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RESEARCH ARTICLE

INTEGRATED ANAESTHESIA AND PHYSIOTHERAPY STRATEGIES TO REDUCE POST-THORACOTOMY PULMONARY COMPLICATIONS

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Abstract

Post-thoracotomy pulmonary complications (PTPCs) remain a major source of postoperative morbidity,prolonged hospital stay,and mortality following thoracic surgery. These complicationsincluding atelectasis, pneumonia, hypoxemia, and respiratory failureresult from a complex interplay of surgical trauma, one-lung ventilation–induced lung injury, impaired diaphragmatic function, postoperative pain, reduced lung volu mes, and ineffective cough. Increasing evidence supports a multidiscipl inary, integrated perioperative approach combining optimized anaesthet ic management with structured physiotherapy interventions to mitigate these risks. Anaesthetic strategies focus on preoperative risk stratificati on and optimization, lung protective ventilation during one lung ventila tion, judicious oxygen use, effective regional and multimodal analgesia to facilitate deep breathing and early mobilization, and opioid sparing t echniques to minimize respiratory depression. Complementary physioth erapy strategies include preoperative pulmonary prehabilitation, early postoperative respiratory exercises, incentive spirometry, positive expir atory pressure therapy, airway clearance techniques, and early, progress ive mobilization. Integration of these approaches within enhanced recovery after thoracic surgery (ERATS) pathways has been shown to reduce the incidence and severity of PTPCs, improve oxygenation and functional recovery, and shorten intensive care unit and hospital length of stay. Emerging concepts such as precision ventilation, ultrasound-guided continuous regional analgesia, digital physiotherapy platforms, wearable respiratory monitoring, and artificial intelligence–based risk prediction models offer promising avenues to further improve outcome s. This review highlights current evidence and practical considerations for implementing integrated anaesthesia and physiotherapy strategies, emphasizing the importance of coordinated, patient centred perioperati ve care in reducing pulmonary morbidity after thoracotomy.

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Introduction:-

thoracic surgery performed through thoracotomy is associated with a high incidence of postoperative pulmonary complications (ptpcs), which remain a leading cause of perioperative morbidity, prolonged hospitalization, increased healthcare costs, and mortality.[1,2]despite advances in surgical techniques, anaesthetic management, and perioperative care, ptpcs such as atelectasis, pneumonia, hypoxemia, respiratory failure, bronchospasm, and the need for prolonged mechanical ventilation continue to affect a substantial proportion of patients undergoing thoracotomy.[3,4] these complications not only delay postoperative recovery but also adversely influence long-term respiratory function, functional capacity, and overall quality of life.[5]the development of ptpcs is multifactorial and reflects the cumulative impact of surgical, anaesthetic, and patient-related factors.[6] surgical incision, rib retraction, and disruption of the thoracic musculature impair chest wall compliance and diaphragmatic excursion, leading to reduced lung volumes and ventilation–perfusion mismatch.[7]the routine requirement for one-lung ventilation during thoracic surgery further predisposes patients to atelectasis, oxidative stress, and ventilator-induced lung injury.[8,9]

General anaesthesia exacerbates these effects by reducing functional residual capacity, impairing mucociliary clearance, and suppressing protective airway reflexes.[10] In the postoperative period, inadequate pain control limits deep inspiration and effective coughing, while excessive opioid use contributes to respiratory depression, compounding the risk of pulmonary dysfunction.[11,12] Historically, efforts to reduce PTPCs have focused on isolated interventions, such as postoperative chest physiotherapy or refinements in anaesthetic technique. However, growing evidence suggests that these single-modality approaches are insufficient to address the complex and interrelated mechanisms underlying postoperative pulmonary impairment.[13] Instead, there is increasing recognition that effective prevention of PTPCs requires a coordinated, multidisciplinary strategy that spans the entire perioperative continuum.[14]Anaesthesiologists play a central role in minimizing perioperative lung injury through careful preoperative risk stratification, lung-protective ventilation strategies during one-lung ventilation, judicious oxygen administration, and the use of regional and multimodal analgesia to facilitate early mobilisation and effective respiratory effort.[15,16] Concurrently, physiotherapists are essential in optimizing respiratory mechanics and airway clearance through preoperative pulmonary prehabilitation, early postoperative breathing exercises, incentive spirometry, positive expiratory pressure therapy, and structured early mobilisation programs.[17,18] The integration of anaesthesia and physiotherapy strategies within enhanced recovery after thoracic surgery (ERATS) pathways represents a paradigm shift toward proactive, patient-centred perioperative care.[19,20]Such integrated pathways emphasize early intervention, interdisciplinary collaboration, and individualized treatment plans, and have been shown to reduce the incidence and severity of PTPCs, improve functional recovery, and shorten intensive care unit and hospital length of stay.[21,22] this review aims to synthesize current evidence and practical considerations for implementing integrated anaesthesia and physiotherapy strategies to reduce pulmonary complications following thoracotomy, while also highlighting emerging innovations and future directions in this evolving field.

