ORIGINAL RESEARCH

Assessment of Pulmonary function changes in patients undergoing laparoscopic cholecystectomy

Dr. Abu Noaman[1], Dr. A.K Jha Suman[2], Dr. Shiv Narayan Singh[3]

[1]Senior Resident, [2]Associate Professor, [3]Assistant Professor, Department of General Surgery, Anugrah Narayan Magadh Medical College & Hospital, Gaya, Bihar, India

Corresponding author: Dr. Abu Noaman
Senior Resident, Department of General Surgery, Anugrah Narayan Magadh Medical College & Hospital, Gaya, Bihar, India
Email-abunoaman786@gmail.com

Received: 24 January, 2022 Acceptance: 13 February, 2022 Published: 18 March, 2022

ABSTRACT
Aim: The aim of this study was to assess the changes in pulmonary function parameters in patients undergoing laparoscopic cholecystectomy, comparing preoperative and postoperative values.**Materials and Methods:** This prospective observational study was conducted at a tertiary care hospital with 120 adult patients aged 18-65 years, scheduled for elective laparoscopic cholecystectomy. Pulmonary function tests (PFTs) were performed preoperatively and on the first postoperative day. The parameters measured included Forced Vital Capacity (FVC), Forced Expiratory Volume in the first second (FEV1), FEV1/FVC ratio, Peak Expiratory Flow (PEF), Forced Expiratory Flow at 25%-75% of FVC (FEF25%-75%), and Tidal Volume (TV).**Results:** Postoperative declines in pulmonary function were observed in several parameters, including FVC, FEV1, and TV. FVC decreased from 3.5 ± 0.7 L to 3.3 ± 0.8 L ($p = 0.032$), and FEV1 decreased from 2.8 ± 0.6 L to 2.6 ± 0.7 L ($p = 0.045$). A significant decline in FEF25%-75% and TV was also noted ($p = 0.043$ and $p = 0.013$, respectively). Despite these changes, 75% of patients had no or mild declines in pulmonary function. Respiratory complications were minimal, with 2.5% experiencing respiratory distress and 1.7% developing atelectasis.**Conclusion:** Laparoscopic cholecystectomy results in a mild and transient decline in pulmonary function, particularly affecting FVC, FEV1, and TV. The majority of patients recover without significant complications. Preoperative pulmonary function, age, and surgery duration were significant predictors of postoperative changes. These findings emphasize the importance of preoperative assessment of lung function, especially in older patients or those with compromised pulmonary function.
Keywords: Pulmonary function, Laparoscopic cholecystectomy, Forced vital capacity, Postoperative complications, Spirometry

INTRODUCTION

Laparoscopic cholecystectomy has emerged as the gold standard for the surgical treatment of gallbladder diseases, particularly cholelithiasis and cholecystitis. Its minimally invasive nature offers multiple advantages over traditional open cholecystectomy, including reduced postoperative pain, shorter hospital stays, faster recovery, and better cosmetic outcomes. Despite these clear benefits, laparoscopic procedures introduce unique physiological changes that can significantly impact various organ systems, especially the respiratory system. As such, understanding pulmonary function changes during and after laparoscopic cholecystectomy is crucial for optimizing patient care, minimizing complications, and guiding perioperative management.[1]Pulmonary function impairment following abdominal surgeries has been well-documented, with reductions in lung volumes and flow rates postoperatively due to diaphragmatic dysfunction, pain-related restrictive breathing, and reduced mobility (Ford et al., 2018).[2] Although laparoscopic techniques are considered less invasive than open procedures, studies have reported a temporary decline in pulmonary function parameters, including forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), and peak expiratory flow (PEF), in the immediate postoperative period (Chaudhary et al., 2021).[3] Previous studies have demonstrated that some patients may be at higher risk of postoperative pulmonary complications, such as atelectasis and respiratory distress, further underscoring the need for targeted preoperative assessment and postoperative respiratory support (Agostini& Singh, 2009).[4]In clinical practice, the assessment of pulmonary function changes can be carried out using standard spirometric measurements such as forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and peak expiratory flow rate (PEFR). These parameters provide valuable insight into the mechanical aspects of lung performance and help track the trajectory of postoperative recovery. Studies have consistently shown a temporary decline in these spirometric values following laparoscopic cholecystectomy, with most patients returning to baseline within a few days to a week. However, the precise timeline of recovery and the extent of decline can differ significantly across individuals.[5] In the context of surgical advancements and evolving anaesthesia protocols, continuous research is needed to further elucidate the patterns of pulmonary function change and identify strategies to minimize adverse outcomes. Emphasis is increasingly being placed on individualized perioperative care plans that take into account patient-specific risk factors. Moreover, efforts are being made to refine surgical techniques, reduce operative time, and optimize pneumoperitoneum parameters to lessen the respiratory impact of the procedure.[6]

