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SURGICAL ENDOSCOPY
and Other Interventional Techniques

Anesthesiologic aspects of laparoscopic fundoplication for gastroesophageal reflux in children with chronic respiratory and gastroenterological symptoms

G. Mattioli,[2] G. Montobbio,[2] A. Pini Prato,[1] P. Repetto,[1] C. Carlini,[1] V. Gentilino,[1] M. Castagnetti,[1] S. Leggio,[1] M. Della Rocca,[2] Z. Kotitsa,[2] V. Jasonni[1]

[1] Department of Pediatric Surgery, University of Genoa, Giannina Children's Hospital, Largo G Gaslini 5, 16147 Genova, Italy
[2] Division of Anaesthesiology, Giannina Children's Hospital, Largo G Gaslini 5, 16147 Genova, Italy

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Abstract
Introduction: During the past three decades laparoscopy has significantly improved. As fundoplication extensively benefits by the great advantages of the minimally invasive approach, many surgeons chose laparoscopic fundoplication for the treatment of gastroesophageal reflux in adults and children as well. Pneumothorax, cardiovascular collapse, hypoxia, and hypercarbia are some of the anesthesiologist's principal fears during carbon dioxide insufflation. Thus, monitoring cardiovascular and respiratory status is mandatory to early detect any complication and to maintain a proper balance during pneumoperitoneum.
Materials and methods: At Gaslini Children's Hospital we performed a prospective nonrandomized study aimed at describing the main cardiorespiratory changes produced by pneumoperitoneum in 33 pediatric patients operated on by laparoscopic fundoplication between January 2000 and June 2001. Patients were divided into two groups; namely, group A and group B. Group A included 14 patients with chronic respiratory symptoms, and group B included 19 children who preoperatively mainly emphasized gastrointestinal symptoms. We monitored intraoperative cardiorespiratory status, timed length of surgery, and described intraoperative complications.
Results: No significant cardiovascular changes occurred during carbon dioxide insufflation. Partial oxygen saturation remained still in all the patients. End tidal CO_2, meanly higher in group A children, increased in all the patients after pneumoperitoneum creation, but never exceeded 45 mmHg. Similarly, peak inspiratory pressure increased in all the patients, but was always maintained within acceptable values. Finally, group B patients required a harder and slower surgery, whose length seems to be negatively influenced by age. No intraoperative complication occurred.
Conclusions: Carbon dioxide insufflation does not impair cardiovascular function, if intraabdominal pressure is maintained lower than 10 mmHg nor does it interfere with gas exchanges. Pneumoperitoneum slightly reduces ventilatory function, mainly in respiratory patients with various degrees of underlying bronchopulmonary impairments, but this effect is easily correctable. Thus, laparoscopic fundoplication is feasible and safe in both respiratory and gastroenterological patients, although surgery is easier and faster if periesophagitis is less evident.

Key words: Laparoscopy — Fundoplication — Pneumoperitoneum — Anesthesiology — Nissen — Gastroesophageal reflux

Correspondence to: G. Mattioli

During the past three decades laparoscopy has significantly improved [1, 5, 8, 16]. However, since the beginning, great skepticism has surrounded this surgical field. The feasibility of certain operations as well as the cardiorespiratory impact of pneumoperitoneum represented important worries concerning laparoscopy [9, 17]. Nevertheless, thanks to technical innovations and improvements, a great variety of operations can now be performed by a minimally invasive approach in adults and children as well [11]. Among the whole spectrum of techniques, fundoplication extensively benefits by the great advantages of laparoscopy. Thus, many surgeons resort to this approach for the treatment of gastroesophageal reflux disease (GERD) [2, 10].

