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ORIGINAL RESEARCH

Impact of Underlying Malignancy Status on Clinical Characteristics and Mortality in Pulmonary Mucormycosis: A Retrospective Cohort Study

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Background: Pulmonary mucormycosis is a life-threatening fungal infection that primarily affects immunocompromised individuals. Underlying malignancy is a recognized risk factor for pulmonary mucormycosis, yet its independent effect on patient outcomes remains uncertain. This study aimed to evaluate the impact of underlying malignancy on the clinical characteristics and 30-day mortality of pulmonary mucormycosis.

Methods: We conducted a retrospective cohort study of 163 adults with proven or probable pulmonary mucormycosis at a single center in Taiwan (2021–2024). Clinical and laboratory variables were compared between groups. Predictors of 30-day all-cause mortality were assessed using Cox proportional hazards regression with purposeful variable selection, and proportional-hazards assumptions were verified using Schoenfeld residuals.

Results: The overall 30-day mortality rate was 18.4% (30 of 163 patients). Kaplan–Meier analysis confirmed lower 30-day survival in malignancy patients (log-rank $\chi^2 = 27.08$, $df = 1$, $p < 0.0001$). In multivariable analysis, malignancy (aHR 3.65, 95% CI 1.40–9.53), neutrophil-to-lymphocyte ratio per 5 units (aHR 1.10, 95% CI 1.05–1.22), and alkaline phosphatase per 50 U/L (aHR 1.16, 95% CI 1.00–1.64) were independent predictors of early death. Clinically, patients with malignancy predominantly exhibited a cytopenic–immunosuppressed phenotype, whereas those without malignancy more frequently exhibited a metabolic–inflammatory profile characterized by chronic kidney disease or recent COVID-19.

Conclusion: Underlying malignancy independently triples 30-day mortality in pulmonary mucormycosis. Easily available laboratory markers—neutrophil-to-lymphocyte ratio and alkaline phosphatase—also stratify early risk, underscoring the need for phenotype-tailored and timely antifungal management strategies.

Keywords: pulmonary mucormycosis, mortality, opportunistic fungal infection, immunocompromised host, cancer

Introduction

Pulmonary mucormycosis (PM) is an infrequent yet fulminant opportunistic infection caused by filamentous fungi of the order Mucorales. The main causative agents of pulmonary mucormycosis are *Rhizopus, Lichtheimia*, and *Mucor* species. Despite advances in antifungal therapy and supportive care, PM persists as one of the most lethal invasive mycoses, with reported all-cause mortality rates ranging from 40% to 70% in contemporary cohorts.[1–3]

Over the past decade, the global incidence of mucormycosis has risen in parallel with the growing population of immunocompromised hosts.[4,5] Key predisposing conditions include uncontrolled diabetes mellitus,[6] prolonged corticosteroid[7] or immunosuppressant therapy, severe COVID-19,[7,8] post-transplant,[9] and hematological or solid organ malignancies.[10–12]

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Although early diagnosis and the use of lipid-formulation amphotericin B have lowered reported mortality from 56–76%[13,14] historically to approximately 29–38% in more recent series,[3] outcomes remain poor in specific subgroups.

Cancer patients constitute one such vulnerable population. Single-center studies and regional registries consistently demonstrate that hematological malignancy confers both a higher incidence of PM and a markedly worse prognosis, with 90-day mortality rates between 40% and 70%.[2,15,16] Nevertheless, the true extent of the risk attributable to malignancy is challenging to ascertain because most existing studies either focus exclusively on cancer populations or include heterogeneous cohorts without adequately adjusting for confounding factors. Accordingly, it remains uncertain whether malignancy itself has an independent effect on mortality or merely reflects the severity of underlying immunosuppression.

Building on prior evidence that malignancy confers a high early mortality rate in PM,[12] we aimed to elucidate whether underlying malignancy independently diminishes short-term survival and to identify clinical factors associated with poor outcomes. By comparing the clinical and laboratory characteristics of patients with and without malignancy, this study sought to clarify disease heterogeneity and highlight potential targets for earlier recognition and tailored management of this high-risk population.

