Reports of Investigation

Haemodynamic effects of mechanical peritoneal retraction during laparoscopic cholecystectomy

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Purpose: Abdominal wall retraction (AWR) was recently proposed as an alternative for CO_2 pneumoperitoneum. In this study we evaluated the cardiorespiratory effects of AWR during laparoscopic cholecystectomy.

Methods: Fifteen patients were studied during laparoscopic cholecystectomy using AWR. Monitoring included heart rate (HR), mean arterial pressure (MAP), pulse oxymetry (SpO_2), end-tidal CO_2 ($P_{ET}CO_2$), minute ventilation, and peak inspiratory pressure (PIP). Using transoesophageal echocardiography, the transgastric short axis view was obtained to derive the end-diastolic area (EDA), the end-systolic area (ESA), and the ejection fraction (EF). These parameters were measured at predetermined periods: 1) five minutes after anaesthetic induction, 2) five minutes after AWR insertion, 3) 15 min after AWR insertion, and 4) after the end of surgery.

Results: No change in any measured parameter was observed over time in the AWR group except for an increase in MAP ($P<0.05$) after AWR insertion. There were no changes in EDA, ESA and EF during the study, reflecting stable global cardiac function. In addition, no embolic episodes were observed during surgery.

Conclusion: Our results demonstrate that the use of gasless abdominal distention for laparoscopic cholecystectomy results in a stable haemodynamic profile in healthy patients without cardiac disease, except for a brief increase in MAP after the AWR insertion. The advantages of AWR over conventional pneumoperitoneum should be confirmed in higher risk patients in a prospective, randomized study.

Objectif : La rétraction de la paroi abdominale (RPA) a été récemment proposée comme solution de rechange au pneumopéritoine au CO_2. Cette étude évalue les effets cardiorespiratoires de la RPA pendant la cholécystectomie laparoscopique.

Méthodes : Quinze patients ont été étudiés pendant une cholécystectomie laparoscopique avec RPA. Le monitorage comprenait la fréquence cardiaque (FC), la pression artérielle moyenne (PAM), l'oxymétrie de pouls (SpO_2), le CO_2 télé-expiratoire ($P_{ET}CO_2$) et la pression inspiratoire de pointe (PIP). Par échocardiographie transoesophagienne, on a obtenu une image du l'axe court transgastrique avec lequel étaient dérivées les surfaces télédiastolique (STD), télésystolique (STS) et la fraction d'éjection (FE). Ces paramètres étaient mesurés à des périodes prédéterminées : 1) cinq minutes après l'induction de l'anesthésie, 2) cinq minutes après l'insertion de la RPA, 3) 15 minutes après l'insertion de la RPA, et 4) une fois la chirurgie terminée.

Résultats : Aucun changement des paramètres mesurés n'a été observé dans le groupe RPA à part une augmentation de la PAM ($P<0,05$) après l'insertion de la RPA. La STD, la STA et la FE n'ont pas changé pendant l'étude, ce qui reflète la stabilité de la fonction cardiaque globale. En outre, on n'a pas observé d'épisodes emboliques pendant la chirurgie.

Conclusion : Nos résultats montrent que la distension abdominale sans insufflation gazeuse procure un profil hémodynamique stable chez des patients bien portants, à l'exception d'une brève augmentation de la PAM après l'insertion de la RPA. L'avantage de la RPA sur le pneumopéritoine conventionnel devrait être confirmé chez des patients à risque plus élevé par une étude prospective et aléatoire randomisée.

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CARBON dioxide (CO_2) gas insufflation has been the mainstay of laparoscopic surgery and enables laparoscopic visualization and manipulation.[1] Complications such as gas embolism,[2-9] pneumomediastinum, pneumothorax,[10] subcutaneous emphysema,[11] and profound hypercarbia[12] have been associated with pneumoperitoneum. Moreover, considerable haemodynamic variations were described during laparoscopic cholecystectomy with pneumoperitoneum consisting of an increase in mean arterial pressure, systemic and pulmonary vascular resistance, a decrease in cardiac index,[13] a decrease in ejection fraction[14,15] while the pulmonary capillary wedge pressure increased.[13] These changes are very dependent on the underlying cardiovascular function, position and intraabdominal pressure attained. Respiratory variations also occur and are related to pulmonary restriction from increased intraabdominal pressure and a gradual increase in end-tidal CO_2 caused by peritoneal absorption of CO_2.[16,17]

More recently, a mechanical retraction system to displace the abdominal wall has been used as a substitute for pneumoperitoneum.[18] The system employs a fan retractor that is inserted into the abdomen in a closed configuration through a minilaparotomy incision, and opens up to define a triangular plane. The fan retractor is attached to a powered arm that provides a simple vertical lift to form the laparoscopic working cavity. To our knowledge, no study has evaluated the cardiorespiratory changes related to the use of this technique.

