

Changes in respiratory compliance at laparoscopy: measurements using side stream spirometry

Markku Oikkonen MD, Minna Tallgren MD

In order to quantify changes in total respiratory compliance (C_{rs}) effected by peritoneal pressurization we measured, under standardized anaesthetic conditions and using side stream spirometry C_{rs} in 32 patients scheduled for abdominal surgery through laparoscopic techniques. To qualify the changes in C_{rs} as to the type (duration and patient's position) of surgery, 20 patients having cholecystectomy, eight having gastric fundoplication, and four having inguinal hernia repair were studied. At CO_2 insufflation to a mean intraabdominal pressure of 11 cmH₂O in the horizontal position, C_{rs} decreased abruptly by 20% in each of the surgical sub-groups ($P < 0.05-0.01$). During the insufflation period a further deterioration was observed, most pronounced in inguinal hernia patients operated upon in a head-down tilt position ($P < 0.05$). In the cholecystectomy and fundoplication patients, operated upon in a head-up tilt, the recovery of C_{rs} was immediate at deflation, whereas an incomplete recovery ($P < 0.05$ vs initial values) was seen in the hernia patients. In evaluating all patients none of the demographic factors, age, sex, body-mass-index, intraabdominal pressure, or duration of pressurization, were associated with the detected changes.

Dans le but de quantifier les changements de compliance pulmonaire totale (C_{rs}) provoqués par la mise sous tension intra-péritonéale, nous avons mesuré par spirométrie et sous des conditions d'anesthésie standardisées, la C_{rs} auprès de 32 patients soumis à une chirurgie abdominale par laparoscopie. Les changements de C_{rs} ont été évalués selon les caractéristiques

Key words

MEASUREMENT TECHNIQUES: side stream spirometry, compliance;

LUNG: compliance, volume;

SURGERY: laparoscopy.

From the Department of Anaesthesia, Surgical Hospital, Fourth Department of Surgery, Helsinki University Hospital.

Address correspondence to: Dr. M. Oikkonen, Vilkenintie 21 D, 00640 Helsinki, SF-Finland.

Accepted for publication 18th February, 1995.

de l'intervention (la durée de l'intervention et la position du sujet): 20 patients subissaient une cholécystectomie, huit une fondoplicature gastrique et quatre une cure de hernie inguinale. En position horizontale, lorsque la pression d'insufflation du CO_2 atteint 11 cm H₂O en moyenne, la C_{rs} baisse subitement de 20% dans chacun des sous-groupes ($P < 0,05-0,01$). Pendant la période d'insufflation, la détérioration s'accroît, surtout chez les opérés pour cure de hernie inguinale en position déclive ($P < 0,05$). Chez les patients soumis à une cholécystectomie ou une fondoplicature en position proclive, le retour à la normale est immédiat dès la déflation, alors qu'il est incomplet ($P < 0,05$ vs la valeur de base) chez les opérés pour hernie inguinale. Dans l'ensemble, aucun des facteurs démographiques, ni l'âge, le sexe, le poids, l'index de masse corporelle, la pression intra-abdominale, et sa durée, ne sont associés aux changements décelés.

Pressurization of the peritoneal cavity for laparoscopic surgery effects an abrupt decrease in total respiratory compliance (C_{rs}), mainly resulting from a decrease in thoracic compliance.¹ Breath by breath monitoring of C_{rs} is made convenient by a commercial side stream spirometry device.² In order to assess the changes in C_{rs} coinciding with CO_2 insufflation and deflation, we recorded the readings in patients, scheduled for laparoscopic cholecystectomy, fundoplication, and inguinal hernia repair. Our assumption was that C_{rs} would remain decreased after deflation, as described after gynaecological laparoscopy.^{3,4} Such a decrement might disturb postoperative respiration.

Methods

The study was approved by the local Ethics committee. We recorded the readings of C_{rs} in 32 successive adult ASA 1-2 patients undergoing laparoscopic surgery. The patients were categorized according to the procedure in order to assess the effect of position and that of varying insufflation pressures and duration of pressurization, as necessitated by different surgery: C = cholecystectomy,

TABLE Group characteristics and total respiratory compliance (C_{rs} , ml · cmH₂O⁻¹) at four stages of measurement as mean (SD).