Methods

Study Design and Setting

We conducted a single-center, retrospective cohort study at a medical center in central Taiwan. All adults (≥ 18 years) who were diagnosed with proven or probable pulmonary mucormycosis who were hospitalized between June 2021 and July 2024 were screened for inclusion.

Inclusion criteria comprised (1) adults aged ≥18 years and (2) a diagnosis of PM established through histopathologic evidence, positive culture, or compatible clinical and radiologic findings consistent with the 2019 Global Guideline for the Diagnosis and Management of Mucormycosis by the European Confederation of Medical Mycology (ECMM) and the Mycoses Study Group Education and Research Consortium (MSGERC).[14]

Exclusion criteria were (1) patients with non-pulmonary mucormycosis, (2) those without adequate clinical or microbiological evidence, and (3) incomplete medical records.

About definition of malignancy, active malignancy was defined as the presence of a hematologic or solid organ cancer that was histologically or cytologically confirmed, radiologically evident, or documented by the treating oncologist within the preceding 6 months. Patients receiving active chemotherapy, radiotherapy, targeted therapy, or immunotherapy at the time of diagnosis were also classified as having active malignancy. In contrast, patients with a remote history of malignancy in remission and not under current treatment were categorized as non-malignant.

Ethical approval for this study was obtained from the Institutional Review Board of Taichung Veterans General Hospital (IRB No. CF24552A, approved on [December 20, 2024]). Given the retrospective design and use of anonymized data, the IRB granted a waiver of informed consent. The study adhered to the principles of the Declaration of Helsinki.

Data Collection

Demographics, comorbidities, cancer type and stage, immunosuppressive therapies (including corticosteroid dosage, chemotherapy, and biologics), laboratory values obtained within 48 hours of diagnosis, antifungal treatments administered, admission to intensive care units, and vital status were systematically extracted from the electronic medical record.

Operational Definitions

Key clinical variables were established based on standard criteria. Acute kidney injury (AKI) was characterized according to the Kidney Disease: Improving Global Outcomes (KDIGO) guidelines.[17] Leukocytosis was defined as a white blood cell count greater than 10×10^9/L, and leukopenia as less than 4×10^9/L.[18] Anemia was defined as hemoglobin levels below 13 g/dL in men or below 12 g/dL in women, in accordance with the criteria established by the World Health Organization (WHO).[19] Thrombocytopenia was defined as a platelet count less than 100×10^9/L.[20] Cytopenia was considered present when any of the following thresholds were met: leukocyte count less than 4,000/μL, hemoglobin less than 12 g/dL, or platelet count less than 150×10^9/L. The neutrophil-to-lymphocyte ratio (NLR) was calculated as absolute neutrophil count divided by absolute lymphocyte count.[21] Definitions of other laboratory and comorbid variables are consistent with those summarized in Supplementary Table S1.

Specimen Collection and Diagnostic Procedures

Respiratory specimens, including bronchoalveolar lavage (BAL) fluid and sputum, were collected for molecular detection of Mucorales. DNA was extracted using the EZ2 Connect instrument (QIAGEN, Germany) with the EZ1 Virus Mini Kit v2.0 (QIAGEN, Germany), in accordance with the assay's validated workflow for respiratory samples. The presence of *Mucorales* DNA was detected using the *MucorGenius*® real-time PCR assay (PathoNostics, Netherlands) following the manufacturer's instructions. No conventional fungal culture or histopathologic examination was included, as molecular testing constituted the sole diagnostic method for pulmonary mucormycosis in this study.

Outcomes

The primary endpoint was 30-day all-cause mortality, measured from the index date, defined as the date of specimen collection. Secondary endpoints encompassed intensive care unit (ICU) admission and the duration of hospitalization.

