

PATHOPHYSIOLOGICAL RATIONALE AND SELECTION CRITERIA FOR MULTIMODAL ANALGESIA INCORPORATING AN ERECTOR SPINAE PLANE (ESP) BLOCK IN PATIENTS WITH PURULENT-SEPTIC THORACIC DISEASES

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ABSTRACT

Objective: This study aimed to develop pathophysiologically grounded criteria for selecting multimodal analgesia with the integration of the erector spinae plane block (ESPB) in patients with purulent-septic diseases of the thoracic cavity.

Methods: The study included 66 patients with mediastinitis, chronic pleural empyema, and rib osteomyelitis who received conventional opioid-centered analgesia. Pain intensity, respiratory function parameters, opioid consumption, and the incidence of postoperative pulmonary complications (PPCs) were assessed.

Results: Pain at rest ≥ 5 points increased the risk of PPCs by 2.4 times (OR: 2.42; 95% CI: 1.17–5.00), reduced spirometry values $< 60\%$ of predicted increased the risk by 2.78 times (OR: 2.78; 95% CI: 1.33–5.82), and opioid consumption ≥ 45 mg morphine equivalents increased the risk by 1.5 times (OR: 1.50; 95% CI: 1.00–2.26).

Conclusion: Based on these findings, the "TAPS-ESPB" and "TAES" scales were developed to predict complication risk and guide analgesia management dynamically. The proposed approach enables a transition to a personalized analgesia model and contributes to a reduction in respiratory complications.

KEYWORDS: erector spinae plane block (ESPB), multimodal analgesia, personalized analgesia, purulent-septic thoracic diseases.

INTRODUCTION

Adequate pain management in thoracic surgery remains one of the key challenges in modern anesthesiology and critical care medicine due to the highly traumatic nature of surgical interventions and the significant impact of pain syndrome on the postoperative course and respiratory function [1,2].

A special category of patients includes those with purulent-septic diseases of the chest, such as mediastinitis, chronic pleural empyema, and rib osteomyelitis, in whom pain syndrome is characterized by high intensity and a complex pathogenesis involving somatic, visceral, and autonomic components [3].