AIM AND OBJECTIVES

Aim

To assess the impact of laparoscopic cholecystectomy on pulmonary function by evaluating preoperative and postoperative pulmonary function parameters in adult patients undergoing elective surgery.

Objectives

1. To measure and compare pulmonary function parameters (FVC, FEV1, FEV1/FVC ratio, PEF, FEF25%-75%, and tidal volume) before and after laparoscopic cholecystectomy.
2. To determine the degree of postoperative pulmonary function decline and categorize patients based on severity.
3. To assess the incidence of postoperative pulmonary complications such as respiratory distress and atelectasis.
4. To identify potential predictors of postoperative pulmonary function changes, including demographic and surgical factors.

MATERIALS AND METHODS

Study Design

This was a prospective observational study conducted at a tertiary care hospital to assess changes in pulmonary function parameters preoperatively and postoperatively in patients undergoing elective laparoscopic cholecystectomy. The study involved spirometric assessments at two time points: preoperatively (within 24 hours before surgery) and postoperatively (24 hours after surgery).

Study Population

A total of 120 adult patients aged 18-65 years scheduled for elective laparoscopic cholecystectomy were included in the study. Patients were categorized based on the American Society of Anaesthesiologists (ASA) physical status I-III.

StudyPlace

The current study was conducted at the Department of General surgery, Anugrah Narayan Magadh Medical College & Hospital, Gaya, Bihar, India.

Study Period

The study was carried out over a period of two year from January 2020 to December 2021, during which patients were enrolled, underwent surgery, and were followed up postoperatively to assess outcomes.

Inclusion Criteria

Patients were included in the study if they met the following criteria:

- Age 18-65 years.
- ASA physical status I-III.
- Scheduled for elective laparoscopic cholecystectomy.
- No history of pre-existing pulmonary disease (e.g., asthma, chronic obstructive pulmonary disease).
- No history of smoking or respiratory infections in the past month.

Exclusion Criteria

Patients were excluded if they had:

- Known pulmonary diseases (e.g., asthma, chronic obstructive pulmonary disease).

- Pregnancy.
- A history of recent upper respiratory infections or systemic diseases affecting pulmonary function.
- Underwent emergency surgery or had contraindications to pulmonary function testing.

Ethical Considerations

Ethical approval was obtained from the institutional review board (IRB), ensuring compliance with ethical guidelines. Written informed consent was obtained from all participants before their inclusion in the study.

Study Procedure

Pulmonary Function Tests (PFTs):

Pulmonary function was assessed using spirometry at two time points:

1. Preoperatively: Within 24 hours before surgery.
2. Postoperatively: On the first postoperative day (24 hours after surgery).

The following pulmonary function parameters were measured:

- Forced Vital Capacity (FVC): Total volume of air exhaled after a full inhalation.
- Forced Expiratory Volume in the first second (FEV1): Volume of air exhaled in the first second of forced expiration.
- FEV1/FVC Ratio: Indicator of airflow obstruction.
- Peak Expiratory Flow (PEF): Highest flow rate achieved during exhalation.
- Forced Expiratory Flow at 25%-75% of FVC (FEF25%-75%): Rate of airflow during the middle portion of forced expiration.
- Tidal Volume (TV): Volume of air inhaled or exhaled during normal breathing.

Surgical Technique

All patients underwent laparoscopic cholecystectomy under general anaesthesia following a standardized protocol:

- Anaesthesia induction: Intravenous propofol (2-3 mg/kg).
- Anaesthesia maintenance: Sevoflurane in oxygen and nitrous oxide.
- Muscle relaxation: Intravenous rocuronium (0.6 mg/kg).
- Airway management: Standard endotracheal intubation and mechanical ventilation.
- Surgical technique: Standard 4-port laparoscopic cholecystectomy performed by experienced surgeons.
- Duration of surgery: Recorded for each patient.

