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Riesgo Respiratorio Perioperatorio y Protección Pulmonar en Cirugía Abdominal Alta: de la Predicción Temprana al Soporte Ventilatorio Escalonado

Perioperative Respiratory Risk and Pulmonary Protection in Upper Abdominal Surgery: From Early Prediction to Stepwise Ventilatory Support

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RESUMEN

Las complicaciones pleuropulmonares continúan siendo una causa frecuente de morbilidad después de la cirugía abdominal alta y se asocian con mayor duración de la hospitalización, incremento en la necesidad de soporte respiratorio y retraso en la recuperación posoperatoria. El presente estudio analizó la evidencia actual relacionada con la predicción, prevención y tratamiento escalonado de las complicaciones pulmonares posoperatorias en pacientes adultos sometidos a procedimientos abdominales altos de mayor complejidad. Se realizó una revisión integrativa estructurada mediante el Método Científico, incorporando ensayos clínicos aleatorizados, estudios observacionales, revisiones sistemáticas, metaanálisis e investigaciones multicéntricas relevantes. La evidencia se organizó en tres dominios principales: predicción del riesgo perioperatorio, estrategias preventivas respiratorias y escalamiento del soporte respiratorio posoperatorio. Los resultados mostraron que variables como baja saturación preoperatoria de oxígeno, edad avanzada, infección respiratoria reciente, anemia, cirugía prolongada, procedimientos de emergencia e incisiones abdominales altas contribuyen al incremento del riesgo pulmonar. La fisioterapia preoperatoria y el entrenamiento de los músculos inspiratorios se asociaron con una disminución de las complicaciones respiratorias en poblaciones seleccionadas. Durante el periodo intraoperatorio, la ventilación pulmonar protectora basada en volúmenes corrientes reducidos y en la valoración individualizada de la PEEP, la distensibilidad respiratoria y la presión de conducción se relacionó con mejores resultados pulmonares, mientras que el uso rutinario de PEEP elevada no mostró una reducción consistente de complicaciones. En el periodo posoperatorio, el CPAP profiláctico no demostró un beneficio universal, mientras que la ventilación no invasiva redujo la reintubación y las infecciones asociadas a la atención sanitaria en pacientes con insuficiencia respiratoria hipoxémica establecida. En conjunto, los hallazgos respaldan una estrategia perioperatoria multimodal, adaptada al riesgo y escalonada, que integre la identificación temprana del riesgo, la protección pulmonar, la vigilancia posoperatoria y el escalamiento oportuno del soporte respiratorio.

PALABRAS CLAVE

complicaciones pulmonares posoperatorias, cirugía abdominal alta, ventilación pulmonar protectora, atención perioperatoria, insuficiencia respiratoria, ventilación no invasiva, fisioterapia preoperatoria, entrenamiento muscular inspiratorio, ARISCAT, soporte respiratorio posoperatorio

ABSTRACT

Pleuropulmonary complications remain a frequent cause of morbidity after upper abdominal surgery and are associated with prolonged hospitalization, greater need for respiratory support, and delayed postoperative recovery. This study analyzed current evidence regarding the prediction, prevention, and stepwise management of postoperative pulmonary complications in adult patients undergoing major upper abdominal procedures. A structured integrative review was conducted using the Scientific Method, incorporating randomized clinical trials, observational studies, systematic reviews, meta-analyses, and relevant multicenter investigations. The evidence was organized into three main domains: perioperative risk prediction, preventive respiratory strategies, and escalation of postoperative respiratory support. The results showed that variables such as low preoperative oxygen saturation, advanced age, recent respiratory infection, anemia, prolonged surgery, emergency procedures, and upper abdominal incisions contribute to increased pulmonary risk. Preoperative physiotherapy and inspiratory muscle training were associated with reductions in postoperative respiratory complications in selected populations. Intraoperatively, lung-protective ventilation based on lower tidal

volumes and individualized assessment of PEEP, respiratory compliance, and driving pressure was associated with improved pulmonary outcomes, whereas routine use of high PEEP did not consistently reduce complications. Postoperatively, prophylactic CPAP did not demonstrate universal benefit, while noninvasive ventilation reduced re-intubation and healthcare-associated infections in patients with established hypoxemic respiratory failure. Overall, the findings support a multimodal, risk-adapted, and stepwise perioperative strategy integrating early risk identification, pulmonary protection, postoperative surveillance, and timely escalation of respiratory support.

KEYWORDS

postoperative pulmonary complications, upper abdominal surgery, lung-protective ventilation, perioperative care, respiratory failure, noninvasive ventilation, preoperative physiotherapy, inspiratory muscle training, ARISCAT, postoperative respiratory support

INTRODUCCIÓN

Postoperative pulmonary complications (PPCs) remain among the most clinically relevant causes of morbidity after major surgery, particularly following upper abdominal procedures. Their spectrum includes postoperative atelectasis, pneumonia, hypoxemic respiratory failure, bronchospasm, aspiration-related lung injury, pleural effusion, and the need for prolonged or unplanned ventilatory support. These events may delay functional recovery, increase intensive care utilization, prolong hospitalization, and contribute to postoperative mortality. Their clinical importance is particularly evident in procedures involving the upper abdomen, where surgical incision, diaphragmatic dysfunction, postoperative pain, anesthesia-induced changes in respiratory mechanics, and reduced mobility interact to impair ventilation and secretion clearance during the early postoperative period (Miskovic & Lumb, 2017; Abbott et al., 2018).

The development of PPCs is multifactorial and reflects the interaction between pre-existing patient vulnerability, the magnitude of the surgical insult, and perioperative management. Advanced age, respiratory disease, reduced functional capacity, smoking exposure, anemia, prolonged surgery, emergency procedures, upper abdominal or thoracic surgical sites, and impaired oxygenation have all been associated with an increased postoperative respiratory risk. This multifactorial nature has stimulated the development of prediction tools that allow clinicians to identify patients in whom preventive strategies may provide the greatest benefit. Among the most influential studies, Canet et al. (2010) demonstrated that a limited number of readily available preoperative variables can stratify the risk of PPCs in surgical populations, supporting the incorporation of structured respiratory risk assessment into perioperative decision-making. Subsequent international data have further shown that PPCs remain frequent among patients receiving general anesthesia and that clinical outcomes worsen substantially when respiratory complications occur (LAS VEGAS Investigators, 2017).

Risk identification alone, however, is insufficient. Contemporary perioperative care increasingly emphasizes prevention through interventions implemented before, during, and immediately after surgery. Preoperative preparation may include optimization of chronic pulmonary disease, smoking cessation when feasible, correction of reversible risk factors, patient education, and respiratory physiotherapy. Evidence from upper abdominal surgery indicates that targeted preoperative physiotherapy can reduce postoperative respiratory complications, particularly when education regarding breathing exercises and early postoperative respiratory care is provided before the surgical insult occurs (Boden et al., 2018). Inspiratory muscle training has also been investigated as a prehabilitation strategy and has been associated with reductions in PPCs and hospital length of stay in selected surgical populations (Katsura et al., 2015; Kendall et al., 2018). More recent analyses support the broader concept that preoperative exercise-based interventions may improve physiological reserve and reduce postoperative respiratory morbidity in patients undergoing major surgery (Assouline et al., 2021).

Intraoperative mechanical ventilation represents another central component of pulmonary protection. General anesthesia promotes reductions in functional residual capacity, dependent lung atelectasis, altered ventilation-perfusion relationships, and impaired oxygenation. These changes can be amplified by abdominal retraction, pneumoperitoneum, prolonged supine positioning, high inspired oxygen concentrations, and inappropriate ventilatory pressures. Landmark randomized evidence demonstrated that ventilation using lower tidal volumes as part of a lung-protective strategy reduced postoperative pulmonary complications in patients undergoing major abdominal surgery compared with more traditional ventilatory approaches (Futier et al., 2013). Nevertheless, protective ventilation cannot be reduced to a

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single tidal-volume target. The relationship among tidal volume, positive end-expiratory pressure (PEEP), recruitment maneuvers, respiratory system compliance, and driving pressure must be considered in an individualized manner (Güldner et al., 2015).