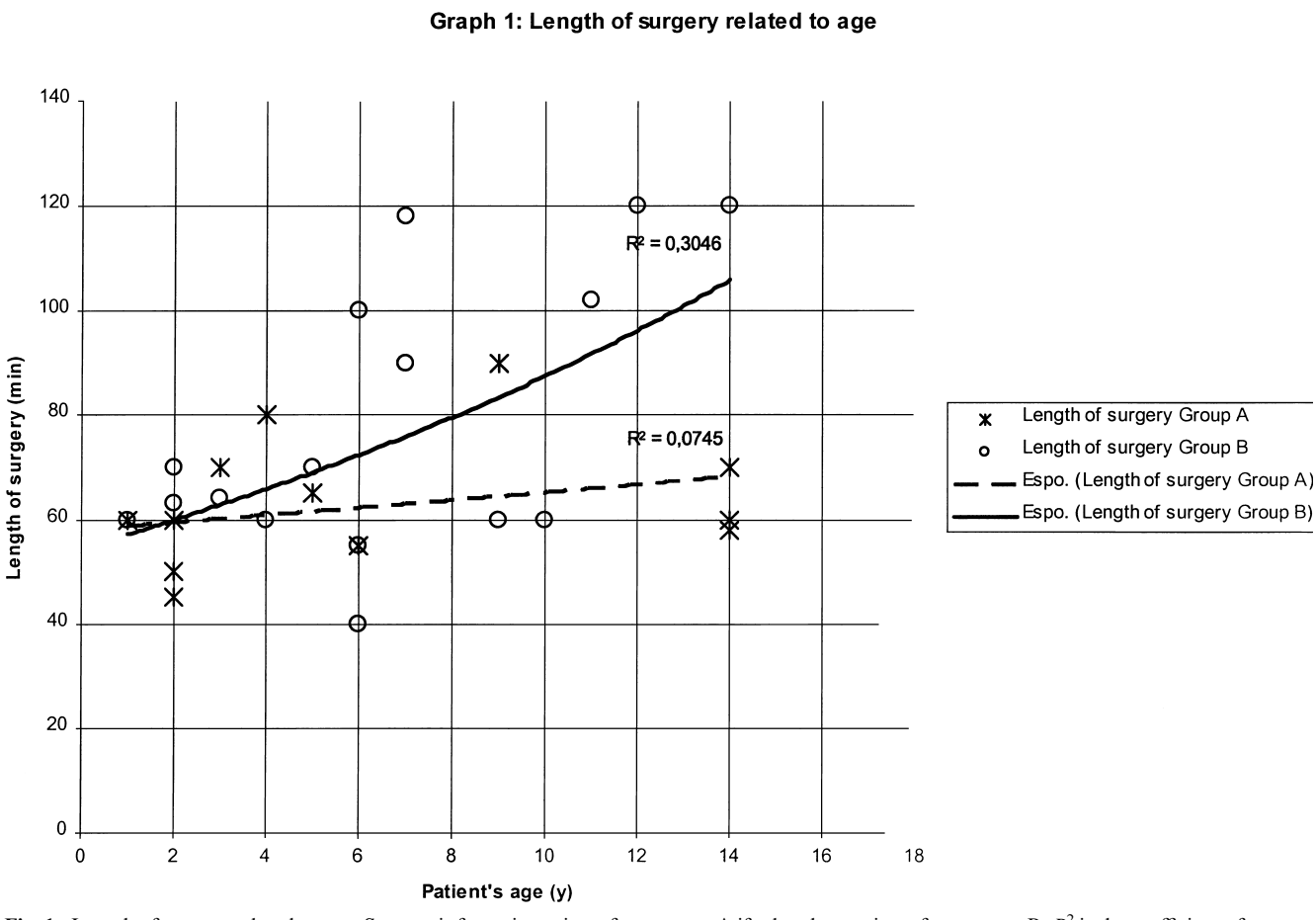


Fig. 1. Length of surgery related to age. Surgery is faster in patients from group A if related to patients from group B. R^2 is the coefficient of a curve which expresses the correlation between age and length of surgery in the two groups. In group B, R^2 is four times higher than in group A. Age influences the length of surgery mainly in patients with gastroenterological symptoms.

As important series of laparoscopic fundoplication grew, the main complications began to be summarized, analyzed, and discussed and the ancient doubts have been investigated. Subcutaneous emphysema, perforation of intestinal loops, and hemorrhage represent important complications related to minimally invasive approaches [4, 12]. Pneumothorax, cardiovascular collapse, hypoxia, and hypercarbia are some of the anesthesiologist's principal fears [15, 18].

Monitoring cardiovascular and respiratory status is thus mandatory for early detection of any complication and to maintain a proper balance during pneumoperitoneum. This necessarily includes electrocardioscopy, noninvasive blood pressure monitoring, pulse oximetry, and capnography [14].

Rarely, invasive monitoring, such as the placement of an indwelling arterial catheter or a transesophageal color-Doppler probe, has been used to better evaluate cardio-respiratory changes in restricted series of high-risk patients [3, 7, 13, 19].

On the ground of these considerations, we performed a prospective, nonrandomized study aimed at describing the main ventilatory and hemodynamic changes related to pneumoperitoneum in a homogeneous series of pediatric patients who underwent laparoscopic Nissen–Rossetti fundoplication for the treatment of gastroesophageal reflux disease (GERD).