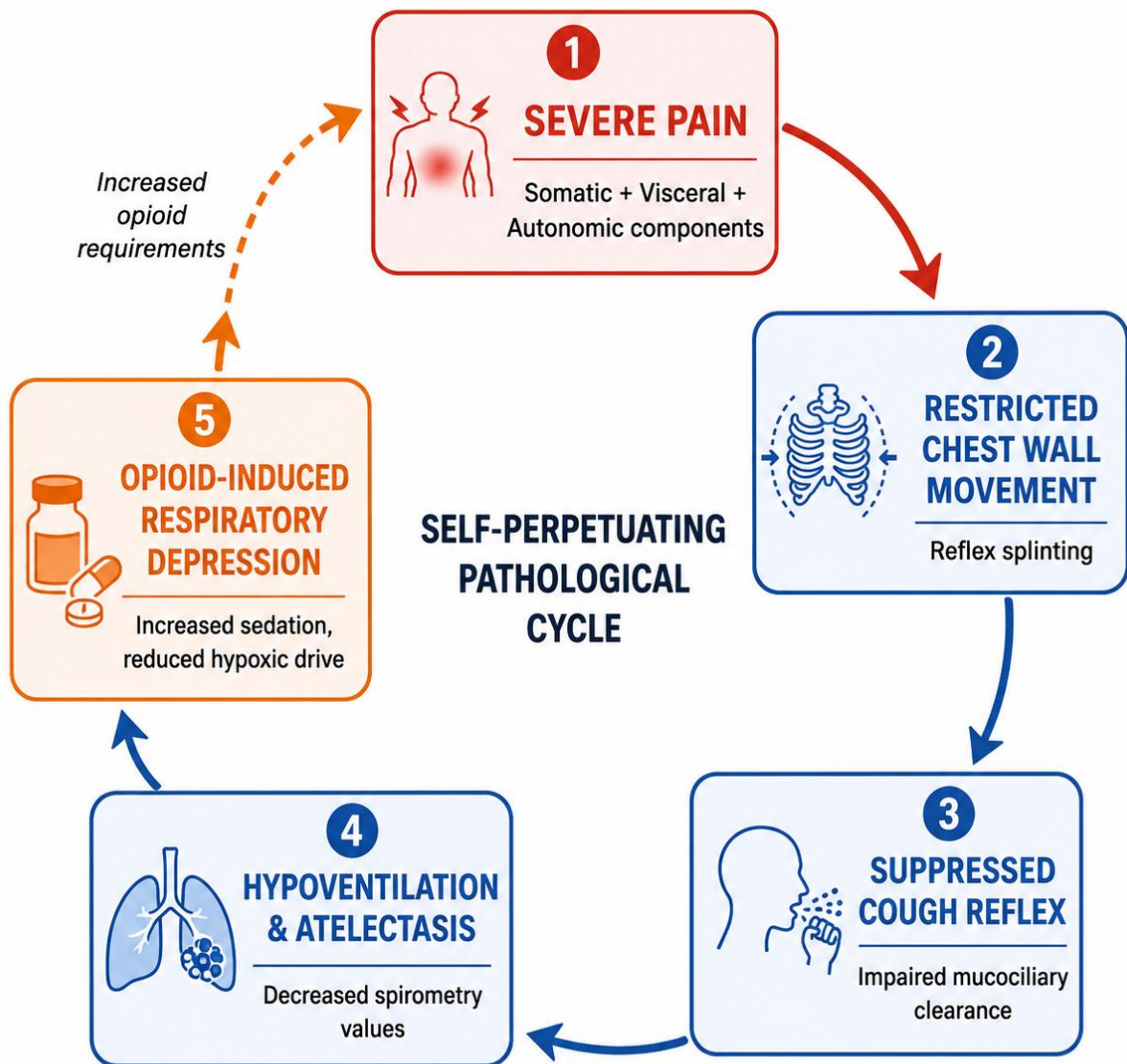
The multifactorial nature of pain is associated with injury to the chest wall structures, involvement of the pleura and intrathoracic organs, as well as activation of the sympathetic nervous system, which significantly reduces the effectiveness of conventional analgesic approaches [4]. Under these conditions, pain becomes not only a subjective symptom but also an important pathophysiological factor contributing to the development of respiratory dysfunction and postoperative complications [5].

Traditionally used opioid-centered analgesic regimens in this patient population have demonstrated limited effectiveness. It has been established that increasing opioid doses does not provide adequate pain relief but is associated with the development of adverse effects, including respiratory depression, excessive sedation, and impaired mucociliary clearance [6,7]. At the same time, severe pain limits chest excursions and suppresses the cough reflex, thereby promoting hypoventilation and the development of atelectasis [5,8].

Thus, a pathophysiological cycle is formed in which pain and opioid therapy mutually reinforce their negative effects on respiratory function (Figure 1). In this context, multimodal analgesia aimed at targeting different mechanisms of nociception and reducing opioid consumption has gained increasing importance [2]. Regional anesthetic techniques occupy a central role in this concept, particularly the erector spinae plane block (ESPB), which provides effective blockade of peripheral pain pathways and partially modulates sympathetic innervation [3,6].

Despite the promising potential of ESPB, its application in patients with purulent-septic diseases of the chest remains insufficiently studied, and the choice of analgesic strategy is often empirical. Therefore, there is a growing need to transition toward a pathogenetically oriented and personalized analgesic model based on objective patient assessment and risk stratification for postoperative complications.

Figure 1. Pathophysiological Cycle of Pain, Opioid Burden, and Respiratory Dysfunction



OBJECTIVE

To develop pathophysiologically based criteria for selecting multimodal analgesia incorporating an erector spinae plane block (ESPB) in patients with purulent-septic diseases of the chest.

MATERIALS AND METHODS

Study Design and Population

The study was conducted at the multidisciplinary clinic of Tashkent State Medical University, in the Surgical Intensive Care Unit with a dedicated purulent-septic care unit. The analysis included 66 patients with purulent-septic diseases of the thoracic organs undergoing surgical treatment, including:

- ✓ Mediastinitis (n = 22)
- ✓ Chronic pleural empyema (n = 21)
- ✓ Rib osteomyelitis (n = 23)

All patients received conventional opioid-centered analgesia. No group allocation was performed, as the study was analytical in nature and aimed at identifying risk factors and substantiating criteria for analgesic selection.

