Surg Endosc (1997) 11: 707–710

Surgical Endoscopy

Acid–base balance alterations in laparoscopic cholecystectomy

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Received: 25 January 1996/Accepted: 29 May 1996

Abstract
Background: The purpose of this study is to determine alterations of acid–base balance originated by pneumoperitoneum with CO_2. Influence of other factors such as anesthetic technique, duration of procedure, and volume of CO_2 insufflated has also been analyzed.
Methods: Some 132 patients were divided in three groups according to anesthetic technique used. Arterial blood gases were determined before pneumoperitoneum, at 20 min after it, and every 30 min, until procedure's end, and in postoperative period up to a total of four samples.
Results: Pneumoperitoneum originated a fall of pH ($p < 0.001$), ion bicarbonate ($p < 0.001$), and base excess ($p < 0.001$) and an elevation of $PaCO_2$ ($p < 0.001$). No correlation was found between these changes and duration of pneumoperitoneum or amount of CO_2 insufflated. Changes were fundamentally of a metabolic type. There were no statistically significant differences among anesthetic techniques.
Conclusions: In conclusion, pneumoperitoneum with CO_2 originates alterations of the acid–base balance, mostly of a metabolic type. This could mean that besides CO_2 absorption, there is a tissular hypoperfusion due to the increase of abdominal pressure.

Key words: Acid–base balance — Laparoscopic surgery — Pneumoperitoneum

Digestive laparoscopic surgery is one of the latest endoscopic techniques to be applied and offers certain advantages compared to the traditional surgical ones. Among them are a better aesthetic result and a faster postoperative recovery period that allows an earlier hospital discharge of the patient [6, 16]. However, compared to other laparoscopic techniques, and regarding anesthetic, the longer insufflations periods usually required in digestive laparoscopic procedures may imply some added risks [13, 19].

Abdominal insufflation with carbon dioxide (CO_2) for laparoscopic techniques implies some degree of hypercapnia and respiratory acidosis. This, which in gynecological techniques is almost of no clinical relevance [9, 14] (because short insufflation periods are used in usually young and healthy women) may imply a greater risk in digestive laparoscopic procedures. The longer insufflations periods, in patients not always young and healthy, may lead to an important imbalance of the acid–base balance (ABB) due to an increase in abdominal pressure and CO_2 absorption through the peritoneum serosa [11, 13]. Controversy exists, among different authors, over which factor in the ABB is basically disrupted—the respiratory or the metabolic one. In this situation, anesthetic drugs may play some sort of role, given their respiratory and hemodynamic effects. Our study analyzes the ABB alterations produced by laparoscopic cholecystectomy and its influence on the immediate postoperative period. The influence of other factors employed in each procedure—such as the duration, total amount of CO_2 and anesthetic technique—is also analyzed.

Materials and methods

A prospective study was carried out with 132 patients referred for laparoscopic cholecystectomy. Patients included were previously selected according to their pathology—only uncomplicated biliary lithiasis, and ASA I and ASA II (anesthetic risk) patients were included. Those who needed of a laparotomy conversion for their cholecystectomy were also excluded. Patients were divided into three groups, in a randomized way, according to the anesthetic technique employed. In group I nitrous oxide/oxygen (O_2) (60%/40%) and in group II isoflurane 1% in O_2/air (FiO_2 0.4) were administered. In group III propofol in continuous infusion (7 mg $kg^{-1}h^{-1}$ the first 30 min and then 5 mg $kg^{-1}h^{-1}$) with O_2/air (FiO_2 0.4) was employed. Other drugs employed were similar in all three groups.

