Parietal Analgesia Decreases Postoperative Diaphragm Dysfunction Induced by Abdominal Surgery

A Physiologic Study

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Background and Objectives: The postoperative analgesic strategy may influence the magnitude of the postoperative diaphragmatic dysfunction (PODD) induced by abdominal surgery. The purpose of this physiologic study was to evaluate the effect of continuous preperitoneal wound infusion (CPWI) of ropivacaine on PODD after open colorectal surgery.

Methods: Twenty patients with American Society of Anesthesiologists physical status I or II undergoing open colorectal surgery were prospectively included during 2 consecutive 2-month periods. During the first period, we evaluated 10 consecutive patients who received conventional parenteral analgesia (intravenously administered morphine via patient-controlled analgesia and acetaminophen) without parietal analgesia (control group). These patients were compared with 10 consecutive patients who received conventional parenteral analgesia along with parietal analgesia using CPWI of 0.2% ropivacaine at 10 mL/hr for 48 hrs (CPWI group). Diaphragmatic function was assessed preoperatively and at 24 and 48 hrs postoperatively using the sniff nasal inspiratory pressure test (Psniff). Supplemental intravenously administered morphine boluses were administered as needed before Psniff assessments in the control group to reduce differences in pain intensity.

Results: Demographic and surgical data did not differ between the 2 groups, nor did preoperative Psniff values (71 cm H_2O [SD, 20 cm H_2O] vs 65 cm H_2O [SD,15 cm H_2O] in the control and CPWI groups, respectively). Postoperative Psniff was significantly decreased in the 2 groups, but the reduction was significantly greater in the control group than in the CPWI group both at 24 hrs (−58% [SD, 18%] vs −24% [SD, 19%]; $P = 0.001$) and at 48 hrs (−44% [SD, 31%] vs –11% [SD, 32%]; $P = 0.027$).

Conclusions: Parietal analgesia delivered via a CPWI of ropivacaine reduces PODD induced by open colorectal surgery.

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Intra-abdominal surgery induces significant ventilatory pattern perturbations.[1] These repercussions are mainly related to pain, abdominal muscle injuries, and diaphragmatic dysfunction (Fig. 1).[2] This postoperative diaphragmatic dysfunction (PODD) may last for several days after surgery and may contribute to postoperative pulmonary complications.[2] The mechanism of this PODD is not yet fully understood but definitely seems to be multifactorial.[3] Analgesic strategies have been shown to influence the magnitude of the PODD after abdominal surgery.[4–6]

Our group has recently shown that continuous preperitoneal infusion of ropivacaine (ie, between the parietal peritoneum and the abdominal fascial layers) provides effective analgesia and accelerates recovery after open colorectal surgery.[7] To our knowledge, no study has evaluated the effect of parietal analgesia on the diaphragmatic function after abdominal surgery.

The aim of this physiologic study was to evaluate the short-term effect of continuous preperitoneal ropivacaine wound infiltration on diaphragmatic function after major open colorectal surgery.

METHODS

This physiologic study was approved by the Committee for the Protection of Human Subjects in Biomedical Research. A written informed consent form was obtained from all patients. Inclusion criteria were as follows: patients with an American Society of Anesthesiologists physical status I or II, between 18 and 80 years of age, and scheduled for elective open colorectal surgery performed through a midline periumbilical incision. Exclusion criteria were obesity (body mass index >30 kg/m), inflammatory bowel diseases, significant pulmonary disease, inability to use the patient-controlled analgesia (PCA) device, and lack of understanding and/or impossibility to perform the sniff nasal inspiratory pressure test (Psniff).

Twenty patients were prospectively included during 2 consecutive 2-month periods. During the first period, we evaluated 10 consecutive patients who received conventional parenteral analgesia without parietal analgesia (control group), which consisted of intravenously administered [IV] morphine via PCA and IV acetaminophen 1 g administered 4 times daily. The morphine PCA was set up to deliver a 1-mg bolus with a 5-min lockout time. During the second period, 10 other consecutive patients were included and received parenteral analgesia as well as parietal analgesia with continuous preperitoneal wound infusion (CPWI) of ropivacaine 10 mL/hr for 48 hrs (H48; CPWI group). Except for the wound catheter infusion,

