Surgical procedure			
Cholecystectomy	29	30	p = 0.98
Fundoplication	18	21	
Heller's myotomy	2	0	
Mean (±SD) duration of the procedure (min)	73 (37)	67 (31)	p = 0.56
Mean (±SD) total gas consumption (l)	187 (126)	179 (130)	p = 0.85

Statistics used chi-square or Kruskall-Wallis tests
[a]Body mass index
[b] American Society of Anesthesiologists

Table 2. Comparison of the secondary end points for the two groups

	Warm gas group (n = 49)	Cold gas group (n = 51)	Statistics
Nausea and vomiting (number of patients)	12	10	p = 0.55
Mean (±SD) length of postoperative ileus (days)	1.4 (0.5)	1.3 (0.4)	p = 0.50
Mean (±SD) length of hospital stay (days)	2.9 (1.3)	2.7 (0.8)	p = 0.60
Number of postoperative complications[a]	1[a]	0	NS

Statistics used chi-square or Kruskall-Wallis H tests
[a] Gastroparesia after a posterior fundoplication
NS, not significant

shoulder tip and subcostal pains after upper abdominal laparoscopic surgery. On the other hand, trocar wound and visceral pains were similar whatever the temperature of gas used, probably because those pains are secondary to parietal and visceral surgical injuries and not to the pneumoperitoneum itself [4]. Results of the current study show also that subcostal pain, which has been considered initially as a secondary end point, appears in fact as an important complaint of patients undergoing upper abdominal laparoscopic procedures.

In this trial, we tried to apply a methodology as rigorously as possible. Risk factors that might confound interpretation of the results were limited. The baseline equivalence of the groups could be stated, in our opinion, even though the data of comparability were skewed by one surgeon who performed more procedures with warm gas. In fact, that surgeon operated on only 14 patients in the current study, and he was not involved with a high level of postoperative pain as compared with the other surgeons on our team. The two groups were well matched for all the other parameters including the operative procedures. Moreover, an unbiased assessment of end points was guaranteed by the double blinding (both the patient and the nurse assessing the pain). Blinding of the surgeon was not possible because the design of the insufflator and inflation tubes could not be identical (in our practice) for the two groups.

The mechanism of postlaparoscopic pain appears to be multifactorial [20]. The CO_2 pneumoperitoneum seems to induce shoulder tip and subcostal pains mostly by a mechanical effect (the subdiaphragmatic gas bubble leading to liver ptosis with stretching of the triangular and coronary ligaments) instead of a chemical effect by a decrease of the intraperitoneal pH [23]. The possible physical effect, suggested by the current study, (i.e., the gas warming as a factor of postoperative pain) remains to be elucidated by further experimental researches because the intraperitoneal temperature at the end of the procedure was not raised by the warming.

Currently, we advocate the use of cold (or normal) CO_2 gas. It could be argued that normal gas may lead to intraoperative hypothermia (particularly for long procedures), but it has been demonstrated that this actually is an insignificant cause of intraperitoneal heat loss [28]. In this matter, prevention of the postlaparoscopy pain remains mandatory.

Despite the encouraging results in gyneacologic surgery [18], the benefits of intraperitoneal anaesthetics (such as bupivacaine) remain controversial. The effectiveness of this method to reduce pain after laparoscopic cholecystectomy has been demonstrated in some studies [3, 8, 22, 32, 33] but negated in others (13, 25–27). Postlaparoscopic pain could be reduced by means of balanced analgesia [14] using NSAIDs [7], intraoperative opiate analgesia, and local anesthetics around the trocar wounds [1], and mainly by removing the residual gas at best with subdiaphragmatic suction drain [11].

Acknowledgments. We are indebted to all the nurses and anesthesists in our department for their active and kind participation in this study.

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