Statistical Analysis

All analyses were performed using IBM SPSS Statistics (version 30). Continuous variables were evaluated for normality using the Shapiro–Wilk test and are presented as mean ± standard deviation. Categorical variables are expressed as frequencies and percentages. Comparative analyses between groups were conducted using the Student's *t*-test, χ^2-test, or Fisher's exact test, as deemed appropriate. The primary endpoint was the 30-day all-cause mortality rate.Survival probabilities were estimated using the Kaplan–Meier method, and differences between groups were compared using the Log rank test.

Univariable associations with 30-day mortality were assessed using Cox proportional hazards models, and variables with $p < 0.10$ or strong clinical plausibility were considered for multivariable modeling. A stepwise backward elimination strategy was applied, with model fit evaluated by the Akaike Information Criterion (AIC). The proportional-hazards assumption was checked using Schoenfeld residuals. For interpretability, continuous predictors were scaled to clinically meaningful increments (eg, alkaline phosphatase per 50 U/L, neutrophil-to-lymphocyte ratio per 5 units).

Missing data were managed through complete-case analysis (listwise deletion), with no imputation applied. All statistical tests conducted were two-sided, and p value less than 0.05 was regarded as indicative of statistical significance.

Results

Baseline Characteristics

During the study period, 163 patients fulfilled the diagnostic criteria for PM, as illustrated in Figure 1. Among them, 74 (45.4%) had underlying malignancies (malignancy group) and 89 (54.6%) did not (non-malignancy group). Baseline demographic and clinical characteristics are summarized in Table 1, with additional details provided in Supplementary Table S2.

As shown Table 1, compared with patients without malignancy, those with malignancy were more likely to have hematologic disorders and to receive immunosuppressive therapy (66.2% vs 31.5%, $p < 0.001$) but less likely to have chronic kidney disease (10.8% vs 37.1%, $p < 0.001$). Autoimmune disease (5.4% vs 22.5%, $p = 0.002$) and recent Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection (29.7% vs 60.7%, $p < 0.001$) were also less frequent among patients with malignancy. Laboratory data showed that the malignancy group had lower blood urea nitrogen (26.09 ± 21.58 vs 38.33 ± 28.88 mg/dL, $p = 0.003$) and serum creatinine (1.26 ± 1.08 vs 2.30 ± 2.31 mg/dL, $p < 0.001$), but more frequent thrombocytopenia (62.6% vs 30.3%, $p < 0.001$). The two groups were otherwise comparable in age (65.08 ± 13.07 vs 68.76 ± 13.43 years, $p = 0.08$) and sex distribution (male 63.5% vs 53.9%, $p = 0.27$).

Additional laboratory details are provided in Supplementary Table S2. Patients with malignancy exhibited lower lymphocyte percentages (18.30 ± 16.83 vs 12.01 ± 8.85%, $p = 0.003$) and higher neutrophil fractions (68.56 ± 25.17 vs 80.71 ± 11.22%, $p < 0.001$) compared with those without malignancy. No significant differences were observed in inflammatory markers such as C-reactive protein, procalcitonin, or hemoglobin A1c (HbA1c) between the two groups.

