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Laparoscopic cholecystectomy using abdominal wall retraction

Hemodynamics and gas exchange, a comparison with conventional pneumoperitoneum

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Abstract

Background: Disadvantages related to CO₂ pneumoperitoneum have led to development of the abdominal wall retractor (AWR), a device designed to facilitate laparoscopic surgery without conventional pneumoperitoneum (15 mmHg CO₂). We investigated the effects of the AWR on hemodynamics and gas exchange in humans. We also investigated whether the use of an AWR imposed extra technical difficulties for the surgeon. A pilot study revealed that cholecystectomy without low-pressure pneumoperitoneum was technically impossible.

Methods: A prospective randomized controlled trial: Twenty patients undergoing laparoscopic cholecystectomy were randomly allocated into group 1: AWR with low-pressure pneumoperitoneum (5 mmHg), or group 2: conventional pneumoperitoneum (15 mmHg).

Results: Surgery using the AWR lasted longer, 72 ± 16 min (mean $\pm$ SD) vs 50 ± 18 min compared with standard laparoscopic cholecystectomy. There were no differences between the groups with respect to hemodynamic parameters, although a small reduction of the cardiac output was observed using conventional pneumoperitoneum (from 3.9 ± 0.7 to 3.2 ± 1.1 l/min) and an increase during AWR (from 4.2 ± 0.9 to 5.2 ± 1.5 l/min). Peak inspiratory pressures were significantly higher during conventional pneumoperitoneum compared to AWR. A slight decrease in pH accompanied by an increase in CO₂ developed during pneumoperitoneum and during the use of the AWR. In both groups arterial PO₂ decreased.

Conclusions: The results indicate that the view was impaired during use of the AWR and therefore its use was difficult and time-consuming. Possible advantages of this devices' effects on hemodynamics and ventilatory parameters could not be confirmed in this study.

Key words: Abdominal wall retraction — Abdominal wall retractor — Pneumoperitoneum

Carbon dioxide (CO₂) pneumoperitoneum of 15 mmHg intraabdominal pressure is generally used for laparoscopic surgery. Side effects of a pneumoperitoneum such as cardiovascular depression and respiratory acidosis have been described and may be potentially dangerous in patients with underlying diseases [12]. In addition, CO₂ embolism is a feared, although rare, complication of laparoscopic surgery with pneumoperitoneum, with potentially fatal outcome [7]. These disadvantages have led to development of alternative strategies.

The abdominal wall retractor (AWR) is a new device designed to create a good view during laparoscopic surgery without the use of a pneumoperitoneum [1, 3, 5, 6, 10, 14, 16]. Recently the feasibility of using the AWR for laparoscopic surgery in pigs has been analyzed [11]. The use of the abdominal wall retractor was associated with fewer hemodynamic side effects and disturbances of gas exchange. However, the effectiveness in humans has not been analyzed.

Although laparoscopic cholecystectomy has generally been performed by experienced surgeons, in our institution a pilot human study with the AWR showed that laparoscopic cholecystectomy without pneumoperitoneum was extremely difficult. It was not always possible to achieve ad-

equate exposure of the triangle of Calot, which is essential for safe dissection of Calot’s triangle. However, the addition of a low-pressure pneumoperitoneum enabled the surgeon to perform the procedure. Therefore, it was decided to add 5 mmHg pneumoperitoneum while using the AWR.

The purpose of this study was to assess the safety and efficacy of the AWR in a prospective, randomized controlled clinical trial, comparing the use of AWR combined with low-pressure pneumoperitoneum with the CO₂ pneumoperitoneum, with particular interest in hemodynamics and gas exchange during laparoscopic cholecystectomy. We were also interested in whether the use of an AWR posed extra technical difficulties for the surgeon.

Patients and methods

Twenty patients with ASA classification 1 or 2 undergoing elective laparoscopic cholecystectomy for uncomplicated symptomatic gallstone disease gave informed consent to participate in the study. The patients were randomly allocated into one of the two groups.

Patients in group 1 underwent laparoscopic cholecystectomy by abdominal wall retraction with a low-pressure pneumoperitoneum of 5 mmHg. Patients in group 2 underwent standard laparoscopic cholecystectomy with CO₂ pneumoperitoneum of 15 mmHg.

The study protocol was approved by the Hospital Ethical Committee.