The PROVHILO trial contributed importantly to this discussion by demonstrating that routinely applying high levels of PEEP with recruitment maneuvers during open abdominal surgery did not necessarily translate into a lower incidence of PPCs and could increase intraoperative hemodynamic instability (PROVE Network Investigators for the Clinical Trial Network of the European Society of Anaesthesiology, 2014). Conversely, analyses focused on driving pressure have suggested that excessive pressure required to deliver tidal volume may be independently associated with postoperative pulmonary morbidity, reinforcing the importance of adapting ventilation to individual respiratory mechanics rather than relying exclusively on fixed ventilatory settings (Serpa Neto et al., 2016). Contemporary evidence therefore favors a multidimensional concept of lung-protective ventilation based on appropriate tidal volumes, cautious PEEP titration, avoidance of excessive driving pressures, selective recruitment maneuvers, and continuous reassessment of respiratory mechanics (Serpa Neto et al., 2015; Mo et al., 2024).

The postoperative period is equally important because respiratory deterioration frequently develops after extubation rather than during surgery itself. Pain, residual anesthetic effects, diaphragmatic inhibition, shallow breathing, secretion retention, and prolonged immobility may create a progressive cycle of alveolar collapse and impaired gas exchange. Early mobilization, adequate multimodal analgesia, respiratory exercises, effective coughing, and physiotherapeutic interventions are therefore central elements of postoperative pulmonary care (Kokotovic et al., 2021). Although incentive spirometry continues to be widely used, available evidence suggests that its effectiveness should be interpreted within a broader respiratory rehabilitation strategy rather than as an isolated intervention capable of preventing all PPCs (Sullivan et al., 2021; Odor et al., 2020).

When preventive interventions are insufficient, treatment should follow an escalation strategy based on the severity and mechanism of respiratory dysfunction. Initial management includes identification and correction of reversible causes, adequate analgesia, positioning, secretion clearance, supplemental oxygen, and treatment of specific complications such as bronchospasm, pneumonia, fluid overload, or significant pleural pathology. Persistent hypoxemia or increased work of breathing may require escalation to noninvasive respiratory support in appropriately selected patients, while progressive respiratory failure, hemodynamic instability, altered consciousness, or failure of noninvasive measures should prompt consideration of invasive mechanical ventilation. The PRISM trial demonstrated that routine prophylactic continuous positive airway pressure after major abdominal surgery did not uniformly prevent pneumonia, re-intubation, or mortality, highlighting the importance of selecting respiratory support according to individual clinical risk and evolving postoperative physiology rather than applying it indiscriminately (PRISM Trial Group, 2021).

Despite considerable advances in perioperative respiratory care, clinically significant heterogeneity persists in the prediction, prevention, and management of pleuropulmonary complications. Some interventions have shown benefit only in selected populations, while others depend strongly on timing, patient phenotype, surgical characteristics, and adherence to multimodal perioperative pathways. This variability makes a fragmented approach problematic. Rather than considering risk scores, prehabilitation, intraoperative ventilation, postoperative physiotherapy, and respiratory support as independent measures, current evidence suggests that they should be interpreted as interconnected components of a continuous perioperative strategy (Odor et al., 2020; Abbott et al., 2018).

Accordingly, the present article examines pleuropulmonary complications following upper abdominal surgery from an integrated perspective encompassing **risk prediction, perioperative prevention, early recognition, and stepwise treatment**. The review is structured around evidence derived from prospective cohorts, randomized controlled trials, systematic reviews, meta-analyses, and international perioperative studies addressing respiratory risk stratification, preoperative conditioning, protective ventilation, postoperative rehabilitation, and noninvasive or invasive respiratory support. Particular emphasis is placed on clinically applicable interventions that can be incorporated across the preoperative, intraoperative, and postoperative phases of care.

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DESARROLLO

Pleuropulmonary complications after upper abdominal surgery represent a complex clinical problem in which surgical trauma, anesthesia, respiratory mechanics, pain, and pre-existing patient vulnerability converge. Their development cannot be attributed to a single mechanism; instead, they result from a sequence of physiological alterations that begin during anesthesia and may persist throughout the postoperative period. Upper abdominal procedures are particularly relevant because they directly affect diaphragmatic function, reduce inspiratory capacity, promote shallow breathing, and impair the effectiveness of coughing. These alterations favor dependent atelectasis, secretion retention, ventilation–perfusion mismatch, and progressive deterioration of oxygenation, especially in patients with limited cardiopulmonary reserve (Miskovic & Lumb, 2017).

General anesthesia itself contributes substantially to these changes. Induction and neuromuscular blockade reduce functional residual capacity and alter chest wall mechanics, facilitating alveolar collapse in dependent lung regions. In addition, prolonged supine positioning, high inspired oxygen fractions, intra-abdominal pressure, surgical retractors, and mechanical ventilation may further modify pulmonary compliance. When these factors coexist with postoperative pain and diaphragmatic dysfunction, pulmonary expansion becomes progressively limited. The resulting reduction in tidal breathing can promote atelectasis and impaired mucociliary clearance, creating conditions favorable for pneumonia and postoperative respiratory failure (Güldner et al., 2015).

The risk of developing these complications is not homogeneous. Patient-related variables such as advanced age, chronic pulmonary disease, smoking history, poor functional status, low preoperative oxygen saturation, anemia, obesity, and relevant comorbidities may increase susceptibility. Procedure-related factors are equally important. Upper abdominal and thoracic surgical sites, prolonged operative duration, emergency surgery, extensive tissue manipulation, and higher surgical complexity are consistently associated with increased respiratory morbidity. The predictive model developed by Canet et al. (2010) demonstrated that a relatively small number of preoperative and perioperative variables can provide clinically useful stratification of pulmonary risk. This concept supports the use of structured risk assessment before surgery rather than waiting for respiratory deterioration to become evident.

International observational evidence has also shown that postoperative pulmonary complications are associated with worse clinical outcomes, including longer hospitalization and greater requirements for intensive postoperative care. The LAS VEGAS study confirmed that PPCs occur across different healthcare systems and are strongly related to perioperative patient characteristics and ventilatory practices (LAS VEGAS Investigators, 2017). This reinforces the idea that prevention must begin before surgery and continue throughout the intraoperative and postoperative periods.

One of the most important preventive strategies is preoperative respiratory preparation. Physiotherapy, breathing exercises, inspiratory muscle training, smoking cessation, and optimization of chronic respiratory disease can improve pulmonary reserve and prepare patients for the physiological stress of surgery. In a multicenter randomized trial, Boden et al. (2018) showed that preoperative physiotherapy education reduced postoperative pulmonary complications in patients undergoing upper abdominal surgery. This intervention is particularly relevant because it allows patients to become familiar with respiratory maneuvers before postoperative pain and sedation interfere with their ability to perform them effectively.

Inspiratory muscle training provides another preventive approach. By strengthening the respiratory musculature before major surgery, this strategy may increase inspiratory reserve and reduce susceptibility to postoperative respiratory dysfunction. Systematic reviews have suggested reductions in pulmonary complications and hospital length of stay, particularly among patients undergoing cardiac and major abdominal operations (Katsura et al., 2015; Kendall et al., 2018). Nevertheless, these interventions are not universally applicable and their effectiveness depends on patient selection, adherence, duration of training, and the interval between preoperative assessment and surgery.

