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Characteristics of symptoms and establishment of a predictive model for PICS in mechanically ventilated patients with severe pneumonia: a retrospective study

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Abstract

Purpose The study aimed to characterize the symptoms of post-intensive care unit (ICU) syndrome in mechanically ventilated patients with severe pneumonia and establish a predictive model for this syndrome.

Methods A retrospective study was conducted on critically ill pneumonia patients requiring mechanical ventilation. Patients were categorized into non-ICU-acquired complication and post-intensive care syndrome (PICS) groups based on the development of ICU-acquired complications. Various demographic, clinical, laboratory, imaging, and symptom-related parameters were collected and analyzed.

Results A total of 133 patients including 62 patients with non-ICU-Acquired Complications Group and 71 patients with PICS Group were included. Significant differences between the non-ICU-acquired complication and PICS groups were observed in demographic characteristics, such as age, body mass index (BMI), and Acute Physiology and Chronic Health Evaluation (APACHE) II score ($p < 0.05$). Clinical parameters, including PaO2/FiO2 (P/F) ratio, white blood cell (WBC) count, serum creatinine, and procalcitonin levels, showed statistical significance ($p < 0.05$). Ventilation and ICU stay characteristics, laboratory parameters at 72 h, imaging findings, and symptom characteristics also displayed significant differences between the groups ($p < 0.05$). The study's joint model exhibited an area under the curve (AUC) value of 0.786 (95% CI 0.746–0.833), indicating a moderate-to-good predictive value for PICS.

Conclusion The study's findings highlight the potential utility of a multi-faceted predictive model integrating demographic, clinical, laboratory, imaging, and symptom-related parameters for identifying patients at risk for PICS.

Keywords Symptoms, Predictive model, PICS, Mechanically ventilated, Severe pneumonia

Introduction

The care of critically ill patients with severe pneumonia requiring mechanical ventilation in the intensive care unit (ICU) poses numerous challenges, including the potential development of post-intensive care syndrome (PICS) [1, 2]. Severe pneumonia, such as that observed in critical cases of viral infections like COVID- 19, can exacerbate these challenges by necessitating prolonged ICU stays and advanced life support measures, which may further increase the risk of PICS [3–6]. PICS was characterized by a spectrum of adverse outcomes encompassing physical, cognitive, and psychological impairments that can persist beyond the acute phase of critical illness and hospitalization. The term PICS serves as an umbrella to encapsulate the debilitating

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sequelae experienced by ICU survivors, which may include but were not limited to, weaknesses, cognitive impairments, anxiety, depression, sleep disturbances, and post-traumatic stress disorder (PTSD) [7–9]. It was increasingly recognized as a significant and multi-faceted challenge in the comprehensive care of critically ill patients, necessitating a deeper understanding of its underlying characteristics and the development of predictive models for early risk identification [10, 11]. This underscores the importance of investigating the specific characteristics of symptoms and the establishment of predictive models for PICS in mechanically ventilated patients with severe pneumonia.

Patients with severe pneumonia who require mechanical ventilation in the ICU represent a vulnerable population at heightened risk for the development of PICS [12–14]. The respiratory compromise and systemic inflammatory response associated with severe pneumonia and mechanical ventilation may serve as precipitating factors for the multi-faceted manifestations of PICS [15]. Consequently, delineating the specific characteristics of symptoms and developing predictive models for PICS in this patient population were of paramount importance [16]. Understanding the intricacies of PICS in mechanically ventilated patients with severe pneumonia was crucial for risk stratification, targeted intervention, and improved long-term outcomes.

The study on the characteristics of symptoms and establishment of a predictive model for PICS in mechanically ventilated patients with severe pneumonia holds significant relevance for nursing practice. As frontline caregivers, nurses play a crucial role in the holistic care of critically ill patients, including those requiring mechanical ventilation in the ICU. PICS poses a multi-faceted challenge for nurses, as it encompasses physical, cognitive, and psychological impairments that can persist beyond the acute phase of critical illness and hospitalization [17]. Understanding the specific characteristics of symptoms and the development of predictive models for PICS in mechanically ventilated patients with severe pneumonia is vital for nurses in identifying at-risk patients, delivering targeted interventions, and providing comprehensive post-critical-care management [18]. By gaining insights into the parameters associated with PICS and leveraging predictive models, nurses can contribute to early risk identification, personalized care planning, and support for patients experiencing the long-term sequelae of critical illness [4, 19]. Therefore, this retrospective study aimed to fill this critical knowledge gap by characterizing the symptoms of PICS in mechanically ventilated patients with severe pneumonia and establishing a predictive model for this syndrome.

Materials & methods

Ethics statement

Based on the guidelines set forth by our institution's Institutional Review Board and Ethics Committee, informed consent was waived for this retrospective study as it solely involved de-identified patient data, thus presenting no risk or impact on patient care.

Study design

This study was a retrospective study conducted on critically ill pneumonia patients who underwent mechanical ventilation at our hospital from February 2022 to April 2023. Patients were categorized into non-ICU-acquired complication and PICS groups based on whether they developed ICU-acquired complications. The study included a total of 133 patients, of which 71 were identified as cases with PICS and 62 as controls without PICS.

Inclusion and exclusion criteria

Inclusion criteria encompassed patients meeting the following conditions: diagnosis of severe pneumonia [20], age over 18 years, ICU stay of at least 3 days, receiving more than 48 h of continuous mechanical ventilation, attending a follow-up consultation 3 month post-ICU discharge, possessing normal cognitive function and the ability to comprehend and engage in questionnaire surveys, completion of a 3-month follow-up, and having comprehensive medical records available.

Exclusion criteria: Patients who passed away either during their hospital stay or within the following 3-month period; primary neurological impairments or documented active psychiatric diseases; receipt of palliative care, enrollment in another randomized-controlled trial with similar end points; other possible diseases causing similar symptoms as mechanically ventilated patients with severe pneumonia (Fig. 1).

Definition of post-intensive care syndrome (PICS)

The official definition of PICS has not yet had not been universally established. Nonetheless, practitioners have reached a consensus that it refers to any new or exacerbated impairment in physical, cognitive, or mental health arising after critical illness, including cognitive impairments alongside physical and psychological sequelae, and enduring beyond the acute care hospitalization period [21].

Data collection

General information

General data, including age, gender, Body Mass Index (BMI), Acute Physiology and Chronic Health Evaluation II (APACHE II) score, smoking history, hypertension, alcohol consumption, diabetes, hyperlipidemia, history