Assessment Methods

The study methods included a comprehensive evaluation of:

- Pain intensity using the Numeric Rating Scale (NRS) at rest and during coughing
- Respiratory function through incentive spirometry parameters and peak cough flow measurement
- Total opioid consumption expressed as morphine equivalent dose over 48 hours (MED-48h)
- Incidence of postoperative pulmonary complications (PPCs)

Statistical Analysis

To identify independent risk factors for the development of complications, multivariate logistic regression analysis was performed with calculation of odds ratios (ORs) and 95% confidence intervals (CIs). Receiver operating characteristic (ROC) curves were also constructed to assess the predictive value of the investigated parameters. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Pain Intensity and Respiratory Function

Analysis of the obtained clinical and functional data demonstrated that patients with purulent-septic diseases of the chest experienced persistent severe pain during the early postoperative period despite receiving standard opioid-centered analgesia. The mean pain intensity during the first postoperative day was 5.95 ± 0.93 points at rest and 7.8 ± 0.81 points during coughing, corresponding to moderate and severe pain, respectively. Importantly, even by the third postoperative day, pain intensity did not decrease to a clinically acceptable level ($\text{NRS} \leq 3$), remaining above 4 points in the majority of patients, which indicates insufficient efficacy of the analgesic regimens used.

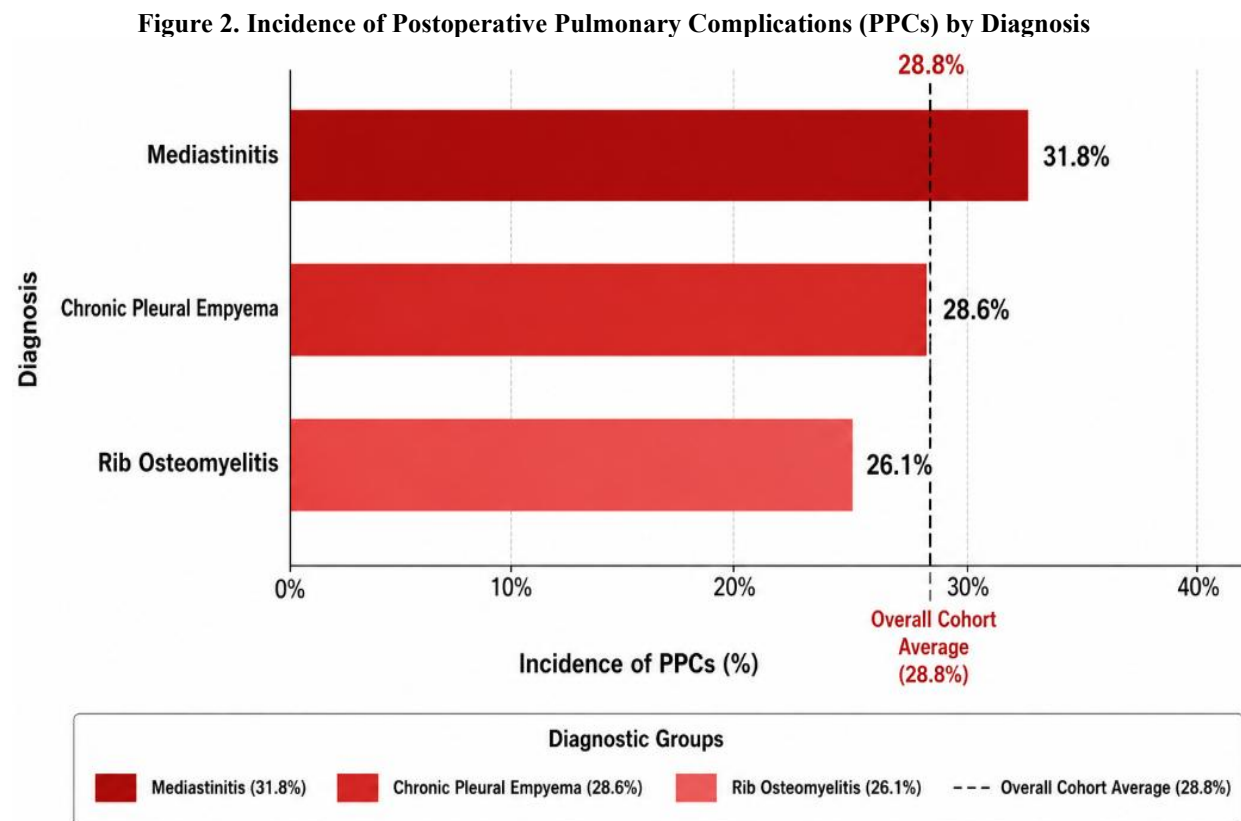
Simultaneously, a significant deterioration in respiratory function was observed. Incentive spirometry values decreased to $61.7 \pm 12.6\%$ of predicted levels, indicating the development of hypoventilation. In addition, a significant reduction in peak cough flow was documented, reflecting impaired bronchial clearance and decreased effectiveness of tracheobronchial secretion evacuation. These changes create favorable conditions for the development of respiratory complications during the early postoperative period.

