

SUPPLEMENTARY TABLE 1. R Packages and Versions Used in the Analysis.

Package	Version
Boruta	9.0.0
glmnet	4.1.10
xgboost	3.1.3.1
randomForestSRC	3.4.1
ranger	0.17.0
shapviz	0.10.3
kernelshap	0.9.1
fastshap	0.1.1
rmda	1.6
dcurves	0.5.1
timeROC	0.4.1
survivalROC	1.0.3.1
mice	3.18.0
car	3.1.3
survival	3.8.3
survcomp	1.60.1
pec	2025.6.24
riskRegression	2025.5.20
Hmisc	5.2.3
survminer	0.5.2
CoxBoost	1.5.1
mboost	2.9.11
caret	7.0.1
pROC	1.19.0.1
PRROC	1.4
ROCit	2.1.2
randomForest	4.7.1.2
e1071	1.7.16
kernelab	0.9.33
nnet	7.3.20
naivebayes	1.0.0
tidyverse	2.0.0
readxl	1.4.5
openxlsx	4.2.8.1
ggplot2	4.0.1
RColorBrewer	1.1.3
gridExtra	2.3
cowplot	1.2.0
scales	1.4.0

SUPPLEMENTARY TABLE 2. Final Models and Predictors by Outcome.

Outcomes	Type	Final model	Predictors (n)	Final predictors
Mechanical ventilation	Binary	XGBoost	7	F-ILD subtype; WBC; NLR; PNI; BUN; LDH; CRP
30-day mortality	Binary	Ridge logistic regression	6	ANC; NLR; albumin; PNI; LDH; CRP
3-month mortality	Binary	XGBoost	5	ANC; NLR; albumin; PNI; LDH
Long-term all-cause mortality	Time-to-event	RSF (ranger)	11	Sex; age; smoking status; diabetes; F-ILD subtype; albumin; AGR; NLR; PWR; BUN; LDH
Long-term cause-specific mortality	Time-to-event	RSF	9	Sex; age; smoking status; F-ILD subtype; albumin; AGR; NLR; PWR; LDH

F-ILD, fibrotic interstitial lung disease; WBC, white blood cell count; ANC, absolute neutrophil count; NLR, neutrophil-to-lymphocyte ratio; PNI, prognostic nutritional index; BUN, blood urea nitrogen; LDH, lactate dehydrogenase; CRP, C-reactive protein; AGR, albumin-to-globulin ratio; PWR, platelet-to-white blood cell ratio; RSF, random survival forest.

SUPPLEMENTARY TABLE 3. Variance Inflation Factors for Mechanical Ventilation.

Variables	Mechanical ventilation	
	VIF	Tolerance
NLR	1.55	0.65
PNI	1.42	0.71
WBC	1.24	0.80
CRP	1.22	0.82
BUN	1.15	0.87
LDH	1.15	0.87
Mean VIF	1.29	0.77

VIF, tolerance = 1/VIF. VIF < 5 indicates no concerning multicollinearity; VIF < 10 suggests moderate multicollinearity that may be acceptable; VIF ≥ 10 indicates severe multicollinearity requiring attention. VIF, variance inflation factor; NLR, neutrophil-to-lymphocyte ratio; PNI, prognostic nutritional index; WBC, white blood cell; CRP, C-reactive protein; BUN, blood urea nitrogen; LDH, lactate dehydrogenase.

SUPPLEMENTARY TABLE 4. Variance Inflation Factors for Short-Term Mortality.

Variables	30-day mortality		3-month mortality	
	VIF	Tolerance	VIF	Tolerance
PNI	5.42	0.18	5.10	0.20
Albumin	4.53	0.22	4.35	0.23
NLR	1.90	0.53	1.89	0.53
ANC	1.46	0.68	1.43	0.70
CRP	1.20	0.83	-	-
LDH	1.13	0.89	1.13	0.89
Mean VIF	2.61	0.38	2.78	0.36

VIF = 1/VIF. VIF < 5 indicates no concerning multicollinearity; VIF < 10 suggests moderate multicollinearity that may be acceptable; VIF ≥ 10 indicates severe multicollinearity requiring attention. VIF, variance inflation factor; NLR, neutrophil-to-lymphocyte ratio; ANC, absolute neutrophil count; CRP, C-reactive protein; LDH, lactate dehydrogenase.

SUPPLEMENTARY TABLE 5. Variance Inflation Factors for Long-Term Mortality.

