Comparison of Postoperative Respiratory Function after Laparoscopy or Open Laparotomy for Cholecystectomy

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Laparoscopic cholecystectomy performed via laparotomy is associated with reduction of lung volumes including functional residual capacity that may lead to postoperative hypoxia and atelectasis. Laparoscopic cholecystectomy is associated with faster recovery compared to open laparotomy and cholecystectomy. To determine whether laparoscopic cholecystectomy was associated with less pulmonary dysfunction, 20 patients (ASA Physical Status I) undergoing elective cholecystectomy were randomized to surgical teams performing either laparoscopy or open laparotomy for cholecystectomy. Patients in whom one or the other surgical technique had to be performed for medical or psychologic indications were excluded from the study. A standardized anesthetic technique and postoperative analgesic regimen were used. Forced vital capacity and forced expiratory volume in 1 s; functional residual capacity determined by a closed-circuit, constant volume helium dilution technique; and arterial O2 and CO2 tensions were measured preoperatively and at 6, 24, and 72 h postcholecystectomy. Forced vital capacity and forced expiratory volume in 1 s were significantly greater (P < 0.05) in the laparoscopy compared to the laparotomy group at 6, 24, and 72 h postoperatively. For 16,000 patients relative to preoperative values was significantly (P < 0.05) greater in patients with laparotomy (24 h, 70 ± 14%; 72 h, 91 ± 6%) compared to open laparotomy (24 h, 57 ± 23%; 72 h, 77 ± 14%). Similarly, forced expiratory volumes in 1 s relative to preoperative values were significantly (P < 0.05) greater in patients with laparotomy (24 h, 54 ± 22%; 72 h, 77 ± 11%). Functional residual capacity was decreased in the laparotomy group at 6 h (P < 0.001) postoperatively and in the open laparotomy group at 6 h (P < 0.01), 24 h (P < 0.005), and 72 h (P < 0.05) postoperatively. The difference in functional residual capacity between the groups was evident at 72 h postoperatively. Significantly higher arterial O2 tension (P < 0.05) was observed in the laparoscopic cholecystectomy group. The authors conclude that respiratory function is less impaired and its recovery improved after laparoscopic cholecystectomy compared to open cholecystectomy. (Key words: Surgery; cholecystectomy; laparotomy; laparoscopy. Lungs, pulmonary function: postoperative period.)

UPPER ABDOMINAL SURGERY is associated with a prolonged reduction of respiratory function.1,2 Postoperatively, lung volumes are reduced in a restrictive pattern; furthermore, the decreased functional residual capacity (FRC) can contribute to hypoxemia and atelectasis.3 The site of the surgical incision, the extent of transected abdominal muscles, and the severity of postoperative pain are determinants of the degree of this deterioration of respiratory function after cholecystectomy.4,5

Laparoscopic cholecystectomy is a new technique gaining increasing popularity because of the small, limited incision and the benefit of better and faster recovery compared to that after open cholecystectomy.5

Recent preliminary data have shown a less pronounced depression of lung volumes after laparoscopic cholecystectomy.6-8 However, until now no controlled clinical trial has investigated the change and recovery in lung volumes including FRC and gas exchange after laparoscopic or open cholecystectomy.

The aim of this prospective, randomized study is to compare the changes in lung volumes including FRC and gas exchange up to 72 h in patients undergoing either laparoscopic cholecystectomy or cholecystectomy via laparotomy.

Methods and Materials

Twenty patients, 15 females and 5 males (ASA Physical Status I), scheduled for elective cholecystectomy gave informed consent to participate in the institutionally approved study protocol. Patients were enrolled in the study if they had no history of previous lung disease, a normal preoperative lung function test result while in the sitting position, no history of smoking, age younger than 65 yr, and no obesity (defined as a body mass index of >29). The patients were randomly assigned to surgical teams performing either laparoscopy or open laparotomy for cholecystectomy. Patients in whom one or the other surgical technique had to be performed for medical or psychologic indications were excluded from the study.