Anesthesia

Premedication consisted of lorazepam 1 mg given orally approximately 1 h before induction of anesthesia. A peripheral intravenous infusion of NaCl 0.9% was administered at a rate of 6 ml · kg⁻¹ · h⁻¹. Electrocardiogram and pulse oximetry were continuously monitored during the procedure. Anesthesia was induced with thiopental 3–5 mg/kg⁻¹, followed by atracurium 0.5 mg/kg to facilitate endotracheal intubation and fentanyl 5-μg/kg. Anesthesia was maintained with isoflurane 1.15% (end-tidal concentration). Additional doses of atracurium were given to maintain one or two responses to train-of-four stimulation. During the operation additional doses of fentanyl were given when signs of insufficient analgesia were present, as indicated by a rise in pulse rate or a blood pressure greater than 20% of preinduction values.

After endotracheal intubation the lungs were ventilated with a mixture of oxygen in air (FiO₂ = 0.5). Total minute ventilation was adjusted until an end-tidal CO₂ value between 30 and 40 mmHg was achieved (Dräger, Cicero, Germany). After induction of anesthesia a 20-gauge catheter was inserted in the left radial artery for blood pressure measurements, cardiac output measurements, and blood gas sampling.

Surgical technique

Laparoscopic cholecystectomy with AWR. For retraction of the abdominal wall an AWR with 10-cm wings was used as described by Smith et al. [14] (Laparolift TM, Origin Med Systems, Inc. Menlo Park, CA). Low-pressure pneumoperitoneum (5 mmHg) was added to the lifting procedure in all patients. The position of the surgeon is between the legs of the patient. First a 10/11-mm trocar is inserted through the umbilicus using an open technique. Second, the fan is introduced through a right subcostal split incision under direct laparoscopic vision to prevent slipping omental fat between the legs of the fan and the abdominal wall. The fan is lifted with the abdominal wall retractor (AWR) up to a pressure of 10–12 on the indicator of the fan. Two additional trocars are inserted, a 5-mm and a 10/11-mm trocar in the right lower and left abdomen, respectively. A 5-mmHg pneumoperitoneum is applied to achieve adequate exposure of Calot’s triangle.

Laparoscopic cholecystectomy with pneumoperitoneum. Abdominal insufflation with CO₂ was obtained with a pressure-controlled insufflator (Elec-

Table 1. Patient characteristics

	Pneumoperitoneum (15 mmHg)	Abdominal wall retraction + low-pressure pneumoperitoneum (5 mmHg)	
Sex F/M	7/2	8/1	ns
Age (years)	30–52	22–50	ns
Weight (kg)	65 ± 11	68 ± 14	ns
Height	168 ± 7	163 ± 9	ns

Table 2. Operation data and complications

	Pneumoperitoneum (15 mmHg)	Abdominal wall retraction + low-pressure pneumoperitoneum (5 mmHg)	
Conversion to open surgery	1	1	
Duration operation (min)	50 ± 18	72 ± 16*	
Postoperative complication	0	0	

* *p* < 0.05 compared with conventional pneumoperitoneum.

tronic Laparoflator 26012, Storz, Tuttlingen, Germany). Intraabdominal pressure was controlled from the manometer on the insufflator. Pneumoperitoneum was achieved by inserting a Veress needle subumbilically. Two additional 10/11-mm and one 5-mm trocars are inserted after establishment of the pneumoperitoneum. The trocars are placed similar to the trocars used with the AWR.

Measurements

Measurements were performed at 1, 5, 10, 15, 30, 45 and 60 min after starting the pneumoperitoneum or introducing the abdominal wall retraction. Control measurements were made 5 min after ceasing the pneumoperitoneum or the abdominal wall retraction. In the final analysis, measurements at 45 and 60 min were not included because in seven patients using conventional pneumoperitoneum the procedure was finished within 45 min. The following hemodynamic variables were measured: heart rate, blood pressure, and cardiac output; arterial blood pressure was recorded using disposable transducers (Baxter, TX). Cardiac output was computed continuously from the radial artery pressure, as described by Wesseling et al. [15]. The following ventilatory parameters were measured; end-tidal CO₂ (EtCO₂), arterial pH, arterial PCO₂, arterial PO₂, and peak inspiratory pressure. End-tidal CO₂ was measured with an infrared mainstream transducer (Hewlett Packard, Saronno, Italy). Blood-gas samples were analyzed by a routine method (ABL 4, Radiometer A/S, Copenhagen, Denmark).