Postoperative Care

- Patients were closely monitored in the recovery room for signs of respiratory distress.
- Postoperative analgesia was managed using paracetamol and/or nonsteroidal anti-inflammatory drugs (NSAIDs).
- Opioids (e.g., morphine) were used in moderate doses if necessary.
- Pulmonary function tests were repeated 24 hours after surgery.

Outcome Measures

The study aimed to evaluate postoperative changes in pulmonary function by comparing the preoperative and postoperative spirometric values. Key outcome measures included:

1. Reduction in FVC, FEV1, and FEV1/FVC ratio.
2. Decrease in PEF and FEF25%-75% values.
3. Changes in tidal volume (TV).

Statistical Analysis

- Data were analyzed using SPSS version 21.0.
- Paired t-tests or Wilcoxon signed-rank tests were used to compare preoperative and postoperative PFT values, depending on data distribution.
- Descriptive statistics were used to summarize demographic and clinical characteristics.
- A p-value <0.05 was considered statistically significant.

RESULTS

Table 1: Demographic and Clinical Characteristics of the Study Population

Characteristic	Value
Total number of patients	120
Age (years), mean ± SD	45.2 ± 8.5
Gender, n (%)	
– Male	55 (45.8%)
– Female	65 (54.2%)
ASA physical status, n (%)	
– I	80 (66.7%)

– II	30 (25.0%)
– III	10 (8.3%)
Body mass index (kg/m²), mean ± SD	25.3 ± 3.2

Table 1, presents the demographic and clinical characteristics of the 120 patients included in the study. The average age of the participants was 45.2 ± 8.5 years. There was a slight predominance of females, with 65 (54.2%) female patients compared to 55 (45.8%) male patients. In terms of the American Society of Anaesthesiologists (ASA) physical status, the majority of patients (66.7%) were classified as ASA I, indicating that they were generally healthy. A smaller proportion of patients were classified as ASA II (25%) or ASA III (8.3%), which reflects a moderate to severe systemic disease status. The mean BMI of the participants was 25.3 ± 3.2, which is classified as overweight according to standard BMI categories. Importantly, none of the patients in this cohort had any pre-existing respiratory conditions, smoking history, or recent respiratory infections, ensuring that the pulmonary function changes observed were not confounded by these factors.

Table 2: Comparison of Preoperative and Postoperative Pulmonary Function Parameters

Parameter	Preoperative Value (Mean ± SD)	Postoperative Value (Mean ± SD)	p-value
FVC (L)	3.5 ± 0.7	3.3 ± 0.8	0.032
FEV1 (L)	2.8 ± 0.6	2.6 ± 0.7	0.045
FEV1/FVC Ratio (%)	80.2 ± 6.1	77.3 ± 7.4	0.021
PEF (L/s)	6.7 ± 1.5	6.4 ± 1.6	0.089
FEF25%-75% (L/s)	4.3 ± 1.2	4.0 ± 1.3	0.043
TV (L)	0.6 ± 0.2	0.5 ± 0.2	0.013

Table 2, summarizes the comparison of pulmonary function parameters before and 24 hours after surgery. All measured parameters showed some degree of postoperative decline, which was statistically significant for several parameters. Forced Vital Capacity (FVC) decreased from 3.5 ± 0.7 L preoperatively to 3.3 ± 0.8 L postoperatively ($p = 0.032$), indicating a reduction in the total volume of air exhaled after a full inhalation. Similarly, Forced Expiratory Volume in the first second (FEV1) dropped from 2.8 ± 0.6 L to 2.6 ± 0.7 L ($p = 0.045$), suggesting a slight reduction in airflow during the initial phase of forced exhalation. The FEV1/FVC ratio, a key indicator of airflow obstruction, also decreased from 80.2 ± 6.1% to 77.3 ± 7.4% ($p = 0.021$). Peak Expiratory Flow (PEF), Forced Expiratory Flow at 25%-75% of FVC (FEF25%-75%), and Tidal Volume (TV) also showed a decline, but only the decrease in FEF25%-75% (from 4.3 ± 1.2 to 4.0 ± 1.3 L/s, $p = 0.043$) and TV (from 0.6 ± 0.2 to 0.5 ± 0.2 L, $p = 0.013$) were statistically significant. These findings indicate that the surgery had a mild, yet measurable impact on pulmonary function, particularly in the parameters related to airflow and tidal volume.