Laparoscopic cholecystectomy as described previously was performed with patients in reverse Trendelenburg's position insufflating the abdomen with CO2 using an automatic insufflator set at 1 l/min to a maximum pressure of 12 mmHg. For open cholecystectomy a subcostal incision was performed. A urinary bladder catheter and a nasogastric tube were placed in all patients.

In all patients, anesthesia was induced using propofol (2 mg/kg, intravenous). After infusion of vecuronium bromide (0.1 mg/kg, intravenous) and fentanyl (5 μg/kg intravenous), the trachea was intubated. Anesthesia
was maintained using a continuous infusion of propofol (6–12 mg · kg\(^{-1}\) · h\(^{-1}\), intravenous). Controlled ventilation was performed with a ventilator connected to a rebreathing circuit (Sulla 808V, Dräger, Lübeck, FRG) with a fresh gas flow of air/O\(_2\) at ≥6 l/min and an inspiratory fraction of O\(_2\) of 0.35. The lungs were ventilated with a tidal volume of 8–10 ml/kg at a respiratory rate sufficient to maintain an end-tidal CO\(_2\) concentration of approximately 35 mmHg with positive end-expiratory pressure of 5 cmH\(_2\)O. After surgery, the neuromuscular blockade was reversed with neostigmine (0.03 mg/kg, intravenous) and atropine (0.01 mg/kg, intravenous). The trachea was extubated when the spontaneous breathing was sufficient. Duration of anesthesia was defined as the time between induction and extubation of the trachea.

Intensity of postoperative pain was assessed employing a linear 100-mm visual analog scale (VAS) (0 = no pain, 100 = severe pain). To provide a standardized postoperative analgesia, pirprofen (Dipidolor\(^\circledR\), Jansen Pharmaceutica, Belgium) (0.1 mg/kg, intramuscular) was administered when VAS pain score at rest was greater than 40 mm. Analgesic requirements in the first 6 h after the end of anesthesia and between the following measurements were recorded and are given in μg · kg\(^{-1}\) · h\(^{-1}\).

Each patient was studied while supine 12 h before surgery and 6, 24, and 72 h after the end of anesthesia.

Spirometry was carried out on a dry rolling-seal spirometer (PFT-Horizon\(^\circledR\), Sensormedics, Anaheim, CA) with patients using nose clips, according to the American Thoracic Society criteria for spirometric technique. Forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV\(_1\)) were measured by instructing the patients to breathe into the total lung capacity and then to perform a maximal forced expiration. Patients unfamiliar with this technique practiced while in the sitting position before the study until consistent values were obtained. Function tests not meeting the American Thoracic Society criteria for reproducibility\(^\circledR\) were excluded from analysis.

Functional residual capacity was determined using a closed-circuit, constant volume helium dilution technique with a fully automated pulmonary function testing system (PFT-Horizon\(^\circledR\), Sensormedics, Anaheim, CA). Oxygen was added to the circuit by a computer-controlled valve to maintain constant O\(_2\). Equilibration was defined as three consecutive breaths with mixed expired helium concentration with a variance of ±0.05%.

All lung volumes were converted to body temperature and pressure saturated. Predicted values for lung volumes in the sitting position were recommended by the American Thoracic Society.\(^\circledR\) Postoperative lung volumes were compared to preoperative values while in the supine position, and recovery as changes relative to preoperative values are given in percent. Arterial O\(_2\) (PaO\(_2\)), CO\(_2\) (PaCO\(_2\)) tension, and pH were measured using an automated blood gas analyzer (Stat profile 5\(^\circledR\), Nova Biomedical, Waltham, MA) and corrected for body temperature.

