Cardiorespiratory changes during gynaecological laparoscopy by abdominal wall elevation: comparison with carbon dioxide pneumoperitoneum

A. CASATI, G. VALENTINI, S. FERRARI, R. SENATORE, A. ZANGRILLO AND G. TORRI

Summary

We have studied the cardiorespiratory changes produced by abdominal wall elevation (AWE) or carbon dioxide pneumoperitoneum (PN) in 20 women undergoing gynaecological laparoscopy. Arterial pressure, heart rate, lung/chest compliance and blood-gas tensions were measured 10 min after induction of general anaesthesia (T0), 10 min after abdominal distension in the supine position (T1) and 10 min after the Trendelenburg position was assumed (T2). Visual analogue scores for pain were recorded 1 and 6 h after the end of surgery. We found that lung/chest compliance was reduced significantly in group PN at T1 and T2 compared with both T0 and group AWE. Diastolic arterial pressure increased significantly in group PN at T1 and T2 compared with both T0 and group AWE, while it remained unchanged in group AWE. Arterial $P_{\text{CO}_2}$ increased significantly only in group PN after pneumoperitoneum, while oxygenation was almost unchanged in both groups. AWE patients had greater abdominal pain 1 h after surgery. Six hours after surgery pain was similar in the two groups. These data indicate that abdominal wall elevation reduced pulmonary compliance less than a pneumoperitoneum in patients undergoing gynaecological laparoscopy. (Br. J. Anaesth. 1997; 78: 51–54)

Key words

Surgery, laparoscopy. Carbon dioxide, pneumoperitoneum. Cardiorespiratory system, effects.

Laparoscopic abdominal surgery has been used increasingly in the past years for gynaecological surgery, cholecystectomy and more complex and difficult surgical procedures (e.g. vagotomy, herniorrhaphies, antireflux procedures, splenectomy, bowel resection).

The limited skin incision with laparoscopic procedures is usually associated with less postoperative pain and faster recovery. Carbon dioxide pneumoperitoneum is the common method used to obtain abdominal distension for laparoscopy. Some complications such as hypercapnia and acidosis, gas embolism, pneumothorax, subcutaneous emphysema and deep venous thrombosis have been reported after carbon dioxide pneumoperitoneum. These complications may adversely affect patient outcome, especially in those with cardiac or respiratory disease.

Alternatives to carbon dioxide pneumoperitoneum, helium and nitrous oxide pneumoperitoneum, have been studied: these gases avoid the increase in $P_{\text{CO}_2}$ and acidosis but do not resolve problems related to the increase in intra-abdominal pressure.

Many methods of abdominal wall elevation have been developed for laparoscopy. The Hanon technique allows for elevation of the abdominal wall ventrally, using an inflatable balloon or a fan retractor inserted into the peritoneal cavity through the base of the umbilicus. The balloon is connected to an automated mechanical lifting arm attached to the operating table. This system is designed to provide 13.6 kg or less of lift to the anterior abdominal wall, which approximates to the pressure provided by 1.95 kPa (15 mmHg) of pneumoperitoneum. Abdominal wall elevation should theoretically reduce the negative effects on the diaphragm and abdominal great vessels caused by pneumoperitoneum.

The aim of this study was to compare the effects of carbon dioxide pneumoperitoneum with abdominal wall lift using a mechanical retractor device in patients undergoing gynaecological pelvic surgery.

Patients and methods

With the approval of the local Ethics Committee and informed consent, we studied 20 women, ASA I, undergoing gynaecological laparoscopy for ovarian surgery.

Premedication comprised diazepam 5 mg orally and atropine 0.5 mg i.m., 30 min before induction of anaesthesia. After a 18-gauge i.v. cannula was inserted into the forearm, anaesthesia was induced with fentanyl 0.001 mg kg$^{-1}$ i.v. and thiopentone 5 mg kg$^{-1}$ i.v. Vecuronium 0.1 mg kg$^{-1}$ i.v. was given to facilitate tracheal intubation with a cuffed tube.

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Anaesthesia was maintained with 1–1.5% end-tidal isoflurane in an oxygen-enriched air mixture ($P_{\text{FIO}_2} = 0.5$) to maintain arterial pressure and heart rate within acceptable ranges. Intermittent positive pressure ventilation (IPPV) was applied using a Drager-Cato volume cycled ventilator, with an inspiratory flow rate of 25 litre min$^{-1}$, ventilatory frequency 12 bpm, tidal volume 10 ml kg$^{-1}$ and an inspiratory:expiratory ratio of 1:2. Ventilatory variables were not changed during the study.