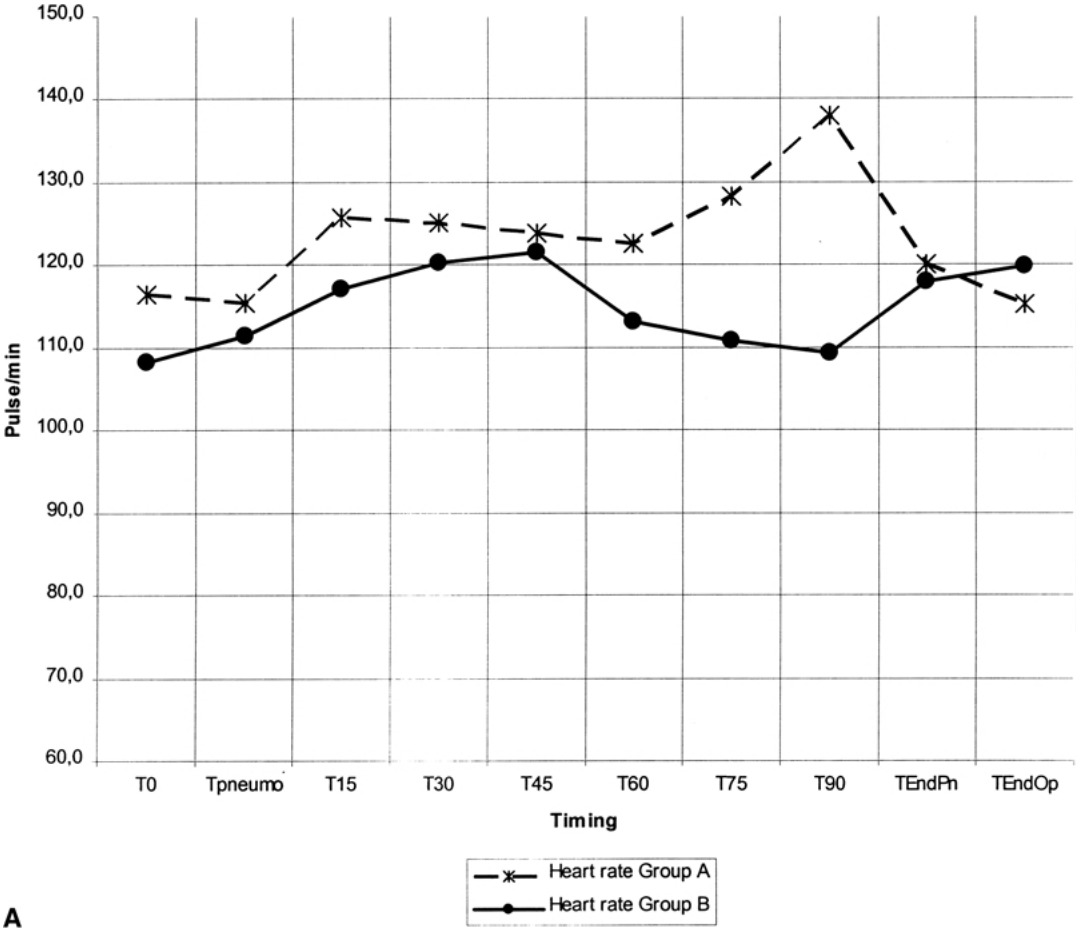
Table 1. Main features of all the patients from the series. Group A and B patients have similar characteristics

		Age (years)	Weight (kg)
All patients	Mean	6.1	24.3
Group A	Mean	5.6	23.3
Group B	Mean	6.6	25.3
	Min	1.0	8.0
All patients	Max	14.0	80.0
	Median	5.0	18.0
	Min	1.0	8.0
Group A	Max	14.0	65.0
	Median	4.0	17.0
	Min	1.0	10.0
Group B	Max	14.0	80.0
	Median	6.0	20.0

Materials and methods

Thirty-three pediatric patients with GERD were included in this study between January 2000 and June 2001; 23 patients were males and 10 were females (male to female ratio, 2.3:1). Mean age at operation was 6 years ±4.2 (median, 5), and mean weight 24 kg ±17 (median, 18) (Table 1).

A preoperative complete gastroenterological and respiratory workup was performed, including 24-h double lumen esophageal pHmetry, upper gastrointestinal barium meal, esophageal manometry, and endoscopy with biopsy. In case of respiratory symptoms, a bronchoscopy and bronchoalveolar lavage with cellular studies were



A

Fig. 2. A Heart rate during surgery. Heart rate slightly increases during pneumoperitoneum with no differences between the two groups, and during carbon dioxide insufflation. Surgery took more than 90 min in only five patients. Thus, T90 data are hardly interpretable and are not statistically significant. Continued on page 562.

performed. CT scans were performed in case of recurrent focal pneumonia to assess the lesions and to exclude bronchiettasia. Pulse oximetry [partial oxygen saturation (%) and pulse rate] was used to check respiratory status before surgery.

On the ground of preoperative symptoms, patients were divided into two groups, namely group A and group B. Group A included 14 patients with respiratory symptoms (3 female and 11 male; mean age, 5.6 years ± 4.8; mean weight, 23.3 kg ± 17.8) and group B included 19 patients with typical gastroenterological symptoms (7 female and 12 male; mean age, 6.6 $\pm$ 3.8; mean weight, 25.3 kg ± 18.3).

Patients from group A suffered from asthma (bronchial increased responsiveness to various allergenic or physical stimuli), recurrent bronchopneumonia, inhalation, recurrent laryngospasm, and other respiratory impairments. Patients from group B complained of typical symptoms of GER (vomiting, pyrosis, burping, sialorrhoea, etc.) with various degrees of esophagitis.

We excluded from this study all the patients with neurological impairments or associated anatomical abnormalities in order to reduce the risk of bias in the interpretations of the results.