Variables	Cause-specific mortality		All-cause mortality	
	VIF	Tolerance	VIF	Tolerance
Albumin	1.81	0.55	1.81	0.55
AGR	1.65	0.61	1.65	0.60
Sex	1.57	0.64	1.58	0.63
Smokers	1.32	0.76	1.33	0.75
NLR	1.22	0.82	1.27	0.79
BUN	-	-	1.23	0.81
LDH	1.2	0.83	1.24	0.81
Age	1.36	0.74	1.44	0.70
PWR	1.13	0.89	1.15	0.87
Diabetes	-	-	1.07	0.94
F-ILD subtype				
CTD-ILD	2.04	0.49	2.05	0.49
Other F-ILD	1.53	0.65	1.55	0.64
Mean VIF	1.48	0.67	1.45	0.69

VIF, tolerance = 1/VIF. VIF < 5 indicates no concerning multicollinearity; VIF < 10 suggests moderate multicollinearity that may be acceptable; VIF ≥ 10 indicates severe multicollinearity requiring attention. VIF, variance inflation factor; AGR, albumin-to-globulin ratio; NLR, neutrophil-to-lymphocyte ratio; BUN, blood urea nitrogen; LDH, lactate dehydrogenase; CRP, C-reactive protein; PWR, platelet-to-white blood cell ratio; F-ILD, fibrotic interstitial lung disease; CTD-ILD, connective tissue disease-associated interstitial lung disease.

SUPPLEMENTARY TABLE 6. Performance of All Models for Predicting Mechanical Ventilation.

Model	Threshold (train)	Train AUC	Test AUC	Overfit (train-test)	Test Brier	External AUC (95% CI)	External PR-AUC	External brier	External sens	External spec	External F1
Logistic regression	0.098	0.863	0.899	-0.036	0.0865	0.902 (0.852-0.952)	0.550	0.0673	0.929	0.689	0.406
Ridge	0.097	0.863	0.898	-0.035	0.0869	0.903 (0.853-0.953)	0.551	0.06675	0.929	0.676	0.397
LASSO	0.098	0.863	0.897	-0.034	0.0832	0.907 (0.859-0.955)	0.545	0.0661	0.929	0.718	0.430
Random forest	0.456	1.000	0.884	0.116	0.0779	0.911 (0.868-0.954)	0.623	0.0639	0.429	0.958	0.480
XGBoost	0.195	0.937	0.890	-0.047	0.0810	0.913 (0.873-0.953)	0.578	0.0698	0.857	0.824	0.511
SVM (linear)	0.166	0.853	0.903	-0.050	0.0862	0.887 (0.826-0.949)	0.497	0.0732	0.786	0.803	0.454
SVM (RBF)	0.140	0.844	0.895	-0.051	0.0964	0.899 (0.845-0.954)	0.498	0.0770	0.929	0.807	0.520
Neural network	0.199	0.928	0.889	0.039	0.0736	0.891 (0.833-0.949)	0.529	0.0689	0.750	0.857	0.506
Naïve Bayes	0.021	0.864	0.883	-0.019	0.1021	0.894 (0.845-0.942)	0.535	0.0877	0.857	0.744	0.425

PR-AUC, area under the precision-recall curve; AUC, area under the curve; CI, confidence interval; SVM, support vector machine; RBF, radial basis function; LASSO, least absolute shrinkage and selection operator.

SUPPLEMENTARY TABLE 7. Performance of All Models for Predicting 30-Day Mortality.

Model	Threshold (train)	Train AUC	Test AUC	Overfit (train-test)	Test brier	External AUC (95% CI)	External PR-AUC	External brier	External sens	External spec	External F1
Logistic regression	0.120	0.847	0.892	-0.045	0.0661	0.926 (0.871-0.980)	0.468	0.0402	0.929	0.821	0.361
Ridge	0.120	0.847	0.892	-0.045	0.0663	0.926 (0.871-0.980)	0.468	0.0402	0.929	0.825	0.366
LASSO	0.128	0.850	0.892	-0.042	0.0607	0.923 (0.866-0.979)	0.435	0.0431	0.929	0.821	0.361
Random forest	0.304	1.000	0.889	0.111	0.0635	0.937 (0.889-0.986)	0.589	0.0414	0.786	0.917	0.478
XGBoost	0.172	0.969	0.877	0.092	0.0717	0.915 (0.861-0.968)	0.428	0.0528	0.929	0.802	0.338
SVM (linear)	0.101	0.829	0.876	-0.047	0.0819	0.913 (0.840-0.986)	0.460	0.0490	0.929	0.750	0.289
SVM (RBF)	0.096	0.702	0.764	-0.062	0.0750	0.861 (0.734-0.987)	0.429	0.0438	0.714	0.857	0.333
Neural network	0.081	0.884	0.893	-0.009	0.0620	0.933 (0.876-0.990)	0.567	0.0431	0.929	0.738	0.280
Naïve Bayes	0.103	0.866	0.875	-0.009	0.0814	0.914 (0.856-0.972)	0.396	0.1020	0.857	0.770	0.286

PR-AUC, area under the precision-recall curve; AUC, area under the curve; CI, confidence interval; SVM, support vector machine; RBF, radial basis function; LASSO, least absolute shrinkage and selection operator.