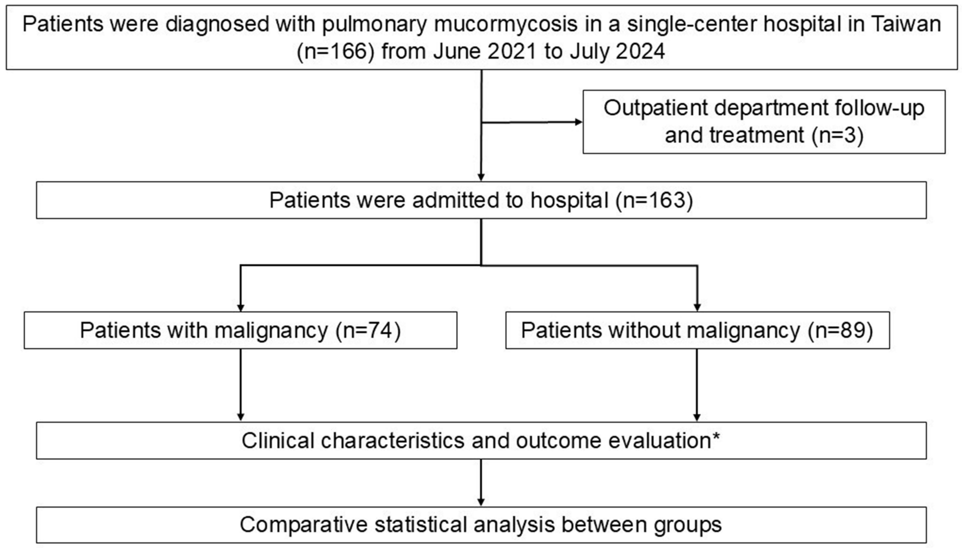

Figure 1 Patient enrollment and study design. A total of 163 patients met the diagnostic criteria for pulmonary mucormycosis (PM), including 74 with underlying malignancy and 89 without malignancy. Patients were categorized into two groups for comparative analysis.
Notes: *Clinical characteristics and outcome evaluation were conducted 30 days after specimen collection, including 30-day mortality, ICU admission status, and length of hospitalization.

Cancer and Treatment Characteristics

Among patients with malignancy, hematologic cancers were the predominant type (56.7%), followed by solid tumors (43.3%). Most patients with malignancies had recently received chemotherapy (69.2%) or corticosteroid therapy (19.2%), while a smaller subset had been treated with biologic or targeted agents (21.1%). The majority of malignancies were in an advanced or active stage at the time of pulmonary mucormycosis diagnosis.

Table 1 Baseline Demographic and Clinical Characteristics of Patients with Pulmonary Mucormycosis, Stratified by Malignancy Status

	All Patients (n=163)	Malignancy (n=74)	Non-malignancy (n=89)	p value[a]
Patient characteristics				
Age — yr	67.09±13.36	65.08±13.07	68.76±13.43	0.08
Sex — no.(%)				0.265
Male	95(58.3%)	47(63.5%)	48(53.9%)	
Female	68(41.7%)	27(36.5%)	41(46.1%)	
Coexisting conditions— no.(%)				
Autoimmune disease	24(14.7%)	4(5.4%)	20(22.5%)	0.002
Coronary artery disease	20(12.3%)	5(6.8%)	15(16.9%)	0.050
Recent SARS-CoV-2 infection[b]	76(46.6%)	22(29.7%)	54(60.7%)	<0.001
Cerebrovascular accident	20(12.3%)	6(8.1%)	14(15.7%)	0.140
Type 2 diabetes mellitus	66(40.5%)	29(39.2%)	37(41.6%)	0.758
Heart failure	20(12.3%)	5(6.8%)	15(16.9%)	0.05

(*Continued*)

Table 1 (Continued).

	All Patients (n=163)	Malignancy (n=74)	Non-malignancy (n=89)	p value[a]
HIV infection	1(0.6%)	0(0%)	1(1.1%)	–[c]
Immunosuppressant use	77(47.2%)	49(66.2%)	28(31.5%)	<0.001
Chronic liver disease	8(4.9%)	7(9.5%)	1(1.1%)	0.017[c]
Chronic kidney disease	41(25.2%)	8(10.8%)	33(37.1%)	<0.001
Chronic lung disease	35(21.5%)	14(18.9%)	21(23.6%)	0.469
Post-transplant status	14(8.6%)	7(9.5%)	7(7.9%)	0.718
Clinical Characteristics				
Clinical condition— no.(%)				
Acute kidney injury	61(37.4%)	22(29.7%)	39(43.8%)	0.064
Antifungal therapy received	45(27.6%)	28(37.8%)	17(19.1%)	0.008
Laboratory value[d]				
Leukocytosis/Leukopenia	81(49.7%)	40(54.1%)	41(46.1%)	0.310
Anemia	132(81%)	64(86.5%)	68(76.4%)	0.102
Thrombocytopenia	73(44.8%)	46(62.6%)	27(30.3%)	< 0.001
Neutrophil-to-lymphocyte ratio	12.07±15.03	10.93±16.37	13.01±13.88	0.381
Blood urea nitrogen (mg/dL)	32.77±26.46	26.09±21.58	38.33±28.88	0.003
Serum creatinine (mg/dL)	1.83±1.92	1.26±1.08	2.30±2.31	<0.001
C-reactive protein (mg/dL)	9.86±8.5	10.31±16.37	9.49±8.57	0.548
Procalcitonin (ng/mL)	3.45±10.74	2.79±8.94	4.05±12.18	0.529

