BRITISH JOURNAL OF HOSPITAL MEDICINE

ARTICLE

Multiple Organ Dysfunction Syndrome Associated With Pneumonia: A Retrospective Study With a Focus on Respiratory Failure

Jie Zhou[1], Shunjin Fang[1], Jianfeng Zhu[1], Yao Su[1], Huifei Zhou[1,*]

[1]Intensive Care Unit, Huzhou Third Municipal Hospital, The Affiliated Hospital of Huzhou University, Huzhou, Zhejiang, China

*Correspondence: zhouhuifei2024@126.com (Huifei Zhou)

Abstract

Aims/Background Pneumonia is a complex condition with rapid progression, often leading to multiple organ dysfunction syndrome (MODS), which significantly impacts patient quality of life and prognosis. This study aims to identify risk factors closely associated with the development of MODS by conducting a retrospective analysis of clinical data from 150 patients with pneumonia, providing insights for informing the prevention and treatment of pneumonia.

Methods We recruited 150 patients with pneumonia admitted to Huzhou Third Municipal Hospital, the Affiliated Hospital of Huzhou University between 2019 and 2022. The patients were divided into two groups according to whether they had developed MODS: the non-MODS group ($n = 100$) and the MODS group ($n = 50$). Patients' data, such as their demographic information, clinical characteristics, laboratory test results, treatment course and outcomes, were collected. Logistic regression analysis was conducted to determine the independent predictors of MODS occurrence.

Results After propensity score matching, the baseline data of the two groups of patients presented no significant difference ($p > 0.05$). The predominant clinical and laboratory manifestations of both groups of patients were fever, cough, decreased arterial partial pressure of oxygen (PaO_2), as well as elevated white blood cell (WBC) count, C-reactive protein (CRP) level, and procalcitonin (PCT) level, but inter-group differences in these metrics were not statistically significant ($p > 0.05$). However, the clinical manifestation of dyspnea was significantly more prevalent in the MODS group ($p < 0.01$). The MODS group also had a significantly higher likelihood of receiving mechanical ventilation and renal replacement therapy ($p < 0.001$), as well as experiencing respiratory failure, cardiac failure, and death ($p < 0.01$). Univariate analysis indicated that factors including age $\geq$65 years, WBC count $\geq 15 \times 10^9$/L, PCT $\geq$2 ng/mL, PaO_2 $\leq$60 mmHg, arterial partial pressure of carbon dioxide ($PaCO_2$) $\geq$50 mmHg, severe pneumonia, and dyspnea were associated with a significantly increased risk of MODS ($p < 0.05$). These factors, except for the PCT, were validated as independent risk factors for MODS in the multivariate logistic regression analysis ($p < 0.05$).

Conclusion Age $\geq$65 years, WBC count $\geq 15 \times 10^9$/L, PaO_2 $\leq$60 mmHg, $PaCO_2$ $\geq$50 mmHg, severe pneumonia, and dyspnea are independent risk factors for developing MODS in patients with pneumonia. Patients with MODS presenting respiratory failure as the main manifestation have a high mortality rate, and timely mechanical ventilation and supportive treatment are essential to improve the prognosis.

Key words: pneumonia; multiple organ failure; respiratory failure; prognosis

Submitted: 1 November 2024 Revised: 26 February 2025 Accepted: 23 March 2025

How to cite this article:
Zhou J, Fang S, Zhu J, Su Y, Zhou H. Multiple Organ Dysfunction Syndrome Associated With Pneumonia: A Retrospective Study With a Focus on Respiratory Failure. Br J Hosp Med. 2025. https://doi.org/10.12968/hmed.2024.0851

Introduction

Pneumonia, a common respiratory disease, has seen a rising incidence globally in recent years, posing one of the major challenges to global public health

(Eshwara et al, 2020). Pneumonia is characterized by the inflammation of the lung parenchyma caused by various pathogens, including bacteria, viruses, and fungi (Quinton et al, 2018), leading to symptoms such as respiratory distress, cough, and fever. Mild cases can resolve spontaneously, while severe cases can result in respiratory failure or even multiple organ dysfunction syndrome (MODS). MODS is a condition where patients without pre-existing organ dysfunction develop simultaneous or sequential dysfunction in two or more organs within 24 hours after acute insults such as severe trauma, infection, shock, major surgery, or acute poisoning (Srdić et al, 2024). Once MODS occurs, the condition often deteriorates rapidly, putting the patients at an extremely high risk for mortality, imposing a heavy psychological and economic burden on patients and their families, and presenting a significant challenge to healthcare resources (Zymliński et al, 2019). Respiratory failure is one of the most common manifestations of MODS and often appears as the initial symptom. The onset and progression of respiratory failure not only directly affect the patient's quality of life but also play a dominant role in the development of MODS (Tong et al, 2021). The respiratory system serves as the first line of defense against factors or agents from the external environment, which could impair lung function and trigger systemic reactions, subsequently affecting other organs (Asada et al, 2019). Furthermore, respiratory failure can lead to tissue hypoxia, further exacerbating organ damage and creating a vicious cycle (Monteiro et al, 2021). Therefore, a deeper understanding of the role of respiratory failure in MODS and its impact on patient outcomes is crucial for improving the survival rates of patients with MODS.