Group	Age (yr)	Sex F/M	Body-mass index	Duration of pressurization (min)	Total respiratory compliance at			
					insufflation		desufflation	
					pre-	post-	pre-	post-
C	50 ± 8	15/5	27 ± 5	85 ± 29	58 ± 15	48 ± 12†/	44 ± 10†/*	62 ± 15*/†
F	52 ± 10	3/5	28 ± 3	178 ± 72	63 ± 15	51 ± 17†/	49 ± 12†/	65 ± 11/†
I	69 ± 6	2/2	26 ± 6	80 ± 28	61 ± 11	49 ± 7*/	37 ± 8†/*	51 ± 15*/†

Significance of changes (* $P < 0.05$, † $P < 0.01$): compared with initial values (= pre-insufflation)/previous values.

$n = 20$; F = fundoplication, $n = 8$, 20° head-up tilt position during the laparoscopy; I = inguinal hernia repair, $n = 4$, 15° head-down tilt position during the laparoscopy. The pre- and postinsufflation recordings were made in the horizontal position. Pre- and postdeflation recordings were taken in the position used for laparoscopy. All C_{rs} values and their changes in the sub-groups as well as those in the whole population were analyzed, seeking to find associations between them and age, sex, body-mass-index (= weight (kg): [height (m)]²), duration of pressurization, and intra-abdominal pressure used.

The patients were anaesthetized using enflurane or isoflurane (end-tidal 0.7–1.3 MAC), or an infusion of propofol (5–7 mg · kg⁻¹ · hr⁻¹) in nine C patients, supplemented with a fixed rate infusion of alfentanil (20 µg · kg⁻¹ · hr⁻¹). Normoventilation (end-tidal CO₂ 5.0–5.5%) was maintained by modifying the tidal volume at 10 breath · min⁻¹, using 40% oxygen-air and a Servo 900 ventilator. At the time of measurement, the patients were momentarily ventilated using a tidal volume of 10 ml · kg⁻¹ and 10 breath · min⁻¹. By infusing atracurium, muscular relaxation was stabilized between 90–95%, as judged by tactile evaluation of twitch in response to supramaximal TOF stimulation of the ulnar nerve in an arm protected against cooling by using thermal coverage.

The C_{rs} was measured using a side-stream spirometry device (D-lite[™] flow sensor and Capnomac Ultima[™], Datex Instrumentarium Corp., Helsinki, Finland), which continuously computes flow and pressure readings derived via a pressure sensor system, attached between the proximal end of the endotracheal tube and the Y-piece. Plateau pressure is signaled for the calculation of compliance.² The technique is accurate (±3.5%), the readings reproducible, and calibration simple using a calibration piston.^{2,5}

The recordings were made prior to peritoneal insufflation, after reaching the desired intraabdominal pressure (10–12 cmH₂O), and again immediately before and after deflation to atmospheric pressure. The mean of two readings was calculated. The quality of the recordings was ensured by choosing compliance loops not disturbed by

surgical manipulation. The results were analyzed as absolute values, as percentages of the initial values, and as absolute and percentage changes from the initial and antecedent values. The absolute values were analyzed using factorial or repeated measures ANOVA, as indicated. The percentage values were compared using Mann-Whitney U test. Linear regression analysis was employed to attest possible associations.

Results

In the three groups, C_{rs} decreased abruptly and equally by about 20% after CO₂ insufflation (Table). The decrement continued during the insufflation period, the change being statistically significant in Groups C and I, and most severe in Group I ($P < 0.05$ vs the other two groups for the change). Each group showed an equal instantaneous improvement in C_{rs} immediately after deflation. The C_{rs} values of Group C even exceeded the preinsufflation level, but those in Group I remained depressed by about 15% ($P < 0.05$).

No differences among the mean C_{rs} values of the three groups were seen at any of the corresponding measurement stages.