Indications to surgical treatment were different in the two groups: Group A patients underwent initial medical therapy with proton pump inhibitors (omeprazole) and prokinetics (domperidone). Laparoscopic Nissen–Rossetti fundoplication was performed because of severe respiratory impairments correlated to GER nonresponsive to conservative treatment.

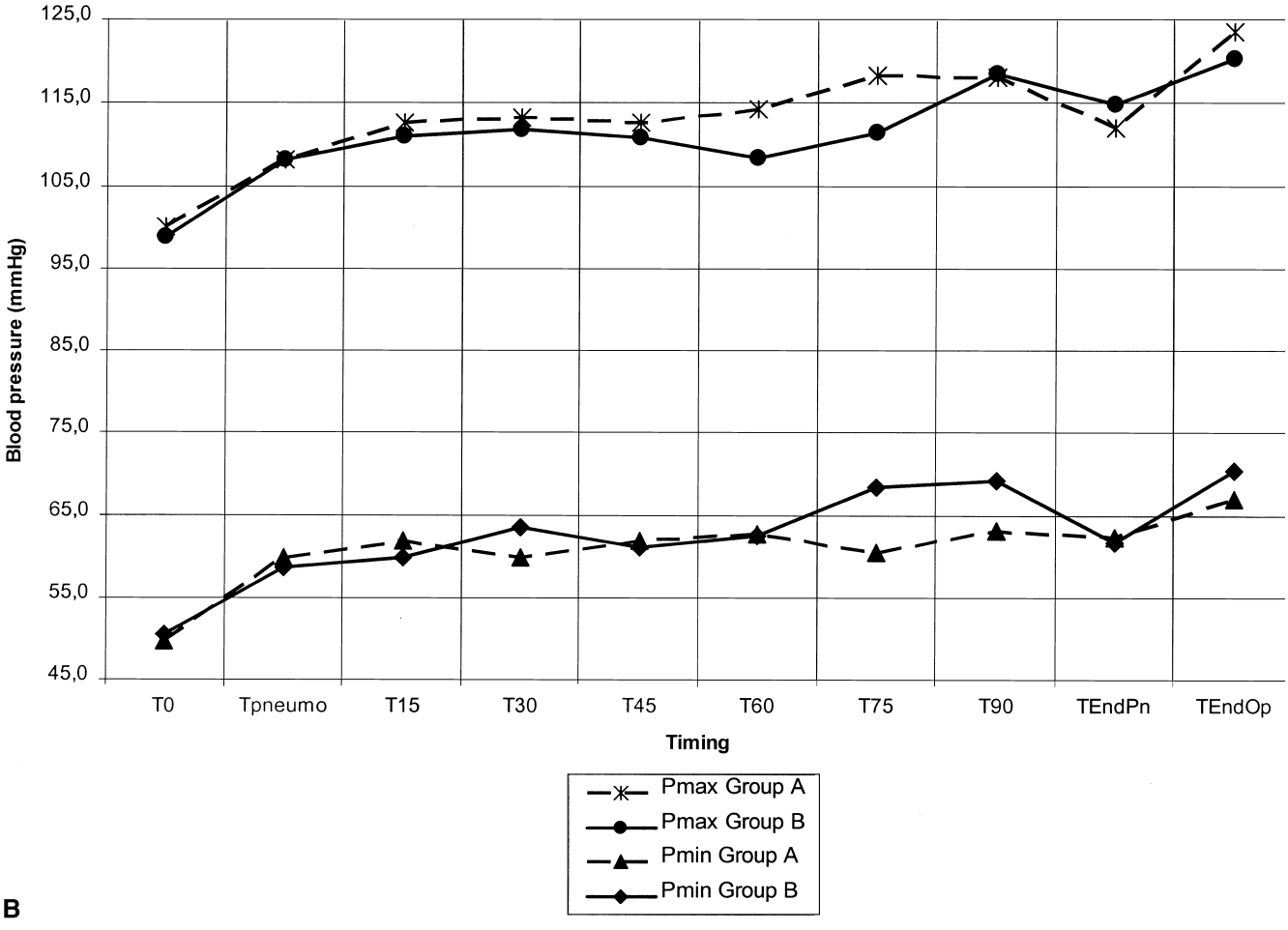
Group B patients first underwent the same pharmacological treatment. Laparoscopic fundoplication was required if symptoms and/or anatomopathological findings (signs of esophagitis) did not improve after repetitive cycles of medical therapy (at least 12 months).

To ensure homogeneity of the series, all the patients included in this study were operated on by the same experienced surgical team. A floppy Nissen–Rossetti wrap was performed through a laparoscopic approach. Pneumoperitoneum was obtained by low-flow (1 L/min) continued carbon dioxide insufflation, always maintaining intraabdominal pressure (IAP) lower than 10 mmHg. Short gastric vessel division was done only to allow a floppy wrap.