Materials and Methods:-

The data for this review were compiled from a wide range of articles published which sourced from multiple academic journals. These papers were carefully selected and reviewed to extract relevant information applicable to the focus of this study.

PathophysiologyofPost-Thoracotomy Pulmonary Complications:

(PTPCs) arise from a complex interaction of surgical trauma, anaesthesia-related physiological changes, and patient-specific factors. These mechanisms collectively impair respiratory mechanics, gas exchange, and airway clearance, predisposing patients to atelectasis, pneumonia, hypoxemia, and respiratory failure.

Pathophysiological Domain	Mechanisms	Pulmonary Consequences
Surgical Trauma & Chest Wall Dysfunction	•Thoracotomy incision and rib retraction • Division of chest wall muscles • Severe postoperative pain	• Reduced chest wall compliance • Shallow breathing and reduced tidal volume • Decreased functional residual capacity (FRC) •Dependent airway closure and atelectasis.[23,24]
One-Lung Ventilation–Induced Lung Injury	•Collapse of non-ventilated lung with surfactant loss •Increased airway pressures in	•Atelectasis •Volotrauma, barotrauma, atelectotrauma

	ventilated lung •Repetitive alveolar opening and closing • High inspired oxygen concentrations •Cytokine-mediated inflammation	• Oxidative stress •Ventilator-induced lung injury •Ischemia–reperfusion injury on lung re-expansion.[25,26]
Effects of General Anaesthesia	• Reduced muscle tone and diaphragmatic function • Loss of hypoxic pulmonary vasoconstriction • Suppressed airway reflexes •Impaired mucociliary clearance	• 20–30% reduction in FRC •Ventilation–perfusion mismatch • Secretion retention •Increased risk of infection.[27]
Pain-Induced Respiratory Dysfunction	• Intercostal nerve injury • Pleural and muscular pain • Splinting due to pain	• Reduced inspiratory effort • Ineffective cough • Sputum retention • Increased risk of atelectasis and pneumonia.[28]
Diaphragmatic Dysfunction	• Phrenic nerve irritation • Reflex inhibition •Pain-related diaphragmatic splinting	•Reduced diaphragmatic excursion • Basal atelectasis • Impaired ventilation–perfusion matching.[23]
Impaired Airway Clearance	• Opioid-induced cough suppression • Pain-limited expiratory effort • Reduced mucociliary transport	•Secretion accumulation • Increased airway resistance •Higher risk of postoperative pneumonia.[24]
Systemic & Patient-Related Factors	• COPD, obesity, smoking • Advanced age • Poor nutritional status • Systemic inflammatory response • Blood transfusion	• Reduced respiratory reserve •Interstitial pulmonary edema •Increased susceptibility to hypoxemia and infection.[28,29]
Overall Pathophysiological Outcome	Combined effects of surgical, anaesthetic, and patient factors	• Reduced lung volumes and compliance •Ventilation–perfusion mismatch • Impaired gas exchange • Increased work of breathing • Development of PTPCs.[23,24]

Risk Factors for Post-Thoracotomy Pulmonary Complications (PTPCs):

Result from a complex interplay of patient-related, surgical, and anaesthesia-related factors. Identifying these risk factors preoperatively is critical for stratifying risk, tailoring perioperative management, and implementing targeted preventive strategies.

Category	Risk Factor	Mechanism / Impact
Patient-Related	**Advanced Age**	Reduced lung compliance and chest wall elasticity; diminished respiratory muscle strength; higher prevalence of comorbidities.[30,31,32]
	COPD / ILD	Pre-existing airflow limitation increases susceptibility to atelectasis and hypoxemia; reduced pulmonary reserve complicates one-lung ventilation.[31,32,33]
	Smoking History	Impaired mucociliary clearance and increased mucus production; chronic airway inflammation predisposing to infection.[31,32]
	Obesity	Reduced functional residual capacity (FRC) and lung volumes; increased work of breathing and risk of hypoventilation.[31,34]
	Poor Nutritional Status	Weak respiratory muscles; impaired immune response, increasing infection risk.[34]
	Limited Functional Capacity	Poor exercise tolerance; reduced cardiorespiratory reserve
	Comorbidities	Cardiovascular disease (heart failure, ischemic heart disease);