Intraoperative monitoring included continuous ECG (lead II), non-invasive arterial pressure using an automated cuff, pulse oximetry, inspired oxygen fraction, end-tidal carbon dioxide concentration, end-tidal isoflurane concentration, airway pressure and minute ventilation.

Static compliance of the whole respiratory system (lung/chest wall compliance (CPL RES)) was calculated by dividing expired tidal volume by static pressure (plateau pressure) after a 1-s inspiratory pause. To evaluate $\dot{V}O_2$ mismatching, we calculated the ratio of arterial oxygen to inspired oxygen partial pressure ($P_{\text{A}O_2}/P_{\text{F}O_2}$) as an index of pulmonary shunt, and arterial to end-tidal carbon dioxide gradient, as an index of dead space.

Patients were allocated randomly to receive abdominal distension by standard carbon dioxide pneumoperitoneum (group PN) or by the abdominal wall elevation device (group AWE). Carbon dioxide pneumoperitoneum was created using a Veress needle inserted into a small intra-umbilical incision. An electronic variable-flow insufflator terminated flow when an intra-abdominal pressure of 1.6 kPa (12 mm Hg) was reached. A 10-mm trocar was inserted in place of the needle to provide and maintain insufflation adequate for surgery. A video laparoscope was then inserted through the same trocar and the operative field was seen. In group AWE, an inflatable ring-shaped retractor was introduced into the peritoneal cavity (mesogastrium) via a small incision at the base of the umbilicus, using the Hanon technique, and then inflated. The retractor was attached to an automated mechanical arm and the abdominal wall was elevated using 13.6 kg of tension to provide adequate vision of the operating field. The laparoscope was then inserted into the peritoneal cavity via the umbilical incision and through the hole present in the inflatable retractor to see the pelvic and abdominal organs. Positive pressure insufflated gases were not necessary for surgery.

Patients were then placed in a 30° Trendelenburg position. Heart rate (HR), systolic (SAP) and diastolic (DAP) arterial pressures, and static lung/chest compliance (CPL RES) were recorded 10 min after induction of general anaesthesia before abdominal insufflation or wall elevation (T0), 10 min after abdominal distension or carbon dioxide insufflation (T1) and 10 min after Trendelenburg positioning (T2). At the same time, arterial blood was obtained for measurement of blood-gas tensions (IL BGM 1312; Instrumentation Laboratory, Lexington, MA, USA). All measurements were made before surgery was started.

At 1 and 6 h after the end of surgery, the intensity of abdominal pain was recorded using a visual analogue score (VAS 10 cm).

Data were collected and analysed using a statistical software package (StatView II SE, Abacus Concepts Inc., Berkeley, CA, USA). Analysis of variance for repeated measures with Sheffe and Dunnet’s tests of multiple comparison, Mann–Whitney test and chi-square test were used to assess changes over time both within and between groups. $P<0.05$ was considered significant. Data are reported as mean (sd) or median (range) for ordinal data.

**Results**

Patient data are shown in table 1. Patients with pre-operative hypotension or cardiopulmonary disease were excluded from the study. There were no

**Table 1 Characteristics of patients undergoing laparoscopy by carbon dioxide pneumoperitoneum (PN) or abdominal wall elevation (AWE). (Mean (sd) or range)). No significant differences between groups**

<table>
<thead>
<tr>
<th></th>
<th>PN $n = 10$</th>
<th>AWE $n = 10$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>38.5 (26–48)</td>
<td>44.0 (25–51)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>55.2 (9.0)</td>
<td>59.2 (9.9)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164 (4.3)</td>
<td>163 (3.9)</td>
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</tbody>
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<table>
<thead>
<tr>
<th></th>
<th>T0</th>
<th>T1</th>
<th>T2</th>
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<tbody>
<tr>
<td>AP (mm Hg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR (beat min$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CPL RES (ml cm H$_2$O$^{-1}$)</td>
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**Figure 1** Non-invasive arterial pressure (AP—systolic and diastolic), heart rate (HR) and lung/chest compliance (CPL RES) measured 10 min after induction of general anaesthesia (T0), 10 min after abdominal distension or pneumoperitoneum (T1), and 10 min after Trendelenburg positioning (T2), in patients undergoing gynaecological laparoscopy by carbon dioxide pneumoperitoneum (■) or abdominal wall elevation (●). *$P<0.05$ vs T0; †$P<0.05$ vs abdominal wall elevation.
perioperative complications caused by anaesthesia or surgery. Mean baseline HR was similar in both groups and did not change significantly during the study \((P=0.26)\) (fig. 1). In group PN, DAP increased significantly after abdominal insufflation and after Trendelenburg positioning compared with both before insufflation (T0) and group AWE \((P=0.04\) and 0.02, respectively). SAP did not change significantly in either group during the study \((P=0.11)\).

