Article

The Factors for the Occurrence of Pulmonary Infection after Gastrointestinal Surgery and the Construction of a Predictive Model Using sTREM-1 and TIM-4: A Retrospective Study

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AIM: Identifying and intervening with high-risk postoperative pulmonary infections patients pose challenges in clinical practice. This study aims to conduct a comprehensively analysis of the risk factors and predictive factors associated with post-gastrointestinal surgery pulmonary infections and to develop a predictive model that can predict occurrence of pulmonary infection.
METHODS: A retrospective analysis was conducted on 96 patients who underwent gastrointestinal surgery at our hospital from May 2021 to October 2023. The occurrence rate of postoperative pulmonary infections was calculated, and patients were categorized into two groups: those with pulmonary infections (the occurrence group) and those without pulmonary infections (the non-occurrence group). Logistic regression analysis was utilized to identify the risk factors for post-gastrointestinal surgery pulmonary infections and to evaluate the predictive value of soluble triggering receptor expressed on myeloid cells-1 (sTREM-1) and T cell immunoglobulin and mucin domain-4 (TIM-4) using nomograms, calibration curves, and Receiver Operating Characteristic (ROC) curves.
RESULTS: Out of 96 patients, 20 (20.83%) developed postoperative pulmonary infections. Significant differences were noted between occurrence and non-occurrence groups in terms of smoking (65.00% vs. 34.21%, $p = 0.013$), surgical duration (70.00% vs. 31.58%, $p = 0.002$), Preoperative hemoglobin level (35.00% vs. 65.79%, $p = 0.013$), sTREM-1 levels (23.57 $\pm$ 3.16 pg/mL vs. 15.62 $\pm$ 2.48 pg/mL, $p < 0.001$), and TIM-4 levels (61.48 $\pm$ 6.35 pg/mL vs. 44.73 $\pm$ 5.22 pg/mL, $p < 0.001$). Logistic regression analysis leads to the development of a risk prediction model for post-gastrointestinal surgery pulmonary infections. The high predictive values of sTREM-1 (Area Under Curve (AUC) = 0.962, 95% confidence interval (CI) 0.917~0.999) and TIM-4 (AUC = 0.970, 95% CI 0.925~1.000) were highlighted by the AUC values, underscoring their clinical importance.
CONCLUSIONS: A predictive model utilizing sTREM-1 and TIM-4 for pulmonary infection following gastrointestinal surgery was developed. Additionally, other risk factors such as smoking, surgical duration, and preoperative hemoglobin level were evaluated. This finding can be applied in clinical practice to identify potentially susceptible patients and facilitate early intervention measures.

Keywords: soluble myeloid cell-triggering receptor-1 (sMCT-1); pulmonary infection; gastrointestinal surgery; T cell immunoglobulin and mucin domain-4 (TIM-4); nomogram

Introduction

In recent years, with the increasing incidence of gastrointestinal diseases and rapid advancements in medical technology, surgical intervention has emerged as one of the primary treatment modalities for gastrointestinal conditions [1]. However, owing to the invasive nature of surgical procedures, postoperative infections have become a common complication, with pulmonary infections being particularly prevalent with an incidence rate of approximately 4.1%–15.0% [2]. Furthermore, previous study indicated while the occurrence of postoperative pulmonary complications in general surgical patients is around 5%, the rate for abdominal surgeries can be as high as 12%–58% [3]. Ding H *et al.*'s study [4] has revealed that gastrointestinal surgery contributes to secondary bacteremia, thereby increasing the risk of postoperative pulmonary infections and other complications. Therefore, it is clear that pulmonary infections have become a significant postoperative complication that cannot be ignored, emphasizing the critical importance of understanding and identifying the factors that contribute to pulmonary infections following gastrointestinal surgery.

The onset of pulmonary infections following gastrointestinal surgery can directly exacerbate the patient's condition. Failure to promptly detect and intervene can lead to disease progression, leading to multi-organ failure and substantially impacting the patient's physical and mental well-being. Therefore, early diagnosis and timely intervention for pulmonary infections following gastrointestinal surgery hold significant importance. Currently, clinical assessment of pulmonary infections relies on pathogenic culture as the gold standard [5], providing precise guidance for anti-infective therapy. However, this method is time-

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consuming and patients may miss the optimal treatment window while awaiting culture results. Thus, the adoption of a precise and convenient diagnostic approach to predict the risk of pulmonary infections is crucial for improving patient prognosis. Research has demonstrated that soluble triggering receptor expressed on myeloid cells-1 (sTREM-1) is readily detectable and is significantly overexpressed in the inflammatory response to Gram-positive bacteria and fungi in skin, lymph nodes, lung tissues, and alveolar macrophages [6]. Additionally, previous study have highlighted sTREM-1 as an important serum biomarker for bacterial lung infections [7]. T cell immunoglobulin and mucin domain-4 (TIM-4) is a transmembrane protein that promotes epithelial-mesenchymal transition, migration, and invasion of non-small cell lung cancer cells [8]. Recently, TIM-4 was provided related to lipopolysaccharide-induced inflammation reaction, which is a key process in pulmonary infection [9]. However, there is limited clinical literature on the predictive value of these two biomarkers for the occurrence of pulmonary infections following gastrointestinal surgery. Further exploration of these indicators could offer insights into the early detection of pulmonary infections, offering an optimal opportunity to develop subsequent treatment strategies.