Intraoperative management is equally decisive. Protective mechanical ventilation has become a central principle of anesthetic care because ventilator-induced stress can contribute to postoperative lung injury even in patients without pre-existing pulmonary disease. Lower tidal volumes have been associated with reduced postoperative complications when used as part of a protective ventilation strategy in abdominal surgery (Futier et al., 2013). However, the concept

of pulmonary protection extends beyond tidal volume alone. The balance among tidal volume, PEEP, plateau pressure, recruitment maneuvers, and driving pressure must be adapted to the mechanical characteristics of each patient.

Evidence from the PROVHILO trial demonstrated that high PEEP combined with recruitment maneuvers did not reduce postoperative pulmonary complications in open abdominal surgery when compared with lower PEEP and was associated with more frequent intraoperative hemodynamic compromise (PROVE Network Investigators for the Clinical Trial Network of the European Society of Anaesthesiology, 2014). These findings challenged the concept that higher PEEP should be routinely applied to all surgical patients. Instead, they favored individualized ventilatory management, especially when the potential pulmonary benefits of recruitment must be balanced against reductions in venous return and cardiac output.

Driving pressure has also emerged as an important physiological variable. Serpa Neto et al. (2016) found an association between higher intraoperative driving pressures and increased risk of postoperative pulmonary complications. This suggests that the amount of pressure required to deliver a given tidal volume may reflect the functional size and mechanical condition of the ventilated lung. Consequently, intraoperative ventilation should be adjusted not only according to predicted body weight but also according to compliance, airway pressures, oxygenation, and hemodynamic tolerance.

At the end of surgery, successful extubation does not eliminate pulmonary risk. The early postoperative period is often characterized by residual anesthetic effects, impaired respiratory muscle performance, pain-related restriction of inspiratory effort, reduced cough strength, and immobility. These factors promote progressive alveolar collapse and secretion retention. Adequate multimodal analgesia is therefore an essential component of respiratory prevention because poorly controlled pain can limit deep inspiration and effective coughing. At the same time, excessive systemic opioids may suppress respiratory drive, making the balance between analgesia and respiratory safety particularly important.

Early mobilization and respiratory physiotherapy are also key components of postoperative care. Mobilization improves ventilation distribution, promotes secretion clearance, and reduces the consequences of prolonged bed rest. Respiratory exercises can support lung expansion, although the benefit of isolated incentive spirometry remains uncertain. Sullivan et al. (2021) found that incentive spirometry should not be regarded as a stand-alone preventive intervention, particularly when broader postoperative respiratory care is absent. Similarly, systematic evidence suggests that postoperative respiratory strategies are more effective when incorporated into multimodal pathways rather than applied individually (Odor et al., 2020; Kokotovic et al., 2021).

Clinical surveillance is essential because postoperative respiratory deterioration may initially present with subtle signs. Decreasing oxygen saturation, tachypnea, shallow breathing, ineffective cough, increasing oxygen requirement, fever, abnormal breath sounds, and altered mental status should prompt early evaluation. Distinguishing between atelectasis, pneumonia, aspiration, pulmonary edema, bronchospasm, pleural effusion, pneumothorax, and thromboembolic disease is critical because treatment differs according to etiology.

Management should therefore follow a stepwise approach. Mild respiratory impairment may respond to positioning, analgesia optimization, respiratory exercises, secretion clearance, mobilization, and supplemental oxygen. When hypoxemia or respiratory workload persists, noninvasive support such as continuous positive airway pressure or noninvasive ventilation may be considered in appropriately selected patients. These modalities can improve alveolar recruitment, reduce work of breathing, and potentially avoid invasive ventilation, but they should not delay intubation when respiratory failure is progressing.

The PRISM trial demonstrated that routine prophylactic CPAP after major abdominal surgery did not significantly reduce the composite outcome of pneumonia, re-intubation, or death, indicating that noninvasive respiratory support should not be applied indiscriminately to all postoperative patients (PRISM Trial Group, 2021). Instead, respiratory support should be guided by the patient's physiological condition, risk profile, oxygenation, work of breathing, and response to initial treatment.

Patients who develop severe hypoxemia, worsening hypercapnia, hemodynamic instability, inability to protect the airway, severe respiratory muscle fatigue, or failure of noninvasive strategies may require invasive mechanical

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ventilation. In such cases, treatment must address both respiratory failure and its underlying cause. Pneumonia requires appropriate antimicrobial therapy when clinically indicated; pulmonary edema requires correction of fluid overload or cardiac dysfunction; bronchospasm requires bronchodilation; and significant pleural complications may require drainage or specific intervention.

The available evidence therefore supports a continuous perioperative model rather than a fragmented approach. Risk prediction identifies vulnerable patients; preoperative respiratory preparation improves physiological reserve; individualized intraoperative ventilation minimizes additional lung stress; postoperative analgesia, mobilization, and physiotherapy reduce functional decline; and early escalation of respiratory support limits progression toward severe respiratory failure. The effectiveness of each intervention depends on its integration with the others.

This concept is particularly relevant in upper abdominal surgery because respiratory dysfunction develops through multiple interacting mechanisms. A single isolated intervention is unlikely to eliminate pulmonary risk. A more rational strategy is to combine early risk stratification, targeted prevention, individualized anesthetic management, postoperative surveillance, and rapid treatment according to severity. Such an approach may reduce both the incidence and clinical impact of pleuropulmonary complications while improving recovery and preserving postoperative cardiopulmonary function.

OBJETIVO GENERAL Y OBJETIVOS ESPECÍFICOS

General Objective

To **analyze and integrate** current evidence regarding the prediction, prevention, and stepwise management of pleuropulmonary complications after upper abdominal surgery, in order to establish a clinically applicable perioperative framework that supports early risk identification, pulmonary protection, and timely respiratory intervention.

Specific Objectives

Cognitive Domain

1. To **identify** the main patient-related, surgical, and anesthetic risk factors associated with postoperative pleuropulmonary complications.
2. To **analyze** the physiological mechanisms involved in postoperative respiratory dysfunction, including diaphragmatic impairment, atelectasis, ventilation–perfusion abnormalities, and secretion retention.
3. To **compare** the effectiveness of preventive strategies such as preoperative physiotherapy, inspiratory muscle training, lung-protective ventilation, analgesia, and early mobilization.
4. To **evaluate** the criteria used to determine escalation from conventional oxygen therapy to noninvasive or invasive ventilatory support.

Psychomotor Domain

5. To **apply** a structured approach for perioperative respiratory risk assessment and postoperative respiratory surveillance.
6. To **demonstrate** the appropriate sequence of clinical interventions for the early management of postoperative respiratory deterioration.
7. To **organize** preventive and therapeutic measures according to the severity and underlying mechanism of the pleuropulmonary complication.

Affective Domain

8. To **promote** awareness of the importance of early recognition and prevention of postoperative respiratory complications.
9. To **value** multidisciplinary collaboration among surgeons, anesthesiologists, respiratory therapists, physiotherapists, and nursing personnel.
10. To **support** patient-centered perioperative care focused on respiratory safety, functional recovery, and reduction of preventable postoperative morbidity.

OBJETO DE ESTUDIO

The object of study is the occurrence, prevention, and clinical management of pleuropulmonary complications in adult patients undergoing upper abdominal surgery. Particular attention is given to postoperative respiratory events such as atelectasis, pneumonia, hypoxemia, respiratory failure, bronchospasm, pleural effusion, and the need for noninvasive or invasive ventilatory support.

The study focuses on the interaction between patient-related risk factors, surgical characteristics, anesthetic management, intraoperative mechanical ventilation, postoperative analgesia, respiratory physiotherapy, mobilization, and escalation of respiratory support. These variables are analyzed as components of a continuous perioperative process rather than as isolated interventions.