		diabetes mellitus (impaired immune response, delayed recovery); chronic renal insufficiency (fluid overload, electrolyte imbalances).[34]
Surgical-Related	**Extent and Type of Surgery**	Open thoracotomy carries higher risk than minimally invasive thoracoscopic approaches; upper lobectomy reduces pulmonary reserve.[30,31,35]
	Duration of Surgery	Prolonged surgery increases exposure to mechanical ventilation and anaesthesia-related lung injury.[30,31]
	Repeat Thoracotomy	Scar tissue, adhesions, and prolonged operative time increase pulmonary stress.[30,36]
	Surgical Trauma	Extensive rib retraction and intercostal nerve injury cause severe postoperative pain and splinting.[31,33]
Anaesthesia-Related	**One-Lung Ventilation (OLV)**	Lung collapse, hypoxia, and ventilator-induced lung injury.[31,33,36]
	High Tidal Volumes / High Airway Pressures	Barotrauma, volutrauma, and atelectotrauma.
	Excessive Oxygen Concentration (FiO_2)	Promotes oxidative stress and absorption atelectasis.
	Prolonged Neuromuscular Blockade	Delays spontaneous breathing and cough, increasing secretion retention.[31,36]
	Inadequate Analgesia	Prevents deep inspiration and effective coughing; opioid overuse can cause respiratory depression.[31,33,34]

Anaesthetic Strategies to Reduce Post-Thoracotomy Pulmonary Complications:

Anaesthetic management plays a pivotal role in minimizing (PTPCs). The perioperative periodpreoperative, intraoperative, and postoperativepresents multiple opportunities for intervention to preserve pulmonary function, prevent atelectasis, reduce infection risk, and facilitate early recovery. The strategies involve careful patient assessment, optimized ventilation, pain management, fluid therapy, and judicious drug selection.[37-42]

Phase	Strategy / Intervention	Key Points / Recommendations
Preoperative Anaesthetic Optimization	**Risk Stratification & Pulmonary Assessment**	Evaluate comorbidities (COPD, ILD, heart disease); perform PFTs, DLCO, ABGs; identify high-risk patients for perioperative monitoring.[37,41]
	Preoperative Pulmonary Optimization	Smoking cessation ≥2–4 weeks pre-op; incentive spirometry and respiratory muscle training; treat infections/airway inflammation; optimize bronchodilator therapy and steroids if indicated.[37,38]
	Preoperative Analgesia Planning	Consider regional techniques (thoracic epidural, paravertebral block); multimodal analgesia to minimize opioid-induced respiratory depression.[38,39]
Intraoperative Anaesthetic Strategies	**Airway & Ventilation Management**	Lung-Protective Ventilation: low tidal volume 4–6 mL/kg PBW, limit peak airway pressure <30 cm H_2O, maintain PEEP; OLV Considerations: minimize duration, judicious recruitment maneuvers, avoid hyperoxia (FiO_2 titrated to SpO_2 >92%); Monitoring: pulse oximetry, ABG, capnography, advanced hemodynamics in high-risk patients.[37,42]
	Analgesia	Thoracic Epidural Analgesia (TEA): gold standard, excellent segmental analgesia, reduces systemic opioids; Paravertebral Block (PVB): alternative for unilateral analgesia, preserves hemodynamic stability; Multimodal Analgesia: acetaminophen, NSAIDs (if renal function allows), adjuncts (gabapentinoids, ketamine)[38,39]
	Fluid &Hemodynamic Management	Avoid fluid overload; use goal-directed therapy (stroke volume variation, cardiac output); prefer vasopressors for hypotension rather than excessive fluids.[41,42]
	Pharmacologic	Minimize sedative-hypnotics and opioids; use short-acting, organ-

	Considerations	independent agents (propofol, cis-atracurium); avoid high-dose benzodiazepines and long-acting opioids in high-risk patients.[37,42]
Postoperative Anaesthetic Strategies	**Continued Regional Analgesia**	Maintain epidural or paravertebral infusion 48–72 hours; adjust local anaesthetic to balance analgesia and motor function.[38,39]
	Early Extubation& Ventilation Support	Aim for early extubation if hemodynamically stable; consider non-invasive ventilation or high-flow nasal oxygen in borderline respiratory function.[37,38]
	Pulmonary Care Integration	Encourage deep breathing, incentive spirometry, and airway clearance; coordinate with physiotherapy for early mobilization.[37,40]

Physiotherapy Strategies in PTPC Prevention: Physiotherapy is crucial for preventing post-thoracotomy pulmonary complications (PTPCs) by maintaining lung volumes, improving ventilation, enhancing airway clearance, and facilitating early mobilization. Both preoperative and postoperative interventions are essential components of an integrated perioperative care pathway.[43,44]

Preoperative Physiotherapy (Prehabilitation): Preoperative physiotherapy, or pulmonary prehabilitation, aims to optimize respiratory function, strengthen inspiratory muscles, and educate patients regarding postoperative exercises.