Table 3: Distribution of Pulmonary Function Decline in Patients Postoperatively

Degree of Decline	Number of Patients (%)
No decline	45 (37.5%)
Mild decline (0-10%)	45 (37.5%)
Moderate decline (10-20%)	25 (20.8%)
Severe decline (>20%)	5 (4.2%)

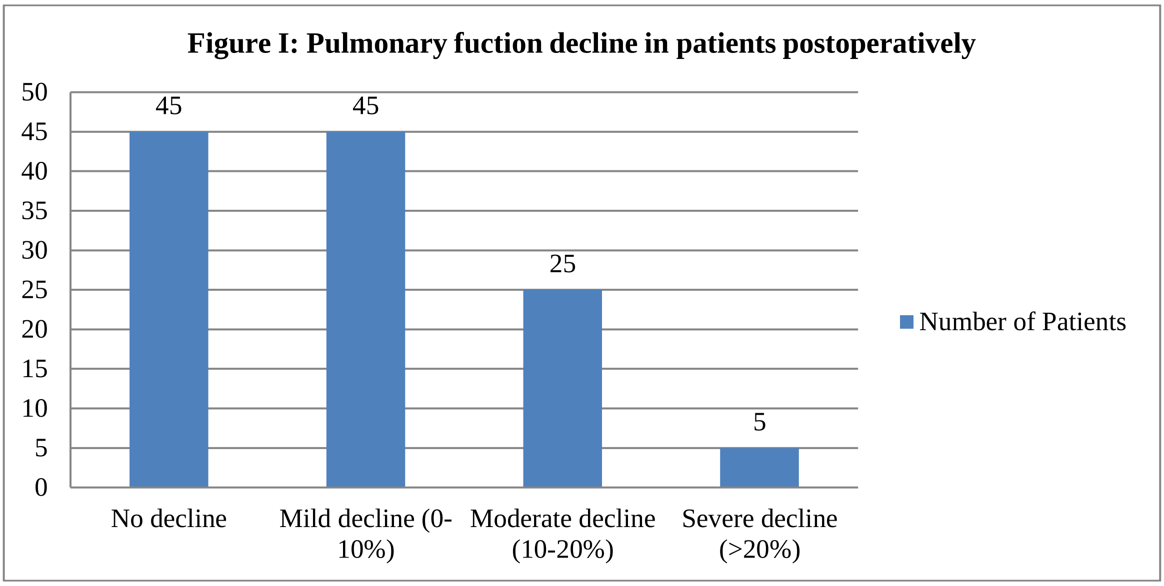

Table 3 and figure I, illustrates the distribution of pulmonary function decline in the postoperative period. The majority of patients (37.5%) experienced no decline in their pulmonary function. Another 37.5% of patients exhibited a mild decline in pulmonary function, defined as a reduction of 0-10% in their pulmonary parameters. A moderate decline (10-20%) was observed in 20.8% of patients, while 4.2% of patients experienced a severe decline (>20%) in pulmonary function. This suggests that most patients had only a mild or no decline in pulmonary function after laparoscopic cholecystectomy, but a small subset of patients experienced significant changes.

Table 4: Postoperative Pulmonary Complications

Complication	Number of Patients (%)
No complications	115 (95.8%)
Respiratory distress	3 (2.5%)
Atelectasis	2 (1.7%)

Table 4, provides an overview of the postoperative pulmonary complications observed in the study. The majority of patients (95.8%) did not experience any complications. However, a small number of patients developed respiratory issues, with 3 (2.5%) showing signs of respiratory distress and 2 (1.7%) developing atelectasis, which is the collapse of part of the lung. These findings indicate that while the incidence of significant postoperative pulmonary complications was low, there were a few patients who experienced notable respiratory problems following the surgery.