In recent years, with advancements in critical care medicine, our understanding of the pathophysiological mechanisms of MODS has been growing. However, effectively preventing and treating MODS, particularly when respiratory failure is the main manifestation, remains a significant challenge in clinical practice. Although numerous studies have reported on the clinical characteristics and therapeutic advancements of MODS (Acharya et al, 2022; Soni et al, 2022), research specifically focusing on the role of respiratory failure in MODS and its impact on prognosis remains relatively limited. Therefore, this study aims to conduct a retrospective analysis to investigate the clinical features, treatment strategies, and outcomes of patients with MODS primarily characterized by respiratory failure. The goal of this study is to provide a scientific basis for clinical diagnosis and treatment and to lay a foundation for future research.

Methods

Study Participants

A total of 150 patients with pneumonia who were hospitalized in Huzhou Third Municipal Hospital, the Affiliated Hospital of Huzhou University between September 2019 and April 2022 were selected. The inclusion criteria are as follows: (1) Confirmed diagnosis of pneumonia according to the diagnostic criteria for pneumonia (Cao et al, 2018); (2) Age >18 years; (3) Complete clinical data; and (4) Duration of hospital stay exceeding 24 hours. The exclusion criteria of the present

study are as follows: (1) Presence of congenital organ dysfunction; (2) Concurrent malignant tumors or other terminal-stage diseases; (3) Refusal to participate in the study. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Review Committee of Huzhou Third Municipal Hospital, the Affiliated Hospital of Huzhou University (No. 2024-636). Written informed consent was obtained from all patients for the use of clinical and laboratory data obtained from their medical records.

Propensity Score Matching

After screening for inclusion and exclusion criteria, 79 patients were assigned to the MODS group and 237 to the non-MODS group. To minimize confounding factors, propensity score matching was performed between the non-MODS group and the MODS group. Propensity score matching was performed using a nearest neighbor matching procedure with a 2:1 ratio, along with a caliper size of 0.02 for age, gender, history of alcoholism, history of smoking, and past medical history; the procedure was conducted without replacement. The detailed screening process for patients is shown in Fig. 1.

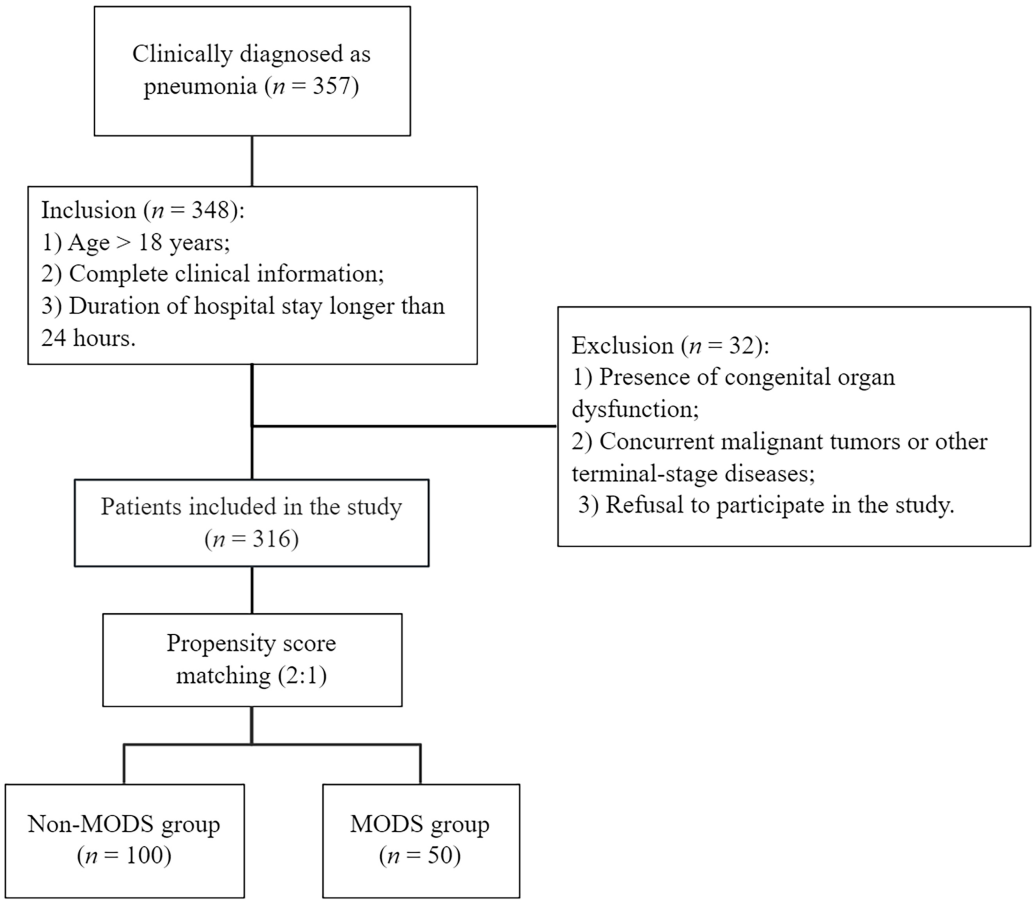

Fig. 1. Flow chart for patient inclusion. Note: *n* indicates the number of patients. Abbreviations: MODS, multiple organ dysfunction syndrome.