In the pneumoperitoneum group, lung/chest compliance decreased significantly after (T1) compared with before insufflation (T0) \((P=0.01)\) and with group AWE \((P=0.0011)\); there was a further reduction in CPLRES when the Trendelenburg position was assumed (T2) compared with both T0 \((P=0.01)\) and group AWE \((P=0.0006)\) (fig. 1). In AWE patients, lung/chest compliance did not change after abdominal elevation (T1) compared with values after induction (T0) \((P=0.25)\), but it was significantly reduced after Trendelenburg positioning compared with T0 values \((P=0.005)\). Compliance was significantly higher in group AWE compared with group PN both at T1 and T2 \((P=0.0001\) and 0.0006, respectively).

There were no significant changes in pH after abdominal distension and positioning (table 2). \(P_{\mathrm{a}CO_2}/F_{\mathrm{IO}_{2}}\) and arterial to end-tidal carbon dioxide gradient did not change significantly after insufflation or abdominal lift or after Trendelenburg positioning in both groups (table 2). In contrast, \(P_{\mathrm{a}CO_2}\) increased significantly in group PN after pneumoperitoneum \((P=0.02)\) with a mean difference compared with group AWE of approximately 0.665 kPa (5 mm Hg), 10 min after Trendelenburg positioning (table 2). One hour after the end of surgery, patients treated with the abdominal wall retraction procedure had greater abdominal pain than group PN \((P=0.03)\). None of the patients received postoperative analgesic drugs and the nociceptive stimulus was short-acting; 6 h after surgery there were no significant differences in abdominal pain between the two groups (table 3).

### Discussion
The two different techniques used for laparoscopy produce a difference in diaphragm displacement and consequently lead to different degrees of reduction in functional residual capacity (FRC) in the two groups of patients during anaesthesia. Respiratory system compliance was reduced significantly using the pneumoperitoneum technique. Changes in respiratory compliance in this study were in agreement with previously reported data.\(^1\) Another significant reduction in respiratory system compliance was caused by Trendelenburg positioning.\(^1\)

In the AWE group, airway pressure and respiratory system compliance were almost unaffected by abdominal wall distension. When Trendelenburg position was used, respiratory system compliance was lower than values measured after induction of anaesthesia; values of CPLRES, however, were significantly higher at this time in the AWE compared with the PN group.

Despite the relevant effects on lung/chest compliance, in this study we did not observe a significant difference in gas exchange in the two groups. In group PN, only \(P_{\mathrm{a}CO_2}\) increased progressively because of its rapid absorption into the circulation via the peritoneum. Our data were obtained 10 min after abdominal distension and then 10 min after Trendelenburg positioning. This time interval might have been insufficient to produce effects on pulmonary gas exchange; consequently, the decrease in FRC, produced by reduction in compliance, could be expected to worse oxygenation in group PN after a prolonged observation time.

Carbon dioxide load, with its direct and indirect haemodynamic effects,\(^2\) together with known increased cardiac afterload produced by intra-abdominal pressure elevation,\(^3\) might be the determinant of the increase in diastolic arterial pressure in group PN. These modifications may lead to an

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**Table 2** Arterial pH, ratio of arterial oxygen to inspired oxygen partial pressure \((P_{\mathrm{a}O_2}/F_{\mathrm{IO}_{2}})\), arterial to end-tidal carbon dioxide gradient \((\text{grad. CO}_2)\) and arterial carbon dioxide partial pressure \((P_{\mathrm{a}CO_2})\) measured 10 min after induction of general anaesthesia (T0), 10 min after abdominal distension or pneumoperitoneum (T1), and 10 min after Trendelenburg positioning (T2), in patients undergoing gynaecological laparoscopy by carbon dioxide pneumoperitoneum (PN) or abdominal wall elevation (AWE) (mean (sd)). \(*P<0.05\) vs T0