This study aims to investigate the risk factors and predictive factors of pulmonary infections following gastrointestinal surgery, therefore, develop predictive models. This interdisciplinary research perspective is expected to predict pulmonary infection risk for patients after gastrointestinal surgery. It has the potential to facilitate earlier identification of infection risk in clinical settings, enabling timely intervention to reduce infection incidence, improve patient survival rates and quality of life, and offer new insights and strategies for clinical prevention and treatment. As such, it holds significant theoretical and practical significance.

Materials and Methods

General Information

A retrospective study was conducted, and a total of 96 gastrointestinal surgical patients admitted to our hospital between May 2021 and October 2023 were selected to assess the incidence of postoperative pulmonary infections. This study obtained approval from the Medical Ethics Committee of The First People's Hospital of Zunyi (Approval No.:2024-1-39), and all procedures were conducted following ethical standards based on the 1964 Helsinki Declaration and its subsequent amendments. Informed consent was waived by the Institutional Review Board and Ethics Committee of The First People's Hospital of Zunyi for this retrospective study due to the exclusive use of de-identified patient data, which posed no potential harm or impact on patient care.

Inclusion criteria: (1) all patients underwent gastrointestinal surgery at our hospital; (2) complete clinical data without missing items; (3) no preoperative distant lymph node metastasis; (4) absence of cognitive or consciousness disorders. Exclusion criteria: (1) patients with infection detected by routine examination and infectious disease examination before surgery; (2) concurrent conditions such as pulmonary embolism, lung cancer, or pulmonary tuberculosis; (3) concurrent immunological disorders or severe cardiac, hepatic, or renal diseases.

Data Collection

General information and disease-related characteristics of the patients were retrieved from the medical record system, including patient age, sex, body weight, diabetes, hypertension, nature of the disease, smoking history, type of surgery, American Society of Anesthesiologists (ASA) classification, duration of surgery, preoperative hemoglobin, surgical site, preoperative albumin, prophylactic antimicrobial use, and blood loss.

Grouping

Patients were grouped based on the occurrence of post-gastrointestinal surgical within 1-week pulmonary infections. The following criteria were used to diagnose pulmonary infections post-gastrointestinal surgery [10]: (1) elevated body temperature ($\geq$38 °C) with a subsequent or sustained increase following initial postoperative temperature decrease; (2) postoperative coughing, sputum production, and dyspnea, with significant sputum production and exclusion of cardiac-related interference; (3) persistent elevation of white blood cells and continuous decrease in blood oxygen saturation; (4) distinct auscultatory findings of moist rales, tubular breath sounds, or diminished breath sounds in the lungs; (5) radiographic evidence consistent with signs of pulmonary infection; (6) pathogen growth in bacterial cultures of patient sputum. Patients who developed pulmonary infections were included in the occurrence group, while those who did not were included in the non-occurrence group.

Laboratory Examinations

sTREM-1 and TIM-4 concentrations were measured 24 hours post-gastrointestinal surgery. A fasting venous blood sample of 5 mL was collected from the patients in the early morning, left at room temperature for 30 minutes, then centrifuged at 8000 rpm for 15 minutes. The supernatant was collected and stored at –80 °C. Enzyme-linked immunosorbent assay was utilized for testing sTREM-1 (ab270884, Abcam, Boston, MA, USA) and TIM-4 (ab222093, Abcam, Boston, MA, USA).

Statistical Analysis

SPSS 25.0 statistical software (SPSS Inc, Chicago, IL, USA) was used for data analysis. Frequency data were presented as percentages and analyzed using the χ^2 test. Normally distributed continuous data were expressed as mean $\pm$ standard deviation and analyzed using the *t*-test. Factors

Table 1. Basic demographic and clinical characteristics of the two groups (n = 96).

Clinical data		n	Occurrence group (n = 20)	Non-occurrence group (n = 76)	t/χ^2	p
Age (years)		96	63.52 ± 1.48	62.54 ± 3.46	1.233	0.221
Gender	Male	55	13 (65.00%)	42 (55.26%)	0.613	0.433
	Female	41	7 (35.00%)	34 (44.74%)		
Weight (kg)		96	63.45 ± 2.74	64.54 ± 2.79	1.560	0.122
Diabetes	Yes	35	5 (25.00%)	30 (39.47%)	1.432	0.231
	No	61	15 (75.00%)	46 (60.53%)		
Hypertension	Yes	40	9 (45.00%)	31 (40.79%)	0.115	0.734
	No	56	11 (55.00%)	45 (59.21%)		
Disease nature	Benign	62	14 (70.00%)	48 (63.16%)	0.324	0.569
	Malignant	34	6 (30.00%)	28 (36.84%)		
Smoking	Yes	39	13 (65.00%)	26 (34.21%)	6.223	0.013
	No	57	7 (35.00%)	50 (65.79%)		
Surgery type	Laparotomy	30	7 (35.00%)	23 (30.26%)	0.165	0.684
	Laparoscopy	66	13 (65.00%)	53 (69.74%)		
ASA classification	0–2	81	16 (80.00%)	65 (85.53%)	0.367	0.545
	3–4	15	4 (20.00%)	11 (14.47%)		
Duration of surgery (h)	>2	38	14 (70.00%)	24 (31.58%)	9.773	0.002
	≤2	58	6 (30.00%)	52 (68.42%)		
Preoperative hemoglobin (g/L)	>90	57	7 (35.00%)	50 (65.79%)	6.223	0.013
	≤90	39	13 (65.00%)	26 (34.21%)		
Surgical site	Upper GI	52	8 (40.00%)	44 (57.89%)	2.042	0.153
	Lower GI	44	12 (60.00%)	32 (42.11%)		
Preoperative albumin (g/L)	>30	51	10 (50.00%)	41 (53.95%)	0.099	0.753
	≤30	45	10 (50.00%)	35 (46.05%)		
Prophylactic antibiotic use (h)	>48	27	5 (25.00%)	22 (28.95%)	0.122	0.727
	≤48	69	15 (75.00%)	54 (71.05%)		
Blood loss (mL)	>150	35	8 (40.00%)	27 (35.53%)	0.137	0.711
	≤150	61	12 (60.00%)	49 (64.47%)		

GI, Gastrointestinal; ASA, American Society of Anesthesiologists.