Table 1. MODS scores (Marshall criteria).

Organ system	Scores				
	0	1	2	3	4
Respiratory system (PaO_2/FiO_2)	>300	226–300	151–225	76–150	≤75
Kidney system (creatinine, μmol/L)	≤100	101–200	201–350	351–500	>500
Hepatic system (total bilirubin, μmol/L)	≤20	21–60	61–120	121–240	>240
Cardiovascular system (PAR = HR × CVP/MAP)	≤10.0	10.1–15.0	15.1–20.0	20.1–30.0	>30.0
Coagulation system (platelet count, 10^9/L)	>120	81–120	51–80	21–50	≤20
Neurologic system (Glasgow Coma Scale (Teasdale et al, 2014))	15	13–14	10–12	7–9	≤6

Abbreviations: CVP, central venous pressure; FiO_2, fraction of inspiration O_2; HR, heart rate; MAP, mean arterial pressure; MODS, multiple organ dysfunction syndrome; PaO_2, arterial partial pressure of oxygen; PAR, pulmonary artery pressure.

Diagnosis of Multiple Organ Dysfunction

According to the MODS criteria (Sun et al, 2021), patients were divided into the non-MODS group (n = 100) and the MODS group (n = 50). An organ score of ≥2 on the Marshall score was defined as organ failure. Transient organ failure was considered organ function recovered within 48 hours; otherwise, persistent organ failure was considered. The MODS scoring criteria are shown in Table 1.

Data Collection

Clinical information during hospitalization was collected from patient records, with follow-up ending at either the patient's death or 30 April 2022. The collected data included general clinical characteristics and demographic information, such as gender, age, past medical history, history of alcoholism, history of smoking and final outcomes of hospitalization. Clinical manifestations during the course of the disease included fever, cough and dyspnea. The confusion, urea, respiratory rate, blood pressure, age ≥65 (CURB-65) score (Lim et al, 2003) was used to assess the severity of dyspnea. The scale consists of five simple clinical criteria, each of which is scored as either 0 or 1. The total score ranges from 0 to 5, with higher scores indicating higher illness severity and mortality risk. Laboratory parameters, such as white blood cell (WBC) count, procalcitonin (PCT) and C-reactive protein (CRP), were measured using an automated biochemical analyzer (BC-7500[NR]CS; Mindray, Shenzhen, China). In interpretation, abnormality was considered when WBC was greater than 15 × 10^9/L, PCT greater than 2 ng/mL, and CRP greater than 100 mg/L. Respiratory failure detected in patients was determined as either of the two types: Type 1 respiratory failure is characterized by hypoxaemia with normal arterial partial pressure of carbon dioxide ($PaCO_2$) and an arterial partial pressure of oxygen (PaO_2) of <60 mmHg; type 2 respiratory failure is characterized by hypoxaemia with hypercapnia (PaO_2 <60 mmHg and $PaCO_2$ >50 mmHg). PaO_2 and $PaCO_2$ were measured using cobas b123 Blood Gas Analyzer (Roche, Basel, Switzerland). In the interpretation of the data obtained, PaO_2 of less than 60 mmHg or $PaCO_2$ of more than 50 mmHg was considered abnormal.

Table 2. Baseline data for non-MODS and MODS groups.