Accordingly, the aim of this study was to evaluate the haemodynamic consequences, as determined by transoesophageal echocardiography, of performing laparoscopic cholecystectomy with the mechanical peritoneal retraction system.

Methods

After institutional review board approval and written, informed consent, 15 consecutive patients (ASA physical status I and II) undergoing laparoscopic cholecystectomy using the abdominal wall retraction system (AWR group) were studied. Patients with a history of oesophageal disease or dysphagia, which we regarded as a relative contraindication to TEE examination, were excluded.

Standard intraoperative monitoring included a 5-lead ECG, systemic arterial pressure using automated oscillometry, pulsed oximetry, infrared CO_2 analysis, nasopharyngeal temperature, inspired oxygen fraction, peak airway pressure, and minute ventilation. After induction of anaesthesia and tracheal intubation, a 5.0 MHZ with 64 elements omniplane transoesophageal probe interfaced with a phased array imaging system (Hewlett Packard, Andover, MA) was inserted and used to obtain a transgastric short-axis view of the left ventricle at the midpapillary level. This view was recorded for 30 sec at predetermined intervals. Otherwise, we monitored the four chamber view, which was recorded continuously during surgery, in order to detect eventual episodes of gas embolism as previously described.[15] All TEE images were recorded on VHS tape for further analysis.

The anaesthetic technique was as follows: all patients were sedated with 0.07 $mg \cdot kg^{-1}$ midazolam im given 30 to 60 min before induction of anaesthesia with 1.5 $mg \cdot kg^{-1}$ propofol, 5 $\mu g \cdot kg^{-1}$ fentanyl, 50 $\mu g \cdot kg^{-1}$ alfentanil. Neuromuscular relaxation was provided with 0.5 $mg \cdot kg^{-1}$ atracurium. General anaesthesia was maintained with a propofol infusion (100–150 $\mu g \cdot kg^{-1} \cdot min^{-1}$) and supplemented with a fentanyl and alfentanil infusion (0.025 and 0.25 $\mu g \cdot kg^{-1} \cdot min^{-1}$ respectively) and intermittent atracurium boluses. Neuromuscular relaxation was monitored at the ulnar nerve with a neurostimulator and was adjusted to maintain one to three twitches at the adductor pollicis. For each injection of intravenous medication, we stopped TEE recording until complete disappearance of the echocardiographic contrast created by the iv injection. During anaesthetic induction, patients received a rapid infusion of 1 L Ringer's lactate solution *iv*. This solution was subsequently administered with an infusion pump (AVI 470, 3M, St-Paul, MN) at a rate of 50 $ml \cdot hr^{-1}$. After tracheal intubation, the lungs were ventilated by intermittent positive pressure ventilation with an $FiO_2 = 0.5$ (oxygen in air) using an Ohmeda volume cycled ventilator with an inspiratory flow rate of 25 $L \cdot min^{-1}$, a respiratory rate of 10 bpm, a tidal volume of 10 $ml \cdot kg^{-1}$, and an I:E ratio of 1:2. The ventilation was not altered after the initial setting.

The operative technique involved the use of mechanical peritoneal retractor (Laparolift; Origin Medsystems, inc, Menlo Park, CA) (Figure 1). The fan retractor is typically inserted through an infraumbilical incision. Once introduced into the incision, the closed fan retractor blades are gently advanced in a plane parallel to the abdominal wall and are opened. Then, the sterile-draped lifting arm is attached to the fan retractor. The endoscope is inserted into the abdominal cavity through the fan insertion incision in the space behind the fan legs. Both fan legs are examined in their position against the abdominal wall to ensure that no bowel or omentum has been trapped by the fan during insertion. The lifting arm is elevated to provide sufficient exposure for endoscopic visualization and surgical manipulation. A gauge built into the fan retractor gives an indication of the relative force applied to lift the abdomen. In addition, a force-limiting device incorporated into the motor of the lifting arm halts active elevation of the abdominal wall at a predetermined force. After fan retractor insertion and abdominal lift, ancillary instrument ports are placed in the abdomen.