Moreover, the same anesthesiologist performed anesthesia in all the patients, using the same anesthesiologic methodology. Premedication was done with Midazolam (0.5–0.75 mg/kg for a maximum of 15 mg). A balanced general anesthesia was performed using Tiopentone (5–7 mg/kg) or Propofol (2.5–3 mg/kg) as inductors, Fentanyl (μg/kg) or Remifentanyl (0.2–0.4 mg/kg/min) as analgesic, and Atracurium (0.5 mg/kg) as muscle relaxant. After tracheal intubation, all the patients underwent mechanical ventilation (Siemens Servo 900D) with a mixture of O_2/air ($FiO_2 = 0.4$) and Sevofluorane 1.5–2 vol %.

We chose electrocardioscopy, noninvasive blood pressure monitoring (mmHg), pulse oxymetry [partial oxygen saturation (%) and pulse rate], and capnography (end-tidal CO_2 [mmHg]) to monitor cardiocirculatory and respiratory status during surgery and carbon-dioxide insufflation. Airway respiratory rate (cycles/minute) (AWRR), peak inspiratory pressure (cmH_2O) (PIP), and tidal volume (mL) (TV) were registered during ventilatory support. All data were collected at different moments during operation: just before skin incision, during pneumoperitoneum creation, every 15 min until desufflation, after carbon-dioxide desufflation, and just before extubation.

A venous blood gas analysis was performed after 1 h of pneumoperitoneum (or just before desufflation, if surgery took less than 60 minutes) in order to assess oxygen and carbon-dioxide partial pressures (mmHg), pH values, and bicarbonates concentration (mEq/L). Moreover, we described any procedure eventually adopted to correct acidosis (THAM instillation) or to reduce hypercarbia (increased



B

Fig. 2. B Blood pressure during surgery. Systolic and diastolic pressures slightly increase during pneumoperitoneum, but there is no difference between the two groups or during carbon dioxide insufflation.

AWRR) during surgery. All patients, immediately after awakening, received 0.5 mg/kg ketorolac or 1.5 mg/kg tramadol IV, as postoperative analgesia.

Pneumoperitoneum duration and length of anesthesia were evaluated as well. Finally, we described intraoperative complications, postoperative clinical status, need for further analgesia, time of peristalsis restoration (intestinal movements heard by a stethoscope), and day of discharge in order to characterize short-term postoperative effects of pneumoperitoneum.

Statistical analysis was performed using ANOVA and Student's *t*-test. A difference was considered statistically significant for p less than 0.05. A linear regression curve was used to compare age and length of surgery in these two groups of patients (R^2 represent the coefficient obtained for each group).

Results

Overall pneumoperitoneum duration was 71 min (40–120) ±22 and mean length of anesthesia, from induction to extubation, was 116 min (90–152) ±21. In group A, mean pneumoperitoneum duration was 63 min (45–88) ±13, and mean duration of anesthesia was 114 min (95–152) ±17. In group B, mean pneumoperitoneum duration was 78 min (40–120) ±26, and mean duration of anesthesia was 119 min (90–150) ±24.

Only five patients from group B and one patient from group A went over 90 min of pneumoperitoneum; thus we described but did not statistically evaluate T90 data.

Comparing pneumoperitoneum duration with patient's age, we noticed that age influences length of surgery (the older the patient, the longer surgery takes to be performed), with a relationship which seems to be stronger in respiratory patients if related to gastroenterological ones (Fig. 1).

We observed a slight increase in blood pressure and heart rate after pneumoperitoneum creation, with no difference between the two groups or during the procedure, always remaining within normal ranges (Fig. 2A and 2B). Partial oxygen saturation remained steady in all the patients.

End-tidal CO_2 increased significantly in both groups during carbon dioxide insufflation, but it never exceeded 45 mmHg (Fig. 3). The mean of this parameter was higher in patients from group A. Nevertheless, it remained elevated alter desufflation in only one patient, belonging to group B.

Venous blood gas analysis showed that carbon dioxide partial pressure exceeded 50 mmHg in three cases, all from group A (Table 2). On the whole, carbon dioxide partial pressures proved to be higher in patients from group A than in patients from group B (Table 2, Fig. 4). Moreover, pH was lower than 7.25 in two patients, one from group A and one from group B (mixed acidosis) (Table 2). In these patients, THAM instillation