The population of interest includes adult surgical patients undergoing major upper abdominal procedures under general anesthesia, especially those with increased respiratory risk due to age, comorbidities, reduced functional reserve, smoking history, prolonged surgery, or other perioperative factors associated with postoperative pulmonary complications.

The central phenomenon under investigation is the progression from perioperative respiratory vulnerability to clinically significant pulmonary dysfunction and the extent to which early risk prediction, preventive strategies, and timely treatment can reduce the severity and impact of these complications.

METODOLOGÍA

This study was developed using the **Scientific Method**, applied through a structured integrative review of the scientific literature. This approach was selected to identify, analyze, compare, and synthesize evidence regarding the prediction, prevention, and treatment of pleuropulmonary complications following upper abdominal surgery.

The research process began with the formulation of the clinical problem and the research question concerning whether a multimodal, risk-adapted perioperative strategy could improve the prevention and management of postoperative pulmonary complications. A structured literature search was then performed using scientific databases including **PubMed/MEDLINE, Scopus, and Web of Science**.

Search terms included combinations of: *postoperative pulmonary complications*, *upper abdominal surgery*, *atelectasis*, *postoperative pneumonia*, *respiratory failure*, *lung-protective ventilation*, *PEEP*, *driving pressure*, *preoperative physiotherapy*, *inspiratory muscle training*, *CPAP*, and *noninvasive ventilation*. Boolean operators **AND** and **OR** were used to combine concepts and increase search sensitivity.

Eligible evidence included randomized controlled trials, prospective and retrospective cohort studies, systematic reviews, meta-analyses, and relevant multicenter observational studies involving adult surgical patients. Studies addressing risk prediction, perioperative respiratory interventions, mechanical ventilation, postoperative rehabilitation, or escalation of respiratory support were prioritized. Pediatric studies, publications unrelated to major surgery, isolated case reports, and studies without clinically applicable respiratory outcomes were excluded.

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Relevant information was extracted according to predefined categories: patient risk factors, type of surgery, preventive intervention, intraoperative ventilatory strategy, postoperative respiratory management, pulmonary complications, need for ventilatory support, and clinical outcomes. The findings were subsequently compared and organized into three principal domains: **risk prediction, perioperative prevention, and stepwise treatment**.

Finally, the available evidence was integrated through qualitative comparative analysis to identify consistent findings, areas of clinical disagreement, and interventions with potential applicability throughout the perioperative period. This structured procedure allows the methodological process to be reproduced by other investigators using the same databases, eligibility criteria, search concepts, and analytical categories.

FASES DEL DESARROLLO

Phase 1. Problem Identification

The first phase consisted of defining the clinical problem associated with pleuropulmonary complications after upper abdominal surgery. Particular attention was given to their frequency, clinical impact, associated risk factors, and the need for strategies capable of preventing progression toward postoperative respiratory failure.

Phase 2. Formulation of the Research Question

A central research question was established to determine whether a multimodal and risk-adapted perioperative strategy could improve the prediction, prevention, and management of postoperative pulmonary complications. From this question, the principal hypothesis and the analytical categories of the study were defined.

Phase 3. Evidence Collection

Scientific evidence was identified through structured searches in PubMed/MEDLINE, Scopus, and Web of Science. Studies addressing risk stratification, respiratory physiotherapy, inspiratory muscle training, protective mechanical ventilation, postoperative surveillance, oxygen therapy, CPAP, noninvasive ventilation, and invasive ventilatory support were selected according to predefined inclusion and exclusion criteria.

Phase 4. Analysis and Classification

The selected evidence was critically reviewed and organized into three principal domains: **risk prediction, perioperative prevention, and stepwise treatment**. Findings were compared according to patient characteristics, surgical factors, respiratory interventions, and relevant postoperative outcomes.

Phase 5. Integration and Clinical Interpretation

Finally, the findings were integrated into a continuous perioperative framework. Evidence from the preoperative, intraoperative, and postoperative periods was combined to establish a structured sequence beginning with early risk identification and progressing through preventive measures, clinical surveillance, and escalation of respiratory support when required.

RESULTADOS Y DISCUSIÓN

Figure 1.

Distribution and characteristics of the evidence included in the analysis.

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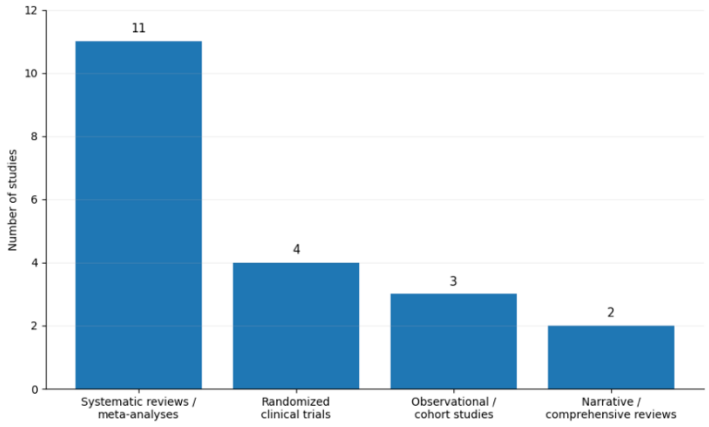

Figure 1 shows the methodological distribution of the **20 scientific sources included in the analysis**. Systematic reviews and meta-analyses represented the largest group, accounting for **11 studies (55%)**, followed by randomized clinical trials with **4 studies (20%)**, observational or cohort studies with **3 studies (15%)**, and narrative or comprehensive reviews with **2 studies (10%)**. This distribution reflects the predominance of evidence synthesis and comparative clinical research within the literature addressing postoperative pulmonary complications.

The high proportion of systematic reviews and meta-analyses provided a broad basis for evaluating preventive and therapeutic interventions across different surgical populations. These studies addressed several relevant perioperative strategies, including lung-protective ventilation, inspiratory muscle training, respiratory physiotherapy, mobilization, and other interventions intended to reduce postoperative pulmonary morbidity (Katsura et al., 2015; Serpa Neto et al., 2015; Kendall et al., 2018; Odor et al., 2020). More recent analyses have also compared different intraoperative ventilation strategies, allowing multiple approaches to be assessed within a common quantitative framework (Mo et al., 2024).

Randomized clinical trials constituted **20% of the selected evidence** and provided direct comparative data regarding specific perioperative interventions. Futier et al. (2013) evaluated a lung-protective ventilation strategy during abdominal surgery, whereas the PROVHILO trial assessed the effects of different levels of positive end-expiratory pressure and recruitment maneuvers during open abdominal procedures (PROVE Network Investigators for the Clinical Trial Network of the European Society of Anaesthesiology, 2014). In the preoperative setting, Boden et al. (2018) evaluated physiotherapy before upper abdominal surgery, while the PRISM trial examined postoperative continuous positive airway pressure after major abdominal surgery (PRISM Trial Group, 2021). Together, these trials supplied controlled evidence from different stages of the perioperative continuum.

Observational and cohort investigations represented **15% of the included literature**. Although these studies did not experimentally assign interventions, they contributed information regarding the epidemiology and prediction of postoperative respiratory complications. Canet et al. (2010) identified variables associated with pulmonary complications and established a clinically applicable predictive model. Similarly, the multinational LAS VEGAS study characterized ventilation practices and postoperative pulmonary outcomes across numerous surgical centers, providing information regarding real-world perioperative respiratory care (LAS VEGAS Investigators, 2017). These studies were particularly relevant for identifying clinical variables that may distinguish patients with different baseline levels of respiratory risk.