Notes: Values are expressed as mean ± standard deviation or n (%), unless otherwise indicated. (a) P values for continuous variables were calculated using independent-samples t tests, while those for categorical variables were determined with the χ^2-test; all p values denote comparisons between the malignancy and non-malignancy groups. (b) Recent SARS-CoV-2 infection was defined as diagnosed in the recent 6 months when PM is diagnosed. (c) Fisher's Exact Test was employed as an alternative to the Chi-square test owing to small sample sizes and expected cell counts less than 5. (d) Laboratory values were documented within 48 hours of the diagnosis of PM.
Abbreviations: PM, pulmonary mucormycosis; AKI, acute kidney injury; CKD, chronic kidney disease; ALP, alkaline phosphatase; NLR, neutrophil-to-lymphocyte ratio; COVID-19, coronavirus disease 2019.

In patients who received systemic antifungal therapy, most commonly liposomal amphotericin B, either as monotherapy or followed by azole-based step-down treatment such as posaconazole or isavuconazole.

Clinical Outcomes

The clinical outcomes are summarized in Table 2. The overall 30-day mortality rate was 18.4% (30 of 163 patients). Kaplan–Meier survival analysis (Figure 2) demonstrated a significantly lower 30-day survival among patients with malignancy compared with those without malignancy (log-rank $\chi^2 = 27.08$, $p < 0.0001$). No significant differences were observed in ICU admission rates (26% vs 18%, p = 0.233) or hospital length of stay (22 vs 18 days, p = 0.093) between groups.

Variables Associated with 30-Day Mortality

Univariable Cox proportional hazards model (Supplementary Table S3) indicated that non-survivors were more frequently characterized by the presence of underlying malignancy, chronic liver disease, AKI, cytopenia (including leukopenia, anemia, and thrombocytopenia), elevated NLR, increased alkaline phosphatase (ALP), and hypoalbuminemia.

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Table 2 Clinical Outcomes of Patients with Pulmonary Mucormycosis, Stratified by Malignancy Status

	All Patients (n=163)	Malignancy (n=74)	Non-malignancy (n=89)	p value[a]
30-day mortality	30(18.4%)	21(28.4%)	9(10.1%)	0.003
ICU admission	35(21.5%)	19(25.7%)	16(18.0%)	0.233
Hospitalization day	20.12±16.02	22.43±15.89	18.19±15.97	0.093

Notes: [a]P values for continuous variables were calculated using independent-samples t tests, while those for categorical variables were determined with the χ^2-test; all p values denote comparisons between the malignancy and non-malignancy groups.

All variables with p<0.05, or deemed biologically significant, were incorporated into a multivariable Cox proportional hazards model, which was subsequently refined using purposeful backward selection (Supplementary Table S4).

The fully adjusted Cox proportional hazards model presented in Table 3 identifies underlying malignancy as the most significant determinant of early mortality, with a tripling of the 30-day hazard (aHR 3.65, 95% CI 1.40–9.53). Elevated NLR was significantly associated with higher mortality: a 5-unit increase in NLR was associated with a 10% higher hazard (aHR 1.10, 95% CI 1.05–1.22). Likewise, increased ALP independently contributed to risk, with a 16% higher hazard per 50 U/L increase (aHR 1.16, 95% CI 1.00–1.64). The final specification achieved the lowest Akaike Information Criterion (AIC ≈ 186), indicating an optimal model fit and confirming the robustness of these four principal predictors. The result is illustrated in Figure 3, the forest plot of adjusted hazard ratios corroborates the multivariable findings in Table 3.

