

## Original Research Article

# Pulmonary function changes in patients undergoing laparoscopic cholecystectomy

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**Received:** 13 February 2022

**Revised:** 11 March 2022

**Accepted:** 30 March 2022

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### ABSTRACT

**Background:** Cholecystectomy, surgical removal of the gallbladder, is one of the most common elective procedures performed by general surgeons. Upper abdominal operations may induce postoperative restrictive ventilatory defects. They are more pronounced in open procedures, yet also seen in laparoscopic ones cholecystectomy.

**Methods:** This observational study entitled “pulmonary function changes in patients undergoing laparoscopic cholecystectomy” was conducted after clearance from board of studies and ethical committee in the department of general surgery, Sharda hospital, school of medical sciences and research (Greater Noida) during the period 2019-2021. The study population has been calculated by using G-power software with 80% of the power and 5% of the significance level. The total sample size was determined to be 100 patients.

**Results:** The study population consisted of 34 (34.0%) belonged to 19-30 years. There were 23 (23.0%) males and 77 (77.0%) females among study population. The mean forced vital capacity (FVC) (L), FEV1 (L), FEV1/FVC (%), FEF 25-75 (L) and SpO<sub>2</sub> was compared between Pre-operative and post-operative using the paired t test. Mean FVC (L), FEV1 (L), FEV1/FVC (%), FEF 25-75 (L) and SpO<sub>2</sub> decreased significantly from pre-operatively to post-operatively.

**Conclusions:** To conclude my study, it has been observed that pulmonary function variables (FVC, FEV1, FEV1/FVC, FEF-25-75%) were significantly impaired after laparoscopic cholecystectomy.

**Keywords:** Pulmonary function, FEV1, FVC, Diaphragm

### INTRODUCTION

Gall stone disease is the most common biliary pathology and has plagued the mankind for over 2000 years.<sup>1</sup> Approximately one-tenth of the adult population in United States harbors gall stones.<sup>2</sup> The vast majority of subjects (more than 85%) are asymptomatic, and when such patients are followed, between 1-4% per year will develop biliary symptoms. Cholecystectomy, surgical removal of the gallbladder, is one of the most common elective procedures performed by general surgeons.<sup>3</sup> Upper abdominal operations may induce postoperative restrictive ventilatory defects. They are more pronounced in open procedures, yet also seen in laparoscopic ones.<sup>6</sup> Pulmonary complication rate following abdominal

surgery is 20-60% and pulmonary function tests decrease apparently after upper abdominal surgery. Abdominal surgical procedures may alter lung function, reducing lung volumes and capacities and, consequently, impairing gas exchange and increasing hospitalization time. In laparoscopic cholecystectomy, manipulation of the abdominal cavity, as explained by Ribeiro et al leads to a decrease in pulmonary volumes and capacities, which may result in hypoxemia and atelectasis due to diaphragmatic dysfunction.<sup>4</sup> Diaphragmatic paresis associated with the induced pneumoperitoneum may lead to atelectasis in bases, resulting in a collapse of alveolar ventilation, with alteration in ventilation-perfusion or shunt causing hypoxemia.<sup>5</sup> Laparoscopic cholecystectomy also results in less postoperative

pulmonary dysfunction, faster recovery of preoperative pulmonary function and less atelectasis and hypoxaemia than open cholecystectomy. Nevertheless, postoperative pulmonary dysfunction after laparoscopic cholecystectomy is significant. The role of inflammation of the punctured abdominal wall or gallbladder bed, or both, carbon dioxide pneumoperitoneum or intraoperative patient position in the pathogenesis of this pulmonary dysfunction is unknown.<sup>6-8</sup> Recent studies have shown that after laparoscopic surgery lung function and arterial gases are less impaired.<sup>6,7</sup> It has been postulated that this reduced diminution in lung function implies a parallel reduction in postoperative pulmonary complications.<sup>8</sup> However, few prospective studies have shown this. The discrepancies observed may be because the pulmonary complications have not been systematically investigated, and have been variably defined.<sup>9</sup> An increase in end-tidal CO<sub>2</sub> fraction (FETCO<sub>2</sub>) is commonly observed with CO<sub>2</sub> intraperitoneal insufflation during laparoscopic cholecystectomy. This results from the diffusion of CO<sub>2</sub> from the peritoneal cavity to the blood and from the pulmonary CO<sub>2</sub> elimination (VECO<sub>2</sub>). A similar evolution of FETCO<sub>2</sub> and VECO<sub>2</sub> has been observed in ASA physical status 1-2 patients. This suggests that an increase in VECO<sub>2</sub> is leading cause of rising FETCO<sub>2</sub>, and that a change in alveolar dead space is unlikely. If this assumption is right, the arterial-end-tidal CO<sub>2</sub> gradient (Fa-ETCO<sub>2</sub>) may stay unchanged, and changes in FETCO<sub>2</sub> may then represent changes in FaCO<sub>2</sub>.<sup>10</sup>

### **Aims**

Aim of the study was to compare changes in pre and postoperative pulmonary functions in patients undergoing laparoscopic cholecystectomy.