Heart rate (HR), systolic (SAP), diastolic (DAP) and mean arterial pressures (MAP), arterial saturation (SpO_2), end-tidal CO_2 ($P_{ET}CO_2$), peak inspiratory pressure (PIP), minute ventilation and echocardiographic transgastric short axis view were recorded at predetermined intervals: 1) five minutes after the anaesthetic induction in a supine position, 2) five minutes after the insertion of the abdominal wall retractor (AWR) with the patients in reverse Trendelenburg position at 20°, 3) 15 min after the AWR insertion (AWR) in reverse Trendelenburg at 20°, and 4) five minutes after the end of surgery while the patient was still anaesthetized in a supine position, with the abdomen deflated and the AWR removed. An arterial blood sample was drawn by a single puncture immediately after the anaesthetic induction and at the end of surgery to measure alveolar-arterial gradient.

The recordings of TEE images on VHS videotape were reviewed by two independent observers and measured echocardiographic variables were the end-diastolic and the end-systolic left ventricular cavity areas (EDA and ESA respectively). The EDA and ESA were measured on an off-line analyser system and areas were delineated by manual tracing of the endocardium, excluding the area occupied by the papillary muscles, using the leading edge to leading edge technique.[19] Three consecutive beats were used and averaged for each value of EDA and ESA for the two observer.[27] The final value of EDA and ESA was the mean of the two observers. End-diastole was defined by the peak of the R wave, and end-systole was given by the smallest endocardial area. The left ventricular ejection fraction area (EF) was calculated with the following formula:((EDA-ESA)/EDA) × 100. Although preload and afterload-dependent,[26] this area based ejection fraction provides a quantitative assessment of global left ventricular performance.[27,28] The videotapes were also reviewed to detect for the occurrence of gas embolism. We determined interobserver and intraobserver variability of two-dimensional echocardiographic measurements in 10 randomly selected acquisition times by two independent observers and by one observer on two occasions. The variability for TEE manually traced area determinations were expressed as the difference between two measurements divided by the mean value and multiplied by 100.[20]

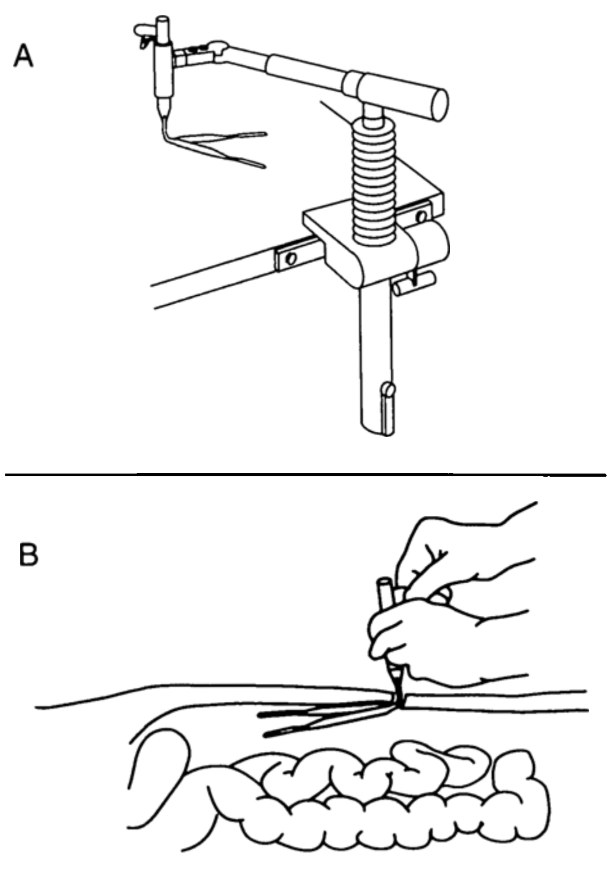

FIGURE 1A The fan retractor and lifting arm. The lifting arm attaches to the side rail of the operating table. B The fan retractor is inserted into the abdomen and connects to the lifting arm. Reprinted with permission from Chin *et al.*[18]

Results are expressed as mean ± SD. Analysis of variance for repeated measurements, followed by paired t tests with the Bonferroni correction where differences were detected, was used to compare measured and derived cardiorespiratory and echocardiographic values. An unpaired Student's t test was used to compare the CO_2 alveolar-arterial gradient between groups at the beginning and at the end of surgery. A P value <0.05 was considered significant.