Discussion

PM continues to be a highly lethal infection, especially in patients with hematologic malignancies who frequently experience profound and sustained immunosuppression. Despite advancements in diagnostics and antifungal therapy, mortality rates within this population continue to be unacceptably high.[16] Current guidelines recommend prompt initiation of liposomal amphotericin B, followed by step-down therapy with isavuconazole or posaconazole upon stabilization.[14] Nevertheless, outcomes for patients with malignancies are consistently poorer than for other host groups, underscoring the complexity of managing PM in severely immunocompromised individuals.[2,15] In our cohort, underlying

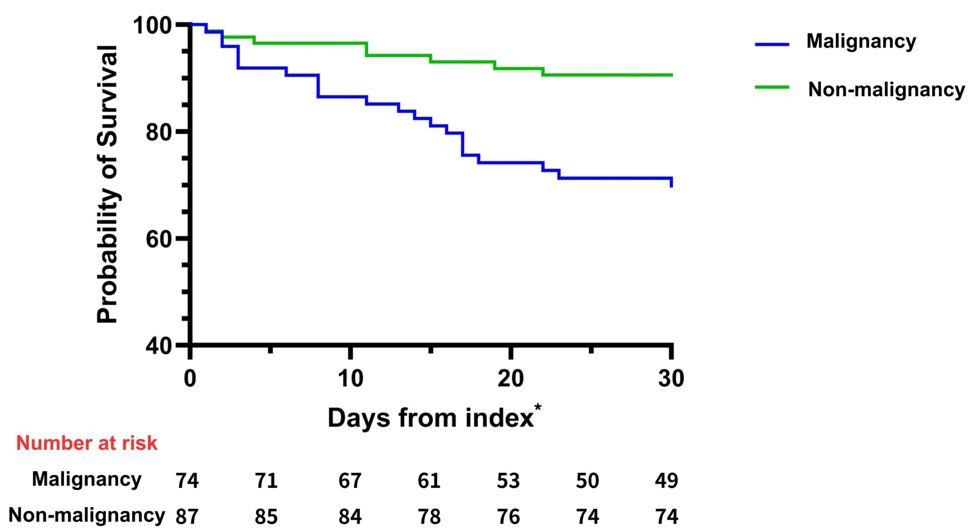

Figure 2 Kaplan–Meier 30-day survival analysis stratified by malignancy status. Patients with underlying malignancy (blue line, n=74) showed significantly lower survival compared with those without malignancy (green line, n=89) (log-rank χ^2=27.08, df=1, p<0.001).
Note: *Index date was the date of specimen collection.

Table 3 Independent Predictors[a] of 30-Day Mortality

Variable	Univariable HR (95% CI)[b]	Multivariable aHR (95% CI)[b]	p value (aHR)
Patient and clinical characteristics			
Malignancy	2.98(1.36–6.51)	3.65(1.40–9.53)	0.008
Acute kidney injury	2.07(1.01–4.25)	2.39(0.94–6.04)	0.066
Clinical Characteristics			
Neutrophil-to-lymphocyte ratio (per 5 units)	1.10(1.05–1.22)	1.10(1.05–1.22)	0.011
Alkaline phosphatase (per 50 U/L)	1.64(1.11–1.42)	1.16(1.00–1.64)	0.046
Serum albumin	0.39(0.20–0.74)	0.76(0.38–1.53)	0.439

Note: [a]Binary variables were coded 1 = yes, 0 = no. Continuous variables were entered per unit increase. [b]HR = hazard ratio from univariable Cox proportional hazards model; aHR = adjusted HR from the final multivariable Cox proportional hazards model.

malignancy independently predicted early mortality, with a more than threefold increased hazard of death within 30 days (aHR 3.65, p = 0.008), consistent with findings from regional and national surveillance studies.[1–3] The observed 30-day mortality rate among patients with malignancy was 28.4%, in comparison to 10.1% among those without. Although this rate is somewhat lower than previous hematology-focused cohorts reporting rates of 40%–70%,[16] it likely reflects differences in patient demographics, the shorter 30-day outcome window, and earlier interventions within our setting. Collectively, these findings reinforce the virulence of PM and the urgent need for timely diagnosis and individualized antifungal management.