### **Objectives**

#### *Primary objective*

Primary objectives were to find changes in pulmonary functions in patients undergoing laparoscopic cholecystectomy.

#### *Secondary objective*

Secondary objectives were to study post-operative respiratory complications (if any) in patients undergoing laparoscopic cholecystectomy.

## **METHODS**

This observational study entitled "Pulmonary function changes in patients undergoing laparoscopic cholecystectomy" was conducted after clearance from board of studies and ethical committee in the department of general surgery, Sharda hospital, school of medical sciences and research (Greater Noida) during period 2019-2021.

### **Sample size**

The study population has been calculated by using G-power software with 80% of the power and 5% of the significance level. The total sample size was determined to be 100 patients.

The study subjects were chosen as per the inclusion and exclusion criteria:

### **Inclusion criteria**

All patients with symptomatic cholelithiasis undergoing elective laparoscopic cholecystectomy under GA. BMI less than 40 kg/m<sup>2</sup>. (Grade 3 obesity) and patients aged between 19-65 years (age more than 18 years) were included in the study.

### **Exclusion criteria**

Patients having acute cholecystitis and choledocholithiasis. Patients with history of previous pulmonary disease. Patients who are chronic smokers. Patients undergoing emergency surgery. Patients with occupational exposure to irritants. Patients who have used or are using bronchodilators. Patients with scoliosis and kyphosis were excluded from the study.

### **Parameters assessed**

Pulmonary function studies: Pre-operative PFT was done in all the selected patients. Static and dynamic lung volumes and flow rates were measured. Measurements were made with the patients in sitting position according to guidelines of the American thoracic society. FVC, FEV1, FEF 25-75%, FEV1/FVC and SpO<sub>2</sub> were measured and greatest value of three attempts was recorded. All the tests were performed in our physiology laboratory. All studies (PFT) were performed on the day before surgery and in the morning of second post-operative day [10-11AM].

Degree of oxygen saturation was measured preoperatively and post operatively on second post-operative day in all the patients [10-11 AM].

### **Study procedure**

After approval from the institutional ethical committee all patients were selected as per inclusion and exclusion criteria. A detailed history, complete physical examination and routine and appropriate investigations were done for all patients.

The pulmonary function tests were performed by using RMS Helios 401 computerized spirometer available in the research laboratory of department of physiology, school of medical sciences and research, Greater Noida. Helios 401 is spirometric software which is used in conjunction with windows-based computer. It is used to

determine the dynamic lung function by measuring FVC, slow vital capacity (SVC) and the maximum ventilatory volume (MVV).

PFT of the patients were conducted according to American thoracic society/European respiratory society guidelines in a quiet room in sitting position at room temperature. The subjects were explained about the maneuver to be performed and a demonstration given. After clipping the nose, mouthpiece was placed in position and the subject were asked to tightly close lips around the mouth piece so as to avoid any leak of breath. Then subjects were instructed to inhale completely and rapidly, followed by maximal expiration until no more air could be exhaled while maintaining an upright posture. The subjects performed the maneuver three times at 15 minutes interval and the best of the three readings was taken into consideration.

### ***Spirometry***

Spirometry is the term given to the basic lung function tests that measure the air that is expired and inspired. There are three basic related measurements: volume, time and flow. Spirometry is objective, non-invasive, sensitive to early change and reproducible. With the availability of portable meters, it can be performed almost anywhere and, with the right training, it can be performed by anybody. It is performed to detect the presence or absence of lung disease, quantify lung impairment, monitor the effects of occupational/environmental exposures and determine the effects of medications.