Table 2. Postoperative sTREM-1 and TIM-4 levels of two groups (pg/mL).

Group	sTREM-1	TIM-4
Occurrence group (n = 20)	23.57 ± 3.16	61.48 ± 6.35
Non-occurrence group (n = 76)	15.62 ± 2.48	44.73 ± 5.22
t	12.021	12.191
p	<0.001	<0.001

sTREM-1, soluble triggering receptor expressed on myeloid cells-1; TIM-4, T cell immunoglobulin and mucin domain-4.

demonstrating significant differences in univariate analysis were included in logistic regression analysis, with a significance level set at $\alpha = 0.05$. Nomogram plots, calibration plots, and Receiver Operating Characteristic (ROC) curves were generated to evaluate the predictive value of sTREM-1 and TIM-4 for post-gastrointestinal surgical pulmonary infections, with significance set at $p < 0.05$.

Results

Comparison of Clinical Data between the Two Groups

This study involved a total of 96 gastrointestinal surgical patients, among them 20 (20.83%) developed postoperative pulmonary infections, comprising 8 cases (8.33%) following gastric surgery, 5 cases (5.21%) following colorectal surgery, 4 cases (4.17%) following small intestine surgery, and 3 cases (3.13%) following gastrostomy or jejunostomy, and was categorized into the occurrence group. The remaining 76 cases (79.17%) without postoperative pulmonary infections were included in the non-occurrence group. Significant differences were observed between the occurrence group and the non-occurrence group in terms of smoking history, duration of surgery, and preoperative hemoglobin (all $p < 0.05$). Details are presented in Table 1.

Postoperative Levels of sTREM-1 and TIM-4 of Two Groups

As shown in Table 2, postoperatively, the levels of sTREM-1 were higher (23.57 ± 3.16 pg/mL vs. 15.62 ± 2.48

Table 3. Factors influencing the occurrence of pulmonary infection after gastrointestinal surgery.

Factor	Assignment	Regression coefficient	Standard error	z value	Wald χ^2	p value	Odds ratio	Odds ratio 95% CI
Smoking	0 = No 1 = Yes	1.273	0.527	2.413	5.824	0.016	3.571	1.270∼10.042
Surgery duration	0 = ≤2 1 = >2	1.620	0.547	2.964	8.783	0.003	5.056	1.731∼14.764
Preoperative hemoglobin	0 = >90 1 = ≤90	1.273	0.527	2.413	5.824	0.016	3.571	1.270∼10.042
sTREM-1	Actual value	0.952	0.237	4.019	16.154	<0.001	2.592	1.629∼4.124
TIM-4	Actual value	0.451	0.109	4.125	17.013	<0.001	1.570	1.267∼1.946

CI, confidence interval.

Table 4. Predictive value of various indicators for postoperative pulmonary infection after gastrointestinal surgery.

Indicator	AUC	Standard error	Optimal cut-off value	Sensitivity	Specificity	p value	95% CI
sTREM-1	0.962	0.022	0.837	0.850	0.987	<0.001	0.917∼0.999
TIM-4	0.970	0.019	0.837	0.850	0.987	<0.001	0.925∼1.000

AUC, Area Under Curve; CI, confidence interval.

pg/mL, $p < 0.001$) and the levels of TIM-4 were higher (61.48 ± 6.35 pg/mL vs. 44.73 ± 5.22 pg/mL, $p < 0.001$) in the occurrence group.

Factors Influencing the Occurrence of Postoperative Pulmonary Infections following Gastrointestinal Surgery

From Tables 1,2, the following variables were statistically significant between groups: smoking, operative time, preoperative hemoglobin, sTREM-1 type, and TIM-4. According to the logistic regression analysis, smoking history, duration of surgery, preoperative hemoglobin, sTREM-1, and TIM-4 were identified as influencing factors for the occurrence of postoperative pulmonary infections following gastrointestinal surgery. Details are shown in Table 3.

Predictive Value of Various Indicators for Postoperative Pulmonary Infections following Gastrointestinal Surgery

The construction of ROC curves demonstrated that the corresponding Area Under Curve (AUC) value for sTREM-1 was 0.962 (95% confidence interval (CI): 0.917–0.999), indicating a high diagnostic value of sTREM-1, while the AUC value for TIM-4 was 0.970 (95% CI: 0.925–1.000), signifying a high diagnostic value of TIM-4 (all $p < 0.05$). Details are provided in Table 4 and Fig. 1.

Nomogram and Calibration Curve

Based on the results of the logistic regression analysis, we identified two variables (sTREM-1 and TIM-4) and constructed a nomogram prediction model for postoperative pulmonary infection following gastrointestinal surgery (Fig. 2). Each patient's levels of sTREM-1 and TIM-4 correspond to individual scores, and the total scores for different indicators are calculated. A higher score is associated with a higher incidence of postoperative pulmonary infection following gastrointestinal surgery. That is, the value of sTREM-1 and TIM-4 were rendered into risk probability. The calibration curve illustrates the deviation between predicted probability and actual probability. The model demonstrated an average absolute error of 0.034 between the actual incidence and the predicted incidence, with the calibration curve repeated 1000 times (Fig. 3), indicating good consistency between actual and predicted incidences.