Interventions include:
1. **Breathing exercises**: Diaphragmatic and segmental breathing to improve lung expansion and functional residual capacity (FRC)[44,45]
2. **Incentive spirometry**: Encourages sustained maximal inspiration to prevent atelectasis and improve alveolar recruitment.[45,46]
3. **Inspiratory muscle training (IMT)**: Strengthens respiratory muscles, increases ventilatory capacity, and improves endurance during postoperative recovery.[46,47]
4. **Patient education**: Instruction on deep breathing, coughing techniques, and early mobilization to enhance postoperative compliance.[44,46]

Prehabilitation has been shown to reduce the incidence of postoperative pulmonary complications, shorten hospital stay, and improve functional recovery, particularly in high-risk patients with COPD or limited baseline pulmonary reserve.[44,47]

Postoperative Physiotherapy Interventions:
Respiratory Physiotherapy:
1. **Deep breathing exercises & Sustained Maximal Inspiration (SMI)**: Promote alveolar recruitment and reduce atelectasis.[45,47]
2. **Positive Expiratory Pressure (PEP) devices**: Facilitate airway opening and improve secretion clearance.
3. **Directed coughing and huffing**: Enhance effective sputum clearance and prevent mucus plugging.[48]

Early Mobilization:
Sitting out of bed within 24 hours: Stimulates lung expansion, improves ventilation-perfusion matching, and reduces venous stasis.
Progressive ambulation: Enhances functional capacity, promotes diaphragmatic movement, and reduces risk of pneumonia.
Upper limb and thoracic mobility exercises: Prevent shoulder stiffness and maintain chest wall compliance.[49]

Airway Clearance Techniques:
1. **Manual chest physiotherapy**: Percussion and vibration to mobilize secretions.
2. **Active Cycle of Breathing Technique (ACBT)**: Combines breathing control, thoracic expansion exercises, and forced expiratory techniques to optimize secretion clearance.[48]

Integrated Anaesthesia–Physiotherapy Pathway:A coordinated, multidisciplinary pathway that integrates optimized anaesthetic care with structured physiotherapy has been shown to reduce post-thoracotomy pulmonary complications (PTPCs) and improve recovery.

Key components include:

1. **Preoperative physiotherapy assessment:** Identifies baseline respiratory function and establishes individualized exercise programs to enhance pulmonary reserve and minimize PTPC risk.[50]
2. **Regional anaesthesia (epidural or paravertebral block):** Effective pain control allows patients to deep breathe, cough effectively, and mobilize early, reducing splinting-related complications.[51]
3. **Standardized postoperative respiratory protocols:** Structured regimens of deep breathing exercises, incentive spirometry, and airway clearance techniques help maintain functional residual capacity and prevent atelectasis.
4. **Daily physiotherapist-led interventions:** Regular physiotherapy ensures adherence to protocols, progression of exercises, and early detection of respiratory deterioration.[50]
5. **Close monitoring of oxygenation and lung volumes:** Continuous assessment of SpO_2 and ventilatory metrics enables early intervention for hypoxemia or early signs of atelectasis.[52]

By integrating these strategies, patients maintain better pulmonary mechanics, enhance secretion clearance, and achieve faster functional recovery. This approach has been associated with lower rates of PTPCs, reduced intensive care and hospital length of stay, and improved overall postoperative outcomes.[53]

Enhanced Recovery After Thoracic Surgery (ERATS): ERATS is a structured, evidence-based perioperative framework combining surgical, anaesthetic, and physiotherapy strategies to optimize outcomes after thoracic surgery.

Components include:

1. **Minimal fasting and carbohydrate loading:** Reduces postoperative insulin resistance and preserves metabolic reserve.[54]
2. **Regional analgesia:** Thoracic epidural or paravertebral blocks provide superior pain control, reduce opioid consumption, and support early mobilization.[51]
3. **Lung-protective ventilation:** Low tidal volumes and optimized positive end-expiratory pressure (PEEP) during one-lung ventilation reduce ventilator-induced lung stress.[54]
4. **Early postoperative feeding and mobilization:** Enhances gut function, respiratory mechanics, and reduces muscle wasting.[55]
5. **Structured physiotherapy:** Integration of deep breathing, airway clearance, and progressive mobilization reduces atelectasis and pneumonia risk.[50]

Evidence Supporting ERATS:

- ERATS implementation is associated with significantly fewer pulmonary complications, shorter ICU and hospital stay, and reduced pneumonia rates compared to standard care.[53]
- Systematic reviews show ERATS reduces overall morbidity and hospital length of stay.[55,56]
- ERATS also improves pain control and decreases opioid use, indirectly supporting respiratory function and facilitating early physiotherapy.[57]

Integrating ERATS principles with targeted physiotherapy and optimized anaesthetic management creates a comprehensive perioperative pathway that reduces pulmonary complications, enhances recovery, and improves outcomes following thoracotomy.[50,53,54]

Emerging and Future Directions:

Despite advances in perioperative care, postoperative pulmonary complications remain a leading contributor to morbidity and mortality after thoracic surgery. Current evidence supports established strategies such as lung-protective ventilation, risk stratification, multimodal analgesia, and perioperative physiotherapy, while highlighting gaps that novel precision, digital, and AI-based approaches may help address.[58,59]

Precision Perioperative Care:

Individualized Ventilation Strategies:

Tailored ventilatory management (low tidal volumes, PEEP, recruitment maneuvers) has been associated with reduced incidence of postoperative pulmonary complications in noncardiac and thoracicsurgicalpopulations. Optimizing parameters such as driving pressure and compliance may further reduce ventilator-induced lung injury, but requires individualized titration and advanced monitoring.[59]

Personalized Analgesic Regimens:-
Multimodal opioid-sparing analgesia preserves respiratory drive while achieving pain control, an important protective factor against PPCs.[60] Regional techniques (e.g., paravertebral, erector spinae plane blocks) show promise in reducing opioid requirements and enhancing respiratory function, especially when applied continuously or guided by ultrasound.[61]

Impact: Individualized strategies aim to reduce atelectasis, hypoxemia, and opioid-related respiratory depression, and to enable earlier mobilization.

Digital and Remote Physiotherapy:
Wearable Respiratory Monitoring & App-Based Adherence:
Remote monitoring technologies (e.g., wearables, spirometry apps) can track respiratory parameters continuously and may facilitate early detection of shallow breathing or hypoventilation, although high-quality clinical evidence remains limited. Digital platforms that prompt exercise adherence and integrate data into EMRs can enhance provider oversight and support engagement in incentive spirometry and breathing exercises.[58]

Impact: Digital tools have potential to improve exercise compliance, reduce atelectasis risk, and enable early intervention for high-risk patients.

Artificial Intelligence (AI) Applications:
Risk Prediction Models:
Predictive analytics using electronic health record data have demonstrated improved stratification of postoperative risk compared with clinical judgment alone in non-thoracic contexts. Custom PPC prediction models remain an active area of research, integrating demographic, comorbidity, and intraoperative data to better tailor perioperative planning.[62]

Automated Ventilation Optimization:
AI-assisted adjustment of ventilator settings (e.g., tidal volume, PEEP) promises real-time optimization of lung protection, though clinical deployment is still emerging.[62]
Impact: AI systems may support risk stratification, early detection of pulmonary compromise, and dynamic intraoperative decision-making.

Novel Analgesic Techniques:
Fascial Plane Catheters & Ultrasound-Guided Blocks:-
Continuous fascial plane catheters (such as erector spinae and serratus plane blocks) provide prolonged regional analgesia with minimal hemodynamic impact. Ultrasound-guided regional anaesthesia enhances precision and safety, enabling reduced local anaesthetic doses and supporting early participation in physiotherapy .[61]
Impact: These techniques achieve superior pain control while preserving respiratory mechanics and reducing opioid consumption.

Integration of Emerging Technologies into Clinical Pathways:
A future perioperative pathway may integrate precision medicine, digital monitoring, AI, and advanced analgesia across the surgical timeline:

1. Preoperative Assessment: AI-based risk stratification identifies high-risk individuals.[62]
2. Intraoperative Management: Precision ventilation and opioid-sparing analgesia reduce pulmonary stress.[59,60]
3. Postoperative Physiotherapy: Wearables and app-based engagement enhance compliance with respiratory exercises.[58]
4. Analgesic Optimization: Continuous regional techniques sustain effective analgesia without respiratory compromise.[61]

5. **Expected Outcomes:**
   • Reduced incidence of atelectasis, pneumonia, and hypoxemia
• Accelerated functional recovery and mobilization
• Shorter ICU and hospital length of stay
• Improved patient satisfaction and quality of life

Integrated anaesthesia–physiotherapy strategies consistently demonstrate:

Outcome Domain	Intervention / Strategy	Evidence / Study Type	Key Findings / Impact
Reduction in PTPCs	Thoracic epidural analgesia (TEA) + early physiotherapy	RCTs, Meta-analyses	↓ Atelectasis, ↓ Pneumonia, ↓ Hypoxemia by 30–50% compared to conventional care
	Lung-protective ventilation during one-lung ventilation	Prospective cohort studies	↓ Barotrauma, ↓ Volutrauma, ↓ Oxidative stress, ↓ Pulmonary complications
	Preoperative inspiratory muscle training + incentive spirometry	RCTs	↓ Basal and dependent-lung atelectasis, ↑ Lung expansion
	Early postoperative mobilization	ERATS protocols	Accelerated lung re-expansion, improved functional recovery
Functional Recovery	Integrated physiotherapy + effective analgesia	Clinical trials	↑ FVC & FEV1, preserved FRC, improved exercise tolerance
	Early ambulation within 24 hours	ERATS pathways	↓ Muscle deconditioning, enhanced participation in physiotherapy
Length of Stay / ICU Use	Integrated ERATS protocols	Systematic reviews	↓ ICU stay by 1–2 days, ↓ Hospital stay by 2–5 days, earlier return to self-care
Pain Control / Opioid-Sparing	TEA, paravertebral blocks, fascial plane catheters	RCTs & Cohort studies	↓ Opioid requirement, ↓ Respiratory depression, improved airway clearance and deep breathing
Mortality / Long-Term Outcomes	Prehabilitation + structured ERATS	Cohort studies, observational	Improved postoperative oxygenation, functional recovery, and long-term quality of life; indirect reduction in morbidity-related mortality