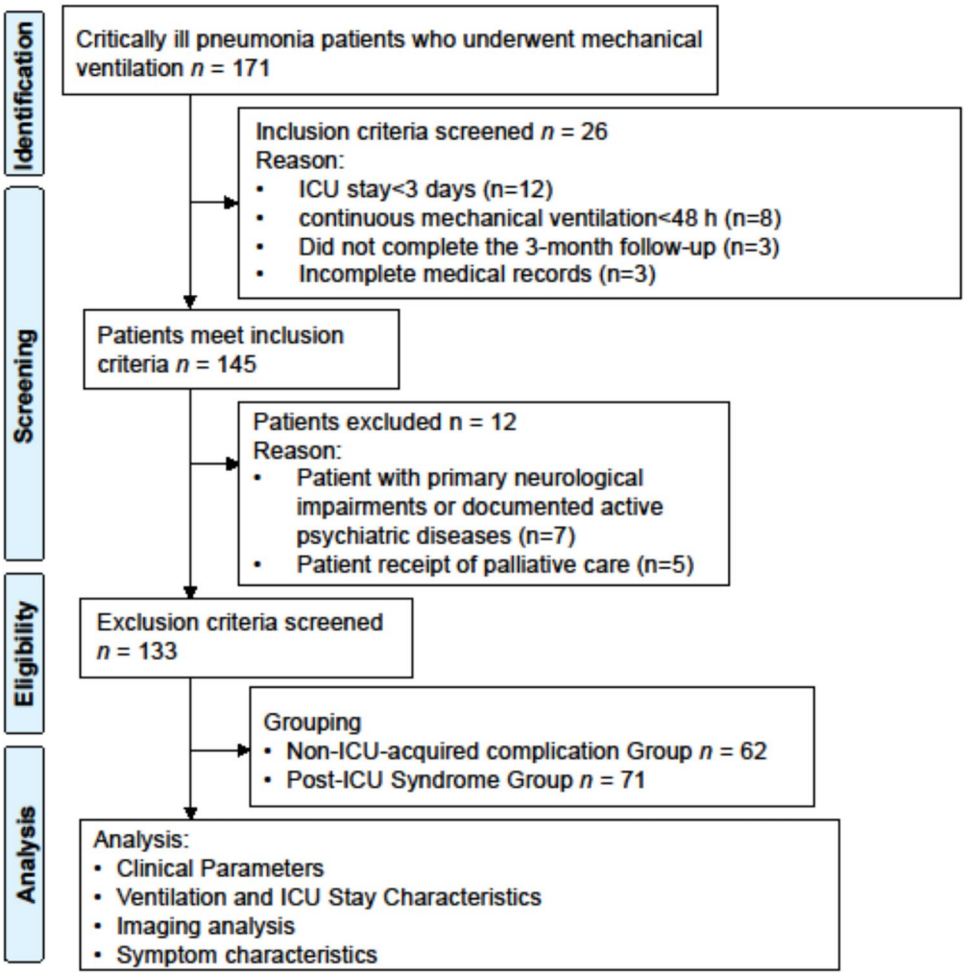

Fig. 1 Flowchart of patient selection process

of pneumonia, Chronic Obstructive Pulmonary Disease (COPD), education level, and etiology were collected from the medical records system. Additionally, ICU length of stay, Ventilator-Associated Pneumonia (VAP) incidence, duration of mechanical ventilation, Sequential Organ Failure Assessment (SOFA) score, sedation duration, vasopressor use, and sedation days were obtained from the medical records system. Pneumonia is a common lung infection that can be caused by a variety of different pathogens, including bacteria, viruses, fungi, and other microorganisms. The course of pneumonia can range from acute to chronic, depending on factors such as the type of pathogen, the overall health status of the patient, and whether timely treatment is received. Generally speaking, symptoms of acute pneumonia can rapidly develop within a few days, while chronic pneumonia may last for weeks or longer. Pneumonia itself and its etiology may indirectly affect the development of PICS through factors, such as disease severity, treatment process, complications, the patient's basic health status, and psychological factors.

Clinical parameter

Upon admission, 3 mL of fasting venous blood was drawn from the patients, and after serum separation, white blood cell count (WBC), platelet count, and serum creatinine (Cr) were measured using a fully automatic biochemical analyzer (BS- 280, Mindray, China), along with the measurement of procalcitonin and Human neutrophil elastase (HNE) levels using enzyme-linked immunosorbent assay (ELISA).

Additionally, at 72 h after ICU admission, 3 mL of fasting venous blood was collected from the patients, and after serum separation, aspartate aminotransferase (AST), serum lactate, and blood glucose levels were measured using a fully automatic biochemical analyzer (BS- 280, Mindray, China), along with the measurement of C-reactive protein (CRP), IL- 1β, IL- 6, as well

as IL- 8 levels using enzyme-linked immunosorbent assay (ELISA).

The Pulse Oximetry (SpO2), Fraction of Inspired Oxygen (FiO2), and Partial Pressure of Oxygen in Arterial Blood (PaO2) were measured through the blood gas analyzer (PL2000PLUS, PERLONG, China) at admission, and the SpO2/FiO2 and PaO2/FiO2 ratio was calculated. Arterial Ph was measured by blood gas analyzer at 72 h after ICU.

Imaging findings

In the supine position, patients underwent posterior chest radiography X-ray (CXR). The radiologist was blinded to the patients' clinical and laboratory data.

The participants underwent unenhanced chest Computed Tomography (CT) scans using the SOMATOM Perspective system. These images were acquired, while the participants held their breath immediately after a full inhalation, with scans covering the upper thoracic inlet to the inferior level of the costophrenic angle. The CT parameters included a detector collimation width of 64 ×0.6 mm, a tube voltage of 120 kV, and automatic exposure control using CARE Dose 4D by Siemens Healthineers to regulate tube current. For follow-up CT scans, reconstruction involved a slice thickness and interval of 1 mm. Additionally, the images were reconstructed using a pulmonary B70 s kernel and a mediastinal I31 s kernel, with a matrix size of 512 ×512. To ensure impartial evaluation, all CT images were randomly assigned and independently assessed by three senior radiologists who were blinded to any identifying information. Patients were assessed for pleural effusion, pulmonary edema, and pulmonary consolidation using CXR and CT scans. The CXR findings were the primary outcome of this study. This choice was based on the fact that CXR findings are a key indicator of the severity and progression of pneumonia, and they are closely associated with the development of PICS [22, 23].

Medical research council (MRC) scale

Intensive Care Unit Acquired Weakness (ICU-AW) diagnosis involved the utilization of the Medical Research Council (MRC) scale to assess muscle strength in both the lower and upper extremities. The evaluation encompassed various muscle groups, including neck flexors and extensors, deltoid, biceps brachii, triceps brachii, wrist flexors and extensors, finger flexors and extensors, opponents pollicis, iliopsoas, quadriceps femoris, biceps femoris, tibialis anterior, and gastrocnemius. Each muscle was assigned an integer value ranging from 0 to 5 based on the MRC scale, indicating different levels of strength. ICU-acquired weakness was identified as an MRC score below 48. The Cronbach's α for this assessment was 0.939, and the inter-rater reliability was recorded at 0.902 [24].

Pittsburgh sleep quality index (PSQI)

The Pittsburgh Sleep Quality Index (PSQI) was administered to the participants. This self-reported assessment tool was utilized to evaluate sleep quality over a 1-month period, generating a global score and seven component scores. These component scores encompassed subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction. Each component was rated on a scale from 0 to 3, with the total score ranging from 0 to 21, where a higher score indicated poorer sleep quality. A total PSQI score exceeding 5 has been validated as highly sensitive and specific in discriminating good from poor sleepers in various populations. The PSQI demonstrated good internal consistency with a Cronbach's α coefficient of 0.78 [25].

Critical-care pain observation tool (CPOT)

The critical-care pain observation tool (CPOT) comprised four behavioral domains: facial expression, body movements, muscle tension, and compliance with the ventilator for intubated patients. Each domain was evaluated using a responsive scoring system ranging from 0 to 2, resulting in a total score range of 0 to 8. Particularly during endotracheal suctioning, the"compliance with the ventilator"item was appraised once the suction catheter had been fully withdrawn from the endotracheal tube. The CPOT exhibited satisfactory internal consistency, as indicated by Cronbach's α value of 0.79 [26].

Intensive care delirium screening checklist (ICDSC)

The assessment of delirium was conducted using the Intensive Care Delirium Screening Checklist (ICDSC), which encompassed the evaluation of eight domains, including level of consciousness, inattention, disorientation, hallucination, psychomotor activity, speech or mood disturbance, sleep disturbance, and symptom fluctuation. Delirium was diagnosed in patients with an ICDSC score of ≥4. The overall internal consistency of all ICDSC scores was notably high, demonstrating Cronbach's alpha coefficient of 0.839 [27].

Hospital anxiety and depression scale (HADS)

An assessment of anxiety and depression was carried out using the Hospital Anxiety and Depression Scale (HADS), which comprised two distinct subcomponents: anxiety and depression. Each subcomponent consisted of 7 items, with each item scored from 0 to 3. The total score spanned from 0 to 21, with a range of 0–7 indicating normal, 8–10 indicating mild, 11–14 indicating moderate,

and 15–21 indicating severe levels. The internal consistency reliability was found to be high, with Cronbach's alpha values of 0.890 for the anxiety scale (HADS-A) and 0.856 for the depression scale (HADS-D) [28].