As preanesthetic medication, droperidol (30 μg kg^{-1}), atropine (0.01 mg kg^{-1}), and fentanyl (2 μg kg^{-1}) were intravenously administered. Anesthetic induction was achieved with thiopental in groups I and II (5–6 mg kg^{-1}) and with propofol in group III (2 mg kg^{-1}). For intubation, succinylcholine (1 mg kg^{-1}) was administered. A bolus of atracurium followed by a continuous infusion (5 mg $kg^{-1}h^{-1}$) was employed to obtain muscular relaxation. Fentanyl (3–5 ug $kg^{-1}h^{-1}$) was used as analgesic. For mechanical ventilation a volumetrical respirator (EXCEL 210 Ohmeda) was em-

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Table 1. Patient group characteristics

	Global	N_2O	Isoflurane	Propofol
Patients (number)	132	44	44	44
Age (years)	46 ± 12	46 ± 12	47 ± 13	46 ± 13
Sex (M/F)	27/105	9/35	9/35	9/35
Weight (kg)	66 ± 11	68 ± 11	67 ± 10	64 ± 11
ASA (I/II)	76/56	25/19	23/21	28/16
Intraabdominal pressure (mmHg)	14 ± 1.3	14 ± 1.3	14 ± 1.1	13.7 ± 1.5
CO_2 volume (l)	57 ± 17	58 ± 16	57 ± 16	56 ± 18
Surgery duration (min)	99 ± 35	101 ± 33	99 ± 34	96 ± 38

ployed. To better appreciate the peritoneum absorption of CO_2, respiratory parameters were not modified during the procedures if not necessary, being previously established in a tidal volume of 10 ml kg^{-1} and a respiratory rate = 12 breaths/min. Intraoperative venous fluid therapy was supported with crystalloid solution at a infusion rate of 6 ml $kg^{-1}h^{-1}$, avoiding lactate-containing ones to prevent altering the ABB. At the end of the procedure, all the patients were translated to the recovery room awake, exubated, and with spontaneous breathing.

Pneumoperitoneum was established with CO_2 insufflated through a Veress needle, with an intraabdominal pressure of between 13 and 15 mmHg, sustained through all the surgical procedure. Patients were positioned in dorsal decubitus with a slight reversed Trendelenburg and with the lower limbs in the ''French'' position.

Arterial blood gases were obtained previously to the pneumoperitoneum, 20 min after it, and then every 30 min until the procedure was finished (PP, P20, P60, P90, P120). Additional measures were obtained at recovery-room arrival and then every 30 min until four samples were taken (R, R30, R60, R90).

Regarding criteria of acid–base changes, a blood pH range of 7.35–7.45 was considered normal—greater and lower values were considered alkalotic and acidotic, respectively. Alkalosis was considered of respiratory origin when $PaCO_2$ decreased under 35 mmHg with a normal serum bicarbonate and of metabolic nature when $PaCO_2$ was normal and bicarbonate was above 24 mEq/l. Acidosis was considered respiratory in origin when $PaCO_2$ was greater than 40 mmHg with a normal bicarbonate and as metabolic acidosis when there was a lowering of the pH due to a decreased level of bicarbonate and $PaCO_2$ was within normal limits. Mixed acidosis and alkalosis where considered when both parameters were simultaneously altered.

For statistical analysis a chi-square test was used for qualitative variables and the Student's *t* test was used for the quantitative ones. ANOVA has been used to compare groups, applying a Newman-Kuhls test if the contrast was significant. Pearson's correlation coefficient was calculated to determine the correlation between two quantitative variables. Only the determinations at recovery-room arrival were employed to correlate the blood analysis changes with the duration of the procedures and the total amount of CO_2 used. Values were expressed in terms of their mean and standard deviations. Significance level was established at 0.05, accepting the hypothesis for lower values and rejecting it for higher ones.

Results

Age, sex, weight, anesthetic risk, intaabdominal pressure, total amount of CO_2 insufflated, and duration of procedures (Table 1) were comparable between groups.

Blood pH lowered significantly ($p < 0.001$) with pneumoperitoneum from its first determination, reaching its lowest level at the recovery-room arrival determination ($p < 0.001$). From this moment on, a significant gradual increase was observed, with nearly normal values 90 min later. No correlation was found between these parameters and duration of procedures ($r = 0.083$) or total amount of CO_2 used ($r = 0.012$). No significant differences were found between the anesthetic groups (Fig. 1).