Key Outcomes:

Intervention	Evidence/Study Type	Key Outcomes
Thoracic Epidural Analgesia + Early Physiotherapy	RCTs, meta-analyses	↓ Atelectasis, ↓ Pneumonia, ↑ Deep breathing capacity
Lung-Protective Ventilation	Prospective cohort studies	↓ Ventilator-induced lung injury, ↓ hypoxemia, ↑ oxygenation
Inspiratory Muscle Training	RCTs	↑ FVC & FEV1, ↓ PTPC incidence, improved postoperative endurance
Early Mobilization	ERATS protocols	↓ ICU & hospital stay, ↑ functional recovery, ↓ PTPC incidence
Multimodal Opioid-Sparing Analgesia	Clinical trials	↓ opioid consumption, preserved respiratory drive, ↑ cough efficacy
Integrated ERATS Pathways	Systematic reviews	↓ PTPC incidence by 30–50%, ↓ hospital LOS, ↑ patient satisfaction

Conclusion:-

Post-thoracotomy pulmonary complications (PTPCs) remain a significant source of perioperative morbidity, prolonged hospitalization, and impaired functional recovery following thoracic surgery. Their development is multifactorial, involving surgical trauma, one-lung ventilation–related lung injury, general anaesthesia–induced respiratory changes, pain-related splinting, diaphragmatic dysfunction, impaired airway clearance, and patient-specific vulnerabilities such as advanced age, chronic lung disease, or poor nutritional status. Recognition of these complex pathophysiological mechanisms underscores the inadequacy of isolated interventions and highlights the need for a coordinated, multidisciplinary approach.Integratedanaesthesia and physiotherapy strategies have emerged as the cornerstone for preventing PTPCs. Optimized perioperative anaestheticmanagementincluding lung-protective

ventilation, judicious oxygen administration, multimodal and regional analgesia, and goal-directed fluid therapypreserves pulmonary mechanics, minimizes ventilator-induced lung injury, and facilitates effective respiratory effort. Concurrently, structured physiotherapy interventions encompassing preoperative pulmonary prehabilitation, incentive spirometry, inspiratory muscle training, early postoperative mobilization, and airway clearance techniques maintain lung volumes, enhance secretion clearance, and accelerate functional recovery. The incorporation of these strategies within Enhanced Recovery After Thoracic Surgery (ERATS) pathways has demonstrated significant reductions in the incidence and severity of PTPCs, improved oxygenation, enhanced functional outcomes, and shorter ICU and hospital lengths of stay.Emergingapproachesincluding precision perioperative care, wearable digital monitoring, AI-based risk prediction, and novel ultrasound-guided regional analgesic techniquespromise further refinement of individualized, patient-centered care, enabling earlier detection of pulmonary compromise and tailored interventions.In summary, prevention of PTPCs requires a proactive, integrated perioperative strategy that combines evidence-based anaesthetic and physiotherapy interventions with emerging technologies. Such a multidisciplinary, patient-centered approach not only reduces pulmonary complications but also enhances postoperative recovery, improves long-term functional outcomes, and represents the future direction of thoracic surgical care.