No associations between age, sex, body-mass-index, duration of pressurization, or pressures used and changes in C_{rs} were observed, except that the increment of C_{rs} in the small subgroup I at deflation was inversely rectilinearly correlated with the body-mass-index ($R^2 = 0.943$, $P < 0.029$).

Discussion

This study confirmed the rapid decrease in C_{rs} at peritoneal pressurization. The extent of progression of the detriment in the course of pressurization depended on the posture of the patients. The instant return of C_{rs} at deflation in patients operated upon in a head-up tilt position was unexpected.

The decrease in C_{rs} by 20% at insufflation made in horizontal position agrees with the earliest measurements published on the effect of pneumo-peritoneum¹ and approximated results given in a recent report on patients

undergoing laparoscopic cholecystectomy.⁶ Hence, the decrease was less than the 40% decrement previously described at insufflation made in a head-down position for gynaecologic laparoscopy, where the final decrement to 50% of the initial level was observed during the maximum tilt used,⁴ or at the end of the brief procedures.³ Recoveries were 80–85% of initial C_{rs} values.^{3,4} Thus, the findings in Group I patients were much like those seen in young gynaecological patients, and correspond with a later report of a 40% decrease in lung compliance after two hours in the head-down position for laparoscopy.⁷ The incomplete return of C_{rs} in Group I patients, as compared with that in Groups C and F patients, was most probably effected by the prolonged head-down position combined with pressurization. Our results with cholecystectomy patients resembled those of a recent preliminary report showing a 30% decrease in lung compliance, and a complete reversal after deflation.⁸

The rapid return of C_{rs} observed in patients undergoing laparoscopic surgery in the head-up tilt position, combined with a restoration of thoracoabdominal respiratory muscle balance within 75 min following laparoscopic cholecystectomy,⁹ are prerequisites for the improvement of vital capacity, compared with open surgery. Yet, a clinical impression emerged to suggest that breathing was often dis-coordinated and shallow after protracted fundoplication for inguinal hernia surgery. Linked with existing knowledge of early postoperative respiratory muscle imbalance after laparoscopy, accentuated by forced breathing,⁹ the need for vigilant postanaesthetic monitoring of the adequacy of respiration still remains viable.

Respiratory monitoring using side stream spirometry revealed a 20% decrease in total respiratory compliance at insufflation for laparoscopy. The decrement continued during laparoscopy, being deepest (–40%) in patients operated upon in head-down tilt. Recovery was instantaneous after deflation in patients operated upon in head-up position.

References

- 1 *Drummond GB, Martin LVH.* Pressure-volume relationships in the lung during laparoscopy. *Br J Anaesth* 1978; 50: 261–70.
- 2 *Meriläinen P, Hänninen H, Tuomaala L.* A novel sensor for routine continuous spirometry of intubated patients. *J Clin Monit* 1993; 9: 374–80.
- 3 *Bardoczky GI, Engelmann E, Levarlet M, Simon P.* Ventilatory effects of pneumoperitoneum monitored with continuous spirometry. *Anaesthesia* 1993; 48: 309–11.
- 4 *Johannsen G, Andersen M, Juhl B.* The effect of general anaesthesia on the haemodynamic events during laparoscopy with CO₂ insufflation. *Acta Anaesthesiol Scand* 1989; 33: 132–6.
- 5 *Bardoczky GI, d'Hollander A.* Continuous monitoring of the flow-volume loops and compliance during anaesthesia (Letter). *J Clin Monit* 1992; 8: 251–2.
- 6 *Feinstein R, Ghouri A.* Changes in pulmonary mechanics during laparoscopic cholecystectomy. *Anesth Analg* 1993; 76: S102.
- 7 *Monk TG, Weldon BC, Lemon D.* Alterations in pulmonary function during laparoscopic surgery. *Anesth Analg* 1993; 76: S274.
- 8 *Mäkinen M-T.* Dynamic lung compliance during laparoscopic cholecystectomy. *Anesth Analg* 1994; 78: S261.
- 9 *Couture JG, Chartrand D, Gagner M, Bellemare F.* Diaphragmatic and abdominal muscle activity after endoscopic cholecystectomy. *Anesth Analg* 1994; 78: 733–9.