Statistical analysis

Results are expressed as mean ± SD. Data were analyzed with two-way ANOVA for repeated measures between and in between the groups. When indicated, differences between means within the groups were analyzed using paired *t*-test means and unpaired *t*-tests for differences between means between the groups. Patient characteristics and operation time were analyzed with the Mann-Whitney U test. *p* values of <0.05 were considered statistically significant.

Results

Patient characteristics are presented in Table 1. There were no significant differences between the study groups. Operations performed using the AWR with supplemental low-

Fig. 1. Hemodynamic parameters. Data are mean $\pm$ SD. * $p < 0.05$: (□) pneumoperitoneum, (●) abdominal wall retractor compared with baseline.

pressure pneumoperitoneum lasted significantly longer compared to conventional surgery (Table 2). In two patients (one in each group) the operation could not be completed due to technical difficulties for which the operation was converted (Table 2).

Hemodynamic and ventilatory data are presented in Figs. 1 and 2. There were no significant differences between the groups with respect to baseline and changes in heart rate and systolic blood pressure. Transient increases in diastolic blood pressure during abdominal wall retraction did not result in significant differences with pressures measured during conventional pneumoperitoneum. Cardiac output remained unchanged during conventional pneumoperitoneum and showed a significant increase during abdominal wall retraction with low-pressure pneumoperitoneum, whereas at the start of insufflation a significant reduction of the cardiac output was observed with conventional pneumoperitoneum.

Peak inspiratory pressures increased significantly during laparoscopy using conventional pneumoperitoneum. In contrast, peak inspiratory pressures remained unchanged during abdominal wall retraction with supplemental low-pressure pneumoperitoneum. Differences between both groups were significant in this respect. A decrease in arterial pH accompanied by an increase in CO_2 occurred during both conventional and low-pressure pneumoperitoneum with abdominal wall retraction although these changes appeared earlier during conventional pneumoperitoneum. During both techniques blood gas analysis showed a decrease in partial arterial oxygen pressure, although values at which hemoglobin oxygen saturation may become impaired were not reached.

Discussion

The pilot study indicated that laparoscopic cholecystectomy using the AWR without pneumoperitoneum was technically difficult. The major problem during laparoscopy without pneumoperitoneum was a view obscured by bowel movement in front of the camera. Clear exposure of Calot's tri-

angle, essential for safe dissection of the cystic duct, was impossible. Adding a positive intraabdominal CO_2 pressure of 5 mmHg was enough to solve this problem.

Although this technique was feasible as shown in the present study, the operation lasted longer when compared with the procedure using conventional pneumoperitoneum. The results also indicate that the use of the AWR combined with low-pressure pneumoperitoneum leads to similar hemodynamic and gas-exchange changes as compared with conventional pneumoperitoneum. These results are in contrast with other studies, which suggest that laparoscopic cholecystectomy can be performed with AWR without pneumoperitoneum [3, 6, 14]. This contradiction may be explained by differences in abdominal wall retraction methods, such as wiring of the subcutaneous tissues [6]. This may result in a better view as compared with the view using the abdominal wall retractor. However, these techniques involve difficult and lengthy assembly and require extra stab wounds, which makes them unpopular with most surgeons. On the other hand, some authors used the same abdominal wall retractor as in this study [3, 14]. Smith used the device without pneumoperitoneum successfully in 81% of the laparoscopic cholecystectomies. The results may be due to extensive training.

The results of this study also contrast with our previous study in which the hemodynamic effects of abdominal wall retraction were assessed in pigs [11]. The V-shaped chest of a pig as compared to the more flat human chest may have enabled a clear vision in this particular experimental model.

The mean duration of laparoscopic cholecystectomy using the AWR was longer as compared with conventional pneumoperitoneum. Smith et al. did not report the average operation duration [14]. It is unlikely that lack of experience negatively influenced our results. The patients were operated upon by two surgeons with extensive experience in laparoscopic surgery. Furthermore, there was no difference in operation time between the first and last procedure while using the abdominal wall retractor; there was also no difference in operation time between the two surgeons.

Fig. 2. Ventilatory and gas exchange parameters: (●) abdominal wall retractor; (□) pneumoperitoneum. Data are mean $\pm$ SD. * $p < 0.05$ and $\dagger p < 0.001$ compared with baseline. # $p < 0.05$ compared with pneumoperitoneum.