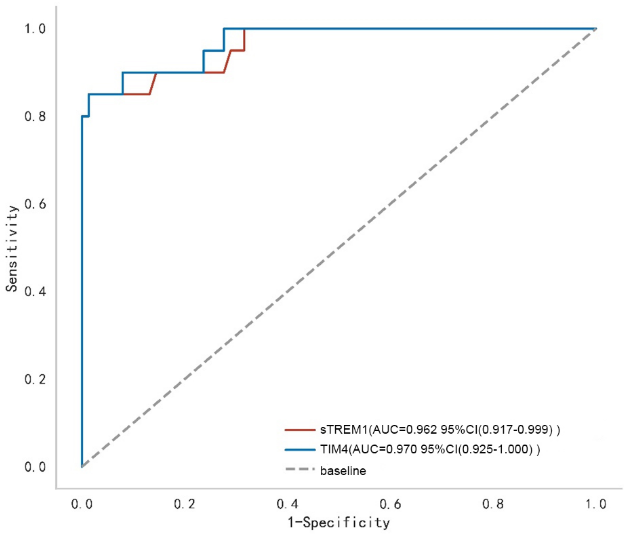

Fig. 1. Receiver Operating Characteristic (ROC) diagram of each indicator for diagnosis of pulmonary infection after gastrointestinal surgery.

Discussion

Due to the distinctive physiological characteristics of the gastrointestinal tract, patients undergoing gastrointestinal surgery face an elevated risk of postoperative infections compared to other surgical patients, notably a higher incidence of pulmonary infections [11]. To explain, the potential impact of gastrointestinal surgery on the normal func-

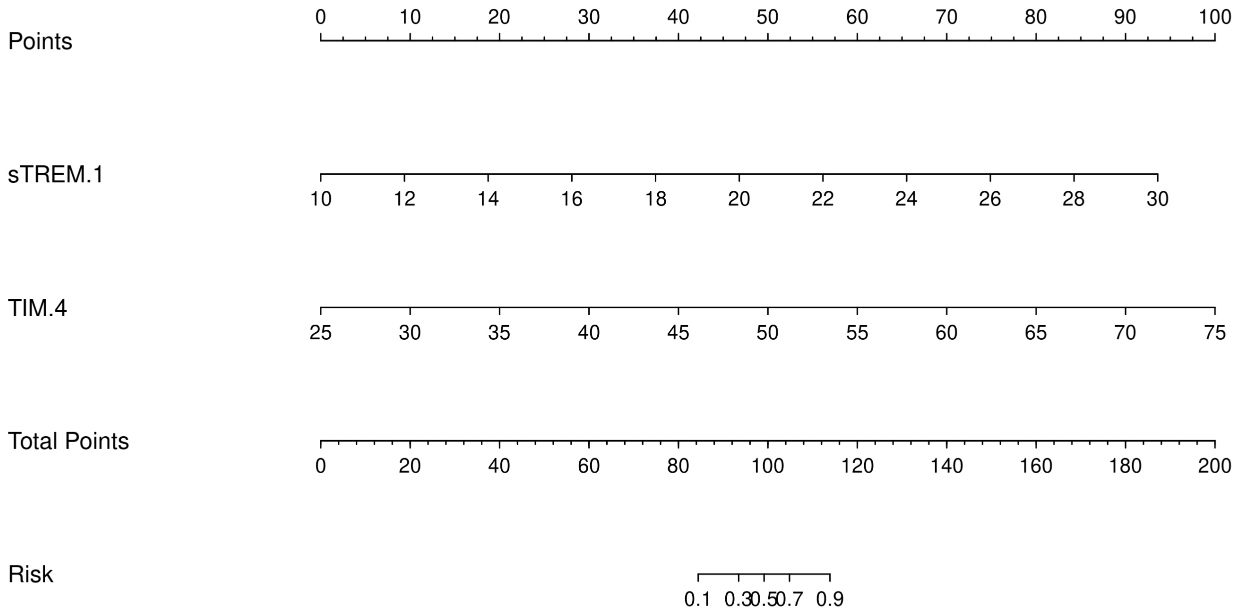

Fig. 2. A nomogram model for predicting the risk of pulmonary infection after gastrointestinal surgery.