All results are expressed as the mean ± standard deviation. A two-way analysis of variance (ANOVA), followed by Dunnet's test for multiple comparison with a control, determined the significance of changes in the continuous variables within each treatment group. Statistical comparison between the treatment groups was performed using a two-way ANOVA, followed by an unpaired t test with Bonferroni correction to determine the significance of between-group differences preoperatively and at 6, 24, and 72 h postoperatively. A P < 0.05 was accepted as statistically significant. A statistical power analysis was performed to determine the probability of a type II (or β) error. The power analysis suggested that the number of the subjects was adequate to determine with a certainty of 95% whether a difference in the lung volumes and the arterial blood gas tensions existed between the laparoscopy and open laparotomy groups.

Results

The patient groups were similar with respect to age, height, and weight (table 1). Preoperative lung function testing while in the sitting position showed normal values for the laparoscopy (FVC = 3.79 ± 0.68 l, 114 ± 12% predicted; FEV\(_1\) = 3.23 ± 0.7 l, 111 ± 9% predicted; FRC = 2.68 ± 0.32 l) and the open laparotomy (FVC = 3.95 ± 1.02 l, 106 ± 8% predicted; FEV\(_1\) = 3.33 ± 0.86 l, 103 ± 10% predicted; FRC = 2.89 ± 0.33 l) groups. Duration of anesthesia was similar in the laparoscopy (104 ± 25 min) and the open laparotomy (112 ± 37 min) groups.

Changes in lung volumes while in the supine position for patients undergoing laparoscopy or open laparotomy cholecystectomy are summarized in table 2. In both groups, FVC was significantly decreased (P < 0.05) at 6 and 24 h postoperatively (table 2). Forced vital capacity after laparoscopic cholecystectomy significantly exceeded that after laparotomy cholecystectomy at 6 h (P < 0.05), 24 h (P < 0.05), and 72 h (P < 0.05) postoperatively (table 2). Forced vital capacity relative to preoperative values was significantly (P < 0.05) greater in patients with laparoscopy (24 h, 70 ± 14%; 72 h, 91 ± 6%) compared to open laparotomy (24 h, 57 ± 23%; 72 h, 77 ± 14%) for cholecystectomy.

<table>
<thead>
<tr>
<th>Table 1. Demographic Data</th>
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<td><strong>Group</strong></td>
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</tr>
<tr>
<td>Laparoscopy</td>
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<td>Laparotomy</td>
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Values are mean ± SD.
For both groups, FEV\(_1\) was significantly decreased at 6 h (\(P < 0.01\)), 24 h (\(P < 0.05/P < 0.01\)), and 72 h (\(P < 0.05/P < 0.01\)) postoperatively. Forced expiratory volume in 1 s was significantly greater in the laparoscopy compared to the open laparotomy group at 6 h (\(P < 0.05\)) and 24 h (\(P < 0.01\)) (table 2). Forced expiratory volume in 1 s relative to preoperative values was significantly (\(P < 0.05\)) greater in patients with laparoscopy (24 h, 85 ± 13%; 72 h, 92 ± 9%) compared to open laparotomy (24 h, 54 ± 22%; 72 h, 77 ± 11%) for cholecystectomy.

Functional residual capacity decreased significantly in the laparoscopy group only at 6 h (\(P < 0.05\)) postoperatively. In the open laparotomy group, FRC decreased significantly at 6 h (\(P < 0.01\)), 24 h (\(P < 0.05\)), and 72 h (\(P < 0.05\)) postoperatively (table 2). Functional residual capacity relative to preoperative values was significantly (\(P < 0.05\)) greater in patients with laparoscopy (24 h, 85 ± 15%; 72 h, 105 ± 16%) compared to open laparotomy (24 h, 64 ± 19%; 72 h, 67 ± 17%) for cholecystectomy.

Gas exchange variables for the laparoscopy and open laparotomy groups while breathing room air are given in table 3. In the laparoscopy group, \(P_{\text{a}O_2}\) was significantly decreased at 6 h postoperatively (\(P < 0.05\)). In the open laparotomy group, it was significantly decreased at 6 h (\(P < 0.05\)) and 24 h (\(P < 0.05\)) postoperatively. Overall \(P_{\text{a}CO_2}\) was significantly higher (\(P < 0.05\) by ANOVA) in the laparoscopy compared to open laparotomy group. No differences between the groups were observed for \(P_{\text{a}CO_2}\) and pH (table 3).