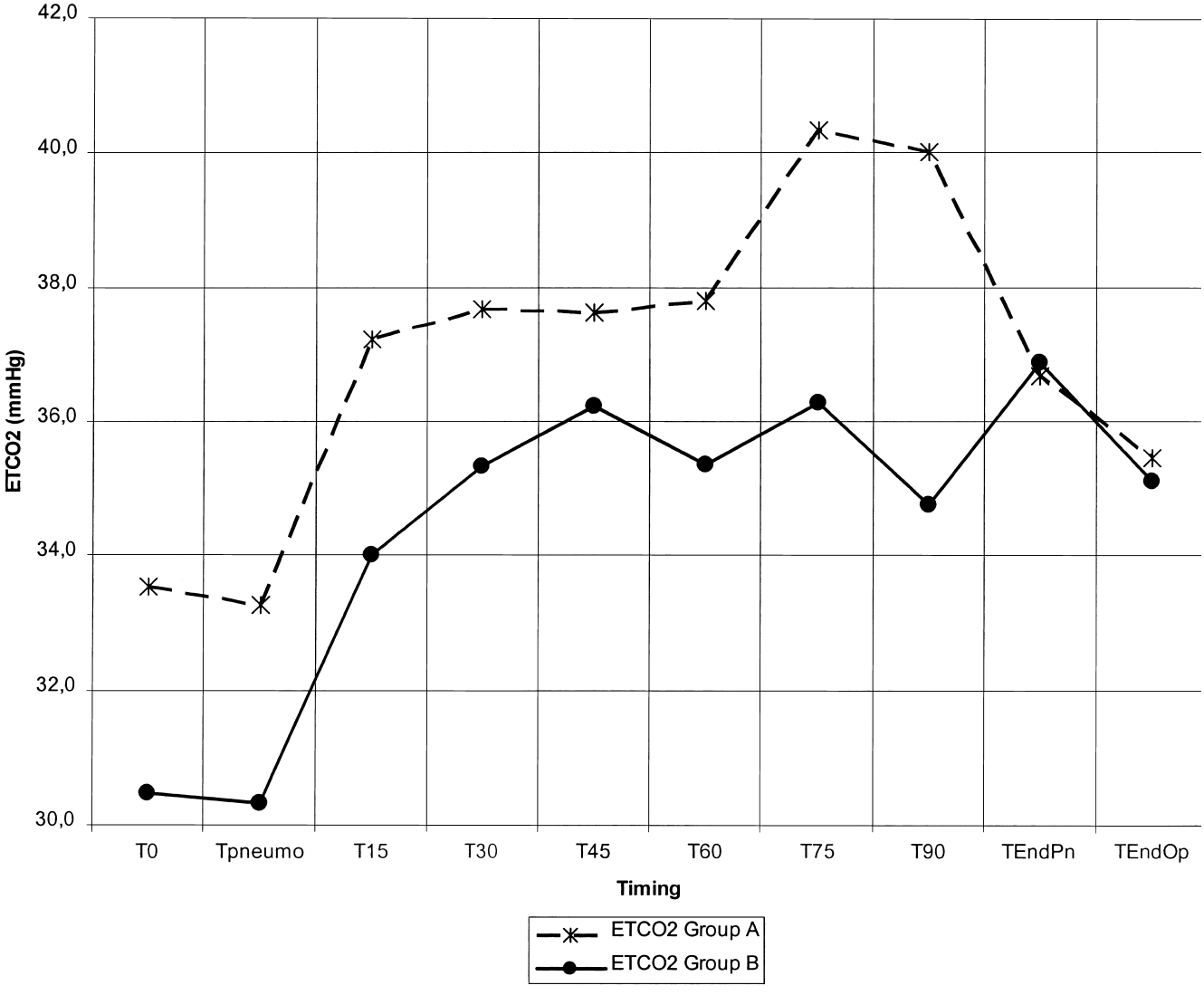


Fig. 3. $ETCO_2$ during pneumoperitoneum. End–tidal CO_2 increases during carbon dioxide insufflation but never exceeds 45 mmHg. T90 data are not statistically significant.

Table 2. Venous blood gas analysis obtained after 60 min of carbon dioxide partial insufflation[a]

		pH	PO_2	PCO_2	HCO_3	BE
All patients	Mean	7.339	75.6	41.2	21.7	−3.3
Group A	Mean	7.331	77.2	43.9	22.4	−2.9
Group B	Mean	7.346	74.3	38.7	21.0	−3.6
	Min	7.201	47.0	31.1	15.9	−11.2
All patients	Max	7.460	146.0	54.9	25.7	0.2
	Median	7.340	70.5	40.0	22.0	−2.9
	Min	7.211	53.0	36.7	19.6	−7.0
Group A	Max	7.427	146.0	54.9	25.7	0.2
	Median	7.351	68.0	43.8	22.5	−2.4
	Min	7.201	47.0	31.1	15.9	−11.2
Group B	Max	7.460	107.0	43.0	22.9	−1.0
	Median	7.338	71.0	39.0	21.9	−3.0

[a] Mean values of pH, carbon dioxide partial pressure and bicarbonate concentration remained within normal range