Opioid Consumption

The mean opioid consumption reached 42.9 ± 16.2 mg of morphine equivalents during the first 48 hours after surgery, indicating the need for substantial doses of analgesics to achieve even partial pain control. However, increasing opioid doses was not associated with adequate pain relief, suggesting the limited effectiveness of this strategy in patients with purulent-septic thoracic pathology.

Postoperative Pulmonary Complications

The incidence of postoperative pulmonary complications (PPCs) in the study cohort reached 28.8%, with the highest complication rate observed among patients with mediastinitis, where the incidence was 31.8% (Figure 2). These findings confirm that disease-specific characteristics have a significant impact on the risk of an unfavorable postoperative course.



Risk Factor Analysis

The results of the multivariate logistic regression analysis identified independent predictors of PPC development, reflecting the key components of the underlying pathophysiological process (Table 1).

Table 1. Multivariate Analysis of Risk Factors for Postoperative Pulmonary Complications (PPCs)

Variable	OR	95% CI	p-value
Pain at rest ≥ 5 points	2.42	1.17–5.00	<0.05
Pain during coughing ≥ 7 points	2.10	1.05–4.18	<0.05
Incentive spirometry <60% of predicted	2.78	1.33–5.82	<0.01
Peak cough flow <250 L/min	2.21	1.12–4.36	<0.05
Morphine Equivalent Dose ≥ 45 mg	1.50	1.00–2.26	<0.05

The obtained data indicate that the development of postoperative complications is driven not by isolated parameters but by their combined effect, reflecting the functional status of the integrated "pain–respiration–pharmacological burden" system.

The analysis demonstrates that the postoperative condition of patients with purulent-septic diseases of the chest is determined by the complex and interrelated influence of pain syndrome, respiratory dysfunction, and pharmacological burden. The findings confirm that these factors constitute a unified pathogenetic framework in which inadequate analgesia acts as a triggering mechanism for the development of respiratory complications.

Pain Intensity as a Predictor

Pain intensity was identified as a key predictor of an unfavorable postoperative course. When pain at rest reached ≥ 5 points on the NRS, the likelihood of developing postoperative pulmonary complications (PPCs) increased more than twofold. This effect can be explained by the fact that severe pain leads to reflex restriction of chest wall movement, reduced inspiratory depth, and suppression of the cough reflex. As a result, hypoventilation develops, creating conditions favorable for the occurrence of atelectasis and infectious pulmonary complications (Table 2).

Table 2. Association Between Pain Intensity and the Incidence of Postoperative Pulmonary Complications (PPCs)

Pain Level (NRS)	Incidence of PPCs (%)
≤ 3 points	12%
≥ 5 points	48%

The data demonstrate that clinically adequate pain control is not only an indicator of patient comfort but also a critical prerequisite for preserving respiratory function.

Respiratory Function as a Predictor

In addition, impaired respiratory function was found to have an independent and even stronger prognostic significance. Specifically, a reduction in incentive spirometry values to less than 60% of the predicted level was associated with an almost threefold increase in the risk of postoperative pulmonary complications (PPCs) (Table 3). This finding confirms that hypoventilation represents a central mechanism in the pathogenesis of postoperative complications in this category of patients.