The remaining **10% corresponded to narrative or comprehensive reviews**. These publications contributed physiological and clinical context for understanding the mechanisms underlying postoperative respiratory deterioration. Güldner et al. (2015) reviewed the interaction among tidal volume, PEEP, and recruitment maneuvers during intraoperative ventilation, whereas Miskovic and Lumb (2017) summarized the mechanisms, risk factors, clinical manifestations, and management principles associated with postoperative pulmonary complications.

Figure 2.

Main factors associated with increased risk of postoperative pleuropulmonary complications.

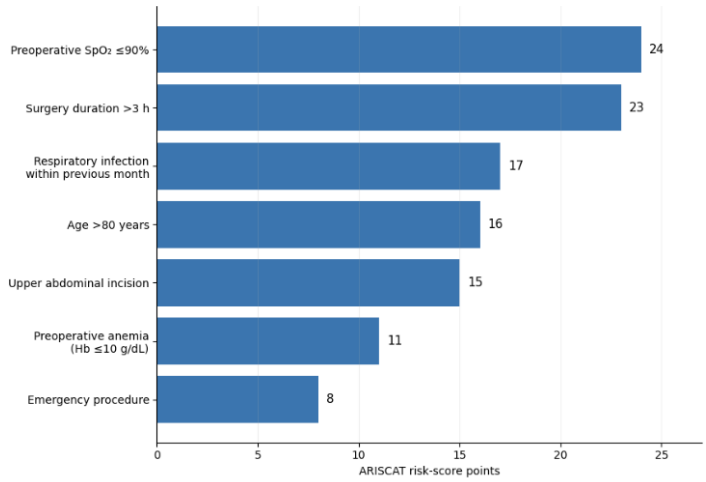

Figure 2 summarizes the principal variables incorporated into the ARISCAT model for the prediction of postoperative pulmonary complications. The values shown correspond to the **risk-score points assigned to each factor and should not be interpreted as odds ratios or percentages of complications**. Higher values indicate a greater contribution to the overall predictive score developed by Canet et al. (2010).

Among the evaluated variables, **preoperative oxygen saturation ≤90%** received the highest weighting, with **24 points**. This finding emphasizes the relevance of impaired baseline oxygenation as an indicator of reduced cardiopulmonary reserve before surgery. Preoperative oxygen saturation represents an easily obtainable physiological measurement and contributes substantially to the identification of patients who may be more susceptible to postoperative respiratory deterioration (Canet et al., 2010).

A **surgical duration greater than three hours** contributed **23 points**, representing the second highest weighting. Prolonged procedures expose patients to longer periods of general anesthesia, mechanical ventilation, neuromuscular blockade, immobilization, and alterations in respiratory mechanics. Duration of surgery therefore constitutes an important procedure-related component of pulmonary risk and should be considered together with patient-related variables rather than as an isolated predictor (Canet et al., 2010; LAS VEGAS Investigators, 2017).

A **respiratory infection during the previous month** contributed **17 points**, while **age greater than 80 years** contributed **16 points**. Recent respiratory infection may be associated with persistent airway inflammation, secretion production, or incomplete recovery of pulmonary function. Advanced age, meanwhile, may coexist with reduced respiratory reserve and diminished capacity to compensate for the physiological stress produced by major surgery (Canet et al., 2010; Miskovic & Lumb, 2017).

Of particular relevance to the present study, an **upper abdominal surgical incision contributed 15 points** to the ARISCAT score. Upper abdominal surgery can interfere with diaphragmatic excursion and postoperative inspiratory effort and is therefore specifically recognized as an important anatomical determinant of postoperative pulmonary risk. This quantitative weighting supports the decision to consider patients undergoing these procedures as a population requiring structured respiratory assessment and perioperative preventive measures (Canet et al., 2010).

Preoperative anemia, defined in the model as hemoglobin ≤10 g/dL, contributed **11 points**, whereas an **emergency procedure** contributed **8 points**. Although their individual weighting is lower than that assigned to severe hypoxemia or prolonged surgery, these variables remain clinically relevant because pulmonary risk is cumulative. Several moderate-risk characteristics occurring simultaneously may therefore move a patient into a substantially higher overall risk category.

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The ARISCAT model integrates these factors into a cumulative score rather than treating each predictor independently. Patients with scores below 26 are classified as low risk, those with scores between 26 and 44 as intermediate risk, and those with scores of 45 or greater as high risk. In the original validation sample, the reported incidence of postoperative pulmonary complications increased markedly across these categories, supporting the use of combined risk assessment rather than reliance on a single clinical characteristic (Canet et al., 2010).

Figure 3.

Effect of preoperative and postoperative preventive interventions on pulmonary complications.

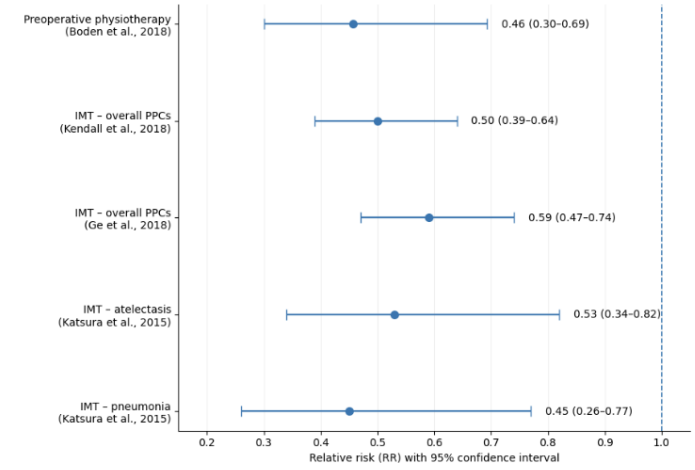

Figure 3 presents representative relative effect estimates for preventive respiratory interventions evaluated before major surgery. In all estimates shown, a relative risk below 1.0 indicates a lower frequency of postoperative pulmonary complications in the intervention group. The confidence intervals remained below the line of no effect, although the magnitude and precision of the estimates differed among studies.

In the randomized trial conducted by Boden et al. (2018), postoperative pulmonary complications occurred in **27 of 218 patients (12%)** who received a single preoperative physiotherapy education and breathing-training session, compared with **58 of 214 patients (27%)** receiving the control intervention. Based on these event frequencies, the unadjusted relative risk was approximately **0.46 (95% CI 0.30–0.69)**. The original adjusted analysis similarly reported a hazard ratio of 0.48, indicating a substantial reduction in PPC occurrence after upper abdominal surgery.

Evidence from inspiratory muscle training showed a similar direction of effect. Kendall et al. (2018), analyzing 12 randomized trials for the pulmonary complication outcome, reported an overall **RR of 0.50 (95% CI 0.39–0.64)**. This corresponds to approximately half the relative risk of PPCs among patients receiving inspiratory muscle training compared with control groups. The meta-analysis included cardiac, pulmonary, and abdominal surgical populations, and therefore represents broader major-surgery evidence rather than exclusively upper abdominal surgery.

Ge et al. (2018) evaluated 13 randomized trials including 784 patients undergoing cardiothoracic or upper abdominal surgery. Preoperative inspiratory muscle training was associated with a **RR of 0.59 (95% CI 0.47–0.74)** for postoperative pulmonary complications. Although the magnitude was somewhat smaller than that observed in other pooled analyses, the confidence interval remained entirely below 1.0, indicating a consistent reduction in respiratory complications across the included trials.

Katsura et al. (2015) separately analyzed specific postoperative respiratory outcomes in adults undergoing cardiac or major abdominal surgery. Preoperative inspiratory muscle training was associated with a lower incidence of **atelectasis, RR 0.53 (95% CI 0.34–0.82)**, and **pneumonia, RR 0.45 (95% CI 0.26–0.77)**. These results demonstrate that the observed effect was not limited to a composite pulmonary outcome but was also detected in clinically defined respiratory complications.