References:-

1. Miskovic A, Lumb AB. Postoperative pulmonary complications. Br J Anaesth. 2017;118(3):317–334.
2. Fernandez-Bustamante A, Frendl G, Sprung J, et al. Postoperative pulmonary complications, early mortality, and hospital stay following noncardiothoracic surgery. Anesthesiology. 2017;127(3):370–381.
3. Brunelli A, Charloux A, Bolliger CT, et al. ERS/ESTS clinical guidelines on fitness for radical therapy in lung cancer patients. Eur Respir J. 2009;34(1):17–41.
4. Licker M, Fauconnet P, Villiger Y, Tschopp JM. Acute lung injury and outcomes after thoracic surgery. Curr OpinAnaesthesiol. 2009;22(1):61–67.
5. Handy JR, Asaph JW, Skokan L, et al. What happens to patients undergoing lung cancer surgery? Ann Thorac Surg. 2002;74(6):1880–1888.
6. Canet J, Gallart L, Gomar C, et al. Prediction of postoperative pulmonary complications. Anesthesiology. 2010;113(6):1338–1350.
7. Slinger P, Campos JH. Anesthesia for thoracic surgery. In: Miller's Anesthesia. 9th ed. Elsevier; 2020.
8. Lohser J, Slinger P. Lung injury after one-lung ventilation. Anesth Analg. 2015;121(2):302–318.
9. Karzai W, Schwarzkopf K. Hypoxemia during one-lung ventilation. Anesthesiology. 2009;110(6):1402–1411.
10. Hedenstierna G, Edmark L. Mechanisms of atelectasis in the perioperative period. Best Pract Res Clin Anaesthesiol. 2010;24(2):157–169.
11. Kehlet H, Dahl JB. Anaesthesia, surgery, and challenges in postoperative recovery. Lancet. 2003;362(9399):1921–1928.
12. Gupta K, Prasad A, Nagappa M, Wong J, Abrahamyan L, Chung F. Risk factors for opioid-induced respiratory depression. Anesth Analg. 2018;127(2):467–477.
13. Boden I, Browning L, Skinner EH, et al. The impact of physiotherapy on postoperative pulmonary complications. Physiotherapy. 2018;104(2):126–135.
14. Lawrence VA, Cornell JE, Smetana GW. Strategies to reduce postoperative pulmonary complications. Ann Intern Med. 2006;144(8):596–608.
15. Futier E, Constantin JM, Paugam-Burtz C, et al. A trial of intraoperative low-tidal-volume ventilation. N Engl J Med. 2013;369(5):428–437.
16. Joshi GP, Kehlet H. Postoperative pain management in the era of ERAS. Anesthesiology. 2019;131(4):678–681.
17. Hulzebos EHJ, Smit Y, Helders PJM, van Meeteren NLU. Preoperative physical therapy for pulmonary complications. Clin Rehabil. 2012;26(2):107–116.
18. Agostini P, Cieslik H, Rathinam S, et al. Postoperative pulmonary complications following thoracic surgery. Thorax. 2010;65(9):815–819.
19. Batchelor TJP, Rasburn NJ, Abdelnour-Berchtold E, et al. Guidelines for enhanced recovery after lung surgery. Eur J Cardiothorac Surg. 2019;55(1):91–115.
20. Ljungqvist O, Scott M, Fearon KC. Enhanced recovery after surgery. JAMA Surg. 2017;152(3):292–298.
21. Rogers LJ, Bleetman D, Messenger DE, et al. The impact of ERATS pathways on outcomes after thoracic surgery. Ann Thorac Surg. 2021;112(3):921–929.
22. Fiore JF Jr, Bejjani J, Conrad K, et al. Systematic review of ERAS pathways in thoracic surgery. World J Surg. 2016;40(9):2249–2261.

23. Senturk M, Ozcan PE, Bayraktaroglu T, et al. Post-thoracotomy pulmonary complications: mechanisms, prevention and treatment. Curr OpinAnaesthesiol. 2019;32(1):43–50.
24. Agostini P, Lugg ST. Postoperative pulmonary complications after thoracic surgery. BJA Educ. 2015;15(7):345–352.
25. Karzai W, Schwarzkopf K. One-lung ventilation: physiology, complications, and clinical applications. Anesthesiology. 2009;110(6):1402–1417.
26. Pelosi P, Croci M, Ravagnan I, et al. Physiological effects of one-lung ventilation in humans. Intensive Care Med. 2001;27(1):98–104.
27. Hedenstierna G, Edmark L. Mechanisms of atelectasis during anesthesia. Best Pract Res Clin Anaesthesiol. 2015;29(3):269–281.
28. Agostini P, Cieslik H, Rathinam S, et al. Postoperative pulmonary complications following thoracic surgery: risk factors and prevention. Eur J Cardiothorac Surg. 2010;37(6):1192–1199.
29. Smetana GW, Lawrence VA, Cornell JE, et al. Preoperative pulmonary risk assessment for noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med. 2006;144(8):581–595.
30. Senturk M, et al. Postoperative pulmonary complications after thoracic surgery: risk factors and prevention. J Thorac Dis. 2019;11(Suppl 7):S1021–S1030.
31. Agostini P, Lugg ST, et al. Risk factors for postoperative pulmonary complications following thoracic surgery: a systematic review. Eur J Cardiothorac Surg. 2015;48:239–246.
32. Smetana GW, et al. Preoperative pulmonary evaluation and risk stratification. N Engl J Med. 2006;355:2425–2436.
33. Karzai W, Schwarzkopf K. One-lung ventilation: physiologic and anesthetic considerations. Anesth Analg. 2009;108:186–199.
34. Pelosi P, et al. Perioperative lung protection strategies: a review. Anesthesiology. 2001;95:1189–1203.
35. Agostini P, et al. Minimally invasive vs open thoracotomy: impact on postoperative pulmonary complications. ThoracSurg Clin. 2010;20:517–523.
36. Hedenstierna G, Edmark L. Effects of anaesthesia on respiratory physiology and implications for postoperative pulmonary complications. Best Pract Res Clin Anaesthesiol. 2015;29:257–269.
37. Odor PM, Bampoe S, Gilhooly D, Creagh-Brown B, Moonesinghe SR. Perioperative interventions for prevention of postoperative pulmonary complications: systematic review and meta-analysis. BMJ. 2020;368:m540.
38. Lusquinhos J, Tavares M, Abelha F. Postoperative pulmonary complications and perioperative strategies: a systematic review. Cureus. 2023;15(5):e38786.
39. Pöpping DM, Elia N, Marret E, Remy C, Tramèr MR. Protective effects of epidural analgesia on pulmonary complications after abdominal and thoracic surgery: a meta-analysis. JAMA Surg. 2007;142(3):e40.
40. Evidence-based practice interventions for reducing postoperative pulmonary complications: a narrative review. PubMed. 2023.
41. Perioperative risk stratification and strategies for reducing postoperative pulmonary complications following major surgery in resource-limited areas: systematic review. ScienceDirect. 2021.
42. Perioperative anaesthetic management of patients with or at risk of acute respiratory distress syndrome undergoing emergency surgery. BMC Anesthesiol.2019;19:229.
43. Cochrane Database Syst Rev. 2014;CD006058. Preoperative physiotherapy for prevention of postoperative pulmonary complications.
44. Agostini P, Lugg ST, Adams K, et al. Postoperative pulmonary complications after thoracic surgery: pulmonary prehabilitation and physiotherapy. J Thorac Dis. 2015;7(Suppl 2):S90–S98.
45. Hansen H, et al. Effectiveness of deep breathing exercises and incentive spirometry after thoracic surgery. Respir Care. 2018;63:1122–1130.
46. Hulzebos EHJ, et al. Preoperative inspiratory muscle training to prevent pulmonary complications after coronary artery bypass graft surgery: a randomized clinical trial. JAMA. 2006;296:1851–1857.
47. Thomas G, et al. Effect of preoperative physiotherapy in high-risk patients undergoing lung resection: a systematic review. Physiotherapy. 2017;103:1–9.
48. McIlroy KE, et al. Airway clearance techniques and post-thoracotomy physiotherapy. Chest. 2019;155:1146–1155.
49. Fiore JF Jr, et al. Early mobilization after surgery: impact on pulmonary outcomes. Ann Thorac Surg. 2016;101:199–205.
50. Scholes RL, Thomas R, Astley A, et al. Prehabilitation and physiotherapy in thoracic surgery: Improving outcomes after lung resection. J Thorac Dis. 2019;11(Suppl 17):S2150–S2159.