Table 3. Impact of Respiratory Function on the Incidence of Postoperative Pulmonary Complications (PPCs)

Incentive Spirometry (% of predicted)	Incidence of PPCs (%)
$\geq 80\%$	12%
<60%	48%

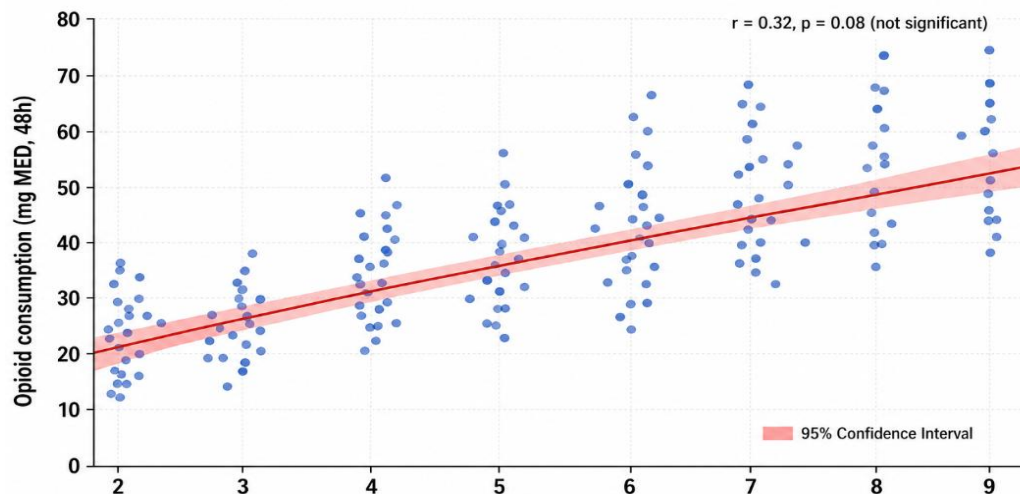
A reduction in peak cough flow further complements this clinical picture, reflecting impaired effective airway clearance and thereby increasing the risk of infectious complications.

The Role of Opioid Burden

Particular attention in the present study was given to the role of opioid burden. It was found that an increase in total opioid consumption (morphine equivalent dose, MED ≥ 45 mg) was associated with more than a twofold increase in the incidence of complications. This finding is of fundamental importance, as it demonstrates a paradoxical effect of conventional analgesic strategies. Specifically, while opioid dose escalation is intended to alleviate pain, it simultaneously leads to respiratory center depression, reduced sensitivity to hypoxia and hypercapnia, and sedation. Thus, a self-perpetuating pathological cycle is formed in which intensified analgesia is accompanied by deterioration of respiratory function and an increased risk of complications.

Figure 6 illustrates the weak correlation between pain intensity and opioid consumption, demonstrating that higher opioid doses do not correspond to lower pain scores, further supporting the limited efficacy of opioid-centered analgesia.

Figure 6. Correlation Between Postoperative Pain Intensity and Cumulative Opioid Consumption



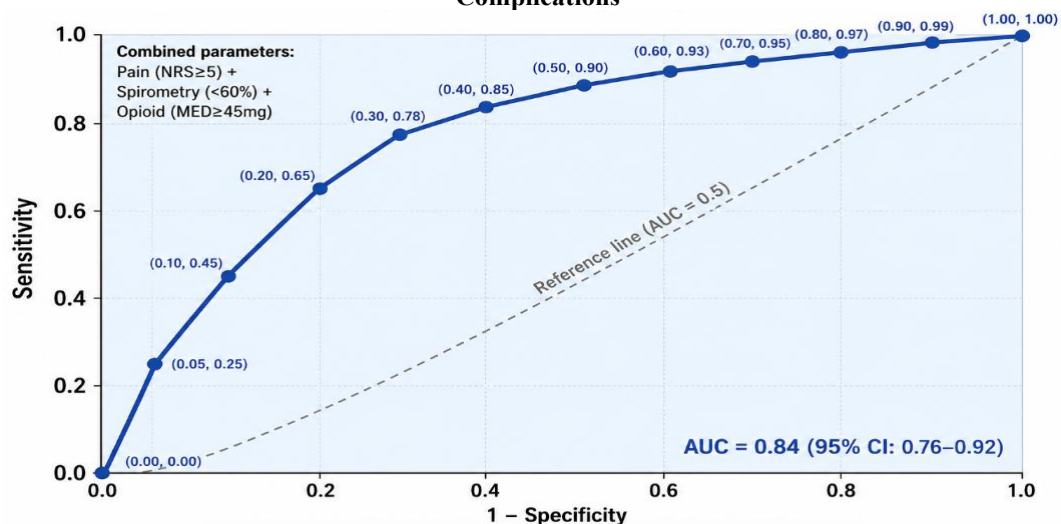
Disease-Specific Considerations

An important finding of the study is that the highest risk of complications was observed in patients with mediastinitis. This is explained by the combination of pronounced somatic and visceral pain components as well as the high invasiveness of surgical interventions. This underscores the necessity of accounting for nosological characteristics when selecting analgesic strategies.