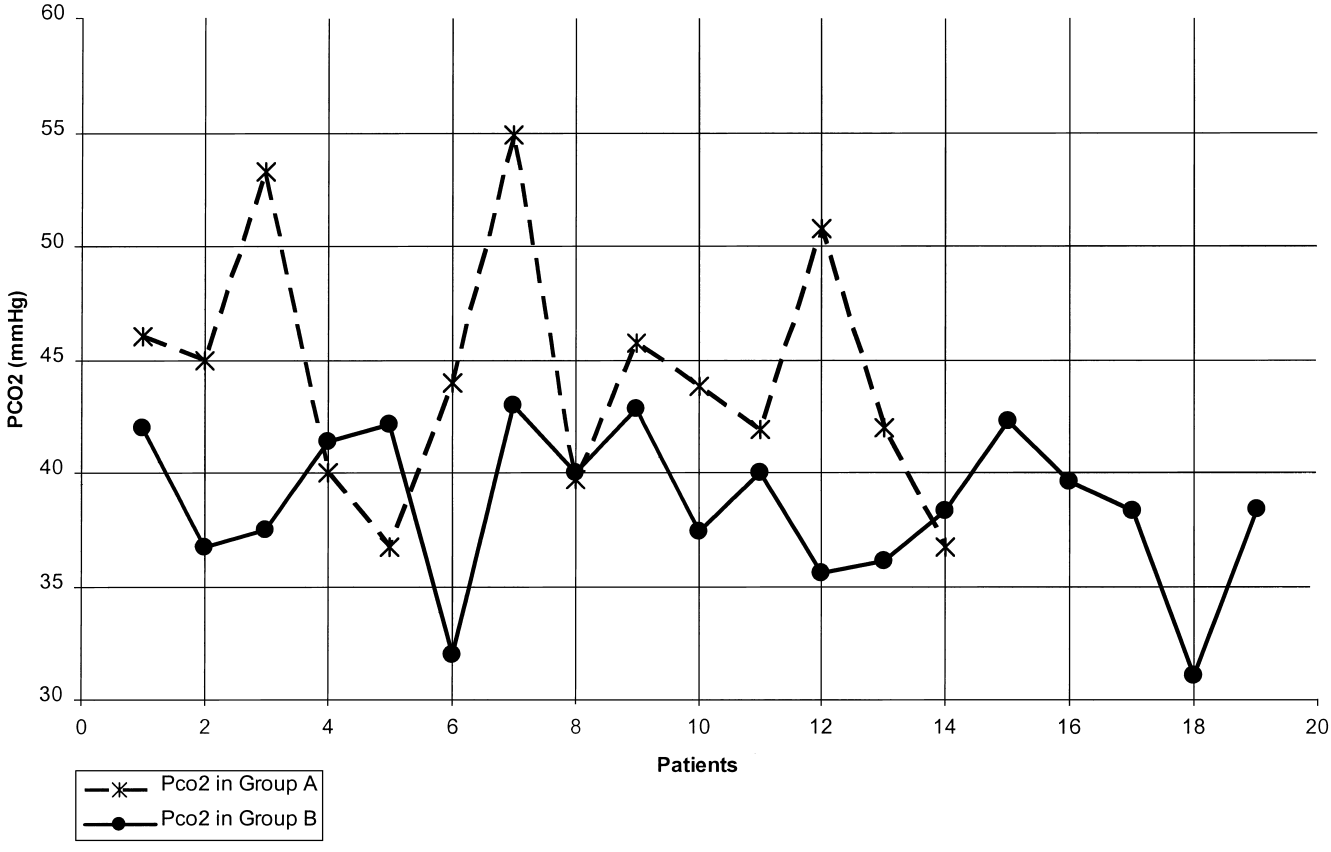


Fig. 4. Carbon dioxide partial pressures. Values expressed by venous blood gas analysis (PCO_2). Carbon dioxide partial pressures are meanly higher in patients from group A but globally lower than 50 mmHg.

was required to correct acidosis; a venous blood gas analysis was repeated just before extubation and showed a pH within normal ranges in both patients. Venous bicarbonates concentration and basis excess were within normal ranges in all the patients during pneumoperitoneum.

After pneumoperitoneum creation, we noticed a statistically significant rise in peak inspiratory pressure, which remained elevated during surgery.

The anesthesiologist never modified tidal volume to avoid excessive rise in peak inspiratory pressure, but only increased respiratory rate in order to improve alveolar ventilation and reduce end-tidal CO_2 (Fig. 5).

All the patients ended the procedure uneventfully and no complications were experienced. Bowel movements were restored at a mean of 4.7 h (range, 2.5–6.5) from desufflation without significant differences between the two groups. No patient required further analgesia during the postoperative period.

All the patients but one started eating on postoperative day 1 and were discharged on postoperative day 2. One patient, a 12-year-old girl from group B, presented upper abdominal distension, nausea, and vomiting. These symptoms were due to a gastroplegia, which probably occurred because of a lesion of the hepatic branches of the vagal nerve. In this patient, gastric emptying was restored in a couple of weeks and she was finally discharged, 18 days after surgery, free of symptoms and in good clinical condition.

Discussion

Esophagitis in patients with GERD leads to important chronic periesophageal inflammatory reaction, which makes surgery difficult and slow. The older the patient, the worse is the anatomical situation. Periesophageal damage is, on the contrary, minimal in patients with chronic respiratory symptoms. Therefore, in these patients, age has less impact on surgery.