Results

Fifteen patients were included in the study (AWR) (nine female and six male) with a mean age of 46.5 ± 13.3 yr. The mean duration of the operation was 1.66 ± 0.34 hr. There was no intra-operative complication. The echocardiographic images were excellent in all patients after AWR insertion, abdominal wall elevation and during the entire study period.

TABLE 1 Cardiorespiratory parameters during laparoscopic cholecystectomy using abdominal wall retractor (n = 15)

Time	*Control*	*AWR insertion*	*15 min after AWR insertion*	*End*
MAP (mmHg)	72 ± 8	85 ± 10*	79 ± 7	80 ± 9
HR (bpm)	67 ± 15	67 ± 15	71 ± 14	69 ± 13
$P_{ET}CO_2$ (mmHg)	27 ± 2	27 ± 2	28 ± 3	29 ± 3
PIP (cm H_2O)	15 ± 4	14 ± 4	14 ± 3	15 ± 4
VE ($L \cdot min^{-1}$)	5.1 ± 1.0	4.9 ± 1.0	5.0 ± 1.1	4.9 ± 1.1
EDA (cm^2)	11.5 ± 3.7	12.4 ± 3.2	11.8 ± 2.5	12.1 ± 3.5
ESA (cm^2)	5.6 ± 2.5	6.7 ± 2.7	6.0 ± 2.0	6.1 ± 2.7
EF (%)	53 ± 10	48 ± 9	50 ± 13	50 ± 11

Values are expressed as mean ± SD.

Control = post anaesthetic induction; AWR = five minutes after the abdominal wall retractor insertion; 15 min = 15 min after the abdominal wall retractor insertion; End = end of surgery.

MAP = mean arterial pressure; HR = heart rate; $P_{ET}CO_2$ = end-tidal CO_2; PIP = peak inspiratory pressure; VE = minute ventilation; EDA = end-diastolic area; ESA = end-systolic area; EF = ejection fraction.

*$P < 0.05$ compared with control value.

Cardiorespiratory variables measured during the study in group AWR are shown in Table I. The MAP increased after the AWR insertion ($P < 0.05$) but returned to the baseline value 15 min later. There was no change in HR, minute ventilation, PIP, $P_{ET}CO_2$, EDA, ESA or EF over time during the entire study period (Table I).

There was no episode of acute desaturation, SpO_2 90%. The alveolar-arterial gradient in CO_2 was 6.8 ± 2.1 mmHg at the beginning of surgery and 7.5 ± 3.2 at the end of surgery (P = NS). No CO_2 embolism was observed during the study.

Intraobserver variability for TEE manually traced EDA and ESA were 1.9 ± 2.6 % and 4.7 ± 0.9% respectively. Interobserver variability for EDA and ESA were 9.1 ± 4.6 % and 10.7 ± 6.2 % respectively.

Discussion

Gasless abdominal distention for laparoscopic cholecystectomy is associated with a stable cardio-respiratory profile in healthy patients without cardiac disease. This is manifested by no change over time in $P_{ET}CO_2$, peak inspiratory pressure, minute ventilation, HR, and EDA, ESA and EF as measured by TEE. The only change was an increase in MAP which occured after the AWR insertion. The latter is in agreement with a recent study evaluating gasless abdominal distention in swine where the authors found an increase in systemic vascular resistance with the use of AWR.[22] They suggested that the direct, surface-to-surface contact between the peritoneum and the AWR plus the stress imposed on the abdominal wall during distention may have stimulated catecholamine release, resulting in peripheral vasoconstriction.[22] In our study, however, MAP returned to baseline thereafter, emphasizing the need for a sufficient level of anaesthesia during the period of AWR insertion.