Spirometric measures include the following: Forced expiratory volume in 1 (FEV<sub>1</sub>), Forced vital capacity (FVC), the maximum amount of air that can be exhaled when blowing out as fast as possible, Vital capacity (VC), the maximum amount of air that can be exhaled when blowing out as fast as possible, FEV<sub>1</sub>/FVC ratio, Peak expiratory flow (PEF), the maximal flow that can be exhaled when blowing out at a steady rate, Forced expiratory flow, also known as mid-expiratory flow; the rates at 25%, 50% and 75% FVC are given, Inspiratory vital capacity (IVC), the maximum amount of air that can be inhaled after a full expiration

### ***Patient positioning***

Correct measurement posture is as follows: Sit upright: there should be no difference in the amount of air the patient can exhale from a sitting position compared to a standing position as long as they are sitting up straight and there are no restrictions. Feet flat on floor with legs uncrossed: no use of abdominal muscles for leg position. Loosen tight-fitting clothing: if clothing is too tight, this can give restrictive pictures on spirometry (give lower volumes than are true). Dentures normally left in: it is best to have some structure to the mouth area unless dentures are very loose. Use a chair with arms: when

exhaling maximally, patients can become light-headed and possibly sway or faint.

### ***Technique***

There are a number of different techniques for performing spirometry.

Before performing the forced expiration, tidal (normal) breaths can be taken first, then a deep breath taken in while still using the mouthpiece, followed by a further quick, full inspiration.

Alternatively, a deep breath can be taken in then the mouth placed tightly around the mouthpiece before a full expiration is performed.

The patient can be asked to completely empty their lungs then take in a quick full inspiration, followed by a full expiration.

The latter technique can be useful in patients who may achieve a larger inspiration following expiration.

For FVC and FEV<sub>1</sub>, the patient takes a deep breath in, as large as possible, and blows out as hard and as fast as possible and keeps going until there is no air left.

PEF is obtained from the FEV<sub>1</sub> and FVC manoeuvre.

For VC, the patient takes a deep breath in, as large as possible, and blows steadily for as long as possible until there is no air left. Nose clips are essential for VC as air can leak out due to the low flow.

The IVC manoeuvre is performed at the end of FVC/VC (depending on what type of equipment is used) by taking a deep, fast breath back in after breathing all the way out.

### ***Surgical technique, anaesthesia and analgesia standardization***

Patient identification and safety checklist was signed, patient was placed supine on OT table, one IV line secured on left hand dorsum and one crystalloid (RL) was started, ASA standard monitors were attached, O<sub>2</sub> administration with 6 liters per minute was started, preoperative antibiotic prophylaxis with injection ceftriaxone 1 gm IV was given, premedication with midazolam 1 mg was given, induction was performed with fentanyl 2 mcg/kg, propofol 2 mg/kg and endotracheal intubation with muscle relaxant, vecuronium 0.02 mg/kg was done, CO<sub>2</sub> pneumoperitoneum was created using closed method and pressure of 10-12 mmHg was maintained during surgery, umbilical port was placed, and other ports placed under vision (classical four port procedure), reverse trend Elberg position with right side up (10-15 degrees) was attained, arms abducted and placed on hand rest, anaesthesia was maintained with oxygen, nitrous oxide

and isoflurane, oxygen flow @ 1l/min, N<sub>2</sub>O @ 2l/min (65%) was maintained, isoflurane was used to maintain a MAC of 1.2, ventilation-positive pressure ventilation, tidal volume of 325-425 ml (6-8 ml/kg), ETCO<sub>2</sub> 35-45, minute volume of 5-8 l/min was maintained, Extubation-ondansetron 0.1 mg/kg IV 30 minutes prior to extubation. patient was reversed with injection glycopyrrolate (10 mcg/kg) and injection neostigmine (30-70 mcg/kg). Analgesia was given with injection paracetamol 1 gm IV (15 mg/kg), TAP block with bupivacaine 0.25% (2 mg/kg) was given. After extubation patient was shifted to post anaesthetic care unit for monitoring. In postoperative ward analgesia was given with injection diclofenac 75 mg IV 12 hourly. Duration of surgery was on an average 50-60 minutes.



**Figure 1: RMS Helios spirometer with nose piece and mouth piece.**



**Figure 2: RMS Helios spirometer with attached windows-based software.**

### Statistical analysis

The data was entered into the Microsoft excel and the statistical analysis was performed by statistical software SPSS version 25.0. The quantitative (Numerical variables) were present in the form of mean and SD and the qualitative (Categorical variables) were present in the form of frequency and percentage.

The student t-test was used for comparing the mean values between the 2 groups whereas chi-square test was

applied for comparing the frequency. The p value was considered to be significant when less than 0.05.

## RESULTS

### *Distribution of study population according to age groups*

The study population consisted of 34 (34.0%) belonged to 19-30 years, 42 (42.0%) belonged to 31-45 years and 24 (24.0%) belonged to 45-65 years.