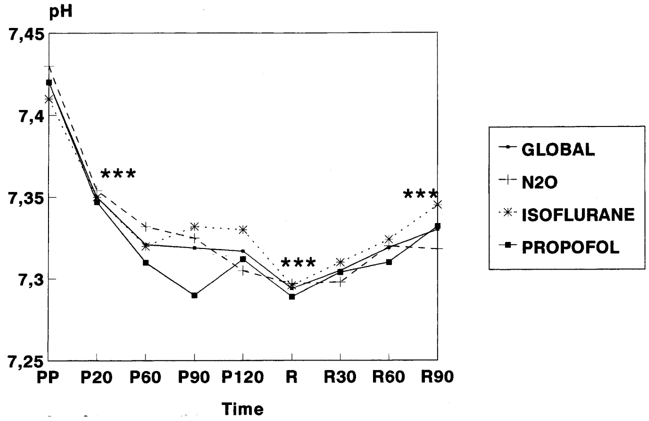

Fig. 1. Illustration of changes in pH from prepneumoperitoneum phase (PP), during pneumoperitoneum (P20–P120), and in postoperative period in recovery room (R–R90). Falls in a significant way ($p < 0.001$) with establishment of pneumoperitoneum (P20) and at arrival in the recovery room (R). At 90 min after the postoperative process (R90), values reach close to normal.

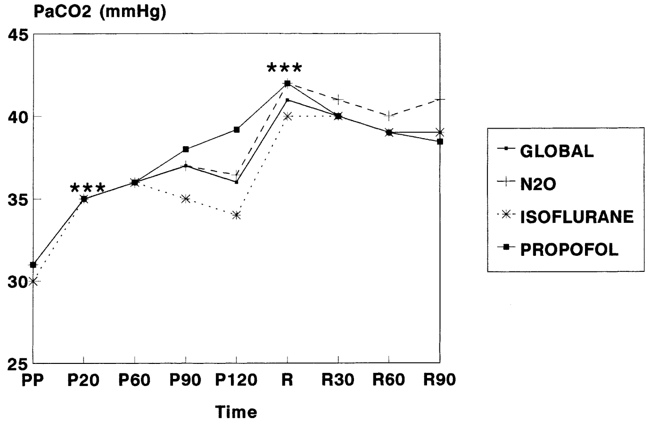

Fig. 2. Illustrates $PaCO_2$. A statistically significant increase is observed ($p < 0.001$) with production of pneumoperitoneum (P20) and on its withdrawal (R). During this time, a stabilization is observed.

$PaCO_2$ increased significantly with pneumoperitoneum ($p < 0.001$). There was a slight trend to increase thereafter, and it stabilized after 60 min; most patients kept CO_2 within normal levels. At recovery-room arrival a maximum increase first ($p < 0.001$) and then a progressive decrease were observed (Fig. 2). No correlation was found between the $PaCO_2$ and duration of surgery ($r = 0.1312$) or total amount of CO_2 used ($r = 0.1981$).

None of the patients presented hypercapnia before the pneumoperitoneum. Thirty-six patients (27%) presented it during pneumoperitoneum and 74 (56%) at recovery-room stage.

Bicarbonate decreased significantly with pneumoperitoneum ($p < 0.001$) insufflation and continued to decrease all along it. At recovery-room arrival an increase ($p < 0.01$) was initially observed and then posterior progressive normalization (Fig. 3). No correlation was found between plasma bicarbonate at recovery-room arrival and duration of procedure ($r = 0.0244$) or total amount of CO_2 used ($r = 0.1988$).