Using TEE and the same anaesthetic technique, we had previously assessed 16 patients undergoing laparoscopic cholecystectomy with conventional pneumoperitoneum for the occurence of gas embolism and cardiovascular changes.[15] Pneumoperitoneum was maintained with a variable flow insufflator at 15 mmHg throughout surgery. In that study,[15] we observed an increase in peak inspiratory pressure, minute ventilation, $P_{ET}CO_2$, MAP and HR ($P < 0.01$) with peritoneal insufflation and during the surgery. Moreover, these patients showed a small but significant decrease in EF after peritoneal insufflation and during the surgery, a finding that has also been reported by Dorsay *et al.*[14] The small decrease in global cardiac function that we observed, as reflected by the decrease in ejection fraction area, is more likely related to changes in pre- and afterload rather than to changes in contractility. In contrast, except for the brief increase in MAP after the AWR insertion, no cardiorespiratory changes occured during the present study. Another potential advantage of the AWR was that no episode of gas embolism was found in the AWR group while such a finding was common with the use of conventional pneumoperitoneum.[15] However, these data are taken from two consecutively studied groups, and error may be introduced when current and historical data are compared.

Several other studies[13,14,24] have described haemodynamic changes during laparoscopic cholecystectomy with conventional pneumoperitoneum. These consist of increases in MAP,[13,14,24] systemic vascular resistance,[13] pulmonary vascular resistance,[13] left ventricular end-systolic meridional stress (an index of left ventricular afterload),[24] a decrease in cardiac index,[13,14] stroke volume index,[14] end-diastolic area,[24] left ventricular end-diastolic volume index and ejection fraction area as measured with TEE.[14] The combined effects of anaesthesia, patient position (10° head-up) and increased intraabdominal pressure (14 mmHg) can reduce cardiac output to as much as 50% of preoperative values.[29] The decrease in cardiac output may be related to a decline in venous return caused by the increased intraabdominal pressure, and to an increase in systemic vascular resistance.[29]

Only one animal study has evaluated the haemodynamic changes with the use of gasless abdominal distention compared with CO_2 pneumoperitoneum.[22] In that study, performed in swine and monitored with pulmonary artery and invasive arterial catheters, the authors found that, during mechanical ventilation without positive end-expiratory pressure, central venous pressure, pulmonary artery pressure, pulmonary capillary wedge pressure, and $PaCO_2$ were lower for gasless abdominal distention than for peritoneal insufflation with CO_2, while the PaO_2 and the cardiac index were higher.[22] Another recent study, performed in humans, evaluated the haemodynamic effects of a conventional pneumoperitoneum with the abdominal wall lift for laparoscopic cholecystectomy.[23] In this study, Lindgren *et al.*[23] used a trocar which was introduced in the left upper abdomen and brought beneath the rectus abdominus muscles and falciform ligament, and then left the abdomen through an incision in the upper right abdomen. Both ends of this trocar were attached to a horizontal bar which enabled the abdominal wall to be elevated 10–15 cm upwards. In contrast with our study, these authors also used carbon dioxide insufflation with a small amount of CO_2 (9 ± 7 l *vs* 40 ± 23 for conventional pneumoperitoneum). They demonstrated that the abdominal wall lift method with minimal carbon dioxide insufflation was associated with greater pulmonary compliance, less marked increase in arterial pressure and a lower central venous pressure than a conventional pneumoperitoneum. The results of our study, demonstrating less cardiorespiratory disturbances with the abdominal wall retractor than with conventional pneumoperitoneum, agree with these two previous studies.[22,23]

As previously described,[15,25] measurements of EDA and ESA with TEE using transgastric short axis view during laparoscopic cholecystectomy with conventional pneumoperitoneum are sometimes difficult to obtain due to a decrease in image quality. In this study using AWR, such measurements were easily and reliably obtained in all the patients with only minor adjustments of the TEE probe, and thus enabled us to evaluate EDA, ESA and EF as measures of global cardiac function. Although the use of AWR results in a stable haemodynamic profile in healthy patients, it remains to be determined if the advantages of this technique apply to higher risk patients.

In summary, we have demonstrated that the use of gasless abdominal distention for laparoscopic cholecystectomy results in a stable haemodynamic profile in healthy patients without cardiac disease. The only change that we observed was a brief increase in MAP after AWR insertion. Another potential advantage of the AWR was that no episode of gas embolism occurred with AWR while such a finding is common with the conventional pneumoperitoneum. The clinical advantages of AWR over conventional pneumoperitoneum should be confirmed in higher risk patients in a prospective, randomized study.

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