Posttraumatic stress scale (PTSS- 10)

For screening post-traumatic stress disorder, the PTSS-10 was employed, where patients rated the frequency of ten common PTSD symptoms using a seven-point Likert scale from 1 (never) to 7 (always). The individual scores from these items were aggregated to produce a composite score within the range of 10–70. A total score exceeding 35 was indicative of clinically significant PTSD symptoms. The PTSS- 10 demonstrated a robust level of internal consistency, with Cronbach's alpha coefficients ranging from 0.83 to 0.85[29].

Post-hoc analysis

Utilizing G*Power 3.1.9.7, the"Means: Difference between two independent means (two groups)"option based on t-tests was selected for post hoc analysis with the following settings: Two-tailed mode, Effect size $d = 0.5$, α error prob = 0.05. Subsequently, the sample sizes for the two groups were inputted, and the power (1-βerror prob) was calculated, resulting in a value of 0.815.

Statistical analysis

The data were analyzed using SPSS 29.0 statistical software (SPSS Inc., Chicago, IL, USA). For categorical data, [n (%)] was used for representation. The Chi-square test was applied with the basic formula when the sample size was ≥ 40 and the theoretical frequency T was ≥ 5, with the test statistic represented by χ^2. When the sample size was ≥ 40 but the theoretical frequency $1 \leq T < 5$, the Chi-square test was adjusted using the correction formula. In cases where the sample size was < 40 or the theoretical frequency was $T < 1$, statistical analysis was conducted using Fisher's exact probability method. Continuous variables were first tested for normal distribution using the Shapiro–Wilk method, and the results are provided in Table S1. All variables were found to be normally distributed and were analyzed using parametric tests. For normally distributed continuous data, the format (X ± s) was employed. Non-normally distributed data were analyzed using Wilcoxon rank-sum test, and the [median (25% quantile,75% quantile)] was used for presentation. $P < 0.05$ were considered as statistical significance. To identify the independent predictors of PICS, we performed a logistic regression analysis. Variables were selected for inclusion in the model based on their clinical relevance and statistical significance in univariate analysis ($p < 0.05$). The following variables were included in the logistic regression model: APACHE II score, serum creatinine, duration of mechanical ventilation, VAP incidence, chest X-ray findings, and pleural effusion (Table 7). The diagnostic performance of each parameter for PICS symptoms in mechanically ventilated patients with severe pneumonia was assessed using the area under the receiver-operating characteristic (ROC) curve (AUC).

The STROBE guidelines

The study report follows the STOBE guidelines.

Results

Demographic and basic data

A total of 133 patients including 62 patients with non-ICU-Acquired Complication Group and 71 patients with PICS Group were included. Based on the demographic characteristics presented in Table 1, significant differences were observed between the non-ICU-acquired complication and PICS groups in terms of age (55.41 ± 10.12 vs. 59.75 ± 9.88 years, $t = 2.494$, $P = 0.014$), BMI (22.18 ± 3.45 vs. 23.85 ± 4.23 kg/m^2, $t = 2.508$, $P = 0.013$), and APACHE II score (16.42 ± 4.61 vs. 18.43 ± 4.15, $t = 2.628$, $P = 0.010$). The average values of the above indicators in the PICS group were significantly higher than those in the non-ICU-acquired complications' group. No statistically significant differences were found in gender distribution, smoking history, alcohol consumption, hypertension, diabetes, hyperlipidemia, history of pneumonia, education level, and etiology. The p values of these indicators are all greater than 0.05. These findings suggest that age, BMI, and APACHE II score may be associated with the development of PICS in mechanically ventilated patients with severe pneumonia, while other demographic factors may not play a significant role in the manifestation of this syndrome.

Clinical parameters

Based on the clinical parameters presented in Table 2, statistically significant differences were observed between the non-ICU-acquired complication and PICS groups in P/F ratio (260.54 ± 50.21 vs. 240.67 ± 60.89 mmHg, $t = 2.062$, $P = 0.041$), WBC count (11.13 ± 3.45 vs. 12.47 ± 3.14 ×10^9/L, $t = 2.329$, $P = 0.021$), platelet count (225.61 ± 40.12 vs. 210.75 ± 35.67 ×10^9/L, $t = 2.244$, $P = 0.027$), serum creatinine (0.98 ± 0.45 vs. 1.21 ± 0.61 mg/dL, $t = 2.549$, $P = 0.012$), procalcitonin (1.94 ± 0.93 vs. 2.35 ± 1.27 ng/mL, $t = 2.171$, $P = 0.032$), PaO2/FiO2 (258.45 ± 35.64 vs. 240.87 ± 45.36 mmHg, $t = 2.500$, $P = 0.014$), and HNE (116.35 ± 12.58 vs. 122.17 ± 13.79, $t = 2.545$, $P = 0.012$). These findings indicate that these clinical parameters on admission may be predictive factors for the development of PICS in mechanically ventilated patients with severe pneumonia, suggesting their

Table 1 Demographic characteristics of study participants

Parameter	Non-ICU-acquired complication group ($n=62$)	PICS group ($n=71$)	t/χ^2	P
Age (years)	55.41 ± 10.12	59.75 ± 9.88	2.494	0.014
Gender (M/F)	34 (54.84%)/28 (45.16%)	41 (57.75%)/30 (42.25%)	0.026	0.871
BMI (kg/m^2)	22.18 ± 3.45	23.85 ± 4.23	2.508	0.013
APACHE II score	16.42 ± 4.61	18.43 ± 4.15	2.628	0.010
Smoking history (%)	16 (25.81%)	27 (38.03%)	1.736	0.188
Alcohol consumption (%)	13 (20.97%)	22 (30.99%)	1.235	0.266
Hypertension (%)	12 (19.35%)	20 (28.17%)	0.966	0.326
Diabetes (%)	8 (12.9%)	15 (21.13%)	1.043	0.307
Hyperlipidemia	9 (14.52%)	12 (16.9%)	0.019	0.890
History of pneumonia	6 (9.68%)	11 (15.49%)	0.550	0.458
Education Level			6.439	0.011
-Junior high school and below	14 (22.58%)	32 (45.07%)		
-Junior high school and above	48 (77.42%)	39 (54.93%)		
Etiology			1.442	0.837
-Streptococcus pneumoniae	21 (33.87%)	26 (36.62%)		
-Haemophilus influenzae	13 (20.97%)	17 (23.94%)		
-Klebsiella pneumoniae	9 (14.52%)	7 (9.86%)		
-Pseudomonas aeruginosa	5 (8.06%)	8 (11.27%)		
-Other	14 (22.58%)	13 (18.31%)		

Table 2 Clinical parameters on admission

Parameter	Non-ICU-acquired complication group ($n=62$)	PICS group ($n=71$)	t	P
P/F ratio (mmHg)	260.54 ± 50.21	240.67 ± 60.89	2.062	0.041
WBC count (× 10^9/L)	11.13 ± 3.45	12.47 ± 3.14	2.329	0.021
Platelet count (× 10^9/L)	225.61 ± 40.12	210.75 ± 35.67	2.244	0.027
Serum creatinine (mg/dL)	0.98 ± 0.45	1.21 ± 0.61	2.549	0.012
Procalcitonin (ng/mL)	1.94 ± 0.93	2.35 ± 1.27	2.171	0.032
PaO2/FiO2 (mmHg)	258.45 ± 35.64	240.87 ± 45.36	2.500	0.014
HNE	116.35 ± 12.58	122.17 ± 13.79	2.545	0.012

potential utility in establishing a predictive model for this syndrome.