After the initial increase due to the squeezing of venous vessels in splanchnic circulation, we should expect a decrease in arterial blood pressure as IAP reduces venous drainage. Nevertheless, systolic and diastolic pressures remain high (always within normal ranges) during pneumoperitoneum as a consequence of a rise in peripheral vascular resistances, probably due to mechanical compression of splanchnic circulation or adrenergic and rennin incretion [6, 20]. Thus, pneumoperitoneum produces only minimal hemodynamic modifications in either respiratory or gastroenterological patients.

The mechanical effect of increased IAP on the diaphragm leads to a reduction of pulmonary compliance, to the collapse of basal alveoli, and to the formation of intrapulmonary shunts. Moreover, carbon dioxide insufflation leads to CO_2 resorption. Consequently, hypercarbia and acidosis can result from these alterations. Yet, minimal modifications in airway respiratory rate, rarely associated with THAM instillation, usually allow maintenance of adequate ventilation and avoidance

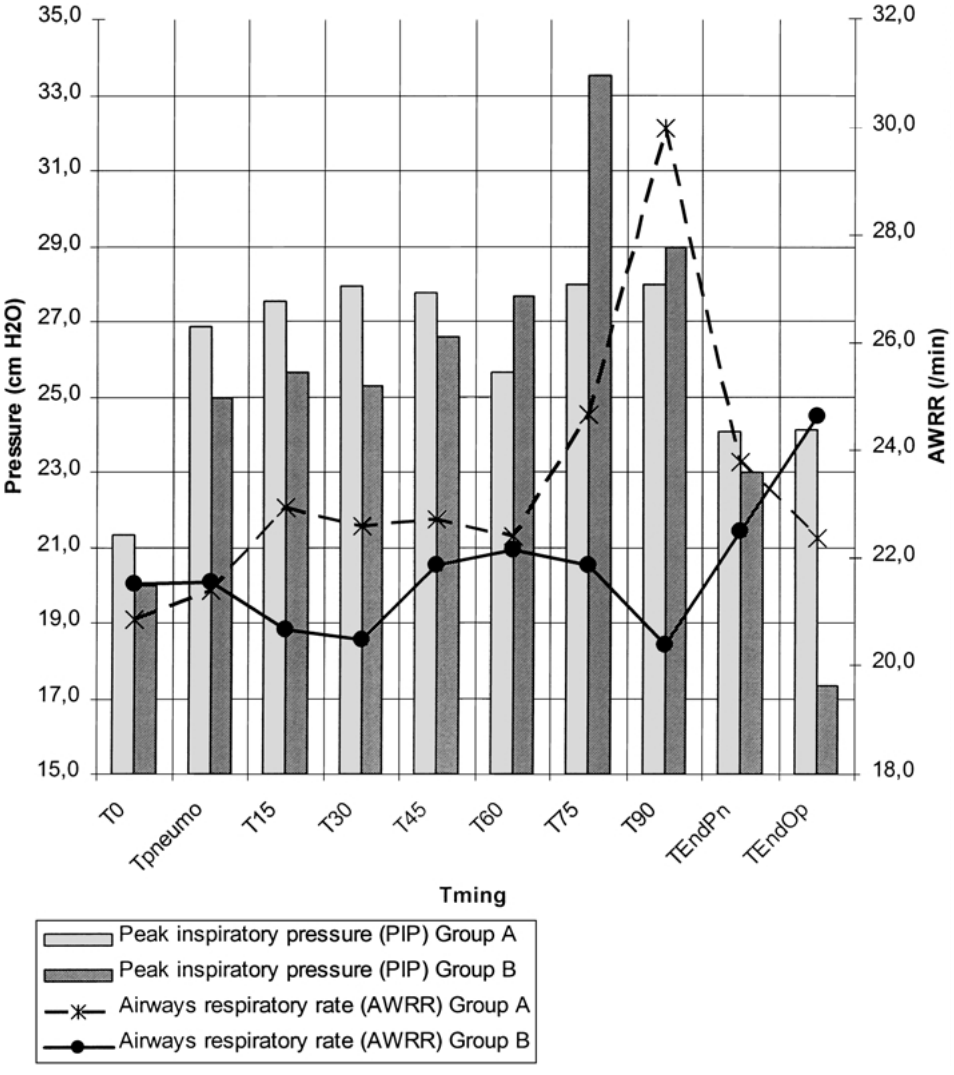


Fig. 5. Ventilation parameters (PIP and AWRR). Peak inspiratory pressures (PIP) rise during pneumoperitoneum as a consequence of the mechanical effect of increased IAP on diaphragm. Airway respiratory rate (AWRR) required minimal variations during pneumoperitoneum. T90 data cannot be considered statistically significant.

of acidosis. In our experience, pneumoperitoneum does not impair ventilation in gastroenterological patients at all; on the other hand, respiratory patients can undergo minimal modifications in ventilatory parameters which, nevertheless, rarely need the anesthesiologist's intervention.

In conclusion, laparoscopic approach is feasible and safe, with minimal and easily correctable respiratory and hemodynamic effects, independent of age, in both respiratory and gastroenterological patients, although surgery in gastroenterological patients is easier and faster if performed earlier, as periesophagitis is less evident.

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