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The estimates should not be interpreted as a direct ranking of preventive strategies because the populations, definitions of pulmonary complications, intervention protocols, and follow-up periods were heterogeneous. Some analyses included cardiac and thoracic surgery in addition to abdominal procedures, and several meta-analyses incorporated partially overlapping randomized trials. Consequently, the figure is intended to demonstrate the **consistency and approximate magnitude of the reported preventive effect**, rather than establish superiority between individual interventions.

Figure 4.

Relationship between intraoperative lung-protective ventilation strategies and postoperative respiratory outcomes.

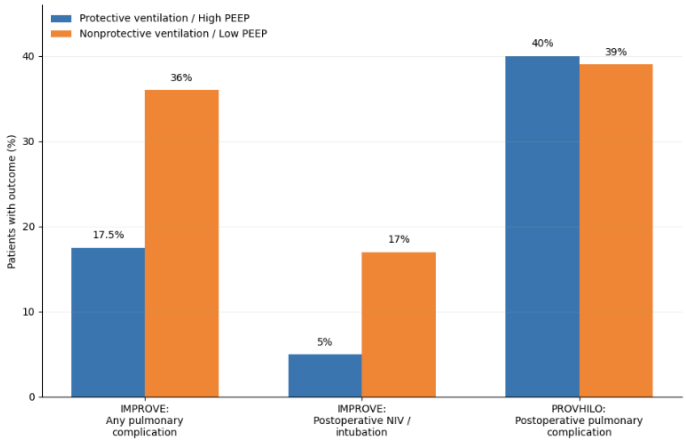

Figure 4 presents quantitative findings from two major randomized trials evaluating intraoperative ventilatory strategies in patients undergoing abdominal surgery. The data show that the effect of mechanical ventilation on postoperative respiratory outcomes depends not only on tidal volume reduction but also on how PEEP and recruitment maneuvers are incorporated into the ventilatory strategy.

In the IMPROVE trial, patients undergoing major abdominal surgery who received lung-protective ventilation experienced postoperative pulmonary complications in **17.5%** of cases, compared with **36.0%** in patients receiving conventional nonprotective ventilation. The adjusted relative risk was **0.49 (95% CI 0.32–0.74)**, demonstrating a marked reduction in pulmonary complications among patients managed with the protective strategy (Futier et al., 2013).

A similar pattern was observed for clinically significant postoperative respiratory failure. Only **5.0%** of patients assigned to protective ventilation required noninvasive ventilation or endotracheal intubation during the first seven postoperative days, compared with **17.0%** in the nonprotective group. This corresponded to a relative risk of **0.29 (95% CI 0.14–0.61)**, indicating a substantial difference in the requirement for advanced respiratory support between the two groups (Futier et al., 2013).

However, the results of the PROVHILO trial demonstrate that increasing PEEP does not necessarily produce additional pulmonary protection. In this trial, postoperative pulmonary complications occurred in **40% of patients receiving PEEP of approximately 12 cmH_2O combined with recruitment maneuvers**, compared with **39% of patients treated with low PEEP of 0–2 cmH_2O without routine recruitment maneuvers**. The relative risk was **1.01 (95% CI 0.86–1.20; p=0.86)**, indicating no significant reduction in PPCs with the higher-PEEP strategy. High PEEP was also associated with more intraoperative hypotension and greater use of vasoactive medication (PROVE Network Investigators, 2014).

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These findings demonstrate that the concept of lung-protective ventilation should not be reduced to the routine application of high PEEP. The IMPROVE data support a multimodal protective strategy incorporating lower tidal volumes and appropriate PEEP, whereas PROVHILO showed that systematically increasing PEEP to high levels with recruitment maneuvers did not further reduce pulmonary complications. The ventilatory approach therefore depends on the interaction among tidal volume, PEEP, respiratory mechanics, and the individual physiological response of the patient.

Driving pressure provides additional information regarding this relationship. An individual-patient meta-analysis of 17 randomized trials involving **2,250 surgical patients** found that each unit increase in intraoperative driving pressure was associated with greater odds of postoperative pulmonary complications, with an **OR of 1.16 (95% CI 1.13–1.19)**. In contrast, tidal volume alone was not independently associated with PPCs after adjustment. Furthermore, when an increase in PEEP produced an increase in driving pressure, pulmonary complications were also more frequent (Serpa Neto et al., 2016).

Figure 5.

Clinical outcomes associated with escalation of postoperative respiratory support, from conventional oxygen therapy to noninvasive and invasive ventilation.

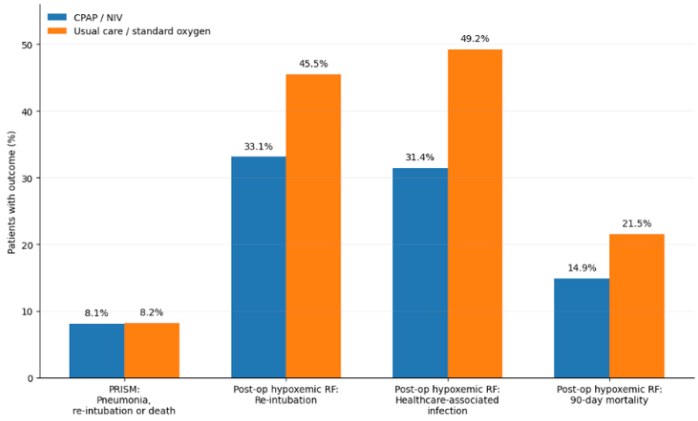

Figure 5 summarizes two different clinical situations involving postoperative noninvasive respiratory support after major abdominal surgery: **routine prophylactic CPAP immediately after surgery** and **therapeutic noninvasive ventilation (NIV) in patients who had already developed hypoxemic respiratory failure**. These populations should not be directly compared with each other; instead, the figure illustrates how the effectiveness of respiratory support varies according to the timing and clinical indication for its use.

In the PRISM trial, 4,793 patients were included in the primary analysis. The composite outcome of **pneumonia, endotracheal re-intubation, or death within 30 days** occurred in **8.1% of patients receiving prophylactic CPAP and 8.2% of those receiving usual postoperative care**. The adjusted odds ratio was **1.01 (95% CI 0.81–1.24; p=0.95)**, showing no measurable reduction in the primary outcome with routine CPAP administration in this population.

These findings indicate that applying CPAP systematically to patients after major abdominal surgery did not modify the overall incidence of the principal respiratory and mortality outcomes evaluated in PRISM. Adverse events related to CPAP were reported in **8.9%** of treated patients, most commonly claustrophobia, oronasal dryness, air leakage, vomiting, and discomfort. The trial therefore provided quantitative evidence that prophylactic CPAP should not be considered an intervention that necessarily benefits every postoperative patient regardless of respiratory status.

A different pattern was observed when NIV was used therapeutically in patients who had already developed **hypoxemic respiratory failure following abdominal surgery**. In a randomized clinical trial involving 293 patients, tracheal re-intubation within seven days occurred in **33.1% of patients treated with NIV compared with 45.5%**

receiving standard oxygen therapy, representing an absolute difference of approximately **12.4 percentage points**. This difference was statistically significant (p=0.03).

The same trial reported healthcare-associated infections in **31.4% of patients receiving NIV compared with 49.2% in the standard oxygen group**. The absolute difference was **17.8 percentage points**, and the difference was statistically significant (p=0.003). Patients treated with NIV also experienced a greater number of days free from invasive mechanical ventilation during the 30-day follow-up period.