Ventilation and ICU stay characteristics

Based on the ventilation and ICU stay characteristics presented in Table 3, statistically significant differences were observed between the non-ICU-acquired complication and PICS groups in the duration of mechanical ventilation (6.32 ± 2.24 vs. 7.45 ± 3.83 days, $t=2.107$, $P=0.037$), ICU length of stay (10.54 ± 3.87 vs. 12.35 ± 4.45 days, $t=2.513$, $P=0.013$), VAP incidence (8 (12.9%) vs. 21 (29.58%), $\chi^2=4.463$, $P=0.035$), SOFA score (6.18 ± 2.36 vs. 7.21 ± 3.14, $t=2.153$, $P=0.033$), sedation duration (48.23 ± 10.35 vs. 53.45 ± 15.47 h, $t=2.313$, $P=0.022$), vasopressor use (24.19% vs. 45.07%, $\chi^2=5.432$, $P=0.020$), and sedation days (4.85 ± 1.58 vs. 5.68 ± 2.37, $t=2.390$, $P=0.018$). These findings suggest that the duration of mechanical ventilation, ICU length of stay, VAP incidence, SOFA score, sedation duration, vasopressor use, and sedation days may be associated with the development of PICS in mechanically ventilated patients with severe pneumonia. These parameters may be valuable for establishing a predictive model for this syndrome (Table 4).

Laboratory Parameters

Based on the laboratory parameters presented in Table 4, significant differences were observed between the Non-ICU-acquired complication group and the PICS group at 72 hours. Specifically, CRP levels were higher in the PICS

group (60.84±15.68 mg/L vs. 54.21±16.35 mg/L, t=2.377, P=0.019), as were lactate levels (2.33±1.25 mmol/L vs. 1.93±0.75 mmol/L, t=2.287, P=0.024). Arterial pH was significantly lower in the PICS group (7.35±0.47 vs. 7.55±0.43, t=2.615, P=0.010). Serum glucose levels were also elevated in the PICS group (134.87±25.67 mg/dL vs. 126.65±20.43 mg/dL, t=2.054, P=0.042). Moreover, AST levels were significantly increased in the PICS group (60.45±15.32 U/L vs. 54.63±10.25 U/L, t=2.602, P=0.010). Levels of inflammatory markers such as IL-1β (3.36±1.62 ng/L vs. 2.83±1.14 ng/L, t=2.195, P=0.030), IL-6 (22.16±5.46 ng/L vs. 19.48±6.35 ng/L, t=2.592, P=0.011), and IL-8 (1.14±0.56 ng/L vs. 0.96±0.41 ng/L, t=2.130, P=0.035) were all significantly higher in the PICS group. These findings suggest that patients in the PICS group exhibit more pronounced systemic inflammation and metabolic disturbances compared to those without ICU-acquired complications.

Imaging findings

Based on the imaging findings presented in Table 5, statistically significant differences were observed between the non-ICU-acquired complication and PICS groups in chest X-ray findings (normal/abnormal) (66.13%/33.87% vs. 42.25%/57.75%, $\chi^2 = 6.652$, $P = 0.010$), CT findings (normal/abnormal) (30.65%/69.35% vs. 14.08%/85.92%, $\chi^2 = 4.397$, $P = 0.036$), pleural effusion (11.29% vs. 26.76%, $\chi^2 = 4.101$, $P = 0.043$), pulmonary edema (6.45% vs.

Table 3 Ventilation and ICU stay characteristics

Parameter	Non-ICU-acquired complication group ($n = 62$)	PICS group ($n = 71$)	t/χ^2	P
Duration of mechanical ventilation (days)	6.32 ± 2.24	7.45 ± 3.83	2.107	0.037
ICU length of stay (days)	10.54 ± 3.87	12.35 ± 4.45	2.513	0.013
VAP incidence (%)	8 (12.9%)	21 (29.58%)	4.463	0.035
SOFA score	6.18 ± 2.36	7.21 ± 3.14	2.153	0.033
Sedation duration (hours)	48.23 ± 10.35	53.45 ± 15.47	2.313	0.022
Vasopressor use (yes/no)	15 (24.19%)/47 (75.81%)	32 (45.07%)/39 (54.93%)	5.432	0.020
Sedation days	4.85 ± 1.58	5.68 ± 2.37	2.390	0.018

Table 4 Laboratory parameters at 72 h

Parameter	Non-ICU-acquired complication group ($n = 62$)	PICS group ($n = 71$)	t	P
CRP level (mg/L)	54.21 ± 16.35	60.84 ± 15.68	2.377	0.019
Lactate level (mmol/L)	1.93 ± 0.75	2.33 ± 1.25	2.287	0.024
Arterial pH	7.55 ± 0.43	7.35 ± 0.47	2.615	0.010
Serum glucose (mg/dL)	126.65 ± 20.43	134.87 ± 25.67	2.054	0.042
AST level (U/L)	54.63 ± 10.25	60.45 ± 15.32	2.602	0.010
IL- 1β(ng/L)	2.83 ± 1.14	3.36 ± 1.62	2.195	0.030
IL- 6(ng/L)	19.48 ± 6.35	22.16 ± 5.46	2.592	0.011
IL- 8(ng/L)	0.96 ± 0.41	1.14 ± 0.56	2.130	0.035

Table 5 Imaging findings

Parameter	Non-ICU-acquired complication group ($n = 62$)	PICS group ($n = 71$)	t/χ^2	P
Chest X-ray findings (normal/abnormal)	41 (66.13%)/21 (33.87%)	30 (42.25%)/41 (57.75%)	6.652	0.010
CT findings (normal/abnormal)	19 (30.65%)/43 (69.35%)	10 (14.08%)/61 (85.92%)	4.397	0.036
Pleural effusion (%)	7 (11.29%)	19 (26.76%)	4.101	0.043
Pulmonary edema (%)	4 (6.45%)	14 (19.72%)	3.909	0.048
Consolidation (%)	5 (8.06%)	16 (22.54%)	4.181	0.041

19.72%, $\chi^2 = 3.909$, $P = 0.048$), and consolidation (8.06% vs. 22.54%, $\chi^2 = 4.181$, $P = 0.041$). These findings indicate that these imaging findings may have relevance in the predictive modeling for PICS in mechanically ventilated patients with severe pneumonia.

Symptom characteristics

Based on the symptom characteristics presented in Table 6, statistically significant differences were observed between the non-ICU-acquired complication and PICS groups in weakness (50.23 ± 6.52 vs. 46.54 ± 5.15, $t = 3.587$, $P < 0.001$), sleep disturbance (5.79 ± 2.56 vs. 7.27 ± 3.48, $t = 2.812$, $P = 0.006$), pain (1.37 ± 0.62 vs. 0.85 ± 0.43, $t = 5.575$, $P < 0.001$), delirium incidence (3.26 ± 1.46 vs. 5.89 ± 3.57, $t = 5.678$, $P < 0.001$), depression (9.74 ± 4.38 vs. 12.12 ± 6.43, $t = 2.525$, $P = 0.013$), PTSD (30.79 ± 2.04 vs. 37.13 ± 5.96, $t = 8.407$, $P < 0.001$), and anxiety (10.75 ± 4.69 vs. 13.28 ± 6.83, $t = 2.514$, $P = 0.013$). These findings underscore the significant associations between these symptoms and the development of PICS in mechanically ventilated patients with severe pneumonia. The average weakness score and average pain score of patients in the non-ICU-acquired complications group were significantly higher than those in the PICS group. On the contrary, the average sleep disturbance score, average delirium incidence rate score, average depression score, average PTSD score and average anxiety score of patients in the non-ICU-acquired complications group were significantly lower than those in the PICS group.

Logistic regression analysis

The results of the logistic regression analysis are presented in Table 7. The APACHE II score was found to be a significant predictor of PICS (OR = 1.129, 95% CI 1.025–1.244, $p = 0.014$). Other significant predictors included serum creatinine (OR = 3.849, 95% CI 1.701–8.710, $p = 0.001$), VAP incidence (OR = 4.084, 95% CI 1.454–11.472, $p = 0.008$), chest X-ray findings (OR = 0.239, 95% CI 0.101–0.568, $p = 0.001$), and pleural effusion (OR = 3.627, 95% CI 1.167–11.273, $p = 0.026$). The duration of mechanical ventilation (OR = 1.134, 95% CI 0.997–1.289, $p = 0.055$) also showed marginal significance.