Base excess also decreased significantly during pneu-

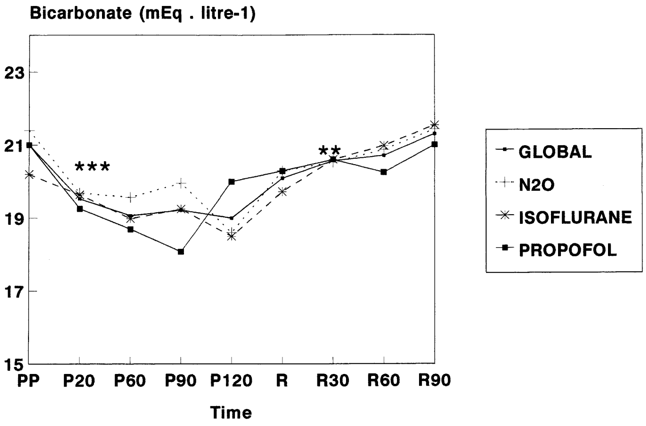

Fig. 3. Illustrates changes observed in bicarbonate ion. A statistically significant fall is observed with pneumoperitoneum ($p < 0.001$) continued throughout it. There is an increase ($p < 0.01$) with posterior progressive normalization in the immediate postoperative time (R–R90).

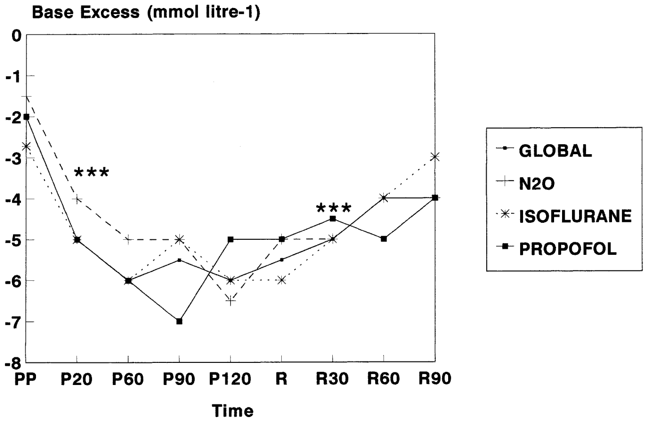

Fig. 4. Illustrates the changes in base excess. With establishment of pneumoperitoneum and throughout it (P20–P120), a statistically significant drop is observed ($p < 0.001$); a raise occurs after its withdrawal ($p < 0.001$) in recovery room (R–R90).

moperitoneum ($p < 0.001$), but normalized ($p < 0.001$) during the recovery period (Fig. 4). No correlation was found between these values and duration of procedure ($r = 0.255$) or total amount of CO_2 used ($r = 0.1514$).

Hemodynamically, during the pneumoperitoneum period there was a significant increase in mean arterial pressure, basically due to an increase in the diastolic arterial pressure.

Arterial blood gases obtained previous to pneumoperitoneum insufflation showed 28 patients (21%) with respiratory alkalosis and three patients (2%) with metabolic acidosis. During insufflation 88 patients (67%) developed some type of acidosis; ten (8%) respiratory, 58 (44%) metabolic, and 27 (21%) mixed; seven patients developed more than one type of acidosis. At recovery-room arrival the acidosis rate increased to 89% (118 patients): 16% respiratory, 42% mixed with a greater respiratory component, and 36% metabolic, the only type whose rate decreased. No significant differences were found between anesthetic groups at any period. Percentage data of each group are shown in Table 2.

Table 2. Alterations of acid–base balance

Acidosis	PPN	PN	Recovery
Respiratory	0	10(8%)	21(16%)
Metabolic	3(2%)	58(44%)	47(36%)
Mixed	0	27(21%)	55(42%)
Total	3(2%)	88(67%)	118(89%)

Discussion

Longer-duration procedures such as are usually needed for digestive laparoscopic surgery, could cause an important alteration of the acid–base balance due to increase in intraabdominal pressure and CO_2 absorption through the peritoneum serosa. According to some authors, the consequences could be hypercapnia and respiratory acidosis [2, 9, 11, 13, 14, 17]. Our study results, however, differ significantly, not only quantitatively but qualitatively, from other authors.