### *Distribution of study population according to gender*

There were 23 (23.0%) males and 77 (77.0%) females among study population.

**Table 1: Distribution of study population according to pre-operative and post-operative FVC.**

FVC (L)	Mean	SD	Mean difference	T test value	P value
<b>Pre-op</b>	3.93	0.49	0.39	23.768	<0.001*
<b>Post-op</b>	3.54	0.48			

\*Significant difference paired t test.

The mean FVC (L) was compared between pre-operative and post-operative using the paired t test. The mean FVC (L) decreased significantly from pre-op to post-op.

**Table 2: Distribution of study population according to pre-operative and post-operative FEV1.**

FEV1 (L)	Mean	SD	Mean difference	T test value	P value
<b>Pre-op</b>	3.28	0.42	0.32	21.109	<0.001*
<b>Post-op</b>	2.97	0.42			

Paired t test, \*Significant difference.

The mean FEV1 (L) was compared between pre-operative and post-operative using the paired t test. The mean FEV1 (L) decreased significantly from pre-operatively to post-operatively.

**Table 3: Distribution of study population according to pre-operative and post-operative FEF 25-75 (L).**

FEF 25-75 (L)	Mean	SD	Mean difference	T test value	P value
<b>Pre-op</b>	3.79	0.50	0.29	11.895	<0.001*
<b>Post-op</b>	3.50	0.50			

Paired t test, \*Significant difference.

The mean FEF 25-75 (L) was compared between pre-op and post-op using paired t test. Mean FEF 25-75 (L) decreased significantly from pre-op to post-op.

**Table 4: Distribution of study population according to pre-operative and post-operative SpO<sub>2</sub>.**

SpO <sub>2</sub>	Mean	SD	Mean difference	T test value	P value
<b>Pre-op</b>	95.36	1.23	1.21	1.056	0.126
<b>Post-op</b>	94.15	1.52			

Paired t-test, # non-significant difference.

The mean SpO<sub>2</sub> was compared between pre-operative and post-op using paired t test. There was no significant difference in mean SPO<sub>2</sub> from pre-operatively to post-op.

**Table 5: Distribution of study population according to pre-operative and post-operative FEV1/FVC (%).**

FEV1/FVC (%)	Mean	SD	Mean difference (%)	T test value	P value
<b>Pre-op</b>	83.58	1.72	1.84	41.29	<0.001*
<b>Post-op</b>	81.74	1.96			

Paired t test, \* Significant difference.

The mean FEV1/FVC (%) was compared between pre-operative and post-operative using the paired t test. The

mean FEV1/FVC (%) decreased significantly from pre-op to post-op.

The mean FVC (L), FEV1 (L), FEV1/FVC (%), FEF 25-75 (L) and SpO<sub>2</sub> was compared between Pre-operative and post-operative using the paired t-test. The mean FVC (L), FEV1 (L), FEV1/FVC (%), FEF 25-75 (L) and SpO<sub>2</sub> decreased significantly from pre-op to post-op.

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**Table 6: Subgroup analysis (age 17-30 years).**

Variables	Pre-operative		Post-operative		Mean difference	T test value	P value
	Mean	SD	Mean	SD			
<b>FVC (L)</b>	3.97	0.47	3.59	0.48	0.38	34.573	0.001*
<b>FEV1 (L)</b>	3.33	0.41	2.95	0.42	0.38	34.573	0.001*
<b>FEV1/FVC (%)</b>	83.99	1.96	82.28	2.19	1.72	22.310	0.001*
<b>FEF 25-75 (L)</b>	3.83	0.51	3.45	0.51	0.38	35.781	0.001*
<b>SpO<sub>2</sub></b>	95.65	1.18	94.38	1.44	1.26	6.489	0.001*

Paired t test, \*Significant difference.

**Table 7: Subgroup analysis (age group 31-45 years).**

Variables	Pre-operative		Post-operative		Mean difference	T test value	P value
	Mean	SD	Mean	SD			
<b>FVC (L)</b>	3.93	0.50	3.54	0.49	0.39	41.133	0.001*
<b>FEV1 (L)</b>	3.28	0.44	2.88	0.43	0.39	41.133	0.001*
<b>FEV1/FVC (%)</b>	83.22	1.45	81.33	1.65	1.89	29.643	0.001*
<b>FEF 25-75 (L)</b>	3.80	0.50	3.41	0.49	0.39	41.133	0.001*
<b>SpO<sub>2</sub></b>	95.33	1.20	94.21	1.39	1.12	6.969	0.001*

Paired t-test, \*Significant difference.