ROC

The predictive value of various indicators for the development of post-intensive care unit (ICU) syndrome in mechanically ventilated patients with severe pneumonia was assessed (Table 8). The AUC values for different indicators varied, indicating differing levels of predictive accuracy. Serum creatinine and APACHE II score showed relatively higher AUCs of 0.632 (95% CI 0.584–0.680) and 0.626 (95% CI 0.578–0.674), respectively, suggesting a moderate level of predictive ability for PICS. In contrast, chest X-ray findings also demonstrated a modest AUC of 0.619 (95% CI 0.571–0.667). However, duration of mechanical ventilation, VAP incidence, pleural effusion, and pulmonary edema presented lower AUCs of 0.587 (95% CI 0.539–0.635), 0.583 (95% CI 0.535–0.631), 0.577 (95% CI 0.529–0.625), and 0.566 (95% CI 0.518–0.614),

Table 6 Symptom characteristics

Parameter	Non-ICU-acquired complication group ($n = 62$)	PICS group ($n = 71$)	*t*	*P*
Weakness	50.23 ± 6.52	46.54 ± 5.15	3.587	$p < 0.001$
Sleep disturbance	5.79 ± 2.56	7.27 ± 3.48	2.812	0.006
Pain	1.37 ± 0.62	0.85 ± 0.43	5.575	$p < 0.001$
Delirium incidence	3.26 ± 1.46	5.89 ± 3.57	5.678	$p < 0.001$
Depression	9.74 ± 4.38	12.12 ± 6.43	2.525	0.013
PTSD	30.79 ± 2.04	37.13 ± 5.96	8.407	$p < 0.001$
Anxiety	10.75 ± 4.69	13.28 ± 6.83	2.514	0.013

Table 7 Multivariate logistic regression of various indicators on PICS in mechanically ventilated patients with severe pneumonia

Parameter	Std-error	Wald-stat	OR	OR (95% confidence)	*P*
APACHE II score	0.049	2.469	1.129	1.025–1.244	0.014
Serum creatinine	0.417	3.235	3.849	1.701–8.710	0.001
Duration of mechanical ventilation	0.066	1.919	1.134	0.997–1.289	0.055
VAP incidence (%)	0.527	2.670	4.084	1.454–11.472	0.008
Chest X-ray findings	0.441	− 3.241	0.239	0.101–0.568	0.001
Pleural effusion (%)	0.579	2.226	3.627	1.167–11.273	0.026

Table 8 The predictive value of various indicators for PICS in mechanically ventilated patients with severe pneumonia

Parameter	Sensitivities	Specificities	AUC	Youden index
APACHE II score	0.521	0.742	0.626	0.263
Serum creatinine	0.535	0.79	0.632	0.325
Duration of mechanical ventilation	0.366	0.887	0.587	0.253
VAP incidence (%)	0.296	0.871	0.583	0.167
Chest X-ray findings	0.577	0.661	0.619	0.238
Pleural effusion (%)	0.268	0.887	0.577	0.155
Pulmonary edema (%)	0.197	0.935	0.566	0.132

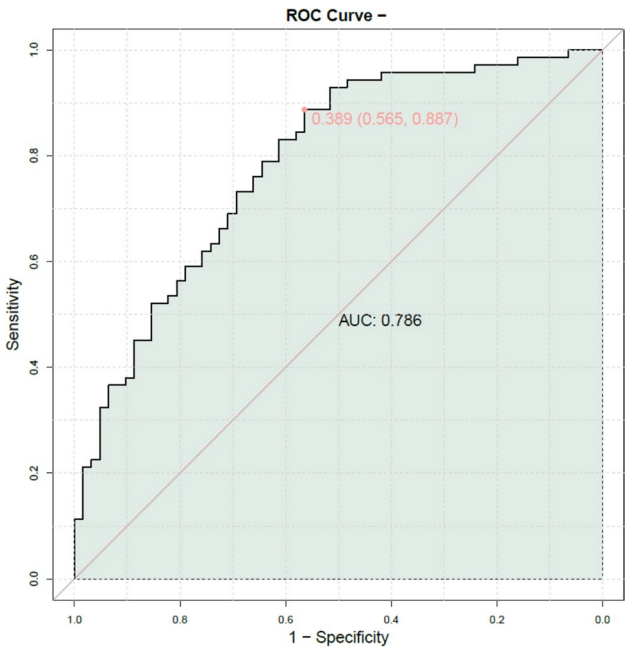

Fig. 2 ROC curve analysis for predictive indicators of pics in mechanically ventilated patients with severe pneumonia. AUC = 0.786. *ROC* Receiver-operating characteristic, PICS post-intensive care syndrome, *AUC* area under the curve

respectively, indicating limited predictive value for these indicators. These findings highlight the varying predictive potential of different indicators for the development of PICS in mechanically ventilated patients with severe pneumonia.

Joint model

Finally, this study combined indicators with predictive value to construct a joint model for predicting the PICS in mechanically ventilated patients with severe pneumonia. The results showed an AUC value of 0.786 (95% CI 0.746–0.833), indicating that the joint model has moderate-to-good predictive ability for the PICS in mechanically ventilated patients with severe pneumonia (Fig. 2).

Discussion

In this retrospective study, we aimed to characterize the symptoms of PICS in mechanically ventilated patients with severe pneumonia and establish a predictive model for this syndrome [30–32].

The incidence of PICS in our study was higher. That is because patients with severe pneumonia usually have a more severe condition and may require longer ICU monitoring and treatment, so they may face a higher risk of ICU syndrome than other types of ICU patients. In addition, patients with severe pneumonia may require treatment such as mechanical ventilation and sedatives in the ICU, which may also increase the risk of ICU syndrome. Therefore, the incidence rate of ICU syndrome in patients with severe pneumonia is higher than that in ordinary patients, and there will be sample bias leading to more patients with Post-Intensive Care Syndrome (PICS) in the study than those without PICS. Our study found that the incidence of post-ICU syndrome in mechanically ventilated patients with severe pneumonia was 53.4%, which is consistent with the 53.6% reported by Meng et al. [33].

The demographic characteristics analyzed in this study revealed that age, body mass index (BMI), and APACHE II score were significantly associated with the development of PICS. This suggests that advanced age and higher disease severity, as reflected by the APACHE II score, may serve as potential risk factors for the manifestation of PICS. These findings were consistent with the previous literature [34] which has identified age and disease severity as key determinants for adverse outcomes in critically ill patients. This provides a rationale for using the APACHE II score to develop a PICS prediction model for mechanically ventilated patients with severe pneumonia in this study. Moreover, the study found that certain clinical parameters, such as the WBC count, platelet count, serum creatinine, and procalcitonin levels, were predictive of PICS. For instance, elevated levels of procalcitonin, a marker of systemic inflammation, have been associated with increased risk

of prolonged ICU stays and subsequent development of PICS [35]. Similarly, serum creatinine, an indicator of renal function, has been linked to the severity of acute kidney injury, which is a significant predictor of long-term morbidity and mortality in ICU survivors [36, 37]. Understanding the role of these biomarkers and clinical features in the pathogenesis of PICS is crucial for developing targeted interventions and improving patient outcomes. Elevated levels of these parameters may reflect underlying inflammatory and organ dysfunction processes, which have been linked to poor clinical outcomes in critically ill patients. The predictive value of these parameters supports their potential utility in identifying patients at risk for PICS [38–40].