Within our cohort, two distinct host phenotypes emerged, reflecting underlying differences in clinical presentation and laboratory profiles. Patients with malignancy more frequently exhibited a cytopenic–immunosuppressed phenotype, characterized by marrow suppression, hypoalbuminemia, and elevated ALP, likely resulting from chemotherapy and endothelial injury. In contrast, individuals without malignancy more frequently exhibited a metabolic–inflammatory profile, which is associated with chronic kidney disease and recent COVID-19 infection, thereby indicating immune dysregulation and metabolic stress as predominant characteristics. This dichotomy aligns with established clinical patterns: angioinvasive necrosis is generally more severe in neutropenic hosts, whereas inflammatory-driven courses predominate in non-malignant settings. Notably, two laboratory parameters—ALP and NLR—emerged from our multivariable model as independent or

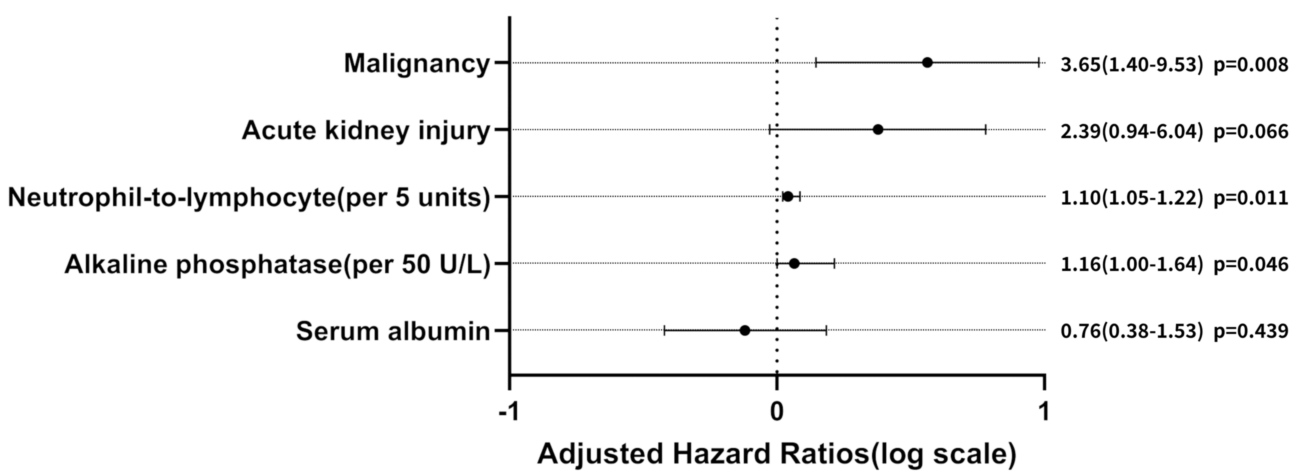

Figure 3 Adjusted Hazard Ratios for 30-day mortality. Forest plot of adjusted hazard ratios (aHR) for predictors of 30-day mortality in pulmonary mucormycosis.
Notes: Variables included in the multivariable Cox model are shown with aHRs, 95% confidence intervals, and adjusted p-values. Error bars represent 95% confidence intervals. *p < 0.05.

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near-independent predictors of 30-day mortality. Elevated ALP may indicate cholestatic injury resulting from disseminated fungal invasion or antifungal toxicity. Additionally, increased NLR has been validated as a marker of systemic inflammation and adverse outcomes in mucormycosis, particularly in patients following COVID-19 settings.[22,23] Together, these findings suggest that host phenotype and associated biomarkers can guide early risk stratification and support the development of individualized treatment strategies beyond a one-size-fits-all approach.