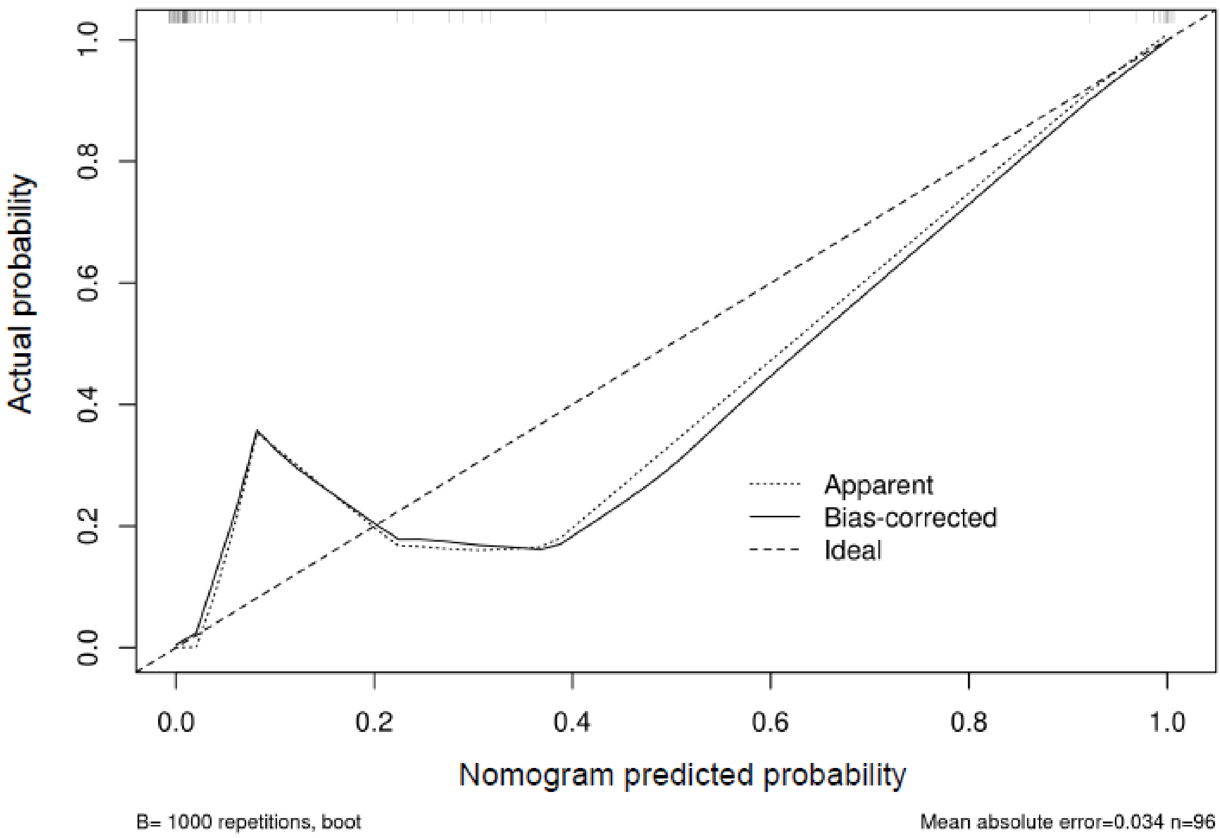

Fig. 3. Calibration curve of the nomogram for predicting pulmonary infection after gastrointestinal surgery.

tioning of the gastrointestinal tract can lead to temporary impairment of gastric function and a decrease in digestive function. This can result in gastric reflux, where refluxed material is aspirated into the airway, potentially leading to pulmonary infections [12].

TIM-4 is widely expressed in immune cells such as monocytes/macrophages, dendritic cells, and is involved in the immune balance of Th1/Th2 cells and the process of inflammation [13,14]. Previously, TIM-4 has been linked with various inflammatory diseases such as ankylosing spondylitis, ischemic stroke, colitis, tumors, and asthma [15]. As shown in the study by Chen D *et al*. [16], the increased expression of TIM-4 is positively correlated with the severity of ankylosing spondylitis. Moreover, Xue G *et al*. [17] proposed that monocytes expressing TIM-4 are a novel indicator for assessing the activity and severity of ulcerative colitis. However, there is currently no report on the use of this indicator to predict post-gastrointestinal surgical pulmonary infections. However, this study, through comprehensive analysis, reveals that TIM-4 holds certain value in predicting pulmonary infections. When patients exhibit elevated TIM-4 levels, it may indicate a highly activated immune system which may induced by gastric refluxed material aspirated into the airway. Therefore, TIM-4 could be a useful indicator in predicting post-gastrointestinal surgical pulmonary infections.

sTREM-1 is an inflammatory trigger receptor that activates immune cells such as monocytes, neutrophils, and promotes the expression of inflammatory factors in immune cells [18]. It can also inhibit the differentiation of T lymphocytes involved in immune regulation and is associated with various inflammatory diseases [6]. High expression of sTREM-1 has been observed in patients with rheumatoid arthritis, sepsis, pneumonia, and postoperative pulmonary infections [19,20,21]. For instance, Yang ZQ *et al*. [22] previously stated that sTREM-1 serves as a useful biomarker for predicting neonatal ventilator-associated pneumonia in pediatrics. Additionally, Zheng S and Zhang W [23] found that sTREM-1 has high predictive value for pulmonary infections associated with acute respiratory distress syndrome induced by various traumas. It revealed in this study sTREM-1 had a high predictive AUC value for postoperative pulmonary infections. Since post-gastrointestinal surgical pulmonary infections are typically caused by bacteria, leading to the activation of the body's inflammatory response, including the activation of immune cells and the release of inflammatory mediators, sTREM-1, as part of the inflammatory response, may alter in its levels. This could offer clinical insights into the infection status and enable early response in the initial stages of infection. Consequently, clinicians may identify pulmonary infections sooner [24].

Elderly patients frequently contend with underlying chronic systemic diseases, particularly those with pre-existing pulmonary conditions. These conditions can limit pulmonary ventilation, compromise compensatory and reserve functions, and consequently, impact the incidence of postoperative pulmonary infections. Research has shown that patients aged 60 and above exhibit a significantly increased incidence of postoperative pulmonary infections, largely due to decreased pulmonary elasticity and chest wall compliance, increased residual air volume in the alveoli, leading to heightened susceptibility to respiratory muscle fatigue and upper airway obstruction, thus elevating the risk of postoperative pulmonary infections [25]. In this study, 20 cases, accounting for 20.83%, developed post-gastrointestinal surgical pulmonary infections, which is consistent with the findings reported by Chai J *et al*. [26], who observed a postoperative pulmonary complication rate of 11% in a study involving 445 elective colorectal surgery patients. In clinical practice, to mitigate the risk of post-gastrointestinal surgical pulmonary infections, it is crucial to identify and minimize factors that can induce pulmonary infections during treatment.