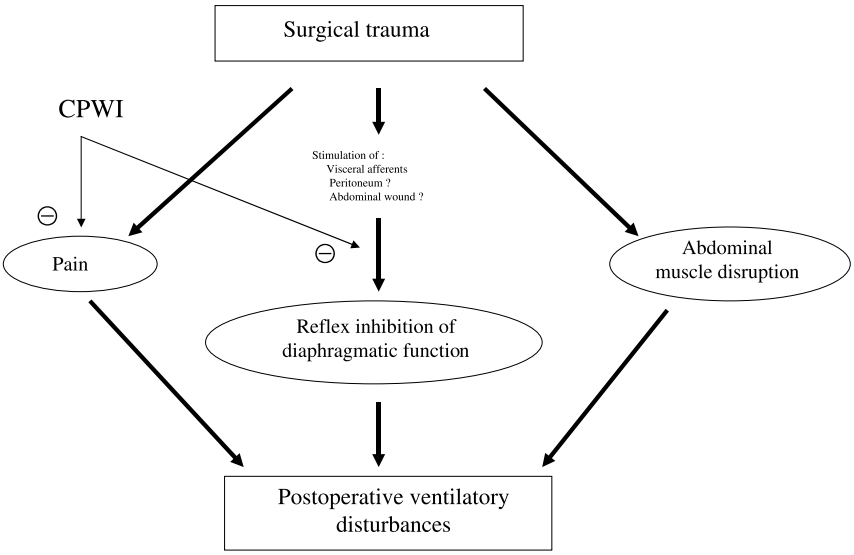

FIGURE 1. Schematic representation of the determinants of postoperative ventilatory disturbances induced by abdominal surgery. The eventual beneficial effects of CPWI are illustrated.

postoperative pain management was strictly identical for all patients. Before surgery, each patient had received information on the PCA device and had to demonstrate the ability to use it effectively.

All patients were premedicated with oral hydroxyzine (1 mg/kg) administered 1 hr before the induction of anesthesia. After arrival in the operating room, standard monitors were used, and general anesthesia was induced using IV thiopental (3–4 mg/kg), sufentanil (0.2–0.3 μg/kg), and atracurium (0.5 mg/kg). After intubation of the trachea, mechanical ventilation was initiated with a mixture of oxygen and 50% N_2O and adjusted to keep end-tidal CO_2 pressure between 30 and 35 mm Hg. Anesthesia was maintained with desflurane and a continuous infusion of atracurium (0.4–0.5 mg/kg per hr) and sufentanil (0.1–0.2 μg/kg per hr). At the end of the procedure, volatile agents were switched off, and 100% oxygen was administered with 8-L/min fresh gas flow. A warming forced-air blanket (Bair-Hugger; Arizant Health Care Inc, Eden Prairie, Minn) covering the upper part of the body was used routinely to prevent intraoperative hypothermia.

In the CPWI group, at the end of the surgery, after closure of the parietal peritoneal membrane with running sutures, the surgeon inserted a 20-gauge multiholed Soaker catheter (On-Q Pain Buster, ref PS12507; I-flow Corp, Lake Forest, Calif) approximately 3 cm from the lower end of the midline incision through an introducer needle, as previously described.[7] Once the wound was closed, a 10-mL bolus of 0.2% ropivacaine was administered through the catheter. A prefilled elastomeric pump (provided with the On-Q kit), set to deliver a 10-mL/hr constant rate during H48, was connected immediately thereafter. The catheter was covered with a transparent dressing.

The primary parameter of evaluation was diaphragmatic function, assessed with a noninvasive and validated method: the Psniff (Fig. 2).[8,9] Measurements were performed preoperatively and at 24 hrs (H24) and H48 postoperatively. Pressure at the nose was measured via an 80-cm catheter held in the nostril by a specific nasal plug (Micro RPM; Micro Medical Limited, Rochester, UK). Nasogastric suction tubes were removed before assessment. The contralateral naris was occluded. Sniffs were performed with the subject in a semisitting position. Maximal inspiratory efforts through the nose were encouraged verbally. Patients were asked to maintain their mouth firmly closed during the inspiration. They were trained until they became familiar with the method. The definite value was the average of 3 repeated consecutive maneuvers. Maneuvers were separated by at least 30 secs of rest. Concomitantly, maximal mouth inspiratory (MIP) and expiratory (MEP) pressures were measured. To reduce the influence of pain in the diaphragm function evaluation, all respiratory measurements were performed in patients with verbal rating scale (VRS) at rest of 3 or less. Overall pain at rest and at mobilization was assessed before the respiratory evaluation using the verbal numerical scale from 0 (no pain) to 10 (worst pain imaginable). At the time of the respiratory assessments, if the patient reported a VRS at rest of greater than 3, supplemental boluses of IV morphine were administered until a VRS of 3 or less was obtained. Morphine consumption was registered at H24 and H48.