Variables	Before PSM					After PSM				
	Total (n = 316)	Non-MODS group (n = 237)	MODS group (n = 79)	t/χ^2	p	Total (n = 150)	Non-MODS group (n = 100)	MODS group (n = 50)	t/χ^2	p
Age, mean ± SD	65.91 ± 19.46	60.07 ± 18.99	77.60 ± 14.61	t = 7.49	<0.001	67.46 ± 13.58	64.38 ± 17.76	70.12 ± 14.87	t = 1.97	0.051
Gender, n (%)				χ^2 = 0.432	0.511				χ^2 = 0.00	1.000
Female	134 (42%)	98 (41%)	36 (46%)			60 (40%)	40 (40%)	20 (40%)		
Male	182 (58%)	139 (59%)	43 (54%)			90 (60%)	60 (60%)	30 (60%)		
History of alcoholism, n (%)				χ^2 = 5.73	0.017				χ^2 = 1.99	0.159
No	270 (85%)	209 (88%)	61 (77%)			118 (79%)	82 (82%)	36 (72%)		
Yes	46 (15%)	28 (12%)	18 (23%)			32 (21%)	18 (18%)	14 (28%)		
History of smoking, n (%)				χ^2 = 2.29	0.130				χ^2 = 2.08	0.149
No	183 (58%)	143 (60%)	40 (51%)			96 (64%)	68 (68%)	28 (56%)		
Yes	133 (42%)	94 (40%)	39 (49%)			54 (36%)	32 (32%)	22 (44%)		
Past medical history										
COPD, n (%)				χ^2 = 3.47	0.063				χ^2 = 3.45	0.063
No	211 (67%)	165 (70%)	46 (58%)			102 (68%)	73 (73%)	29 (58%)		
Yes	105 (33%)	72 (30%)	33 (42%)			48 (32%)	27 (27%)	21 (42%)		
Diabetes, n (%)				χ^2 = 2.91	0.088				χ^2 = 1.99	0.159
No	253 (80%)	195 (82%)	58 (73%)			118 (79%)	82 (82%)	36 (72%)		
Yes	63 (20%)	42 (18%)	21 (27%)			32 (21%)	18 (18%)	14 (28%)		
Hypertension, n (%)				χ^2 = 2.10	0.147				χ^2 = 1.93	0.165
No	275 (87%)	210 (89%)	65 (82%)			131 (87%)	90 (90%)	41 (82%)		
Yes	41 (13%)	27 (11%)	14 (18%)			19 (13%)	10 (10%)	9 (18%)		
Others, n (%)				χ^2 = 0.96	0.327				χ^2 = 0.41	0.521
No	292 (92%)	217 (92%)	75 (95%)			142 (95%)	96 (96%)	46 (92%)		
Yes	24 (8%)	20 (8%)	4 (5%)			8 (5%)	4 (4%)	4 (8%)		

Note: n indicates the number of patients. Abbreviations: COPD, chronic obstructive pulmonary disease; MODS, multiple organ dysfunction syndrome; PSM, propensity score matching; SD, standard deviation.

All patients received intravenous fluid resuscitation, nutritional support, and anti-inflammatory therapy. Patients with respiratory failure were treated with mechanical ventilation. Patients with gastrointestinal failure were given drugs to restore bowel motility. Patients with kidney failure were treated with continuous renal replacement therapy (CRRT).

Statistical Analysis

EpiData (version 3.1, EpiData Association, Odense, Denmark) was used for data recording, GraphPad Prism (version 9.0, GraphPad Software, San Diego, CA, USA) was used for generating charts, and SPSS (version 25.0, IBM, Armonk, NY, USA) was used for statistical analysis. The Shapiro-Wilk test was used to assess the normal distribution of data. Continuous variables, expressed as mean ± standard deviation, were compared between the two groups using *t*-test. Categorical variables, expressed as frequency and percentage, were compared using χ^2 test. Multivariate logistic regression analysis was used to determine independent predictors of MODS occurrence. $p < 0.05$ was considered statistically significant.

Results

Baseline Data Before and After Propensity Score Matching

Before propensity score matching, there were 237 patients in the non-MODS group and 79 patients in the MODS group, which presented significant differences in terms of age and alcohol history ($p < 0.05$). After propensity score matching with a 2:1 ratio, there were 100 patients in the non-MODS group and 50 patients in the MODS group, and the differences in the baseline data between the two groups were found to be insignificant. Detailed data are shown in Table 2.

Clinical Characteristics

In the MODS group, 46 patients had fever, with 35 having a body temperature ≥38.5 °C; in the non-MODS group, 86 patients had fever, with 64 having a body temperature ≥38.5 °C. There was no significant difference in the incidence of fever or the degree of temperature elevation between the two groups ($p > 0.05$). In the MODS group, 44 patients experienced cough and sputum production, with 28 producing purulent sputum; in the non-MODS group, 90 patients experienced cough and sputum production, with 52 producing purulent sputum. There was no significant difference in the incidence of cough and the nature of the sputum between the two groups ($p > 0.05$). With 37 and 46 patients in the MODS group and the non-MODS group experiencing dyspnea, the incidence of dyspnea between the two groups presented a significant difference ($p = 0.001$).

In the MODS group, 44 patients had elevated WBC counts; in the non-MODS group, 81 patients had elevated WBC counts. There was no significant difference in the proportion of patients with elevated WBC counts between the two groups ($p > 0.05$). In the MODS group, 43 patients had elevated CRP levels; in the non-MODS group, 88 patients had elevated CRP levels. There was no significant difference in the proportion of patients with elevated CRP levels between the two groups ($p > 0.05$). In the MODS group, 39 patients had elevated PCT levels; in the non-MODS

Table 3. Relationship between clinical characteristics and laboratory results with MODS.