SUPPLEMENTARY TABLE 8. Performance of All Models for Predicting 3-Month Mortality.

Model	Threshold (train)	Train AUC	Test AUC	Overfit (train-test)	Test brier	External AUC (95% CI)	External PR-AUC	External brier	External sens	External spec	External F1
Logistic regression	0.138	0.826	0.773	0.053	0.1053	0.805 (0.716-0.894)	0.376	0.0813	0.769	0.700	0.339
Ridge	0.131	0.826	0.773	0.053	0.1118	0.806 (0.717-0.895)	0.380	0.0882	0.769	0.708	0.345
LASSO	0.139	0.826	0.770	0.056	0.0989	0.802 (0.710-0.894)	0.383	0.0783	0.769	0.692	0.333
Random forest	0.219	0.983	0.765	0.218	0.1034	0.799 (0.692-0.906)	0.409	0.0809	0.692	0.804	0.396
XGBoost	0.184	0.897	0.760	0.137	0.1072	0.813 (0.723-0.903)	0.415	0.0850	0.731	0.779	0.388
SVM (linear)	0.147	0.826	0.754	0.072	0.1034	0.790 (0.699-0.882)	0.349	0.0798	0.692	0.808	0.400
SVM (RBF)	0.136	0.820	0.734	0.086	0.1033	0.769 (0.665-0.874)	0.347	0.0808	0.731	0.729	0.345
Neural network	0.138	0.852	0.762	0.090	0.1077	0.800 (0.712-0.889)	0.376	0.0863	0.769	0.742	0.370
Naïve Bayes	0.153	0.848	0.763	0.085	0.1600	0.770 (0.669-0.871)	0.265	0.1452	0.769	0.713	0.348

PR-AUC, area under the precision-recall curve; AUC, area under the curve; CI, confidence interval; SVM, support vector machine; RBF, radial basis function; LASSO, least absolute shrinkage and selection operator; XGBoost, extreme gradient boosting.

SUPPLEMENTARY TABLE 9. Threshold-Dependent Performance of Final Short-term Models in External Validation.

Outcome	Final model	Cut-off	Sensitivity (95% CI)	Specificity (95% CI)	F1 score (95% CI)
Mechanical ventilation	XGBoost	0.195	0.857 (0.673-0.960)	0.824 (0.769-0.870)	0.511 (0.379-0.627)
30-day mortality	Ridge logistic regression	0.120	0.929 (0.661-0.998)	0.825 (0.773-0.870)	0.366 (0.215-0.500)
3-month mortality	XGBoost	0.184	0.731 (0.522-0.884)	0.779 (0.721-0.830)	0.388 (0.259-0.505)

CI, confidence interval; MV, mechanical ventilation; XGBoost, extreme gradient boosting. Confidence intervals for sensitivity and specificity were calculated using exact binomial methods; confidence intervals for F1 score were estimated by bootstrapping.

SUPPLEMENTARY TABLE 10. Confusion Matrices for the Final Short-Term Models in the External Validation Cohort at Training-Derived Cut-Offs.

Outcome	Final model	Cut-off	Predicted class	Observed non-event	Observed event
Mechanical ventilation	XGBoost	0.195	Event	42	24
Mechanical ventilation	XGBoost	0.195	Non-event	196	4
30-day mortality	Ridge logistic regression	0.120	Event	44	13
30-day mortality	Ridge logistic regression	0.120	Non-event	208	1
3-month mortality	XGBoost	0.184	Event	53	19
3-month mortality	XGBoost	0.184	Non-event	187	7

Rows represent predicted classes and columns represent observed outcomes. Event indicates occurrence of the corresponding outcome; non-event indicates absence of the corresponding outcome. MV, mechanical ventilation; XGBoost, extreme gradient boosting.

SUPPLEMENTARY TABLE 11. Calibration Intercept and Slope in the External Validation Cohort for Short-Term Outcome Models.

Outcomes	Final model	Calibration-in-the-large (Intercept), estimate (95% CI)	Calibration slope, estimate (95% CI)	E/O ratio
Mechanical ventilation	XGBoost	-0.6734 (-1.1009, -0.2458)	1.5411 (1.0799, 2.0023)	1.6163 (1.1160, 2.3409)
30-day mortality	Ridge logistic regression	-0.8511 (-1.4259, -0.2763)	1.7575 (1.0314, 2.4837)	1.9950 (1.1815, 3.3685)
3-month mortality	XGBoost	-0.9248 (-1.3674, -0.4822)	1.0355 (0.6677, 1.4034)	1.9137 (1.3030, 2.8107)

CI, confidence interval; XGBoost, extreme gradient boosting.