Hemodynamic data indicate that blood pressure and heart rate are affected similarly by both methods (ANOVA). Although cardiac output increased during abdominal wall retraction compared with a small decrease during conventional pneumoperitoneum, differences in cardiac output between the two techniques were not significant. These findings are not in accordance with a previous study in pigs which indicated that laparoscopy using abdominal wall retraction results in less cardiovascular depression compared to conventional pneumoperitoneum [11]. Others also showed that in pigs, positive and expiratory pressure (PEEP) affected hemodynamics less during AWR than during conventional pneumoperitoneum [16]. The finding that adding 5 mmHg of pneumoperitoneum results in hemodynamic changes similar to those of higher intraabdominal pressures may indicate that these changes are not caused by increased intraabdominal pressure. It has been suggested that the hemodynamic changes during laparoscopy are at least partly due to the pharmacological effects of the absorbed CO₂. Our findings support this contention.

One may say that cardiac output was measured by a new noninvasive method, as described before [15]. Using this device, the cardiac output measurements were computed continuously from the radial artery pressure. The cardiac output changes observed during conventional pneumoperitoneum are similar to those reported in the literature using established cardiac output measurement techniques. It is possible that the computer model does not measure the absolute values of cardiac output; however, it reliably tracks relative changes of cardiac output, which is sufficient for this study.

Respiratory acidosis develops using conventional pneumoperitoneum as shown by the increase of the arterial PCO₂ and pH. The use of AWR was also associated with the gradual development of respiratory acidosis. This finding is in agreement with those of others who showed that the increase of PCO₂ during laparoscopy is not linearly related to the intraabdominal pressure of CO₂ pneumoperitoneum [8]. It is suggested that recruitment of peritoneal absorption area is an important factor to determine the rate of CO₂ absorption from the peritoneal cavity [8, 9]. It is conceivable that recruitment of more gas-exchange area during abdominal wall retraction may result in an increase of PCO₂ similar to the increase observed at higher intraabdominal pressures. Alveolar dead space ventilation is also an important contributor to respiratory acidosis during laparoscopy [8]. The alveolar dead space was not measured in this study. However, it seems possible that alveolar dead space ventilation increases to the same extent during both methods.

The decrease in pH during conventional pneumoperitoneum seems larger, compared with the use of the abdominal wall retractor, although statistical significance was not reached. It is possible that with a longer operation time this difference might reach statistical significance. However, the majority of the laparoscopic cholecystectomies using conventional pneumoperitoneum lasted on average 50 min. Consequently we were unable to complete a full set of hemodynamic and gas-exchange values after 30 min in all cases. It seems reasonable to assume that the abdominal wall retractor might be of value with respect to acid-base equilibrium during operations of longer duration, such as bowel surgery.

Arterial oxygenation shows a gradual reduction of the arterial PO_2 during the laparoscopic procedures, without significant differences between both methods. Increased intrapulmonary shunt or decreased ventilation perfusion ratio as a result of atelectases secondary to the cranial movement of the diaphragm, may be the underlying mechanism of this phenomenon. There is only one case report that describes severe hypoxemia in a patient with sickle cell anaemia undergoing laparoscopic cholecystectomy [4]. Because arterial PO_2 values remained much higher than values at which hemoglobin oxygen desaturation occurs, it remains doubtful whether the decrease in arterial PO_2 is of any clinical relevance.

During laparoscopy, using conventional pneumoperitoneum the cranial shift of the diaphragm is associated with diminished intrathoracic volume. When mechanical ventilation with fixed tidal volumes is applied, increased airway pressures will be generated. Indeed, in our study peak airway pressures increased during laparoscopy using conventional pneumoperitoneum. This finding is in agreement with those of others who reported increased peak and plateau airway pressures secondary to reduced compliance during laparoscopy [2]. In contrast, during abdominal wall retraction peak airway pressures did not increase. High airway pressures may have damaging effects on lungs with bullous emphysema that are prone to the development of barotrauma [13]. In theory, the use of the abdominal wall retractor might be advantageous in these patients because its use is not associated with increased airway pressures.

Conclusion

In conclusion, the results of this study are disappointing with respect to the use of the abdominal wall retractor. In the first place, the use of this device is difficult and does not permit laparoscopic cholecystectomy entirely without pneumoperitoneum. This takes away some of the suggested advantages of using the abdominal wall retractor, such as low costs [6], and the possibility of using conventional instruments [14]. Second, the beneficial effects suggested by several experimental studies with respect to hemodynamics and gas exchange could not be confirmed in this human study.

Considering the results, AWR should not be used during laparoscopic cholecystectomy. AWR might be valuable for lower abdominal surgery, although this has to be evaluated by further study.

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