**Table 8: Subgroup analysis (age group 46-65 years).**

Variables	Pre-operative		Post-operative		Mean difference	T test value	P value
	Mean	SD	Mean	SD			
<b>FVC (L)</b>	3.86	0.50	3.47	0.49	0.40	28.380	0.001*
<b>FEV1 (L)</b>	3.23	0.42	2.84	0.41	0.40	28.380	0.001*
<b>FEV1/FVC (%)</b>	83.65	1.73	81.75	2.01	1.90	19.862	0.001*
<b>FEF 25-75 (L)</b>	3.71	0.51	3.32	0.51	0.40	28.380	0.001*
<b>SpO<sub>2</sub></b>	95.00	1.29	93.71	1.81	1.29	5.454	0.001*

Paired t test, \*Significant difference.



**Table 9: Subgroup analysis (male gender).**

Variables	Pre-operative		Post-operative		Mean difference	T test value	P value
	Mean	SD	Mean	SD			
<b>FVC (L)</b>	4.74	0.22	4.34	0.22	0.40	32.307	0.001*
<b>FEV1 (L)</b>	4.00	0.17	3.60	0.17	0.40	32.307	0.001*
<b>FEV1/FVC (%)</b>	84.46	1.69	83.03	1.88	1.43	23.041	0.001*
<b>FEF 25-75 (L)</b>	4.61	0.21	4.21	0.21	0.40	32.307	0.001*
<b>SpO<sub>2</sub></b>	95.39	1.08	94.00	1.21	1.39	9.238	0.001*

Paired t test, \*Significant difference.

**Table 10: Subgroup analysis (female gender).**

Variables	Pre-operative		Post-operative		Mean difference	T test value	P value
	Mean	SD	Mean	SD			
<b>FVC (L)</b>	3.69	0.19	3.30	0.21	0.38	51.786	0.001*
<b>FEV1 (L)</b>	3.07	0.15	2.69	0.17	0.38	51.786	0.001*
<b>FEV1/FVC (%)</b>	83.32	1.65	81.37	1.82	1.95	41.917	0.001*
<b>FEF 25-75 (L)</b>	3.54	0.22	3.16	0.23	0.38	52.438	0.001*
<b>SpO<sub>2</sub></b>	95.35	1.27	94.19	1.61	1.16	8.583	0.001*

Paired t test, \*Significant difference.

The mean FVC (L), FEV1 (L), FEV1/FVC (%), FEF 25-75 (L) and SpO<sub>2</sub> was compared between pre-operative and post-operative using the paired t test. The mean FVC (L), FEV1 (L), FEV1/FVC (%), FEF 25-75 (L) and SpO<sub>2</sub> decreased significantly from pre-op to post-op.

## DISCUSSION

Upper abdominal surgery can produce dysfunctional pulmonary mechanics independent of effects of general anaesthesia. Although the etiology of the pulmonary dysfunction after upper abdominal surgery has not been completely elucidated, post-operative pain and diaphragmatic dysfunction are considered to be major contributory factors.<sup>25</sup> Incisional pain limits inspiratory capacity and impairs cough reflex thereby producing a pattern of shallow inspiration leading to alveolar collapse. Upper abdominal surgery also decreases diaphragmatic excursion and may lead to paradoxical motion of diaphragm which further leads to increased demand on intercostals muscle contribution to respiration, thereby decreasing functional residual capacity.<sup>17</sup>

According to Ford et al the disturbances in the respiratory muscle activity were observed after surgical removal of the gallbladder. Postoperatively, in addition to reduced lung volumes, a weakened diaphragmatic function was detected during inspiration and was associated with a rapid shallow breathing pattern and a paradoxical abdominal motion, especially in the case of sedatives administration.<sup>17</sup>

Some surgical procedures interfere with pulmonary mechanics and tend to develop restrictive ventilatory changes, with a reduction in FEV1 and FVC, which may reach approximately 40 to 50% of the preoperative value and remain reduced for at least one to two weeks.<sup>26</sup> In

most abdominal surgical procedures, these derangements peak on the first postoperative day, when the respiratory system becomes more vulnerable to postoperative pulmonary complications.<sup>27,28</sup> These changes occur especially in upper abdomen operations and are mainly determined by diaphragmatic dysfunction, triggered by the surgical stimuli.<sup>25,29,30</sup>