For 90-day mortality, the observed proportion was **14.9% in the NIV group and 21.5% in the standard oxygen group**. Although the numerical difference favored NIV, it did not reach statistical significance, with an absolute difference of −6.5 percentage points and p=0.15. Consequently, this mortality difference should be described as an observed numerical variation rather than evidence of a confirmed mortality reduction.

The results therefore reveal an important distinction according to the **clinical stage at which positive-pressure respiratory support is introduced**. Routine CPAP administered prophylactically to a broad postoperative population did not reduce the composite incidence of pneumonia, re-intubation, or death. In contrast, NIV initiated in patients with established postoperative hypoxemic respiratory failure was associated with fewer re-intubations and healthcare-associated infections than standard oxygen therapy.

DISCUSIÓN

The findings of this review support the concept that pleuropulmonary complications after upper abdominal surgery are best understood as the consequence of multiple interacting perioperative factors rather than as isolated postoperative events. The evidence analyzed consistently showed that respiratory risk begins before surgery, is modified by intraoperative management, and may progress during the postoperative period according to the patient's physiological reserve and response to treatment. This reinforces the need for a continuous strategy integrating **risk prediction, prevention, surveillance, and timely escalation of respiratory support**.

Risk stratification represents the first component of this approach. The ARISCAT model demonstrated that variables such as low preoperative oxygen saturation, prolonged surgery, advanced age, recent respiratory infection, upper abdominal incision, anemia, and emergency procedures contribute differently to cumulative respiratory risk (Canet et al., 2010). Of particular importance for the present analysis, upper abdominal surgery itself constitutes a relevant risk component. This is physiologically plausible because abdominal incisions, postoperative pain, and diaphragmatic dysfunction can substantially reduce inspiratory capacity and impair effective coughing. Therefore, risk assessment should not be limited to identifying chronic pulmonary disease but should include the characteristics of the surgical procedure and the patient's baseline physiological reserve.

The preventive evidence also showed that intervention before surgery can modify postoperative respiratory outcomes. Preoperative physiotherapy and inspiratory muscle training were repeatedly associated with lower rates of pulmonary complications, including atelectasis and pneumonia (Katsura et al., 2015; Boden et al., 2018; Kendall et al., 2018). These findings suggest that respiratory prevention should begin before induction of anesthesia rather than being restricted to postoperative respiratory exercises. Patient education may be especially relevant because breathing and coughing techniques can be learned before pain, sedation, and postoperative weakness interfere with their execution.

Intraoperative ventilation represents another major determinant of postoperative respiratory function. The IMPROVE trial showed that lung-protective ventilation reduced pulmonary complications and the subsequent need for noninvasive ventilation or intubation compared with a more conventional ventilatory strategy (Futier et al., 2013). However, the PROVHILO trial demonstrated that increasing PEEP to high levels with recruitment maneuvers did not independently reduce postoperative pulmonary complications and produced more hemodynamic adverse effects (PROVE Network Investigators for the Clinical Trial Network of the European Society of Anaesthesiology, 2014). Together, these results indicate that pulmonary protection cannot be defined by a single ventilatory parameter.

The analysis of driving pressure provides further support for individualized ventilation. Higher driving pressure was associated with increased postoperative pulmonary complications, suggesting that respiratory mechanics may provide

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more clinically meaningful information than tidal volume alone in some patients (Serpa Neto et al., 2016). Consequently, a protective ventilatory strategy should consider tidal volume according to predicted body weight, PEEP, compliance, airway pressures, driving pressure, oxygenation, and hemodynamic tolerance as interconnected variables.

Postoperative management should follow the same individualized principle. Routine prophylactic respiratory support is not necessarily beneficial for all patients. In the PRISM trial, prophylactic CPAP after major abdominal surgery did not reduce the combined incidence of pneumonia, re-intubation, or death compared with usual care (PRISM Trial Group, 2021). These findings argue against the indiscriminate use of positive-pressure support in otherwise stable postoperative patients.

In contrast, noninvasive ventilation appears more relevant when respiratory deterioration has already become clinically evident. In patients who developed hypoxemic respiratory failure after abdominal surgery, NIV was associated with fewer re-intubations and fewer healthcare-associated infections compared with standard oxygen therapy. This distinction between prophylactic and therapeutic respiratory support is important because it suggests that timing and patient selection influence treatment effectiveness. Noninvasive support should therefore be considered according to clinical severity rather than applied universally.

A practical implication of these findings is the need for a **stepwise respiratory management pathway**. Patients without respiratory failure may be managed with adequate analgesia, early mobilization, respiratory physiotherapy, secretion clearance, and oxygen supplementation when required. Patients who develop persistent hypoxemia, increasing respiratory effort, or progressive gas-exchange impairment may benefit from noninvasive respiratory support. In contrast, worsening respiratory fatigue, severe hypoxemia, hemodynamic instability, altered consciousness, inability to protect the airway, or failure of noninvasive treatment should prompt escalation toward invasive mechanical ventilation.

The interdisciplinary nature of this problem should also be emphasized. Prevention and management involve anesthesiologists, surgeons, respiratory therapists, physiotherapists, nursing staff, and critical care teams. The contribution of each discipline varies throughout the perioperative period, but coordination is essential to maintain continuity between preoperative evaluation, intraoperative ventilation, postoperative recovery, and treatment of respiratory deterioration.

The findings should nevertheless be interpreted considering several limitations. The included literature was heterogeneous in terms of surgical populations, definitions of postoperative pulmonary complications, ventilatory protocols, duration of follow-up, and outcome measures. Some systematic reviews included cardiac or thoracic surgery in addition to abdominal procedures, and several meta-analyses incorporated overlapping primary studies. Furthermore, not all interventions demonstrated consistent benefits across every patient population. For these reasons, the numerical estimates presented should not be interpreted as directly comparable measures of superiority between strategies.

Despite these limitations, the overall pattern of evidence is consistent. Better respiratory outcomes appear to depend less on a single isolated intervention and more on the integration of several measures applied at the appropriate stage of care. Risk prediction identifies vulnerable patients, preoperative preparation improves respiratory reserve, individualized intraoperative ventilation reduces additional pulmonary stress, and postoperative surveillance permits early detection of deterioration. When respiratory failure develops, escalation from conventional oxygen therapy to noninvasive and, when necessary, invasive ventilation provides a structured therapeutic sequence.

CONCLUSIÓN

Pleuropulmonary complications after upper abdominal surgery remain a relevant cause of postoperative morbidity and frequently result from the interaction between pre-existing patient vulnerability, surgical characteristics, anesthesia, mechanical ventilation, postoperative pain, and impaired respiratory mechanics. The evidence reviewed indicates that

their prevention and management should be approached as a continuous perioperative process rather than as an isolated postoperative intervention.

Early risk stratification allows identification of patients with greater susceptibility to respiratory deterioration, particularly those with impaired oxygenation, advanced age, recent respiratory infection, anemia, prolonged procedures, emergency surgery, or upper abdominal incisions. Preventive measures such as preoperative physiotherapy, inspiratory muscle training, adequate analgesia, and early mobilization may contribute to reducing respiratory complications in selected patients.

Intraoperatively, lung-protective ventilation is most effective when applied in an individualized manner. Lower tidal volumes, appropriate PEEP, assessment of respiratory compliance, and limitation of excessive driving pressure should be considered together, since high PEEP or recruitment maneuvers applied routinely do not necessarily improve postoperative outcomes.

Postoperative respiratory support should also be guided by clinical severity. Routine prophylactic CPAP does not appear to provide universal benefit, whereas noninvasive ventilation may be useful in selected patients who develop hypoxemic respiratory failure. When respiratory deterioration progresses despite initial measures, escalation to invasive mechanical ventilation should not be delayed.