Variables	Total (n = 150)	Non-MODS group (n = 100)	MODS group (n = 50)	χ^2	p
Fever, n (%)				$\chi^2 = 1.14$	0.286
No	18 (12%)	14 (14%)	4 (8%)		
Yes	132 (88%)	86 (86%)	46 (92%)		
Cough, n (%)				$\chi^2 = 0.14$	0.708
No	16 (11%)	10 (10%)	6 (12%)		
Yes	134 (89%)	90 (90%)	44 (88%)		
Dyspnea, n (%)				$\chi^2 = 10.57$	0.001
No	67 (45%)	54 (54%)	13 (26%)		
Yes	83 (55%)	46 (46%)	37 (74%)		
Elevated WBC count, n (%)				$\chi^2 = 1.18$	0.278
No	25 (17%)	19 (19%)	6 (12%)		
Yes	125 (83%)	81 (81%)	44 (88%)		
Elevated CRP, n (%)				$\chi^2 = 0.12$	0.728
No	19 (13%)	12 (12%)	7 (14%)		
Yes	131 (87%)	88 (88%)	43 (86%)		
Elevated PCT, n (%)				$\chi^2 = 2.29$	0.131
No	45 (30%)	34 (34%)	11 (22%)		
Yes	105 (70%)	66 (66%)	39 (78%)		
Decreased PaO_2, n (%)				$\chi^2 = 1.81$	0.178
No	50 (33%)	37 (37%)	13 (26%)		
Yes	100 (67%)	63 (63%)	37 (74%)		
Elevated $PaCO_2$, n (%)				$\chi^2 = 4.38$	0.036
No	66 (44%)	50 (50%)	16 (32%)		
Yes	84 (56%)	50 (50%)	34 (68%)		

Note: n indicates the number of patients. Abbreviations: CRP, C-reactive protein; MODS, multiple organ dysfunction syndrome; $PaCO_2$, arterial partial pressure of carbon dioxide; PaO_2, arterial partial pressure of oxygen; PCT, procalcitonin; WBC, white blood cell.

group, 66 patients had elevated PCT levels. There was no significant difference in the proportion of patients with elevated PCT levels between the two groups ($p > 0.05$). In the MODS group, 37 patients had decreased PaO_2; in the non-MODS group, 63 patients had decreased PaO_2. There was no significant difference in the proportion of patients with decreased PaO_2 between the two groups ($p > 0.05$). In the MODS group, 34 patients had increased $PaCO_2$; in the non-MODS group, 50 patients had increased $PaCO_2$. There was a significant difference in the proportion of patients with increased $PaCO_2$ between the two groups ($p < 0.05$). Detailed data are shown in Table 3.

Clinical Outcome

36 patients in the MODS group suffered respiratory failure, mainly manifested as hypoxemia, hypercapnia, *etc*. 26 patients in the non-MODS group suffered respiratory failure. There was a significant difference in the incidence of respiratory

Table 4. Comparison of clinical outcomes between MODS and non-MODS groups.

Variables	Total (n = 150)	Non-MODS group (n = 100)	MODS group (n = 50)	χ^2	p
Mechanical ventilation, n (%)				$\chi^2 = 29.34$	<0.001
No	101 (67%)	82 (82%)	19 (38%)		
Yes	49 (33%)	18 (18%)	31 (62%)		
Respiratory failure, n (%)				$\chi^2 = 29.09$	<0.001
No	88 (59%)	74 (74%)	14 (28%)		
Yes	62 (41%)	26 (26%)	36 (72%)		
CRRT, n (%)				$\chi^2 = 13.96$	<0.001
No	130 (87%)	94 (94%)	36 (72%)		
Yes	20 (13%)	6 (6%)	14 (28%)		
Cardiac failure, n (%)				$\chi^2 = 9.57$	0.002
No	144 (96%)	100 (100%)	44 (88%)		
Yes	6 (4%)	0 (0%)	6 (12%)		
Deaths, n (%)				$\chi^2 = 29.68$	<0.001
No	127 (85%)	96 (96%)	31 (62%)		
Yes	23 (15%)	4 (4%)	19 (38%)		

Note: n indicates the number of patients. Abbreviations: CRRT, continuous renal replacement therapy; MODS, multiple organ dysfunction syndrome.

failure between the two groups ($p < 0.001$). Our results showed that significantly more patients were treated with mechanical ventilation and CRRT in the MODS group than in the non-MODS group, and the number of hospital deaths was also significantly higher than in the non-MODS group ($p < 0.001$). Detailed data are shown in Table 4.

Risk Factor Analysis

The results of univariate analysis showed that age ≥65 years, WBC count ≥15 × 10^9/L, PCT ≥2 ng/mL, PaO_2 ≤60 mmHg, $PaCO_2$ ≥50 mmHg, severe pneumonia, and dyspnea were related to the occurrence of MODS in patients with pneumonia ($p < 0.05$), as shown in Table 5.

Statistically significant indicators in the univariate analysis were included in the multivariate logistic regression analyses, and the results showed that age ≥65 years, WBC count ≥15 × 10^9/L, PaO_2 ≤60 mmHg, $PaCO_2$ ≥50 mmHg, severe pneumonia, and dyspnea were the independent risk factors for the development of MODS in patients with pneumonia ($p < 0.05$). Detailed data are shown in Table 6.