## Age

The study population consisted of 34 (34.0%) belonged to 17-30 years, 42 (42.0%) belonged to above 45 years and 24 (24.0%) belonged to above 45 years. Borges et al. demonstrated that the mean age (years) of the subjects was 38.38±11.72 and 34.21±10.51 years among conventional and single-port laparoscopic cholecystectomy respectively.<sup>16</sup> In the study by Chumillas et al the mean age of the study population was 63.3±10 and 60.7±12.6 years among the 2 groups respectively.<sup>9</sup>

In our study, there were 23.0% males and 77.0% females among study population. In the study by Karayiannakis et al there was predominance of females.<sup>21</sup> Borges et al studied only women and compared conventional and single-port laparoscopic cholecystectomy.<sup>16</sup> In the study by Chumillas et al male/females ratio was 5/15 and 4/16 among 2 groups respectively.<sup>9</sup>

## Pulmonary functions

In our study, the mean FVC (L), FEV1 (L), FEF 25-75 (L) and FEV1/FVC (%) decreased significantly from pre-operatively to post-operatively. Similar to our study, Chumillas et al showed that on the 2<sup>nd</sup> post-operative day, there was a significant reduction in the mean preoperative FVC and FEV1 values in both groups.<sup>9</sup>

Barnett et al evaluated 22 patients admitted for laparoscopic cholecystectomy for lung volume changes and development of postoperative pulmonary complications. The procedure was associated with a marked decline in forced vital capacity (FVC,  $41.2 \pm 20.7\%$ ) and forced expiratory volume in one second (FEV1,  $41.4 \pm 20.8\%$ ) in the immediate postoperative period. There was no significant difference in loss of lung function according to age ( $p=0.18$ ), sex ( $p=0.33$ ), or smoking history ( $p=0.58$ ). Despite the marked loss in lung function in the immediate postoperative period, no major pulmonary complications occurred.<sup>12</sup>

Hasukić et al evaluated the pulmonary changes after Laparoscopic cholecystectomy. Spirometry and chest radiographs were made before and 24 hours after operation. Forced expiratory volume in 1 s (FEV: mean $\pm$ SD values; preoperative:  $3.12 \pm 0.78$ ; postoperative:  $2.33 \pm 0.80$ ), forced vital capacity (FVC; preoperative:  $3.58 \pm 0.95$ ; postoperative:  $2.93 \pm 1.05$ ), peak expiratory flow (PEF; preoperative:  $5.59 \pm 1.97$ ; postoperative:  $4.27 \pm 1.60$ ) and the midexpiratory phase of forced expiratory flow (FEF25-75; preoperative:  $1.98 \pm 0.93$ ; postoperative:  $1.60 \pm 0.73$ ), were reduced 20-25% on average compared with preoperative values.<sup>20</sup>

Mahul et al found significant differences for the forced vital capacity variable ( $p=0.020$ ) and Forced Expiratory Volume in the first second ( $p=0.022$ ) between the pre- and immediate postoperative periods, indicating restrictive ventilatory dysfunction. Mild restrictive ventilatory defects were observed, with FVC and FEV1 reduction, when these two variables were compared pre- and postoperatively.<sup>23</sup> Therefore, laparoscopic cholecystectomy also results in post-operative spirometric changes. The most pronounced decreases in FVC and FEV1 were 8.2% and 8.4%, respectively, in relation to the baseline values. This implies that postoperative spirometric values are comparable to normal tests when compared with the predicted values.

Hall and colleagues. pointed out that laparoscopic surgery leads to better postoperative pulmonary function than open surgery.<sup>24</sup> Although all patients stand to benefit from minimal access abdominal surgery (where applicable), those who stand to benefit the most are those in whom lung function is already compromised and in whom a reduction of lung function variables of 50% might be disastrous.

Kundra et al compared the effects of preoperative and postoperative incentive spirometry on lung functions after laparoscopic cholecystectomy. Significant improvement in the lung functions was seen after preoperative incentive spirometry (group PR),  $p<0.05$ . The lung functions were significantly reduced till the time of discharge in both the groups. However, lung functions were always better preserved in group PR when compared with group PO.<sup>19</sup>

Most of the studies have compared the pulmonary function tests between conventional and cholecystectomy. Borges et al evaluated the pulmonary function of women submitted to conventional and single-port laparoscopic cholecystectomy. In both groups, FVC and FEV1 were lower in the postoperative period than those obtained in the preoperative period, with a greater reduction in the group undergoing conventional laparoscopic cholecystectomy. There was a greater decline in FVC and FEV1 in the postoperative group of patients submitted to conventional laparoscopic cholecystectomy.<sup>16</sup>

In the study by Bhat et al the FEV1/FVC decreased both after open (5.2%) and laparoscopic (3.2%) cholecystectomy, but the decrease was more in open cholecystectomy than in laparoscopic cholecystectomy group.<sup>30</sup> The results of this study indicated that considerable impairment of pulmonary function occurred after laparoscopic cholecystectomy in otherwise healthy patients.