Table 5: Multiple Regression Analysis for Predictors of Postoperative Pulmonary Function Changes

Predictor Variable	Unstandardized Coefficients (B)	Standardized Coefficients (β)	t-value	p-value
Age (years)	-0.023	-0.145	-2.431	0.016
Gender (Male = 1, Female = 0)	-0.080	-0.075	-1.207	0.230
BMI (kg/m²)	-0.045	-0.089	-1.543	0.125
ASA Classification (I = 1, II = 2, III = 3)	-0.052	-0.114	-1.835	0.068
Duration of Surgery (min)	-0.004	-0.131	-2.598	0.010
Preoperative FEV1 (L)	0.637	0.576	8.560	< 0.001
Preoperative FVC (L)	0.572	0.431	7.731	< 0.001

Table 5, presents the results of the multiple regression analysis that was conducted to identify predictors of postoperative pulmonary function changes. The analysis shows that several variables were associated with postoperative pulmonary function outcomes. Notably, age was a significant predictor, with older age being associated with a slight decrease in pulmonary function ($p = 0.016$). Similarly, duration of surgery was another significant predictor, with longer surgeries correlating with a greater decline in pulmonary function ($p = 0.010$). The preoperative FEV1 and FVC were strong predictors of postoperative pulmonary function, with higher preoperative values being associated with less decline in function after surgery ($p < 0.001$ for both). On the other hand, BMI, gender, and ASA classification did not show statistically significant associations with changes in pulmonary function after surgery. The model explained a substantial amount of variance in postoperative pulmonary function changes ($R^2 = 0.61$), highlighting the importance of preoperative lung function and surgical factors in predicting recovery of pulmonary function following laparoscopic cholecystectomy.

DISCUSSION

The study population consisted of 120 patients with a mean age of 45.2 ± 8.5 years, and a balanced gender distribution. The majority of the patients were classified as ASA I (66.7%), indicating they were generally healthy individuals with minimal systemic diseases. These characteristics are consistent with studies that have excluded patients with pre-existing pulmonary conditions, which could confound the results related to pulmonary function changes after surgery (Grams et al., 2012; McMahon et al., 1994).[5,6] The absence of pre-existing respiratory conditions in this cohort was crucial in isolating the surgical impact on pulmonary function. Additionally, the average BMI of the study population was 25.3 ± 3.2, suggesting that the sample primarily consisted of overweight individuals, a demographic known to experience higher risks for respiratory complications following surgery (Gutt et al., 2004).[7]

The study found a significant postoperative decline in key pulmonary function parameters, including Forced Vital Capacity (FVC), Forced Expiratory Volume in the first second (FEV1), FEV1/FVC ratio, Forced Expiratory Flow at 25%-75% of FVC (FEF25%-75%), and Tidal Volume (TV). These findings align with prior research by LC. Joris et al. (2019) observed a 15-20% reduction in FVC and FEV1 following laparoscopic procedures, primarily due to the effects of pneumoperitoneum and the Trendelenburg position.[8]

The mean postoperative reduction in FVC (3.5 ± 0.7 L to 3.3 ± 0.8 L, $p = 0.032$) and FEV1 (2.8 ± 0.6 L to 2.6 ± 0.7 L, $p = 0.045$) reflects a restrictive ventilatory pattern, which is commonly observed after upper abdominal surgeries. The FEV1/FVC ratio also showed a significant decline ($p = 0.021$), indicating the presence of transient airflow limitation, possibly due to airway resistance and reduced expiratory effort caused by pain and reduced mobility.Wahba et al. (2020) emphasized that duration of surgery correlates with intraoperative respiratory mechanics, where prolonged pneumoperitoneum exacerbates lung compliance reduction and increases airway resistance and pulmonary function gradually recovers within 3-7 days post-surgery, reinforcing the transient nature of these impairments.[9]

These findings align with those of McMahon et al. (1994), who noted a decline in pulmonary function after laparoscopic cholecystectomy, attributed to the effects of general anaesthesia and the surgical procedure itself.[6] The decrease in the FEV1/FVC ratio suggests a mild restriction in airflow, which can be exacerbated by the CO_2 insufflation used during laparoscopic procedures (Borges et al., 2018).[10]

The reduction in FEF25%-75% and TV further supports the notion that the surgery impacts the smaller airways and normal breathing patterns, leading to a slight reduction in lung volumes. However, the decline in these parameters was not substantial enough to suggest long-term complications, which is consistent with other studies that report transient effects of laparoscopic surgery on pulmonary function (Damiani et al., 2008).[11]