Chen C *et al*. [27] have pointed out that smoking is an independent risk factor for predicting postoperative pulmonary infections. Additionally, McCaffrey N *et al*. [28] found that smoking increases the risk of other postoperative complications associated with surgery, such as pulmonary infections and pneumonia. Long-term heavy smokers show significantly increased lung residual volume and damaged respiratory epithelial cilia, leading to reduced ciliary motility and impaired mucus clearance function [29]. Combined with decreased pulmonary surfactant and increased mucus secretion, this compromises immune function and further elevates the risk of pulmonary infections [30]. The finding of this study was in accordance with Chen C *et al.* [27]. Therefore, for long-term heavy smokers, preventive care before and after surgery is particularly crucial [31]. Smoking cessation with adequate preoperative time has been shown to effectively reduce the incidence of postoperative pulmonary infections in patients [31]. Previous study suggest that improving respiratory system health through exercise and smoking cessation may help reduce the risk of pulmonary infections [32]. Furthermore, patient education on health, respiratory function exercises, and oral care should be emphasized in clinical practice. Postoperatively, sputum clearance should be facilitated through mechanical and pharmacological assistance or guidance from healthcare personnel, and early mobilization of patients should be encouraged to effectively reduce the occurrence of postoperative pulmonary infections.

The independent risk factor status of surgical duration for postoperative pulmonary infections has been reported in relevant studies. For instance, Wang M *et al*. [33] found in their study that delayed cardiac surgery significantly increased the risk of pulmonary infections. In this study, logistic regression analysis also confirmed that surgical duration is a major risk factor for post-gastrointestinal surgical pulmonary infections. Prolonged surgical duration inevitably leads to extended general anesthesia time, increased usage of muscle relaxants, elevated risk of postoperative neuromuscular blockade due to residual muscle relaxants, prolonged mechanical ventilation time, weakened upper respiratory tract defense barriers, decreased ciliary motility and mucus clearance function [34]. Concurrently, mechanical ventilation reduces pulmonary compliance, disrupts the lower respiratory tract defense barriers, thereby affecting effective postoperative respiration and sputum clearance, and increasing the risk of postoperative pulmonary infections in patients. Therefore, for patients expected to undergo prolonged surgery, comprehensive preoperative preparations, close coordination during the operation to shorten the surgical duration and reduce the dosage of anesthetic drugs while ensuring surgical efficacy, and strengthened postoperative care to reduce mechanical ventilation time are imperative.

Previous research [35] has indicated that 30–40% of elective surgical patients experience preoperative anemia, which could complicate surgery, increase the likelihood of transfusion or admission to the intensive care unit, elevate the risk of infection events, and prolong hospital stays. Red blood cells, like white blood cells, play a crucial role in the body's defense mechanism, as they clear immune complexes by binding to C3b receptors [36]. In anemic patients, the immune adherence activity of red blood cells to C3b is significantly reduced, leading to a decline in immune function and weakening of the phagocytic action against pathogens. In clinical practice, a hemoglobin level below 90 g/L is typically considered severe anemia [37]. Therefore, this study observed the preoperative hemoglobin levels in two groups and found it to be an important factor in the occurrence of postoperative pulmonary infections. This conclusion is similar to the findings of Kara S *et al.* [38], who considered low preoperative hemoglobin levels as one of the risk factors for postoperative pulmonary complications following abdominal surgery. Additionally, anemia is not only a risk factor for inducing pulmonary infections but also an adverse prognostic factor for pulmonary infections. Therefore, active correction of anemic conditions in patients before and after surgery is essential to reduce the risk of postoperative pulmonary infections.

It is important to acknowledge the limitations of our study. Several factors influence the occurrence of postoperative pulmonary infections following gastrointestinal surgery. This study primarily identifies smoking, surgical duration, preoperative hemoglobin levels, sTREM-1, and TIM-4 as influencing factors for postoperative pulmonary infections. Since the included patients in this study had predominantly advanced age, similar rates of pulmonary infection, and comparable underlying diseases, no significant differences were observed. Additionally, both laparoscopic and open radical surgeries have certain impacts on intraoperative blood loss and postoperative recovery for patients. In this study, a significant proportion of patients underwent laparoscopic surgery, with relatively lower intraoperative blood loss which did not markedly affect pulmonary infections. Therefore, future research should encompass a broader patient cohort selection and surgical types, and relevant prospective studies on corresponding interventions are warranted to provide a basis for advancing clinical treatment.

Conclusions

In conclusion, there is a certain risk of post-gastrointestinal surgical pulmonary infections, with factors including smoking, surgical duration, and preoperative hemoglobin levels. Significantly elevated levels of sTREM-1 and TIM-4 are observed in patients with pulmonary infections, serving as valuable reference indicators for predicting postoperative infection risk. This finding holds considerable clinical significance, offering insights that can enhance the prevention and control of post-gastrointestinal surgical pulmonary infections.

Availability of Data and Materials

The datasets used or analyzed during the current study were available from the corresponding author on reasonable request.