Summary of Findings

In summary, the obtained data indicate that traditional opioid-centered analgesia does not provide adequate pain control and does not prevent the development of respiratory complications. Moreover, it contributes to a pathophysiological imbalance between analgesic efficacy and preservation of respiratory function. The predictive performance of the combined parameters is demonstrated in the ROC curve analysis (Figure 3).

Figure 3. Receiver Operating Characteristic (ROC) Curve for Prediction of Postoperative Pulmonary Complications



Development of Prognostic Tools

The identified patterns formed the basis for the development of the TAPS-ESPB prognostic score (Thoracic Analgesia Prognostic Score – Erector Spinae Plane Block), which allows quantitative assessment of complication risk and determines the need to include a regional analgesic component (Figure 4).

Risk stratification criteria were developed to assess patient severity and predict postoperative complications. Each factor is associated with an unfavorable clinical course and is assigned 3 points. Significant criteria include:

Presence of mediastinitis

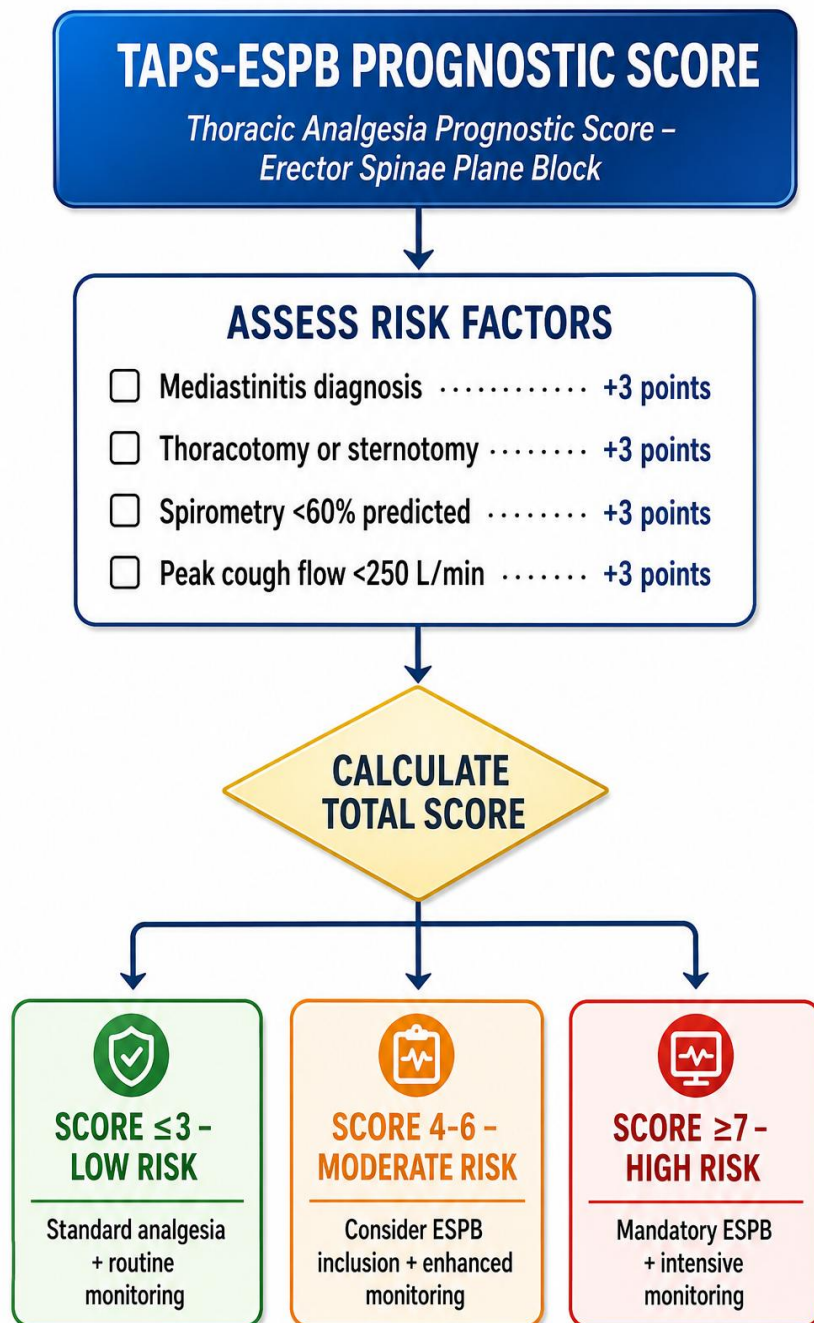
Use of traumatic surgical approaches (thoracotomy or sternotomy)