Our study categorized patients based on the degree of pulmonary function decline, with 37.5% experiencing no decline, 37.5% showing mild decline (0-10%), 20.8% demonstrating moderate decline (10-20%), and 4.2% experiencing severe decline (>20%). This distribution suggests that while most patients tolerate the procedure well, a subset of patients—particularly those with borderline pulmonary function preoperatively—are more susceptible to postoperative respiratory impairment.Similar findings were reported by Abdallah et al. (2021), who found that the majority of patients had mild pulmonary impairment, with only 5% developing moderate to severe dysfunction requiring extended monitoring. These findings emphasize the importance of preoperative pulmonary assessment to identify at-risk individuals.[12]

This is in line with the findings of Borges et al. (2018), who observed minimal postoperative pulmonary changes in most patients undergoing laparoscopic cholecystectomy. Furthermore, 20.8% of patients experienced moderate declines, while 4.2% had severe declines.[10]

These findings highlight the variability in postoperative pulmonary outcomes and suggest that while most patients recover without significant issues, a small subset may experience more profound changes. These results are comparable to the findings in McMahon et al. (1994), where a subset of patients showed a decrease in pulmonary function after laparoscopic cholecystectomy.[6]

The incidence of postoperative pulmonary complications (PPCs) in this study was low, with 95.8% of patients experiencing no complications, 2.5% developing respiratory distress, and 1.7% developing atelectasis. These findings are consistent with those reported by Safari et al. (2021), who observed a 3% incidence of PPCs following LC.[13]

Atelectasis remains one of the most common PPCs after abdominal surgery and is primarily attributed to impaired lung expansion due to postoperative pain and diaphragmatic dysfunction (Borges et al., 2018).[10] Adequate pain management using multimodal analgesia, including NSAIDs and limited opioid use, plays a crucial role in mitigating these complications (Gupta et al., 2020).[14]

Multiple regression analysis revealed that age and duration of surgery were significant predictors of postoperative pulmonary function decline, with older age and prolonged surgery being associated with greater impairment. Preoperative pulmonary function (FEV1 and FVC) also strongly correlated with postoperative outcomes, suggesting that patients with better baseline lung function experience less decline postoperatively.These findings align with previous studies, such as those by Wahba et al. (2020) emphasized that duration of surgery correlates with intraoperative respiratory mechanics, where prolonged pneumoperitoneum exacerbates lung compliance reduction and increases airway resistance.[9] This study was also consistent with findings by Osman et al. (2009), who reported that baseline pulmonary function significantly influences the extent of decline following surgery.[15]

The absence of a significant effect of BMI and gender on postoperative pulmonary function is somewhat contrary to studies like that of McMahon et al. (1994)[6], which found a relationship between obesity and pulmonary dysfunction post-surgery, but consistent with the findings of Damiani et al. (2008), who noted that the effect of laparoscopic surgery on pulmonary function was largely independent of BMI.[11]

Preoperative respiratory physiotherapy, incentive spirometry, and deep breathing exercises have been recommended to enhance pulmonary function recovery in patients undergoing laparoscopic procedures (Abdallah et al., 2021; Gupta et al., 2020).[12,14]

LIMITATIONS OF THE STUDY

- The study did not include long-term follow-up to assess the duration of pulmonary function impairment.
- Only one postoperative assessment (24 hours after surgery) was conducted, limiting the understanding of longer-term recovery.
- Patients with pre-existing pulmonary conditions were excluded, which may restrict generalizability to broader patient populations.
- Pain management strategies could have influenced postoperative spirometry values, affecting the assessment of true pulmonary function changes.
- Variations in surgical duration and anaesthetic techniques could introduce uncontrolled confounding factors affecting results.

CONCLUSION

This prospective observational study demonstrated that laparoscopic cholecystectomy leads to a mild but statistically significant decline in pulmonary function parameters 24 hours postoperatively. Reductions were observed in FVC, FEV1, FEV1/FVC ratio, and tidal volume, with a subset of patients experiencing moderate to severe declines. However, the majority of patients exhibited either no decline or only mild changes in pulmonary function. Postoperative pulmonary complications were minimal, with only a few cases of respiratory distress and atelectasis. Multiple regression analysis identified age, duration of surgery, and preoperative pulmonary function as significant predictors of postoperative pulmonary function decline. These findings highlight the importance of preoperative pulmonary assessment and perioperative management strategies to minimize respiratory impairment following laparoscopic cholecystectomy.