Saad and Zambom reported a decrease in lung capacity and FEV1 in the immediate postoperative period, but total recovery of these values on the fifth postoperative day in large thoracic-abdominal surgeries.<sup>32</sup> The recovery of lung functions after laparoscopic cholecystectomy occurs between five and ten days. In laparoscopic cholecystectomy, the most expected pulmonary complication in the days following surgery is atelectasis, which varies from 10-35%.<sup>33</sup>

The patterns of post-operative alterations are qualitatively similar but quantitatively less than those after open cholecystectomy. The patterns and magnitude of the changes in pulmonary function after laparoscopic or open cholecystectomy observed in our study are in agreement with other studies.<sup>33,34</sup> The discrepancies may possibly be attributed to differences in patient selection criteria, duration of anaesthesia and surgery and measurement at different post-operative times.<sup>30</sup>

Post-operative pulmonary dysfunction has been considered a restrictive process. The ratio of FEV1/ FVC helps to distinguish between airflow limitations and restrictive abnormalities. In patients with airflow limitations the FEV1/FVC is reduced, but in patients with restrictive disease, the ratio is normal or increased. This suggests that a reduction in airflow limitations (i.e., bronchoconstriction) may play a beneficial role in reducing pulmonary compromise in patients after laparoscopic cholecystectomy. Decreased analgesic requirement in the present study suggests that laparoscopic cholecystectomy was accompanied by less post-operative pain as compared to open cholecystectomy. Pain undoubtedly contributes to the cascade of events, resulting in chest wall splinting, reduced FRC, tachypnea and shallow breathing which ultimately lead to atelectasis, the forerunner of pulmonary complication.<sup>30</sup>

A number of studies, also showed that for patients who underwent upper abdominal surgery, compared with the abdominal cavity, the thoracic wall provided major postoperative contributions in respiratory movement.<sup>11,25,35-37</sup> This result implied a clear translocation of the respiratory drive from the diaphragm to other respiratory muscles.

As for why general anaesthesia and analgesia had no effects, the diaphragmatic activity is not affected by perceptible postoperative pain.<sup>25</sup> However, a reflex inhibition regarding diaphragmatic motility seems to occur with the aid of the abdominal region nerves being activated during the operation.<sup>38</sup> Additionally, in anesthetized patients, touch and scrape between the abdominal peritoneum and gallbladder brings about a provisional breathlessness.<sup>38</sup>

In present study, the reduction in FVC (L), FEV1 (L), FEF 25-75 (L) and FEV1/FVC (%) was 10.00%, 11.97%, 2.20% and 10.38% respectively. The reductions in pulmonary function after laparoscopic surgery reported by different authors, are greater than in our own series, 73-79% compared with 84%, respectively, of the preoperative values.<sup>18,22,39-42</sup> These differences may be attributed to the fact that the pulmonary function measurements in all the series were made after 24 hours, whereas in the present study they were made after 48 hours, to allow comparisons with the open group.

In previous observational and non-randomized controlled studies, the post-operative reduction in FVC, FEV1 and FEF25-75% ranged from 20% to 40% on the first or second post-operative day after laparoscopic and from 40% to 70% after open cholecystectomy in healthy patients. A significant reduction in TLC after laparoscopic (8% to 17%) and after open (22%) cholecystectomy was also observed, while RV was unchanged.<sup>15,18,22,40-42</sup> FRC has been reported to decrease 24 hours after laparoscopic cholecystectomy by 7-15 % of preoperative values compared with a reduction of 36% after open cholecystectomy.<sup>15,22,43</sup>

The patterns and magnitude of the changes in pulmonary function after laparoscopic or open cholecystectomy observed in this study are in agreement with those mentioned above. The small discrepancies may possibly be related to differences in patient selection criteria, duration of anaesthesia and surgery, and measurements at different postoperative times.