Importantly, the study also identified symptoms and complications that were significantly associated with the development of PICS. Weakness, pain, delirium incidence, sleep disturbance, depression, post-traumatic stress disorder (PTSD), and anxiety were found to be markedly different between the non-ICU-acquired complication and PICS groups. These symptoms were notably consistent with the constellation of impairments encompassed in the definition of PICS, highlighting their relevance in the context of this syndrome [41, 42]. These symptoms interact with each other and have a profound impact on the long-term physiological, cognitive, and psychological health of patients. For example, pain may lead to sleep disorders, which in turn exacerbate depression and anxiety. Delirium and weakness may further affect patients'rehabilitation ability and quality of life [43, 44]. Additionally, while our study did not analyze the relationship between tobacco and alcohol consumption and delirium, previous literature indicates that both are significant risk factors. Tobacco use and heavy alcohol consumption can lead to cognitive impairment and increased susceptibility to delirium [45, 46]. The findings underscore the importance of recognizing and addressing these symptoms as integral components of PICS in critically ill patients, and emphasize the need for comprehensive management strategies targeting these issues.

The logistic regression analysis identified several independent predictors of PICS. The APACHE II score was a significant predictor. As mentioned in the previous studies, a higher APACHE II scores to be associated with increased risk of post-ICU complications [47]. This is consistent with our study's findings and supports the inclusion of the APACHE II score in the PICS prediction model. Serum creatinine and VAP incidence were also significant predictors, highlighting the importance of renal function and the development of ventilator-associated pneumonia in these patients. Chest X-ray findings and pleural effusion were additional significant predictors, indicating the role of radiographic and pleural abnormalities in post-ICU outcomes. Notably, the duration of mechanical ventilation showed marginal significance ($p = 0.055$). While this variable did not reach the traditional threshold for statistical significance ($p < 0.05$), its clinical importance should not be overlooked. In the context of ICU care, the duration of mechanical ventilation is a critical factor that can significantly impact patient outcomes. Prolonged mechanical ventilation is associated with increased risks of complications, such as ventilator-associated pneumonia (VAP), muscle weakness, and delirium, all of which are known contributors to the development of PICS [48, 49]. These results suggest that early identification and management of these risk factors may improve outcomes in mechanically ventilated patients with severe pneumonia.

The predictive model developed in this study integrated multiple indicators, including demographic, clinical, laboratory, imaging, and symptom-related parameters, to establish a robust predictive value for PICS. The joint model exhibited an impressive area under the curve (AUC) value of 0.786, indicating an exceptionally high predictive value for the development of PICS in mechanically ventilated patients with severe pneumonia. This underscores the potential of a multi-faceted approach in predicting and identifying patients at risk for PICS [50]. The development of a predictive model for PICS in mechanically ventilated patients with severe pneumonia has significant implications for both clinical practice and patient outcomes. By identifying patients at high risk for PICS, healthcare providers can implement targeted interventions to mitigate the development and severity of this syndrome. This approach can lead to improved patient outcomes, reduced hospital readmissions, and enhanced quality of life. Practical Recommendations for Implementation: ① Early Interventions: Initiate early physical rehabilitation programs to prevent muscle weakness and improve mobility. This can include passive and active range-of-motion exercises, strength training, and functional training. ② Patient Education and Empowerment: Develop educational materials and programs to inform patients and their families about PICS, its symptoms, and the importance of early intervention. This can empower patients to actively participate in their recovery process. ③ Long-Term Follow-Up: Continuously track patient outcomes to evaluate the effectiveness of the predictive model and the implemented interventions. Use this data to refine and improve the model and care protocols over time. By implementing these practical recommendations, the predictive model can be effectively translated into clinical practice, leading to better patient outcomes and a more efficient use of healthcare resources.

Additionally, while our retrospective analysis has established a promising predictive model for PICS, it is

essential to validate this model on a prospective cohort in the future to confirm its robustness and generalizability. Prospective validation will provide critical insights into the model's real-world applicability and ensure that it accurately identifies patients at risk for PICS, thereby supporting evidence-based clinical decision-making.

The study's findings also have several important clinical implications. First, the identification of specific parameters associated with PICS may inform clinical decision-making and risk assessment in the management of critically ill patients with severe pneumonia [51]. Early recognition of patients at risk for PICS could facilitate the implementation of targeted interventions aimed at mitigating the development and severity of this syndrome. Additionally, the findings underscore the importance of a multi-disciplinary approach in addressing the various symptoms and complications associated with PICS. Comprehensive post-critical-care management programs tailored to address the specific needs of affected patients may lead to improved long-term outcomes and quality of life [52, 53].

The findings of the study on the characteristics of symptoms and the establishment of a predictive model for PICS in mechanically ventilated patients with severe pneumonia have significant implications for nursing practice. Nurses play a pivotal role in the care of critically ill patients, especially those requiring mechanical ventilation and those at risk for PICS. The identification of specific demographic, clinical, laboratory, imaging, and symptom-related parameters associated with PICS is essential for nurses in their daily patient care activities. Understanding the predictive value of these parameters can aid nurses in early risk identification, patient assessment, and the implementation of targeted interventions to mitigate the development and severity of PICS. Additionally, the recognition of symptoms, such as weakness, pain, delirium, sleep disturbances, depression, PTSD, and anxiety, as significant factors in the development of PICS highlights the crucial role of nurses in symptom management, psychological support, and holistic care for patients recovering from critical illness and mechanical ventilation. The development of a joint predictive model consolidating multiple indicators further emphasizes the importance of a comprehensive and integrated approach to patient care, aligning with the holistic principles of nursing practice. Nurses are well-positioned to contribute to multi-disciplinary teams focused on post-ICU care and can utilize the insights from this study to inform evidence-based nursing interventions, improve patient outcomes, and enhance the quality of care for mechanically ventilated patients with severe pneumonia.

However, this study was not without its limitations. As a retrospective study, it was susceptible to inherent biases and limitations associated with retrospective data analysis. The lack of standardized data collection methods across different time periods and healthcare providers may have introduced variability in the data. To address these limitations in future studies, several strategies can be considered: Implementing a prospective study design would allow for more systematic and standardized data collection, reducing the risk of missing or inconsistent data; using standardized definitions and criteria for diagnosing and measuring outcomes can enhance the comparability and reliability of the data. Future studies should consider a prospective design with systematic matching procedures to better control for confounding variables. The study's single-center design may limit the generalizability of the findings to other patient populations and clinical settings. The absence of a consensus definition for PICS may introduce variability in the interpretation and characterization of this syndrome. Additionally, while we controlled for several demographic and clinical variables, we did not perform detailed adjustments or sensitivity analyses for potential confounders such as medications (e.g., corticosteroids or sedatives). Future studies should aim to address these limitations by employing prospective, multi-center study designs and standardizing the assessment and definition of PICS. Another limitation of this study is the lack of detailed data on the use of corticosteroids and neuromuscular blocking agents (NMBAs), which precludes an assessment of their role as etiological factors in ICUAW. Future research should include a systematic evaluation of these factors to better understand their role in the pathogenesis of ICUAW. Prospective studies with detailed documentation of medication use and a larger sample size would be particularly valuable. Finally, the predictive model developed in this study requires external validation to ensure its generalizability to other populations and settings. External validation is crucial to verify the model's performance and robustness across different healthcare systems and patient demographics. Without external validation, the predictive accuracy and reliability of the model may be questionable, limiting its clinical utility. Future research should address this limitation by conducting multi-center studies and discussing the necessity of external validation to confirm the model's applicability and robustness.

Conclusions

In conclusion, this study sheds light on the characteristics of symptoms and the establishment of a predictive model for PICS in mechanically ventilated patients with severe pneumonia. The findings emphasize the relevance of demographic, clinical, laboratory, imaging, and symptom-related parameters in predicting and identifying patients at risk for PICS. The establishment of a

joint predictive model consolidating multiple indicators significantly strengthened the overall predictive capacity, providing a robust tool for risk stratification and early intervention.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40001-025-02547-x.

Supplementary material 1.