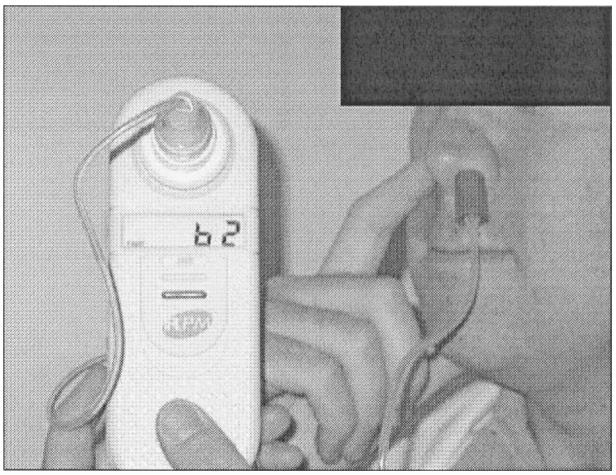

FIGURE 2. Illustration of the sniff-test device in use. The nasal plug is inserted in 1 naris, while the contralateral naris is occluded. The monitor displays the measured inspiratory pressure.

TABLE 1. Demographic Data and Surgical Procedures

	Control (n = 10)	CPWI (n = 10)
Age, y	55 (15)	57 (15)
Sex, no. male/no. female	5/5	5/5
ASA physical status I/II, no. patients	3/7	6/4
Height, cm	168 (8)	168 (10)
Weight, kg	71 (19)	67 (10)
Surgical procedure, n		
Left hemicolectomy	6	8
Right hemicolectomy	2	2
Rectal resection	2	0
Duration of surgery, min	190 (33)	203 (57)
Incision size, cm	21 (6)	21 (6)

Data are presented as mean (SD), unless indicated. No significant difference was found between groups.

ASA indicates American Society of Anesthesiologists.

Statistical Analysis

Sample size was determined according to previous values of variations in Psniff tests between the preoperative and postoperative period.[6] Continuous quantitative variables were analyzed using a 2-tailed Student *t* test. Categorical data were analyzed using a Mann-Whitney *U* test or χ^2 contingency table. Variations in Psniff across the 2 first postoperative days were analyzed using 2-way analysis of variance with adjustment made on the preoperative values, the independent within-subjects variable being the time of evaluation and the intersubject variability being the Psniff values. In case of statistical differences between the 2 groups, post hoc pairwise comparisons were performed (Statview; Abacus Concepts Inc, Berkeley, Calif).

TABLE 2. Preoperative and Postoperative Psniff, MIP, and MEP Values for the 2 Studied Groups

	Control (n = 10)	CPWI (n = 10)	*P* Between Groups
Psniff,* cm H_2O			
Preoperative	71 (20)	65 (15)	NS
H24	31 (17)†	50 (21)‡	0.001
H48	37 (20)†	56 (19)‡	0.027
MIP, cm H_2O			
Preoperative	57 (13)	61 (19)	NS
H24	27 (12)†	41 (16)‡	0.020
H48	43 (18)‡	45 (17)	NS
MEP, cm H_2O			
Preoperative	59 (11)	57 (19)	NS
H24	29 (13)†	36 (15)‡	NS
H48	36 (10)‡	39 (19)‡	NS

*Nasal pressure during a maximal sniff test.

‡$P < 0.05$ in comparison to preoperative values.

†$P < 0.01$ in comparison to preoperative values.

NS indicates not statistically significant.

Results are presented as mean (SD). The threshold for statistical significance was set at $P < 0.05$.

RESULTS

All twenty patients included during the 2 periods of the study fully completed the evaluation. No patient was excluded or withdrew from the study. There were no significant differences between the 2 groups in patient characteristics, surgical procedures (Table 1), and preoperative Psniff, MIP, and MEP values (Table 2).