SUPPLEMENTARY TABLE 12. Sensitivity analysis for PNI–albumin overlap in the Final Short-Term Mortality Models.

Outcome	Final model	Predictor configuration	Cut-off	AUC (95% CI)	Brier score	Sensitivity	Specificity	F1 score
30-day mortality	Ridge logistic regression	PNI + albumin	0.120	0.926 (0.871-0.980)	0.0402	0.929	0.825	0.366
30-day mortality	Ridge logistic regression	PNI only	0.118	0.924 (0.873-0.975)	0.0430	0.929	0.810	0.347
30-day mortality	Ridge logistic regression	Albumin only	0.115	0.916 (0.858-0.974)	0.0418	0.857	0.821	0.338
3-month mortality	XGBoost	PNI + albumin	0.184	0.813 (0.723-0.903)	0.0850	0.731	0.779	0.388
3-month mortality	XGBoost	PNI only	0.164	0.809 (0.716-0.902)	0.0865	0.769	0.746	0.374
3-month mortality	XGBoost	Albumin only	0.248	0.814 (0.722-0.906)	0.0875	0.692	0.846	0.444

AUC, area under the receiver operating characteristic curve; CI, confidence interval; PNI, prognostic nutritional index; XGBoost, extreme gradient boosting.

SUPPLEMENTARY TABLE 13. Discrimination of Final Short-Term Outcome Models Across Prespecified Subgroups in External Validation.

Outcomes	Subgroup	n	Events, n (%)	AUC (95% CI)	PR-AUC
Mechanical ventilation (XGBoost)	IPF	53	9 (16.98)	0.942 (0.875, 1.000)	0.820
	CTD-ILD	180	15 (8.33)	0.909 (0.861, 0.957)	0.466
	Other F-ILD	33	4 (12.12)	NR	NR
	Male	110	19 (17.27)	0.881 (0.807, 0.956)	0.670
	Female	156	9 (5.77)	0.930 (0.885, 0.975)	0.387
	Age ≥65	115	17 (14.78)	0.896 (0.831, 0.961)	0.633
30-day mortality (Ridge)	Age <65	151	11 (7.28)	0.929 (0.882, 0.975)	0.492
	IPF	53	5 (9.43)	0.942 (0.850, 1.000)	0.728
	CTD-ILD	180	8 (4.44)	0.939 (0.887, 0.991)	0.501
	Other F-ILD	33	1 (3.03)	NR	NR
	Male	110	10 (9.09)	0.920 (0.832, 1.000)	0.671
	Female	156	4 (2.56)	NR	NR
3-month mortality (XGBoost)	Age ≥65	115	8 (6.96)	0.900 (0.813, 0.986)	0.427
	Age <65	151	6 (3.97)	0.963 (0.923, 1.000)	0.587
	IPF	53	8 (15.09)	0.889 (0.757, 1.000)	0.659
	CTD-ILD	180	16 (8.89)	0.783 (0.657, 0.908)	0.349
	Other F-ILD	33	2 (6.06)	NR	NR
	Male	110	15 (13.64)	0.804 (0.666, 0.941)	0.547
	Female	156	11 (7.05)	0.823 (0.707, 0.940)	0.288
	Age ≥ 65	115	16 (13.91)	0.815 (0.694, 0.936)	0.479
	Age < 65	151	10 (6.62)	0.821 (0.686, 0.957)	0.346

AUC and PR-AUC were not reported for subgroups with fewer than five events because these estimates were considered unstable and potentially misleading. NR, not reported; PR-AUC, area under the precision-recall curve; AUC, area under the curve; CI, confidence interval; CTD-ILD, connective tissue disease-associated interstitial lung disease; XGBoost, extreme gradient boosting.

SUPPLEMENTARY TABLE 14. Performance of Candidate Survival Models for Predicting Long-Term All-Cause Mortality.

Model	Train C-index	Internal test C-index	Overfit (train-test)	External C-index (95% CI)	External AUC at 12 months (95% CI)	External AUC at 24 months (95% CI)	Brier score at 12 months (95% CI)	Brier score at 24 months (95% CI)
Cox proportional hazards (Cox)	0.732	0.675	0.057	0.735 (0.669-0.800)	0.770 (0.695-0.846)	0.732 (0.643-0.821)	0.1338 (0.1071-0.1605)	0.1622 (0.1280-0