Author Contributions

DT and HG designed the study; all authors conducted the study; ZQT and MZY collected and analyzed the data. DT and JCS participated in drafting the manuscript, and all authors contributed to critical revision of the manuscript for important intellectual content. All authors gave final approval of the version to be published. All authors participated fully in the work, take public responsibility for appropriate portions of the content, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or completeness of any part of the work are appropriately investigated and resolved.

Ethics Approval and Consent to Participate

This study has been approved by the Medical Ethics Committee of The First People's Hospital of Zunyi (Approval No.:2024-1-39). Informed consent was waived by the Institutional Review Board and Ethics Committee of our hospital for this retrospective study due to the exclusive use of de-identified patient data, which posed no potential harm or impact on patient care. All procedures were conducted following ethical standards based on the 1964 Helsinki Declaration and its subsequent amendments.

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Conflict of Interest

The authors declare no conflict of interest.

References

[1] Lau LHS, Sung JJY. Treatment of upper gastrointestinal bleeding in 2020: New techniques and outcomes. Digestive Endoscopy: Official Journal of the Japan Gastroenterological Endoscopy Society. 2021; 33: 83–94.

[2] Huang J, Ge H, Zhu X, Xue C, Su Q, Chen X, *et al.* Risk factors analysis and nomogram construction for postopera-

tive pulmonary infection in elderly patients with hip fractures. Aging Clinical and Experimental Research. 2023; 35: 1891–1899.

[3] Zhou ZF, Fang JB, Wang HF, He Y, Yu YJ, Xu Q, *et al*. Effects of intraoperative PEEP on postoperative pulmonary complications in high-risk patients undergoing laparoscopic abdominal surgery: study protocol for a randomised controlled trial. BMJ Open. 2019; 9: e028464.

[4] Ding H, Xu J, You J, Qin H, Ma H. Effects of enteral nutrition support combined with enhanced recovery after surgery on the nutritional status, immune function, and prognosis of patients with esophageal cancer after Ivor-Lewis operation. Journal of Thoracic Disease. 2020; 12: 7337–7345.

[5] Qin Z, Zou Y, Huang Z, Yu N, Deng Z, Chen Z, *et al*. Metagenomic next-generation sequencing contributes to the diagnosis of mixed pulmonary infection: a case report. Annals of Clinical Microbiology and Antimicrobials. 2022; 21: 52.

[6] Lemarié J, Gibot S. Soluble Triggering Receptor Expressed on Myeloid Cells-1: Diagnosis or Prognosis? Critical Care Clinics. 2020; 36: 41–54.

[7] Wang Z, Chang B, Zhang Y, Chen J, Xie F, Xiang Y, *et al*. Clinical value of serum sTREM-1 and HBP levels in combination with traditional inflammatory markers in diagnosing hospital-acquired pneumonia in elderly. BMC Infectious Diseases. 2022; 22: 773.

[8] Chen S, Wang Y, Liu W, Liang Y, Wang Y, Wu Z, *et al*. N-Glycosylation at Asn291 Stabilizes TIM-4 and Promotes the Metastasis of NSCLC. Frontiers in Oncology. 2022; 12: 730530.

[9] Xu L, Zhao P, Xu Y, Gao L, Wang H, Jia X, *et al*. Tim-4 protects mice against lipopolysaccharide-induced endotoxic shock by suppressing the NF-κB signaling pathway. Laboratory Investigation; a Journal of Technical Methods and Pathology. 2016; 96: 1189–1197.

[10] Yang J, He Y, Liao X, Hu J, Li K. Does postoperative pulmonary infection correlate with intestinal flora following gastric cancer surgery? - a nested case-control study. Frontiers in Microbiology. 2023; 14: 1267750.

[11] Yang Y, Zhang X, Zhang J, Zhu J, Wang P, Li X, *et al*. Prediction models of surgical site infection after gastrointestinal surgery: a nationwide prospective cohort study. International Journal of Surgery (London, England). 2024; 110: 119–129.

[12] Maruyama H, Kusachi S, Makino H, Kanno H, Yoshida H, Niitsuma T. Postoperative Infection after Colorectal Surgery: Subanalysis of Data from the 2015 Japan Postoperative Infectious Complications Survey. Journal of Nippon Medical School = Nippon Ika Daigaku Zasshi. 2020; 87: 204–210.

[13] Liu W, Xu L, Liang X, Liu X, Zhao Y, Ma C, *et al*. Tim-4 in Health and Disease: Friend or Foe? Frontiers in Immunology. 2020; 11: 537.

[14] Begum F, Das S, Mukherjee D, Ray U. Hijacking the Host Immune Cells by Dengue Virus: Molecular Interplay of Receptors and Dengue Virus Envelope. Microorganisms. 2019; 7: 323.

[15] Ye Z, Jin Y, Li H, Xu H, He Y, Chen Y. Association of Tim-4 expression in monocyte subtypes with clinical course and prognosis in acute ischemic stroke patients. The International Journal of Neuroscience. 2020; 130: 906–916.

[16] Chen D, He J, Lu C, Zhou J, Fang K, Liu X, *et al*. Increased expression of T cell immunoglobulin and mucin domain 4 is positively associated with the disease severity of patients with ankylosing spondylitis. Inflammation. 2015; 38: 935–940.

[17] Xue G, Hua L, Liu D, Zhong M, Chen Y, Zhou B, *et al*. Tim-4 expressing monocytes as a novel indicator to assess disease activity and severity of ulcerative colitis. Life Sciences. 2021; 269: 119077.