<table>
<thead>
<tr>
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<th>T0</th>
<th>T1</th>
<th>T2</th>
<th>ANOVA</th>
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<tbody>
<tr>
<td>pH</td>
<td>AWE 7.41 (0.04)</td>
<td>7.40 (0.03)</td>
<td>7.39 (0.04)</td>
<td>0.330</td>
</tr>
<tr>
<td></td>
<td>PN 7.45 (0.04)</td>
<td>7.39 (0.05)</td>
<td>7.36 (0.05)</td>
<td></td>
</tr>
<tr>
<td>(P_{\mathrm{a}O_2}/F_{\mathrm{IO}_{2}})</td>
<td>AWE 428 (116)</td>
<td>464 (114)</td>
<td>414 (103)</td>
<td>0.114</td>
</tr>
<tr>
<td></td>
<td>PN 450 (175)</td>
<td>534 (87)</td>
<td>429 (98)</td>
<td></td>
</tr>
<tr>
<td>Grad. CO2 (kPa)</td>
<td>AWE 0.27 (0.3)</td>
<td>0.29 (0.31)</td>
<td>0.33 (0.28)</td>
<td>0.803</td>
</tr>
<tr>
<td></td>
<td>PN 0.28 (0.14)</td>
<td>0.39 (0.27)</td>
<td>0.30 (0.22)</td>
<td></td>
</tr>
<tr>
<td>(P_{\mathrm{a}CO_2}) (kPa)</td>
<td>AWE 4.70 (0.40)</td>
<td>4.79 (0.25)</td>
<td>4.88 (0.32)</td>
<td>0.221</td>
</tr>
<tr>
<td></td>
<td>PN 4.71 (0.39)</td>
<td>5.18 (0.59)</td>
<td>5.85 (0.74)</td>
<td></td>
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</tbody>
</table>

**Table 3** Visual analogue scores (VAS) for abdominal pain recorded 1 h and 6 h after the end of pneumoperitoneum (PN) and abdominal wall elevation (AWE) laparoscopy

<table>
<thead>
<tr>
<th></th>
<th>PN ((n=10))</th>
<th>AWE ((n=10))</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS 1 h (cm)</td>
<td>3.5 (2.2)</td>
<td>5.5 (1.7)</td>
<td>0.03</td>
</tr>
<tr>
<td>VAS 6 h (cm)</td>
<td>3.6 (2.4)</td>
<td>3.9 (2.7)</td>
<td>0.19</td>
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increase in myocardial work and myocardial oxygen consumption.

It is known that carbon dioxide pneumoperitoneum produces an increase in central venous pressure by forcing blood from the abdominal organs into the central venous reservoir\textsuperscript{19,20} and a high preload reduces coronary flow by decreasing coronary artery perfusion caused by increased ventricular wall stress.\textsuperscript{21}

The abdominal wall elevation method, avoiding the increase in intra-abdominal pressure, might produce less effects on afterload and preload than pneumoperitoneum laparoscopy, further reducing the risks associated with laparoscopic procedures, especially in patients with poor cardiovascular reserve.

One hour after the end of surgery, group AWE had greater abdominal pain than the pneumoperitoneum group. This difference was probably a result of the smaller area of abdominal wall on which traction is applied in AWE compared with PN patients: in carbon dioxide pneumoperitoneum, abdominal distension involves all of the abdominal wall. Moreover, visual analogue scores were similar in the two groups 6 h after surgery. We believe that, unless statistically significant, the difference found 1 h after surgery is not clinically relevant in the postoperative management of patients.

Our data indicated that during gynaecological laparoscopy, abdominal wall elevation did not affect the respiratory system and gas exchange, reduced the negative effects on the cardiorespiratory system produced by pneumoperitoneum and may have improved the risk/benefit ratio of laparoscopic techniques.

Our patients were all young, relatively healthy females, undergoing short duration surgical procedures: they tolerated well pneumoperitoneum and the Trendelenburg position. The physiological effects of prolonged carbon dioxide insufflation into the peritoneum, combined with variations in patient positioning, have a major impact on cardiorespiratory function in elderly patients, with pre-existing cardiac or respiratory disease, undergoing surgical procedures with a longer duration than gynaecological laparoscopy. Further studies are required in these different groups of patients. Nevertheless, we believe that this technique of abdominal wall lifting and gasless laparoscopy should be advocated. The potential benefits of abdominal wall retraction may be useful for patients undergoing laparoscopic upper abdominal procedures of longer duration, in the reverse Trendelenburg position, and particularly when the patients are elderly with co-existing cardiac or respiratory disease, or both.

References

14. Yamanaka MK, Sue DY. Comparison of arterial–end-tidal 
\[ pCO_2 \]