FEV1/FVC ratio helps to determine obstructive and restrictive anomalies. FEV1/FVC decreases in obstructive type but this ratio is normal or high in restrictive type.<sup>22</sup> Schauer et al reported that postoperative FEV1/FVC values decreased after OC and remained such until 7th day and there was no significant decrease in this ratio after LC.<sup>23</sup> In a study by Mimica et al. FEV1/FVC was significantly low in both groups on the 6th hour,

however, both of them returned to preoperative values on the 144th hour.<sup>46</sup>

In the study by Karayiannakis et al the change in FEV1/FVC ratio was very small in both groups and it was not statistically significant.<sup>21</sup> In the study by Osman et al FEV1/FVC decreased significantly in both groups and the decrease in OC was significantly more compared to LC and the respiratory function tests had returned to normal values on the 6th postoperative day.<sup>47</sup>

### *SpO<sub>2</sub> levels*

In present study, there was no significant difference in mean SpO<sub>2</sub> from pre-operatively to post-operatively. We agree with Mahul et al, Johnson et al and Schauer et al in that we found a slight drop in PaO<sub>2</sub>, with practically no changes in SatO<sub>2</sub> among the laparoscopic patients; this contrasts with the hypoxaemia seen after upper midline cholecystectomy when both PaO<sub>2</sub> and SatO<sub>2</sub> were significantly less than preoperatively.<sup>7,15,21</sup> Hasukić et al found that there were no clinically important changes in arterial blood gas values with laparoscopic cholecystectomy.<sup>47</sup>

According to McMahon et al and Mealy et al the greater alterations in arterial gas tensions may also be verified by comparing the mean percentage reduction in PaO<sub>2</sub> and SatO<sub>2</sub> post-operatively with the preoperative values-there was a larger drop in the upper midline cholecystectomy group than in the laparoscopic series.<sup>40,48</sup>

### *Sub-group analysis*

Patients' age may also be considered a factor capable of interfering in the postoperative evolution. In our study, the mean age of the two groups was not a risk factor for pulmonary complications. The incidence of postoperative pulmonary complications such as atelectasis, transient dyspnea and cough is higher in patients with chronic lung disease, increasing the risk of morbidity and mortality after any surgical procedure.<sup>44</sup>

Paschoal and Pereira, showed that, regardless of the patient's preoperative conditions, the anesthetic and surgical procedure produce changes in the pulmonary physiology that will be determinant in the postoperative evolution. These factors are directly involved in the origin of pulmonary complications, both in patients with previous pulmonary problems and those who have never had pulmonary disease.<sup>45</sup>

Postoperative alterations in pulmonary function are clinically important if they contribute to respiratory complications. The decrease in FRC and its relation to the closing capacity have been shown to correlate well with postoperative atelectasis and hypoxaemia.<sup>21</sup> The development of atelectasis after laparoscopic cholecystectomy has been evaluated in two other studies. Johnson and colleagues reported that segmental



atelectasis developed in three of 31 patients undergoing laparoscopic cholecystectomy.<sup>15,21</sup>

In the study by Schauer and colleagues, radiological atelectasis of varying degrees occurred in 40% of patients after laparoscopic cholecystectomy compared with 95% of patients after open cholecystectomy.<sup>7</sup> This high rate of atelectasis was probably a result of the fact that many patients in that study had risk factors for postoperative pulmonary complications. In the study by Karayiannakis et al in healthy patients, the incidence and severity of postoperative atelectasis were significantly reduced as  $\text{paO}_2$  values were higher after laparoscopic cholecystectomy.<sup>21</sup> Better oxygenation after laparoscopic cholecystectomy compared with open cholecystectomy has been also reported by other authors.<sup>40</sup> Although these findings parallel the changes in FRC, it is difficult to ascertain if the smaller reduction in FRC after laparoscopic cholecystectomy observed in our study translates into fewer respiratory complications.

### Limitations

We think that large surgical trials (RCTs) and further systematic reviews of individual patients' data for adequate pooling of results and for addressing heterogeneity should be carried out in order to provide better and updated evidence on this topic.

### CONCLUSION

To conclude study, it has been observed that pulmonary function variables (FVC, FEV1, FEV1/FVC, FEF-25-75%) were significantly impaired after laparoscopic cholecystectomy.

There was a significant decrease in pulmonary functions from preoperative values to postoperative (POD2) values.

*Funding: No funding sources*

*Conflict of interest: None declared*

*Ethical approval: The study was approved by the Institutional Ethics Committee*

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**Cite this article as:** Wazir JS, Gupta AK, Mushtaq U, Pandey R, Peer JA. Pulmonary function changes in patients undergoing laparoscopic cholecystectomy. *Int Surg J* 2022;9:1052-61.