Discussion

In the current study, we analyzed the risk factors for the development of MODS in patients with pneumonia. Age ≥65 years was identified as one of the independent risk factors for MODS in pneumonia patients. Individuals of older age are susceptible to gradual decline of organ function, weakened immunity, and reduced tolerance to disease (Cillóniz et al, 2020; Henig and Kaye, 2017). Elderly patients are

Table 5. Univariate logistic regression analysis for pneumonia-induced MODS.

Variables	β	SE	Z	p	OR (95% CI)
Age ≥65 years					
No					1.00 (Reference)
Yes	1.63	0.41	4.00	<0.001	5.09 (2.29–11.30)
History of alcoholism					
No					1.00 (Reference)
Yes	0.66	0.37	1.77	0.077	1.94 (0.93–4.04)
Severe pneumonia					
No					1.00 (Reference)
Yes	2.07	0.40	5.11	<0.001	7.89 (3.57–17.42)
WBC count ≥15 × 10^9/L					
No					1.00 (Reference)
Yes	0.82	0.31	2.65	0.008	2.27(1.24–4.17)
CRP ≥100 mg/L					
No					1.00 (Reference)
Yes	0.30	0.36	0.83	0.407	1.35 (0.66–2.74)
PCT ≥2 ng/mL					
No					1.00 (Reference)
Yes	0.69	0.35	1.97	0.048	1.99 (1.00–3.96)
PaO_2 ≤60 mmHg					
No					1.00 (Reference)
Yes	0.98	0.36	2.74	0.006	2.66 (1.32–5.36)
$PaCO_2$ ≥50 mmHg					
No					1.00 (Reference)
Yes	1.90	0.39	4.82	<0.001	6.68 (3.08–14.48)
Dyspnea					
No					1.00 (Reference)
Yes	1.80	0.42	4.28	<0.001	6.04 (2.65–13.75)

Abbreviations: CRP, C-reactive protein; MODS, multiple organ dysfunction syndrome; $PaCO_2$, arterial partial pressure of carbon dioxide; PaO_2, arterial partial pressure of oxygen; PCT, procalcitonin; WBC, white blood cell; SE, standard error; OR, odds ratio; CI, confidence interval.

more likely to develop underlying diseases such as chronic obstructive pulmonary disease (COPD), diabetes, and hypertension. These underlying diseases augment the severity of pneumonia and the risk of complications, thereby contributing to the development of MODS (Kouhpayeh, 2022; Yoshimatsu et al, 2024).

In this study, we found that patients with severe pneumonia were more likely to develop MODS. Severe pneumonia typically presents with symptoms such as high fever, cough, sputum production, and dyspnea, and can rapidly progress to serious complications such as respiratory failure, shock, and multi-organ dysfunction (Feng et al, 2023). The severity of pneumonia is influenced by factors such as the virulence of the pathogen, the extent of infection, and the patient's immune status (Haessler et al, 2022). Iwasaki et al (2021) found that the incidence of respiratory failure in coronavirus disease-19 patients was 81–100%, which is highly correlated

Table 6. Multivariate logistic regression analysis for pneumonia-induced MODS.

Variables	β	SE	Z	p	OR (95% CI)
Intercept	–15.12	3.12	–4.85	<0.001	0.00 (Reference)
Age ≥65 years					
No					1.00 (Reference)
Yes	2.96	0.90	3.29	0.001	19.22 (3.30–111.77)
Severe pneumonia					
No					1.00 (Reference)
Yes	4.06	0.92	4.41	<0.001	57.82 (9.54–350.54)
WBC count ≥15 × 10^9/L					
No					1.00 (Reference)
Yes	2.38	0.92	2.60	0.009	10.76 (1.79–64.65)
CRP ≥100 mg/L					
No					1.00 (Reference)
Yes	1.08	0.82	1.33	0.185	2.95 (0.60–14.66)
PCT ≥2 ng/mL					
No					1.00 (Reference)
Yes	0.8	0.73	1.09	0.277	2.22 (0.53–9.31)
PaO_2 ≤60 mmHg					
No					1.00 (Reference)
Yes	2.06	0.76	2.72	0.006	7.88 (1.78–34.82)
$PaCO_2$ ≥50 mmHg					
No					1.00 (Reference)
Yes	3.91	0.94	4.16	<0.001	49.91 (7.90–315.12)
Dyspnea					
No					1.00 (Reference)
Yes	3.82	1.07	3.58	<0.001	45.71 (5.63–371.31)

Abbreviations: CRP, C-reactive protein; MODS, multiple organ dysfunction syndrome; $PaCO_2$, arterial partial pressure of carbon dioxide; PaO_2, arterial partial pressure of oxygen; PCT, procalcitonin; WBC, white blood cell.

with mortality. Early identification of patients with severe pneumonia and timely implementation of effective treatment measures are crucial for preventing the development of MODS. Dyspnea is a common clinical manifestation in pneumonia patients and is also one of the important risk factors for MODS. Dyspnea can result from factors such as pulmonary inflammation, pulmonary edema, and atelectasis, significantly impacting respiratory function and oxygenation (Grewal et al, 2023). Patients with dyspnea are more likely to develop respiratory failure, which can lead to dysfunction in other organs. Therefore, it is essential to promptly assess and manage dyspnea in pneumonia patients to prevent the onset of MODS.