The biological plausibility of these associations is further reinforced by mechanistic evidence.[24,25] Chemotherapy, radiation, and monoclonal antibody therapies hinder the processes of granulopoiesis and platelet formation, while also compromising endothelial integrity. These modifications promote fungal angioinvasion and thrombosis, mediated by Mucorales-specific virulence factors such as CotH proteins and mucoricin toxins. Experimental models have demonstrated that inhibiting CotH3-mediated endothelial binding can mitigate vascular damage, underscoring the pivotal role of host cytopenia in the pathogenesis of fungal infections.[24] Conversely, post-COVID metabolic dysregulation and renal impairment are characterized by cytokine-mediated iron overload, steroid-induced hyperglycemia, and lymphocyte exhaustion, all of which create an environment highly permissive to Mucorales proliferation.[25] These complementary host pathways illustrate how diverse clinical backgrounds converge on a common pathogenic endpoint of vascular invasion and tissue necrosis.[5]

Although antifungal therapy remains the cornerstone of PM management, the optimal approach for hematologic patients remains challenging. In our study, most patients with malignancy received liposomal amphotericin B as initial therapy, often followed by azole-based consolidation with posaconazole or isavuconazole. These patterns reflect current clinical practice and are consistent with findings from previous cohorts.[1–3] Although combination antifungal therapy has been attempted in refractory cases, evidence supporting improved survival remains limited. Surgical resection, a potentially curative intervention for localized disease, is frequently contraindicated due to cytopenia, coagulopathy, or diminished functional reserve in cancer patients. Recent agents, such as isavuconazole, have demonstrated commendable tolerability, especially among patients with renal impairment or those intolerant to amphotericin B.[26] Furthermore, early administration may lead to improved clinical outcomes.[27] The ongoing assessment of antifungal optimization and host-directed adjunctive therapies, such as granulocyte transfusion, thrombopoietic support, or immune-modulating interventions, continues to represent a crucial area of research focus.

This study also provides important regional insights. It represents one of the single-center PM cohorts reported in East Asia and uniquely integrates host phenotype, laboratory biomarkers, and survival analysis within a single analytic framework. The use of purposeful variable selection and model validation using the Akaike Information Criterion further supports the robustness of the analysis. The findings collectively emphasize that early recognition of host vulnerability, combined with rapid initiation of active antifungal therapy and phenotype-tailored supportive care, remains essential to improving outcomes in PM.

Limitations

This study has several limitations.

Firstly, its retrospective, single-center design inherently introduces biases associated with selection and referral processes. Additionally, certain variables of clinical importance (eg, iron indices, cytokine profiles, severity-of-illness scores, and detailed radiological assessments) were either unavailable or inadequately recorded, potentially leading to residual confounding.

Secondly, the heterogeneity within the "malignancy" category restricts interpretative clarity. Hematological and solid organ malignancies were analyzed together to maintain statistical power, despite differences in immunosuppression and cytotoxic therapy. The limited sample size prevented stratified analyses; thus, the independent effect of each cancer subtype remains indeterminate.

Third, treatment data were neither standardized nor comprehensively documented. The timing, dosage, and formulation of antifungal therapy, as well as the use of surgical or hematologic support, varied at the clinician's discretion. Consequently, our findings are subject to confounding by indication, and because antifungal exposure was not defined at a fixed baseline window, immortal-time bias cannot be excluded. Thus, the observed association between antifungal therapy and mortality should be interpreted with caution.

Conclusion

Underlying malignancy independently predicts early mortality in PM, highlighting the dominant role of host-related factors in determining outcomes. Elevated ALP and a higher NLR further serve as accessible prognostic indicators reflecting cholestatic injury and systemic inflammation. Recognizing these divergent phenotypes may help clinicians tailor early diagnostic and therapeutic strategies. Early recognition, prompt initiation of active antifungal therapy, and individualized management are crucial to improving outcomes in this high-risk population. These findings provide a framework for clinical risk stratification and underscore the importance of timely intervention in pulmonary mucormycosis.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The author(s) report no conflicts of interest in this work.

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