[18] Matos ADO, Dantas PHDS, Silva-Sales M, Sales-Campos H. TREM-1 isoforms in bacterial infections: to immune modulation and beyond. Critical Reviews in Microbiology. 2021; 47: 290–306.

[19] Lu L, Liu X, Fu J, Liang J, Hou Y, Dou H. sTREM-1 promotes the phagocytic function of microglia to induce hippocampus damage via the PI3K-AKT signaling pathway. Scientific Reports. 2022; 12: 7047.

[20] Tan J, Huang X, Wu M, Yang B, Luo Z, Li J, *et al*. Value of soluble triggering receptor expression on myeloid cells-1 level of alveolar fluid in early diagnosis of ventilator-associated pneumonia: a Meta-analysis. Zhonghua Wei Zhong Bing Ji Jiu Yi Xue. 2020; 32: 1067–1073.

[21] de Nooijer AH, Grondman I, Lambden S, Kooistra EJ, Janssen NAF, Kox M, *et al*. Increased sTREM-1 plasma concentrations are associated with poor clinical outcomes in patients with COVID-19. Bioscience Reports. 2021; 41: BSR20210940.

[22] Yang ZQ, Mai JY, Zhu ML, Xiao XM, He XX, Chen SQ, *et al*. Soluble Triggering Receptors Expressed on Myeloid Cells-1 as a Neonatal Ventilator-Associated Pneumonia Biomarker. International Journal of General Medicine. 2021; 14: 4529–4534.

[23] Zheng S, Zhang W. Predictive Values of sTREM-1, PCT and CRP for Multiple Trauma-Induced Acute Respiratory Distress Syndrome Complicated with Pulmonary Infection. Clinical Laboratory. 2022; 68: 10.7754/Clin.Lab.2022.211258.

[24] Tang Q, He M, Zhang S, Zhang J, Yang L, Shi H. The Diagnostic Value of Triggering Receptor Expressed on Myeloid Cells-1 in Post-Traumatic Bacterial Endophthalmitis. Investigative Ophthalmology & Visual Science. 2023; 64: 4.

[25] Bai D, Xiang W, Chen XZ, Hu JK. Risk factors of postoperative pulmonary infection of gastric cancer and perioperative intervention measures. Zhonghua Wei Chang Wai Ke Za Zhi = Chinese Journal of Gastrointestinal Surgery. 2021; 24: 185–190. (In Chinese)

[26] Chai J, Sang A, Tan M, Long B, Chen L. Identification of the Risk Factors of Postoperative Pulmonary Complications in Elderly Patients Undergoing Elective Colorectal Surgery. The American Surgeon. 2021; 87: 777–783.

[27] Chen C, Wen T, Zhao Q. The Change of Laboratory Tests Could Be Predictive Factors for Infection after McKeown Esophagogastrectomy. BioMed Research International. 2019; 2019: 9718705.

[28] McCaffrey N, Scollo M, Dean E, White SL. What is the likely impact on surgical site infections in Australian hospitals if smoking rates are reduced? A cost analysis. PloS One. 2021; 16: e0256424.

[29] Dawod YT, Cook NE, Graham WB, Madhani-Lovely F, Thao C. Smoking-associated interstitial lung disease: update and review. Expert Review of Respiratory Medicine. 2020; 14: 825–834.

[30] Lugg ST, Scott A, Parekh D, Naidu B, Thickett DR. Cigarette smoke exposure and alveolar macrophages: mechanisms for lung disease. Thorax. 2022; 77: 94–101.

[31] Kainiemi K, Malmivaara A, Sillman-Tetri S, Lasander M, Heinonen M, Korhonen T, *et al*. Smoking cessation intervention prior to orthopedic surgery: A study protocol to determine patient outcomes and feasibility. Tobacco Prevention & Cessation. 2022; 8: 33.

[32] Häder A, Köse-Vogel N, Schulz L, Mlynska L, Hornung F, Hagel S, *et al*. Respiratory Infections in the Aging Lung: Implications for Diagnosis, Therapy, and Prevention. Aging and Disease. 2023; 14: 1091–1104.

[33] Wang M, Zhu B, Xu X. Follow-Up Investigation of 41 Children After Metallic Airway Stent Implantation: An 8-Year Experience. Frontiers in Pediatrics. 2020; 8: 579209.

[34] Kelava M, Alfirevic A, Bustamante S, Hargrave J, Marciniak D. Regional Anesthesia in Cardiac Surgery: An Overview of Fascial Plane Chest Wall Blocks. Anesthesia and Analgesia. 2020; 131: 127–135.

[35] Macdougall IC, Comin-Colet J, Breymann C, Spahn DR, Koutroubakis IE. Iron Sucrose: A Wealth of Experience in Treating Iron Deficiency. Advances in Therapy. 2020; 37: 1960–2002.

[36] Yang Y, Chen J, Lu L, Xu Z, Li F, Yang M, *et al*. The Antibacterial Activity of Erythrocytes from Goose *(Anser domesticus)* Can Be Associated with Phagocytosis and Respiratory Burst Generation. Frontiers in Immunology. 2022; 12: 766970.

[37] Kearns J, Jacob SG. Real-world evaluation of an intravenous iron service for the treatment of iron deficiency in patients with gastroenterological disorders. Frontline Gastroenterology. 2020; 12: 265–271.

[38] Kara S, Küpeli E, Yılmaz HEB, Yabanoğlu H. Predicting Pulmonary Complications Following Upper and Lower Abdominal Surgery: ASA vs. ARISCAT Risk Index. Turkish Journal of Anaesthesiology and Reanimation. 2020; 48: 96–101.