In our study, we have been able to determine that pneumoperitoneum production with CO_2 at a limited and constant intraabdominal pressure, in healthy patients (ASA I and II), produces significant ABB alterations such as a decrease in pH, bicarbonate, and base excess, and an increase of $PaCO_2$. Consequently, a high incidence of acidosis was observed—67% of patients in our series. This means a statistically significant difference when compared with the acidosis rate in previous stages (2%). Metabolic acidosis was the predominant type observed, as has been reported in other series [3, 8, 10]. Thus, during the CO_2 insufflation period, 44% of patients presented a pure metabolic acidosis, and a 21% a mixed type, with only 8% pure respiratory. In spite of the global increase of $PaCO_2$ during this period, most of the patients (72%) kept it within normal values.

With pneumoperitoneum deflation, these changes were exacerbated; blood pH reached the lowest values and $PaCO_2$ the highest ones. Acidosis increased to 89%, but with important qualitative changes: The respiratory type rose to 16%, the mixed type rose to 42%, and the metabolic type dropped to 36%.

Some authors have stated that changes of pH and $PaCO_2$ produced during pneumoperitoneum follow a progressive tendency, decreasing or increasing respectively, in regard to the time and the total amount of CO_2 used [2, 11, 13]. The fact, in our study, that the greater rise in $PaCO_2$ is observed at pneumoperitoneum insufflation and deflation, with an intermediate stable period, suggests that CO_2 absorption is mainly produced in those two moments. This is supported by the lack of correlation between ABB alterations and the total amount of CO_2 used or the procedure duration, as has also been reported by other series [1, 12, 15]. This could be explained in two ways: first, because patients are kept in hyperventilation, and second, because intraabdominal hyperpressure may produce compressive mechanical phenomena over capillaries, limiting CO_2 absorption [1, 7, 12, 15].

The metabolic component of acidosis observed during pneumoperitoneum in this study has higher significance than respiratory factor. Critchley et al. has explained this fact as a decrease of cardiac output and consequently as a decrease in peripheral perfusion. Other reports support this finding. Metabolic changes could thus be justified by ischemic phenomena induced by the increased intraabdominal pressure, as has been established in other studies. Thus Kotzampassi et al. [10] used helium vs CO_2 in their experimental study to differentiate mechanical hyperpressure effects from the CO_2 absorption ones. During peritoneal insufflation an increase in portal and inferior cava vein pressure ($p < 0.0001$), intestinal hypoperfusion with a decrease of 50% on jejunal blood flow ($p < 0.0001$), and tissular acidosis with a decrease in intramural jejunal pH from 7.4 to 6.8, were noticed in both groups, showing that tissular ischemia is inescapable. Furthermore, only in the CO_2 group was an increase in PCO_2 levels in portal and inferior cava vein blood and arterial and mixed venous blood noticed. Ishizaki et al. [7] have noticed increases in portal and inferior cava vein pressures and a decrease in splachnic blood flow due to the increase in abdominal pressure. Joris et al. [8] have shown an increase in lactate levels during laparoscopic periods, which supports the presence of an anaerobic metabolism, probably due to ischemia tissue phenomena.

Once the pneumoperitoneum was deflated, acidosis showed marked modifications in respect to level, rate, and type. Parameters measured at recovery room showed the lowest levels of blood pH, with a significant increase in acidosis rate in up to 89% of patients, especially of respiratory mechanism. These findings could be explained by the absence of mechanical hyperventilation; by the postoperative ventilatory depression; by an increase in absorption of CO_2 due to cessation of the mechanical factor; and by progressive draining of the deposits of CO_2, up to basal values [4, 5, 18].

Regarding influence of anesthetic technique on ABB alterations, no significant differences have been found between the three groups in our study. For this reason, we think the changes observed are exclusively due to pneumoperitoneum.

In conclusion, pneumoperitoneum with CO_2 at limited and constant pressure causes significant ABB alterations, basically of a metabolic type. This means that beside the CO_2 absorption, phenomena of tissular hypoperfusion due to an increase in the intraabdominal pressure also play a role. No correlations were found between ABB alterations and the duration of procedure or total amount of CO_2 used. Not even the anesthetic technique influenced the results. In healthy patients, these ABB alterations did not have clinical repercussions.

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