Individual values of Psniff obtained preoperatively and at H24 and H48 are given in Figure 3A for the control group and in Figure 3B for the CPWI group. Variations in Psniff as a percentage of preoperative values are given in Figure 4. When compared with the control group, Psniff was significantly better preserved in the CPWI group ($P = 0.002$). Pairwise comparison showed a significant difference between CPWI and control groups in Psniff at H24 ($P = 0.001$) and H48 ($P = 0.02$). Postoperative MIP and MEP are given in Table 2.

All patients had a postoperative pain intensity at rest of less than 4/10 on VRS before each ventilatory evaluation. Pain during coughing was significantly higher in the control group than in the CPWI group at H24 (5.5 [SD, 1.4] vs 4.0 [SD, 1.3]; $P = 0.04$) and at H48 (4.7 [SD, 1.6] vs 2.9 [SD, 1.7]; $P = 0.03$). Morphine consumption was 26 mg (SD, 14 mg) versus 18 mg (SD, 9 mg) at H24 ($P < 0.05$) and was 69 mg (SD, 18 mg) versus

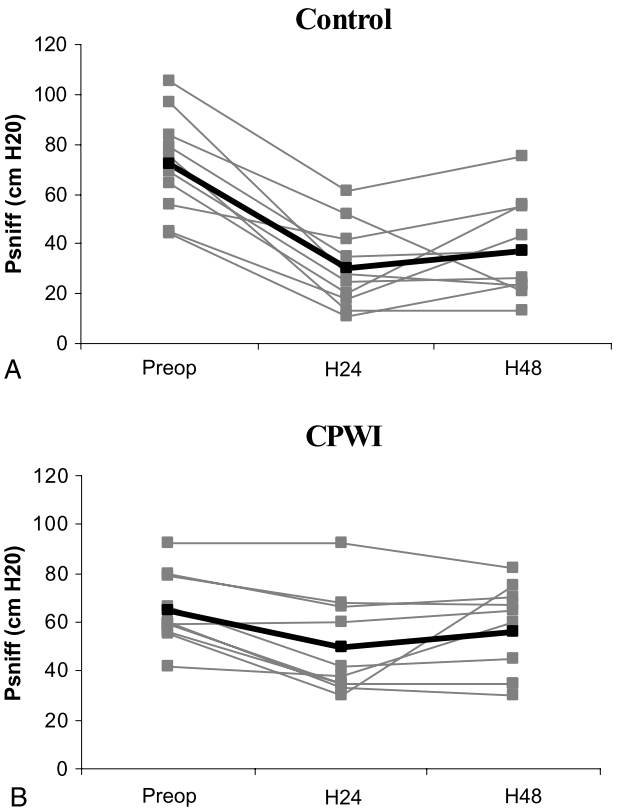

FIGURE 3. Psniff in absolute values in the control group (A) and CPWI group (B). Assessments were made preoperatively and at H24 and H48 postoperatively. Gray thin lines are individual data. Black thick lines represent average values.

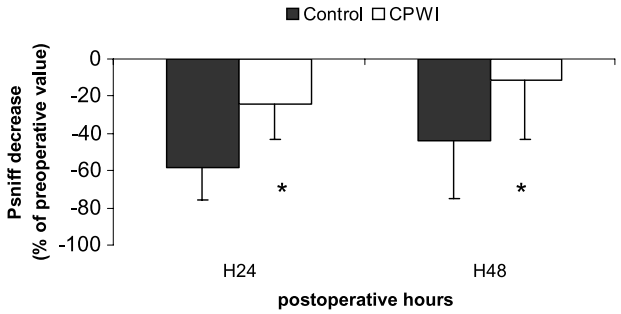

FIGURE 4. Decrease in Psniff in control and CPWI groups, as percentage of preoperative values at H24 and H48 postoperatively. *$P < 0.05$ versus control.

26 mg (SD, 14 mg) at H48 ($P < 0.05$) in the control and CPWI groups, respectively.

DISCUSSION

The main finding of our study is that CPWI of ropivacaine reduced diaphragmatic dysfunction after major open colorectal surgery.

Abdominal surgery triggers diaphragmatic function impairment.[1–3] This is especially important and mainly documented after upper abdominal surgery.[10,11] In our study, and in accordance with the studies by Ford et al,[1] we provide evidence that lower abdominal surgery performed through a midline incision induced a decrease in diaphragmatic performance. This decrease, however, is milder than that observed after upper abdominal surgery.