Elevations in inflammatory markers such as WBC count, CRP, and PCT indicate the presence of an inflammatory response in pneumonia patients, suggesting a more severe infection (Gallo Marin et al, 2021). Blood gas analysis showing decreased PaO_2 (Ullah et al, 2022) and increased $PaCO_2$ indicates respiratory dysfunction, and abnormalities in these indicators are closely associated with the devel-

opment of MODS. According to Cui et al's study (2021), the occurrence of MODS is frequently linked to underlying diseases; in terms of laboratory indicators, low absolute lymphocyte count, elevated troponin T, and low oxygenation index are risk factors for multi-organ failure. In clinical practice, these laboratory parameters should be closely monitored to allow for prompt detection and management of any abnormalities, which is critical for reducing the risk of MODS.

Several limitations of this study should be acknowledged. First, due to its retrospective nature, the study relies on medical records and existing clinical data, which may be incomplete or inaccurate. Recall bias and selection bias are also difficult to completely avoid, potentially affecting the accuracy of the study results. Second, this study used a relatively small sample size, which may affect the stability and reliability of the statistical results. Using a smaller sample is not beneficial for full generalizability of the study findings to the broader population of patients with pneumonia and may miss some less common but important risk factors. Future research should focus on large-scale, multicenter studies to further investigate the pathogenesis of MODS and respiratory failure caused by pneumonia, providing more effective strategies for clinical treatment.

Conclusion

Age $\geq$65 years, WBC count $\geq 15 \times 10^9$/L, PaO_2 $\leq$60 mmHg, $PaCO_2$ $\geq$50 mmHg, severe pneumonia, and dyspnea are potential independent risk factors for pneumonia-induced MODS. These risk factors should be given higher emphasis during patient screening. In addition, early monitoring and intervention for high-risk patients should be conducted to reduce the incidence of MODS and improve the prognosis of patients.

Key Points

- Patients with MODS are more likely than non-MODS patients to develop dyspnea.
- Patients with MODS have a higher mortality rate than patients without MODS.
- Compared to dysfunctions of other organs, there is a higher likelihood of respiratory failure occurrence in patients with pneumonia-induced MODS.
- Age $\geq$65 years, WBC count $\geq 15 \times 10^9$/L, PaO_2 $\leq$60 mmHg, $PaCO_2$ $\geq$50 mmHg, severe pneumonia, and dyspnea are potential independent risk factors for MODS development.

Availability of Data and Materials

The data used to support the findings of this study are available from the corresponding author upon request.

Author Contributions

JZ and HFZ designed the research study and wrote the first draft. SJF and JFZ performed the research. YS analyzed the data. All authors contributed to revising the manuscript critically for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Review Committee of Huzhou Third Municipal Hospital, the Affiliated Hospital of Huzhou University (No. 2024-636) and strictly adheres to the Declaration of Helsinki. The patients themselves included in the study signed the informed consent form.

Acknowledgement

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

References

Acharya M, Berger R, Popov AF. The role of the ADVanced Organ Support (ADVOS) system in critically ill patients with multiple organ failure. Artificial Organs. 2022; 46: 735–746. https://doi.org/10.1111/aor.14188

Asada T, Doi K, Inokuchi R, Hayase N, Yamamoto M, Morimura N. Organ system network analysis and biological stability in critically ill patients. Critical Care. 2019; 23: 83. https://doi.org/10.1186/s13054-019-2376-y

Cao B, Huang Y, She DY, Cheng QJ, Fan H, Tian XL, et al. Diagnosis and treatment of community-acquired pneumonia in adults: 2016 clinical practice guidelines by the Chinese Thoracic Society, Chinese Medical Association. The Clinical Respiratory Journal. 2018; 12: 1320–1360. https://doi.org/10.1111/crj.12674

Cillóniz C, Dominedò C, Pericàs JM, Rodriguez-Hurtado D, Torres A. Community-acquired pneumonia in critically ill very old patients: a growing problem. European Respiratory Review. 2020; 29: 190126. https://doi.org/10.1183/16000617.0126-2019

Cui J, Yuan B, Li Y, Li Z, Yuan Y. The clinical characters and prognosis of COVID-19 patients with multiple organ dysfunction. Medicine. 2021; 100: e27400. https://doi.org/10.1097/MD.0000000000027400

Eshwara VK, Mukhopadhyay C, Rello J. Community-acquired bacterial pneumonia in adults: An update. The Indian Journal of Medical Research. 2020; 151: 287–302. https://doi.org/10.4103/ijmr.IJMR_1678_19

Feng S, Wang F, Wu W, Li Y, Chen C, Li J, et al. Analysis of multiple organ function damage in patients with severe COVID-19 pneumonia. Journal of Medical Biochemistry. 2023; 42: 444–453. https://doi.org/10.5937/jomb0-41502