Author contributions

Juhong Ding, Dongli Wang and Yumei Lu were responsible for research design. Xiaoling Zhou, Ke Ren and Yu Zhu were responsible for conducting the experiments. Juhong Ding, Dongli Wang, Yu Zhu and Yun Cao were responsible for data acquisition. Xiaoling Zhou, Ke Ren, Lei Ding were responsible for data analysis. Yumei Lu, Yun Cao, and Lei Ding were responsible for writing the manuscript. All the authors have contributed to the completion of this paper.

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Availability of data and materials

The datasets used during the present study are available from the corresponding author upon reasonable request. Researchers must sign a data use agreement outlining the terms and conditions of data access, including the purpose of the research, the scope of data usage, and the commitment to maintaining patient confidentiality. Researchers must provide a secure environment for storing and handling the data, adhering to best practices for data protection and security.

Declarations

Ethics approval and consent to participate

This study received approval from the Institutional Review Board and Ethics Committee of the Nantong Third People's Hospital, Affiliated Nantong Hospital 3 of Nantong University. Based on the guidelines set forth by our institution's Institutional Review Board and Ethics Committee, informed consent was waived for this retrospective study as it solely involved de-identified patient data, thus presenting no risk or impact on patient care.

Competing interests

The authors declare no competing interests.

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References

1. Pant U, Vyas K, Meghani S, Park T, Norris CM, Papathanassoglou E. Screening tools for post-intensive care syndrome and post-traumatic symptoms in intensive care unit survivors: a scoping review. Aust Crit Care. 2023;36:863–71.
2. Luetz A, Grunow JJ, Mörgeli R, Rosenthal M, Weber-Carstens S, Weiss B, Spies C. Innovative ICU solutions to prevent and reduce delirium and post-intensive care unit syndrome. Semin Respir Crit Care Med. 2019;40:673–86.
3. Hegazy SK, Hassan AH. Comparing the efficacy of remdesivir, favipiravir, and casirivimab and imdevimab on duration of hospitalization and ICU stay of hospitalized COVID-19 patients. Life Sci Res Commun. 2024;1:21–30.
4. Hassan AH, Hegazy SK, Radwan ST. Clinical study to evaluate the possible efficacy and safety of antibodies combination (casirivimab and imdevimab) versus standard antiviral therapy as antiviral agent against Corona virus 2 infection in hospitalized COVID-19 patients. MedRxiv. 2022. https://doi.org/10.1101/2022.08.20.22279020.
5. Hegazy SK, Hassan AH. The effect of combination treatment with casirivimab and imdevimab versus standard antiviral therapy on clinical outcomes in hospitalized COVID-19 patients. Discov Med. 2024;1:71.
6. Hassan A, Hegazy S, Radwan S. Study to compare the possible efficacy and safety of casirivimab and imdevimab combination versus standard antiviral therapy in hospitalized COVID-19 patients. Res Sq. 2022. https://doi.org/10.21203/rs.3.rs-1991618/v1.
7. Costas-Carrera A, Sánchez-Rodríguez MM, Cañizares S, Ojeda A, Martín-Villalba I, Primé-Tous M, Rodríguez-Rey MA, Segú X, Valdesoiro-Pulido F, Borras R, Peri JM, Vieta E. Neuropsychological functioning in post-ICU patients after severe COVID-19 infection: the role of cognitive reserve. Brain Behav Immun Health. 2022;21:100425.
8. Worsham CM, Banzett RB, Schwartzstein RM. Dyspnea, acute respiratory failure, psychological trauma, and post-icu mental health: a caution and a call for research. Chest. 2021;159:749–56.
9. Raurell-Torredà M, Arias-Rivera S, Martí JD, Frade-Mera MJ, Zaragoza-García I, Gallart E, Velasco-Sanz TR, San José-Arribas A, Blázquez-Martínez E. Degree of implementation of preventive strategies for post-ICU syndrome: multi-centre, observational study in Spain. Enferm Intensiva (Engl Ed). 2019;30:59–71.
10. Ramnarain D, Aupers E, den Oudsten B, Oldenbeuving A, de Vries J, Pouwels S. Post Intensive Care Syndrome (PICS): an overview of the definition, etiology, risk factors, and possible counseling and treatment strategies. Expert Rev Neurother. 2021;21:1159–77.
11. Weinhouse GL, Salomon S, Nisotel L, Levy-Carrick NC, Lamas D. Patients' and their caregivers' interest in learning about post-ICU syndrome and seeking help for It. Crit Care Explor. 2020;2:e0285.
12. Karhu J, Ala-Kokko TI, Vuorinen T, Ohtonen P, Syrjälä H. Lower respiratory tract virus findings in mechanically ventilated patients with severe community-acquired pneumonia. Clin Infect Dis. 2014;59:62–70.
13. Yang L, Haidar G, Zia H, Nettles R, Qin S, Wang X, Shah F, Rapport SF, Charalampous T, Methé B, Fitch A, Morris A, McVerry BJ, O'Grady J, Kitsios GD. Metagenomic identification of severe pneumonia pathogens in mechanically ventilated patients: a feasibility and clinical validity study. Respir Res. 2019;20:265.
14. Schefold JC, Berger D, Zürcher P, Lensch M, Perren A, Jakob SM, Parviainen I, Takala J. Dysphagia in mechanically ventilated ICU patients (DYnAMICS): a prospective observational trial. Crit Care Med. 2017;45:2061–9.
15. Eaton TL, Scheunemann LP, Butcher BW, Donovan HS, Alexander S, Iwashyna TJ. The prevalence of spiritual and social support needs and their association with postintensive care syndrome symptoms among critical illness survivors seen in a post-ICU follow-up clinic. Crit Care Explor. 2022;4:e0676.
16. Eltahan NH, Elsawy NH, Abdelaaty KM, Elhamaky AS, Hassan AH, Emara MM. Atorvastatin for reduction of 28-day mortality in severe and critical COVID-19 patients: a randomized controlled trial. Respir Res. 2024;25:97.
17. Hegazy SK, Tharwat S, Hassan AH. Clinical study to compare the efficacy and safety of casirivimab & imdevimab, remdesivir, and favipravir in hospitalized COVID-19 patients. J Clin Virol Plus. 2023;3:100151.
18. Hegazy SK, Tharwat S, Hassan AH. Comparing the efficacy of regencov, remdesivir, and favipiravir in reducing invasive mechanical ventilation need in hospitalized COVID-19 patients. World J Clin Cases. 2023;11:6105–21.
19. Hegazy SK, Tharwat S, Hassan AH. Study to compare the effect of casirivimab and imdevimab, remdesivir, and favipiravir on progression and multi-organ function of hospitalized COVID-19 patients. Open Med (Wars). 2023;18:20230768.
20. Metlay JP, Waterer GW, Long AC, Anzueto A, Brozek J, Crothers K, Cooley LA, Dean NC, Fine MJ, Flanders SA, Griffin MR, Metersky ML, Musher DM, Restrepo MI, Whitney CG. Diagnosis and treatment of adults with community-acquired pneumonia. An official clinical practice guideline of the American Thoracic Society and Infectious Diseases Society of America. Am J Respir Crit Care Med. 2019;200:e45–67.