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REFERENCIAS

- Abbott, T. E. F., Fowler, A. J., Pelosi, P., Gama de Abreu, M., Møller, A. M., Canet, J., Creagh-Brown, B., Mythen, M., Gin, T., Lalu, M. M., Futier, E., Grocott, M. P. W., Schultz, M. J., & Pearse, R. M. (2018). A systematic review and consensus definitions for standardised end-points in perioperative medicine: Pulmonary complications. *British Journal of Anaesthesia, 120*(5), 1066–1079. DOI: 10.1016/j.bja.2018.02.007.
- Assouline, B., Cools, E., Schorer, R., Kayser, B., Elia, N., & Licker, M. (2021). Preoperative exercise training to prevent postoperative pulmonary complications in adults undergoing major surgery: A systematic review and meta-analysis with trial sequential analysis. *Annals of the American Thoracic Society, 18*(4), 678–688. DOI: 10.1513/AnnalsATS.202002-183OC.
- Boden, I., Skinner, E. H., Browning, L., Reeve, J., Anderson, L., Hill, C., Robertson, I. K., Story, D., & Denehy, L. (2018). Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: Pragmatic, double blinded, multicentre randomised controlled trial. *BMJ, 360*, j5916. DOI: 10.1136/bmj.j5916.
- Canet, J., Gallart, L., Gomar, C., Paluzie, G., Vallès, J., Castillo, J., Sabaté, S., Mazo, V., Briones, Z., & Sanchis, J. (2010). Prediction of postoperative pulmonary complications in a population-based surgical cohort. *Anesthesiology, 113*(6), 1338–1350. DOI: 10.1097/ALN.0b013e3181fc6e0a.
- Futier, E., Constantin, J.-M., Paugam-Burtz, C., Pascal, J., Eurin, M., Neuschwander, A., Marret, E., Beaussier, M., Gutton, C., Lefrant, J.-Y., Allaouchiche, B., Verzilli, D., Leone, M., De Jong, A., Bazin, J.-E., Pereira, B., & Jaber, S. (2013). A trial of intraoperative low-tidal-volume ventilation in abdominal surgery. *The New England Journal of Medicine, 369*(5), 428–437. DOI: 10.1056/NEJMoa1301082.
- Garg, S., Govindaraj, V., Dwivedi, D. P., Raja, K., & Theerthar, E. P. (2025). Postoperative pulmonary complications in patients undergoing upper abdominal surgery: Risk factors and predictive models. *Monaldi Archives for Chest Disease, 95*(1). DOI: 10.4081/monaldi.2024.2915.
- Ge, X., Wang, W., Hou, L., Yang, K., & Fa, X. (2018). Inspiratory muscle training is associated with decreased postoperative pulmonary complications: Evidence from randomized trials. *The Journal of Thoracic and Cardiovascular Surgery, 156*(3), 1290–1300.e5. DOI: 10.1016/j.jtcvs.2018.02.105.
- Güldner, A., Kiss, T., Serpa Neto, A., Hemmes, S. N. T., Canet, J., Spieth, P. M., Rocco, P. R. M., Schultz, M. J., Pelosi, P., & Gama de Abreu, M. (2015). Intraoperative protective mechanical ventilation for prevention of postoperative pulmonary complications: A comprehensive review of the role of tidal volume, positive end-expiratory pressure, and lung recruitment maneuvers. *Anesthesiology, 123*(3), 692–713. DOI: 10.1097/ALN.0000000000000754.
- Katsura, M., Kuriyama, A., Takeshima, T., Fukuhara, S., & Furukawa, T. A. (2015). Preoperative inspiratory muscle training for postoperative pulmonary complications in adults undergoing cardiac and major abdominal

surgery. *Cochrane Database of Systematic Reviews, 2015*(10), CD010356. DOI: 10.1002/14651858.CD010356.pub2.

- Kendall, F., Oliveira, J., Peleteiro, B., Pinho, P., & Bastos, P. T. (2018). Inspiratory muscle training is effective to reduce postoperative pulmonary complications and length of hospital stay: A systematic review and meta-analysis. *Disability and Rehabilitation, 40*(8), 864–882. DOI: 10.1080/09638288.2016.1277396.
- Kokotovic, D., Berkfors, A., Gögenur, I., Ekeloef, S., & Burcharth, J. (2021). The effect of postoperative respiratory and mobilization interventions on postoperative complications following abdominal surgery: A systematic review and meta-analysis. *European Journal of Trauma and Emergency Surgery, 47*(4), 975–990. DOI: 10.1007/s00068-020-01522-x.
- LAS VEGAS Investigators. (2017). Epidemiology, practice of ventilation and outcome for patients at increased risk of postoperative pulmonary complications: LAS VEGAS—An observational study in 29 countries. *European Journal of Anaesthesiology, 34*(8), 492–507. DOI: 10.1097/EJA.0000000000000646.
- Miskovic, A., & Lumb, A. B. (2017). Postoperative pulmonary complications. *British Journal of Anaesthesia, 118*(3), 317–334. DOI: 10.1093/bja/aex002.
- Mo, J., Wang, D., Xiao, J., Chen, Q., An, R., & Liu, H. L. (2024). Effects of lung protection ventilation strategies on postoperative pulmonary complications after noncardiac surgery: A network meta-analysis of randomized controlled trials. *BMC Anesthesiology, 24*(1), 346. DOI: 10.1186/s12871-024-02737-w.
- Odor, P. M., Bampoe, S., Gilhooly, D., Creagh-Brown, B., & Moonesinghe, S. R. (2020). Perioperative interventions for prevention of postoperative pulmonary complications: Systematic review and meta-analysis. *BMJ, 368*, m540. DOI: 10.1136/bmj.m540.
- PRISM Trial Group. (2021). Postoperative continuous positive airway pressure to prevent pneumonia, re-intubation, and death after major abdominal surgery (PRISM): A multicentre, open-label, randomised, phase 3 trial. *The Lancet Respiratory Medicine, 9*(11), 1221–1230. DOI: 10.1016/S2213-2600(21)00089-8.
- PROVE Network Investigators for the Clinical Trial Network of the European Society of Anaesthesiology. (2014). High versus low positive end-expiratory pressure during general anaesthesia for open abdominal surgery (PROVHILO trial): A multicentre randomised controlled trial. *The Lancet, 384*(9942), 495–503. DOI: 10.1016/S0140-6736(14)60416-5.
- Serpa Neto, A., Schultz, M. J., & Gama de Abreu, M. (2015). Intraoperative ventilation strategies to prevent postoperative pulmonary complications: Systematic review, meta-analysis, and trial sequential analysis. *Best Practice & Research Clinical Anaesthesiology, 29*(3), 331–340. DOI: 10.1016/j.bpa.2015.09.002.
- Serpa Neto, A., Hemmes, S. N. T., Barbas, C. S. V., Beiderlinden, M., Fernandez-Bustamante, A., Futier, E., Gajic, O., El-Tahan, M. R., Al Ghamdi, A. A., Günay, E., Jaber, S., Kokulu, S., Kozian, A., Licker, M., Lin, W.-Q., Maslow, A. D., Memtsoudis, S. G., Reis Miranda, D., Moine, P., … Schultz, M. J. (2016). Association between driving pressure and development of postoperative pulmonary complications in patients undergoing mechanical ventilation for general anaesthesia: A meta-analysis of individual patient data. *The Lancet Respiratory Medicine, 4*(4), 272–280. DOI: 10.1016/S2213-2600(16)00057-6.
- Sullivan, K. A., Churchill, I. F., Hylton, D. A., & Hanna, W. C. (2021). Use of incentive spirometry in adults following cardiac, thoracic, and upper abdominal surgery to prevent post-operative pulmonary complications: A systematic review and meta-analysis. *Respiration, 100*(11), 1114–1127. DOI: 10.1159/000517012.

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