Gallo Marin B, Aghagoli G, Lavine K, Yang L, Siff EJ, Chiang SS, et al. Predictors of COVID-19 severity: A literature review. Reviews in Medical Virology. 2021; 31: 1–10. https://doi.org/10.1002/rmv.2146

Grewal JS, Carlsten C, Johnston JC, Shah AS, Wong AW, Ryerson CJ. Post-COVID dyspnea: prevalence, predictors, and outcomes in a longitudinal, prospective cohort. BMC Pulmonary Medicine. 2023; 23: 84. https://doi.org/10.1186/s12890-023-02376-w

Haessler S, Guo N, Deshpande A, Zilberberg MD, Lagu T, Lindenauer PK, et al. Etiology, Treatments, and Outcomes of Patients With Severe Community-Acquired Pneumonia in a Large U.S. Sample. Critical Care Medicine. 2022; 50: 1063–1071. https://doi.org/10.1097/CCM.0000000000005498

Henig O, Kaye KS. Bacterial Pneumonia in Older Adults. Infectious Disease Clinics of North America. 2017; 31: 689–713. https://doi.org/10.1016/j.idc.2017.07.015

Iwasaki M, Saito J, Zhao H, Sakamoto A, Hirota K, Ma D. Inflammation Triggered by SARS-CoV-2 and ACE2 Augment Drives Multiple Organ Failure of Severe COVID-19: Molecular Mechanisms and Implications. Inflammation. 2021; 44: 13–34. https://doi.org/10.1007/s10753-020-01337-3

Kouhpayeh H. Clinical features predicting COVID-19 mortality risk. European Journal of Translational Myology. 2022; 32: 10268. https://doi.org/10.4081/ejtm.2022.10268

Lim WS, van der Eerden MM, Laing R, Boersma WG, Karalus N, Town GI, et al. Defining community acquired pneumonia severity on presentation to hospital: an international derivation and validation study. Thorax. 2003; 58: 377–382. https://doi.org/10.1136/thorax.58.5.377

Monteiro ACC, Flori H, Dahmer MK, Sim MS, Quasney MW, Curley MAQ, et al. Thrombomodulin is associated with increased mortality and organ failure in mechanically ventilated children with acute respiratory failure: biomarker analysis from a multicenter randomized controlled trial. Critical Care. 2021; 25: 271. https://doi.org/10.1186/s13054-021-03626-1

Quinton LJ, Walkey AJ, Mizgerd JP. Integrative Physiology of Pneumonia. Physiological Reviews. 2018; 98: 1417–1464. https://doi.org/10.1152/physrev.00032.2017

Soni S, Martens MD, Takahara S, Silver HL, Maayah ZH, Ussher JR, et al. Exogenous ketone ester administration attenuates systemic inflammation and reduces organ damage in a lipopolysaccharide model of sepsis. Biochimica et Biophysica Acta (BBA) - Molecular Basis of Disease. 2022; 1868: 166507. https://doi.org/10.1016/j.bbadis.2022.166507

Srdić T, Đurašević S, Lakić I, Ružičić A, Vujović P, Jevđović T, et al. From Molecular Mechanisms to Clinical Therapy: Understanding Sepsis-Induced Multiple Organ Dysfunction. International Journal of Molecular Sciences. 2024; 25: 7770. https://doi.org/10.3390/ijms25147770

Sun GD, Zhang Y, Mo SS, Zhao MY. Multiple Organ Dysfunction Syndrome Caused by Sepsis: Risk Factor Analysis. International Journal of General Medicine. 2021; 14: 7159–7164. https://doi.org/10.2147/IJGM.S328419

Teasdale G, Maas A, Lecky F, Manley G, Stocchetti N, Murray G. The Glasgow Coma Scale at 40 years: standing the test of time. The Lancet. Neurology. 2014; 13: 844–854. https://doi.org/10.1016/S1474-4422(14)70120-6

Tong A, Baumgart A, Evangelidis N, Viecelli AK, Carter SA, Azevedo LC, et al. Core Outcome Measures for Trials in People With Coronavirus Disease 2019: Respiratory Failure, Multiorgan Failure, Shortness of Breath, and Recovery. Critical Care Medicine. 2021; 49: 503–516. https://doi.org/10.1097/CCM.0000000000004817

Ullah AR, Masood A, Amin S, Ali I. Predictive factors and outcomes of severe community acquired pneumonia in patients with respiratory failure. Pakistan Journal of Medical Sciences. 2022; 38: 1031–1037. https://doi.org/10.12669/pjms.38.4.5312

Yoshimatsu Y, Thomas H, Thompson T, Smithard DG. Prognostic factors of poor outcomes in pneumonia in older adults: aspiration or frailty? European Geriatric Medicine. 2024; 15: 481–488. https://doi.org/10.1007/s41999-023-00929-0

Zymliński R, Sokolski M, Biegus J, Siwołowski P, Nawrocka-Millward S, Sokolska JM, et al. Multi-organ dysfunction/injury on admission identifies acute heart failure patients at high risk of poor outcome. European Journal of Heart Failure. 2019; 21: 744–750. https://doi.org/10.1002/ejhf.1378