Postoperative diaphragmatic dysfunction is of multifactorial origin. Postoperative pain has been recognized among the etiologic factors. It has been shown that the parenteral administration of meperidine after upper abdominal surgery increased Psniff in comparison with placebo.[6] Similarly, the use of epidural bupivacaine may reduce the magnitude of PODD.[4,5] Our group showed in a previous report that the continuous infusion of ropivacaine through a multiholed catheter provides adequate pain relief and may accelerate the course of the postoperative recovery.[7] This was a catheter that was positioned by the surgeon at the end of the procedure, between the previously closed parietal peritoneum and the underside of transversalis fascia, along the full length of the wound. In accordance, we found in the current study that pain intensity and morphine consumption were significantly reduced in the CPWI as compared with control group both at H24 and at H48 postoperatively. To eliminate the influence of pain relief on the ventilatory pattern, we took great care to reduce the observed differences in pain intensity between groups, asking the patients in the control group to use their PCA devices before the respiratory evaluation. Indeed, pain intensity at rest did not differ between the 2 groups before the evaluation. However, pain during respiratory movements, which was still lower in the CPWI group than in the control group, could play a role in the current results (Fig. 1). Because it has been shown that morphine does not have any action by itself on inspiratory muscle function,[12] our results cannot be ascribed to the observed difference in morphine consumption.

However, the relative contribution of pain in the occurrence of PODD remains debated. Using epidural fentanyl administration, Simonneau et al[13] reported significant PODD after upper abdominal surgery despite optimal pain relief. Another important factor determining the PODD is a reflex inhibition of phrenic activity.[1–3] Afferent pathways of this neural reflex remain unclear, although intra-abdominal viscera and peritoneal injury seem to be involved.[1] It has been shown that the stimulation of the mesenteric region in anesthetized cats, corresponding to peritoneal afferents, immediately triggers diaphragmatic dysfunction.[14] This is further supported by the observation that lower abdominal surgery without peritoneal injury (eg, urological and gynecologic procedures) does not induce PODD despite abdominal pain.[10] Furthermore, laparoscopic abdominal surgery, in reducing parietal damage, induces less PODD than open abdominal surgery.[15,16] We thus could speculate that the blockade of deep parietal wound afferents and possibly parietal peritoneal inputs with a local anesthetic continuous infusion may have contributed, at least partly, to reduce the magnitude of this neural phrenic inhibitory reflex (Fig. 1). The possibility of improving the postoperative ventilatory status by the use of repeated preperitoneal boluses of bupivacaine has been previously addressed for subcostal incisions after cholecystectomy or splenectomy.[17] In this study, forced vital capacity was reduced by more than 50% after the surgery, but bupivacaine injection through the preperitoneal catheter was followed by a significant improvement during the first 3 postoperative days, despite a lack of analgesic effect.[17]

Postoperative diaphragmatic dysfunction can be estimated using several tests of varying complexity and invasiveness.[18] Sniff nasal pressure test is a noninvasive and validated method to assess diaphragmatic dysfunctions.[8,9] It has been successfully used in the postoperative period.[6] The reliability of our sniff-test measurements was attested by the preoperative values, which are similar to those commonly found in healthy subjects. In contrast, the measurement of MIP is more complex to perform and subject to wide variations. Furthermore, it should be noted that, unlike Psniff, MIP does not accurately discriminate for diaphragmatic function during global inspiratory depression.[9] As described in an animal model, diaphragmatic paralysis induced by mesenteric stimulation is associated with an increased activity of external intercostal muscles.[14] Although the relative contribution of intercostal muscles was not specifically addressed in the current study, Psniff has been considered an accurate measurement of diaphragmatic function. Regarding MEP, which does not reflect the diaphragmatic activity, the observed variations at H24 may be mostly related to surgical trauma to the abdominal muscles.

The major limitation of the present study is the sequential rather than randomized method of allocation. However, evidence of causality is reinforced by the homogeneous demographic data between the 2 groups. Although it cannot be excluded that the lack of double-blinding may have skewed the results, it should be stressed that ventilatory pressure parameters are actually objective measurements.

In conclusion, parietal analgesia provided by continuous preperitoneal infusion of a local anesthetic reduces the PODD after open colorectal surgery. This beneficial effect could be related not only to analgesia, but also to the blockade of peritoneal afferents involved in the reflex diaphragmatic dysfunction induced by intra-abdominal surgery.

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