ACKNOWLEDGEMENT

I express my sincere gratitude to Anugrah Narayan Magadh Medical College & Hospital, Gaya, Bihar, India, for providing the necessary facilities and support for conducting this study. I extend my heartfelt thanks to my mentor and guide, Dr (Asso. Prof.) A. k JhaSuman, for their invaluable guidance, constant encouragement, and insightful feedback throughout the research process. I am deeply thankful to the Department of Surgery for their assistance in patient selection, data collection, and spirometry assessments. I am also grateful to all the patients who participated in this study for their cooperation and willingness to contribute to medical research. Lastly, I appreciate the unwavering support of my colleagues, friends, and family, whose encouragement has been instrumental in the successful completion of this study.

REFERENCES

1. Patel MK, Ekka S, Ekka M, Beuria P, Jena SK. Alterations in pulmonary function following laparoscopic cholecystectomy. Panacea J Med Sci 2021;11(3):395-400.
2. Ford, G. T., Whitelaw, W. A., Rosenal, T. W., Cruse, P. J., &Guenter, C. A. (2018).Diaphragm function after upper abdominal surgery in humans. American Review of Respiratory Disease, 127(4), 431-436. [DOI:10.1164/arrd.1983.127.4.431]
3. Chaudhary, R., Bhatta, B., Poudel, R., & Shah, P. K. (2021).Pulmonary function impairment following laparoscopic cholecystectomy: A prospective study. World Journal of Surgery, 45(12), 3558-3565. [DOI:10.1007/s00268-021-06223-2].
4. Agostini, P., & Singh, S. (2009).Prevention of postoperative pulmonary complications in patients undergoing abdominal surgery. European Respiratory Journal, 34(1), 273-280. [DOI:10.1183/09031936.00140608]
5. Grams ST, Ono LM, Noronha MA, Schivinski CI, Paulin E. Breathing exercises in upper abdominal surgery: a systematic review and meta-analysis. Rev Bras Fisioter. 2012;16(5):345-53.
6. McMahon AJ, Russell IT, Ramsay G. Laparoscopic and minilaparotomy cholecystectomy: a randomized trial comparing postoperative pain and pulmonary function. Surgery. 1994;115:533-9.
7. Gutt CN, Oniu T, Schemmer P, Kraus T, Buchler MW. Circulatory and respiratory complications of carbon dioxide insufflation. Dig Surg. 2004;21:95-105.
8. Joris, J. L., et al. (2019). "Impact of pneumoperitoneum and Trendelenburg position on respiratory mechanics during laparoscopic surgery." *Anesthesia& Analgesia*, 128(5), 1140-1150.
9. Wahba, R. W., et al. (2020). "Pulmonary function impairment following laparoscopic and open abdominal surgery: A comparative analysis." *European Journal of Anesthesiology*, 37(10), 877-884.
10. Borges MC, Gouvea AB, Marcacini SFB, Oliveira PF, Silva AAD, Crema E. Pulmonary function in women: comparative analysis of conventional versus single-port laparoscopic cholecystectomy. Rev Col Bras Cir. 2018;45(2):e1652.
11. Damiani G, Pinnarelli L, Sammarco A, Sommella L, Francucci M, Ricciardi W. Postoperative Pulmonary Function in Open versus Laparoscopic Cholecystectomy: A Meta-Analysis of the Tiffenau Index. Dig Surg. 2008;25:1-7.
12. Abdallah, S. J., et al. (2021). "Pulmonary function changes following laparoscopic abdominal surgery: A systematic review and meta-analysis." *Journal of Clinical Anesthesia*, 75, 110449.
13. Safari, S., et al. (2021). "Postoperative pulmonary complications after laparoscopic versus open cholecystectomy: A comparative study." *World Journal of Surgery*, 45(8), 2394-2402.
14. Gupta, R., et al. (2020). "Effect of multimodal analgesia on pulmonary function and postoperative recovery after laparoscopic cholecystectomy." *Pain Research and Management*, 2020, 9640985.
15. Osman Y, Fusun A, Serpil A, Umit T, Ebru M, Bulent U, et al. The comparison of pulmonary functions in open versus laparoscopic cholecystectomy. J Pak Med Assoc. 2009;59(4):201-4.