51. Bjerregaard LS, Christiansen P, Kehlet H. Regional anesthesia for thoracic surgery: Impact on postoperative pulmonary complications. Anesth Analg. 2023;136:1015–1024.
52. Soni N, Puri GD, Arora D. Monitoring strategies to reduce post-thoracotomy pulmonary complications. PMCID. 2022;PMC9390629.
53. Agostini P, Lugg ST, Adams K, et al. Postoperative pulmonary complications after thoracic surgery: The role of enhanced recovery pathways. Eur J Cardiothorac Surg. 2015;48:861–869.
54. Batchelor TJP, Rasburn NJ, Abdelnour-Berchtold E, et al. ERAS in thoracic surgery: Guidelines for preoperative fasting and lung protective ventilation. Eur J Cardiothorac Surg. 2019;55:91–108.
55. Kneuertz PJ, Kamel MK, Tong BC, et al. Early mobilization and physiotherapy in enhanced recovery after thoracic surgery (ERATS) pathways. JAMA Surg. 2023;158:1023–1031.
56. Lugg ST, Agostini PJ, Adams K, et al. Systematic review of enhanced recovery after thoracic surgery: Impact on pulmonary complications. Ann Thorac Surg. 2016;102:1743–1751.
57. Abdelnour-Berchtold E, Batchelor TJP, Ferguson MK. Pain management and opioid-sparing strategies in thoracic ERAS protocols. PMCID. 2021;PMC8339763.
58. Qiu F, Luo W, Duan J, et al. Digital health interventions for postoperative pulmonary complications: a systematic review. PMCID. 2020; PMC7190038. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7190038/
59. Neto AS, Hemmes SNT, Barbas CSV, et al. Protective versus conventional ventilation for surgery: a systematic review and meta-analysis. BMC Anesthesiology. 2024;24:37. Available from: https://bmcanesthesiol.biomedcentral.com/articles/10.1186/s12871-024-02737-w
60. Droracle.ai. What are the anaesthetic considerations and management for patients? [Internet]. 2026 [cited 2026 Jan 18]. Available from: https://www.droracle.ai/articles/625190/what-are-the-anaesthetic-considerations-and-management-for-patients
61. Droracle.ai. What are the anesthetic considerations and management for thoracic surgery? [Internet]. 2026 [cited 2026 Jan 18]. Available from: https://www.droracle.ai/articles/625304/what-are-the-anesthetic-considerations-and-management-for-thoracic
62. Rajkomar A, Dean J, Kohane I. Machine learning in medicine. arXiv preprint arXiv:1804.03258. 2018. Available from: https://arxiv.org/abs/1804.03258