Reduced pulmonary function (incentive spirometry < 60% of predicted values)

Marked impairment of the cough mechanism characterized by reduced peak cough flow (PCF < 250 L/min)

The cumulative score allows objective risk stratification and serves as a basis for selecting anesthetic strategy, determining the extent of respiratory support, and planning postoperative monitoring. The implementation of this scale enabled a shift from an empirical approach to a structured and reproducible clinical decision-making algorithm based on key pathophysiological parameters.

Figure 4. TAPS-ESPB Prognostic Score Algorithm for Risk Stratification



Additionally, the TAES scale (Thoracic Analgesic Effectiveness Score) was proposed for dynamic assessment of analgesic effectiveness in the early postoperative period (Figure 5). Its use allows timely identification of inadequate pain control and supports justified escalation of analgesic therapy, including the use of prolonged regional techniques.

Figure 5. TAES (Thoracic Analgesic Effectiveness Score) Dynamic Assessment Scale

TAES SCALE – DYNAMIC ASSESSMENT

1 ASSESSMENT PARAMETERS
(Every 4 hours)

- ☒ NRS at rest
- ☒ NRS on movement/cough
- ☒ Incentive spirometry (% predicted)
- ☒ Peak cough flow (L/min)
- ☒ Cumulative opioid consumption (MED-24h)
- ☒ Respiratory rate

2 SCORING SYSTEM

Parameter	Points
NRS ≥ 5 at rest	+2
NRS ≥ 7 on cough	+2
Spirometry $< 60\%$ predicted	+1
Peak cough flow < 250 L/min	+1
Opioid > 60 mg/24h	+1

3 CLINICAL ACTION PROTOCOL

Score 0-2	Score 3-4	Score ≥ 5
Continue current regimen – reassess in 4h	Consider rescue analgesia – reassess in 2h	Escalate to regional block (ESPB)

Use the total score to guide clinical decisions and optimize analgesia and respiratory function.

Thus, the proposed tools form an integrated system for analgesia management, ensuring continuity of the clinical process—from preoperative risk stratification to postoperative therapeutic adjustment. This contributes to improved analgesic efficacy and a reduction in the incidence of postoperative respiratory complications.

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Conflict of Interest Statement

The author declares that there are no conflicts of interest regarding the publication of this article.

CONCLUSIONS

The conventional opioid-centered analgesic strategy does not provide adequate pain control in patients with purulent-septic pathology of the chest, as evidenced by mean NRS scores remaining above 4 points on postoperative day 3.

Pain intensity (NRS ≥ 5 at rest) and impaired respiratory function (spirometry $< 60\%$ predicted) are key independent predictors of postoperative pulmonary complications, increasing risk by 2.42-fold and 2.78-fold, respectively.

An increase in opioid consumption (morphine equivalent dose, MED ≥ 45 mg) is associated with a 1.5-fold increase in the risk of complications, demonstrating the paradoxical effect of conventional analgesic strategies.

The use of prognostic scoring systems (TAPS-ESPB, TAES) enables personalized analgesia, facilitates the appropriate inclusion of regional anesthetic techniques, and contributes to a reduction in the incidence of respiratory complications.

The proposed integrated approach to analgesia management ensures continuity from preoperative risk stratification to postoperative therapeutic adjustment, improving analgesic efficacy and patient outcomes in this high-risk population.

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