The VAS pain scores and analgesic requirements are summarized in table 4. Pain score values were not significantly different in the two groups at 6 and 24 h postoperatively. A significantly (\(P < 0.05\)) higher VAS pain score value was found in the open laparotomy group at 72 h postoperatively (table 4). Analgesic requirements (piracetamide) were significantly greater (\(P < 0.05\)) in the open laparotomy compared to the laparoscopy group at 6, 24, and 72 h postoperatively (table 4).

**Discussion**

The main finding of our study is that, in the early postoperative period, lung volumes, including FRC, decreased significantly less after laparoscopic than open cholecystectomy via a subcostal incision. The difference in FRC between the groups was the least pronounced. Recovery of lung volumes, including FRC, to preoperative values was significantly improved after laparoscopic compared to open cholecystectomy.

Immediately after upper abdominal surgery, a marked decrease in lung volumes to approximately 40–50% of the preoperative values has been observed.\(^1\,\!\!^2\,\!\!^12\) Lung volumes remain decreased for 7–14 days.\(^1\,\!\!^2\,\!\!^12\) It has been shown repeatedly that the reduction of lung volumes is
greater the closer the incision is to the diaphragm.\textsuperscript{2,13} Lindell and Hedenstierna\textsuperscript{a} and Ali and Khan\textsuperscript{4} also observed a marked reduction of lung volumes after cholecystectomy that slowly improved over a week. Using different incisions for cholecystectomy, significant differences in decrease and recovery of vital capacity and FEV\textsubscript{1} were noted.\textsuperscript{3,4} Patients with a subcostal incision showed a decrease in vital capacity and FEV\textsubscript{1} to 55% of the preoperative value and a slow recovery,\textsuperscript{3,4} whereas vital capacity and FEV\textsubscript{1} decreased to approximately 75% and recovered faster using a muscle-splitting incision for cholecystectomy was used.\textsuperscript{5} Postoperative decrease of FVC and FEV\textsubscript{1} with delayed recovery as observed in our patients with subcostal open laparotomy were almost identical to the equivalent groups in these previous studies.\textsuperscript{3,4}

In contrast, after laparoscopic cholecystectomy, reduction of lung volumes was less and recovery was faster than in patients with a muscle-splitting or a subcostal incision for open cholecystectomy.\textsuperscript{3}

A decrease of FRC has been reported not to occur until 16 h after abdominal surgery.\textsuperscript{12} Later, the same investigators observed a decrease in FRC by approximately 30% on the first day returning to preoperative values within 7 days postcholecystectomy.\textsuperscript{2} Our data show a similar significant decrease in FRC after both laparoscopy and open laparotomy for cholecystectomy. Whereas FRC remains depressed after subcostal open laparotomy, FRC returns to preoperative values within 72 h after laparoscopic cholecystectomy. Changes in FRC and vital capacity similar to those we observed following laparoscopic cholecystectomy have been reported after superficial surgery.\textsuperscript{12}

Decrease of FRC and the relationship of closing capacity to FRC have been shown to correlate best with postoperative hypoxemia.\textsuperscript{1} The decrease of PaO\textsubscript{2} in the open laparotomy group was similar to that observed by other investigators.\textsuperscript{4,14} In the laparoscopic cholecystectomy group, overall PaO\textsubscript{2} was significantly higher (by ANOVA) compared to the open laparotomy group. Since preoperative PaO\textsubscript{2} did not differ between the groups, the significantly higher overall PaO\textsubscript{2} (by ANOVA) indicates a better oxygenation after laparoscopic cholecystectomy.