21. Hiser SL, Fatima A, Ali M, Needham DM. Post-intensive care syndrome (PICS): recent updates. J Intensive Care. 2023;11:23.
22. Cozzi D, Albanesi M, Cavigli E, Moroni C, Bindi A, Luvarà S, Lucarini S, Busoni S, Mazzoni LN, Miele V. Chest X-ray in new Coronavirus Disease 2019 (COVID-19) infection: findings and correlation with clinical outcome. Radiol Med. 2020;125:730–7.
23. Saelim J, Kritsaneepaiboon S, Charoonratana V, Khantee P. Radiographic patterns and severity scoring of COVID-19 pneumonia in children: a retrospective study. BMC Med Imaging. 2023;23:199.
24. Zhang Z, Wang G, Wu Y, Guo J, Ding N, Jiang B, Wei H, Li B, Yue W, Tian J. Chinesisation, adaptation and validation of the Chelsea critical care physical assessment tool in critically ill patients: a cross-sectional observational study. BMJ Open. 2021;11:e045550.
25. Zhang C, Zhang H, Zhao M, Li Z, Cook CE, Buysse DJ, Zhao Y, Yao Y. Reliability, validity, and factor structure of Pittsburgh sleep quality index in community-based centenarians. Front Psychiatry. 2020;11:573530.
26. Emsden C, Schäfer UB, Denhaerynck K, Grossmann F, Frei IA, Kirsch M. Validating a pain assessment tool in heterogeneous ICU patients: Is it possible? Nurs Crit Care. 2020;25:8–15.
27. Detroyer E, Timmermans A, Segers D, Meyfroidt G, Dubois J, Van Assche A, Joosten E, Milisen K. Psychometric properties of the intensive care delirium screening checklist when used by bedside nurses in clinical practice: a prospective descriptive study. BMC Nurs. 2020;19:21.
28. Fernández-de-Las-Peñas C, Rodríguez-Jiménez J, Palacios-Ceña M, de la Llave-Rincón AI, Fuensalida-Novo S, Florencio LL, Ambite-Quesada S, Ortega-Santiago R, Arias-Buría JL, Liew BXW, Hernández-Barrera V, Cigarán-Méndez M. Psychometric properties of the hospital anxiety and depression scale (HADS) in previously hospitalized COVID-19 patients. Int J Environ Res Public Health. 2022;19:9273.
29. Skogstad L, Hem E, Sandvik L, Ekeberg Ø. The casualty chain inventory: a new scale for measuring peritraumatic responses: a cross-sectional study. BMC Emerg Med. 2011;11:6.
30. Jensen JF, Thomsen T, Overgaard D, Bestle MH, Christensen D, Egerod I. Impact of follow-up consultations for ICU survivors on post-ICU syndrome: a systematic review and meta-analysis. Intensive Care Med. 2015;41:763–75.
31. Baek MS, Kim JH, Lim Y, Kwon YS. Neuromuscular blockade in mechanically ventilated pneumonia patients with moderate to severe hypoxemia: a multicenter retrospective study. PLoS ONE. 2022;17:e0277503.
32. Zuercher P, Schenk NV, Moret C, Berger D, Abegglen R, Schefold JC. Risk factors for dysphagia in ICU patients after invasive mechanical ventilation. Chest. 2020;158:1983–91.
33. Zhou M, Zhang J, Xu Z, Gu H, Chen Z, Ding Y. Incidence of and risk factors for post-intensive care syndrome among Chinese respiratory intensive care unit patients: a cross-sectional, prospective study. Aust Crit Care. 2023;36:464–9.
34. Akinosoglou K, Schinas G, Almyroudi MP, Gogos C, Dimopoulos G. The impact of age on intensive care. Ageing Res Rev. 2023;84:101832.
35. Matsumura Y, Nakada TA, Abe R, Oshima T, Oda S. Serum procalcitonin level and SOFA score at discharge from the intensive care unit predict post-intensive care unit mortality: a prospective study. PLoS ONE. 2014;9:e114007.
36. Wen Y, Parikh CR. Current concepts and advances in biomarkers of acute kidney injury. Crit Rev Clin Lab Sci. 2021;58:354–68.
37. McNair ED, Bezaire J, Moser M, Mondal P, Conacher J, Franczak A, Sawicki G, Reid D, Khani-Hanjani A. The association of matrix metalloproteinases with acute kidney injury following CPB-supported cardiac surgery. Can J Kidney Health Dis. 2021;8:20543581211019640.
38. Haines KJ, Ferrante LE. Prediction of post-ICU impairments-is it possible? Crit Care Med. 2024;52:337–40.
39. Bottom-Tanzer SF, Poyant JO, Louzada MT, Abela D, Boudouvas A, Poon E, Power L, Kim WC, Hojman HM, Bugaev N, Johnson BP, Bawazeer MA, Mahoney EJ. Longitudinal study evaluating post-ICU syndrome differences between acute care surgery and trauma SICU survivors. J Trauma Acute Care Surg. 2023;95:893–8.
40. Ahmad MH, Teo SP. Post-intensive care syndrome. Ann Geriatr Med Res. 2021;25:72–8.
41. Svenningsen H, Langhorn L, Ågård AS, Dreyer P. Post-ICU symptoms, consequences, and follow-up: an integrative review. Nurs Crit Care. 2017;22:212–20.
42. Flaws D, Fraser JF, Laupland K, Lavana J, Patterson S, Tabah A, Tronstad O, Ramanan M. Time in ICU and post-intensive care syndrome: how long is long enough? Crit Care. 2024;28:34.
43. Haack M, Simpson N, Sethna N, Kaur S, Mullington J. Sleep deficiency and chronic pain: potential underlying mechanisms and clinical implications. Neuropsychopharmacology. 2020;45:205–16.
44. Dervan LA, Killien EY, Smith MB, Watson RS. Health-related quality of life following delirium in the PICU. Pediatr Crit Care Med. 2022;23:118–28.
45. Bramness JG, Heiberg IH, Høye A, Rossow I. Mortality and alcohol-related morbidity in patients with delirium tremens, alcohol withdrawal state or alcohol dependence in Norway: a register-based prospective cohort study. Addiction. 2023;118:2352–9.
46. Kim AT, Kim AW. Invited commentary: the association between tobacco use and postoperative delirium is not blowing smoke… or is it? World J Surg. 2022;46:1207–8.
47. Situ OO, Badejo OA, Gwaram UA. Predictive role of acute physiology and chronic health evaluation II (APACHE II) in patients with peritonitis at the National Hospital Abuja. Cureus. 2024;16:e58412.
48. Xiao K, Chen WX, Li XJ. Analysis of risk factors of prolonged mechanical ventilation in patients with severe burn injury. Clin Respir J. 2023;17:791–8.
49. Hamed M, Brandecker S, Rana S, Potthoff AL, Eichhorn L, Bode C, Schmeel FC, Radbruch A, Schäfer N, Herrlinger U, Köksal M, Giordano FA, Vatter H, Schneider M, Banat M. Postoperative prolonged mechanical ventilation correlates to poor survival in patients with surgically treated spinal metastasis. Front Oncol. 2022;12:940790.
50. Voiriot G, Oualha M, Pierre A, Salmon-Gandonnière C, Gaudet A, Jouan Y, Kallel H, Radermacher P, Vodovar D, Sarton B, Stiel L, Bréchot N, Préau S, Joffre J. Chronic critical illness and post-intensive care syndrome: from pathophysiology to clinical challenges. Ann Intensive Care. 2022;12:58.
51. Reyes-Torres CA, Flores-López A, Osuna-Padilla IA, Hernández-Cárdenas CM, Serralde-Zúñiga AE. Phase angle and overhydration are associated with post-extubating dysphagia in patients with COVID-19 discharged from the ICU. Nutr Clin Pract. 2022;37:110–6.
52. Haines KJ, Sevin CM, Hibbert E, Boehm LM, Aparanji K, Bakhru RN, Bastin AJ, Beesley SJ, Butcher BW, Drumright K, Eaton TL, Farley T, Firshman P, Fritschle A, Holdsworth C, Hope AA, Johnson A, Kenes MT, Khan BA, Kloos JA, Kross EK, MacLeod-Smith BJ, Mactavish P, Meyer J, Montgomery-Yates A, Quasim T, Saft HL, Slack A, Stollings J, Weinhouse G, Whitten J, Netzer G, Hopkins RO, Mikkelsen ME, Iwashyna TJ, McPeake J. Key mechanisms by which post-ICU activities can improve in-ICU care: results of the international THRIVE collaboratives. Intensive Care Med. 2019;45:939–47.
53. van Zanten ARH, De Waele E, Wischmeyer PE. Nutrition therapy and critical illness: practical guidance for the ICU, post-ICU, and long-term convalescence phases. Crit Care. 2019;23:368.

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