Our study measured respiratory function for only 72 h after cholecystectomy, compared to 4 days by Lindell and Hedenstierna\textsuperscript{a} and 7 days by Ali and Khan.\textsuperscript{4} Since most patients are discharged from the hospital within 3 days after laparoscopic cholecystectomy, patients were comparable at \( \leq 72 \) h postoperatively in our study. However, the difference in the recovery of the respiratory function was statistically significant at 24 and 72 h postcholecystectomy.

The difference in respiratory function after laparoscopy and open laparotomy cholecystectomy cannot be explained by different anesthesia, duration of operation, or
RESPIRATORY FUNCTION AFTER OPEN LAPAROTOMY AND LAPAROSCOPY

TABLE 4. Visual Analog Scale Pain Score and Analgesic Requirements in the Open Laparotomy and Laparoscopic Group

<table>
<thead>
<tr>
<th>Group</th>
<th>VAS* (mm)</th>
<th>Piritramide* (μg·kg⁻¹·h⁻¹)</th>
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<tbody>
<tr>
<td></td>
<td>POP</td>
<td>6 h</td>
</tr>
<tr>
<td>Laparotomy</td>
<td>32 ± 6</td>
<td>28 ± 7</td>
</tr>
<tr>
<td>Laparoscopy</td>
<td>35 ± 4</td>
<td>33 ± 6</td>
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</tbody>
</table>

Values are mean ± SD.

Piritramide dosage in the first 6 hours after the end of anesthesia (6 h) and between the measurements (24 h, 72 h) was recorded and is given in μg·kg⁻¹·h⁻¹.

VAS = visual analog score; POP = preoperative; 6 h, 24 h, 72 h = 6 h, 24 h, 72 h postoperatively.

* P < .05 between groups (ANOVA).
† P < .05 compared to the open laparotomy group (Bonferroni corrected t-test).
‡ P < .01 compared to 6 h (ANOVA with Dunnet's test).
§ P < .01 compared to 24 h (ANOVA with Dunnet's test).

postoperative care in our patients. Several other mechanisms may be responsible for the marked depression of pulmonary function after upper abdominal surgery including surgical incision, local abdominal pain, and diaphragm dysfunction.

The site of a surgical incision and transection of abdominal muscles has been demonstrated to have a major impact on depressed pulmonary function after cholecystectomy. Abdominal muscles act during forced expiration and coughing. Since open laparotomy is associated with a long subcostal incision and the transection of the rectus abdominis muscle, it is not surprising that expiratory function is impaired. In contrast, laparoscopic cholecystectomy requires only four small skin incisions for the insertion of the trocar. Thus, laparoscopic cholecystectomy might be expected to decrease pulmonary function less than a subcostal incision with muscle splitting.

Although pain is assumed to be an important causative factor, total relief of pain after upper abdominal surgery using epidural analgesia resulted in only partial restoration of vital capacity and a minimal increase in FRC. It is important to note that the changes in postoperative pulmonary function observed in our patients might apply only if the same pain management is used and may vary under any other, perhaps more aggressive analgesic regimen. In the present study with standardized postoperative pain management, VAS pain score did not differ between groups until 72 h postoperatively. However, analgesic requirement (piriramide) was significantly greater in the open laparotomy compared to the laparoscopy group. The total doses of piritramide per hour was relatively small in all patients. But an impact on the pulmonary function due to the higher analgesic doses in the open laparotomy group cannot be ruled out.

Diaphragm dysfunction after upper abdominal surgery is related to pain, an increase in abdominal wall tone and reflexes due to local irritation of the gallbladder. The local stimulation and irritation of the gallbladder should be comparable in both the laparoscopy and open laparotomy surgical approaches. Increased intraabdominal pressures (~14 mmHg) associated with the CO₂ insufflation during laparoscopy on postoperative diaphragm function may have caused the significant decreases in FVC, FEV₁, and FRC in the laparoscopy group. However, this mechanism might be of less importance since depression of respiratory function is less and recovery is improved compared to open laparotomy.

Our study demonstrates that the laparoscopic cholecystectomy is associated with less adverse effect on postoperative respiratory function than that following laparotomy.

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References