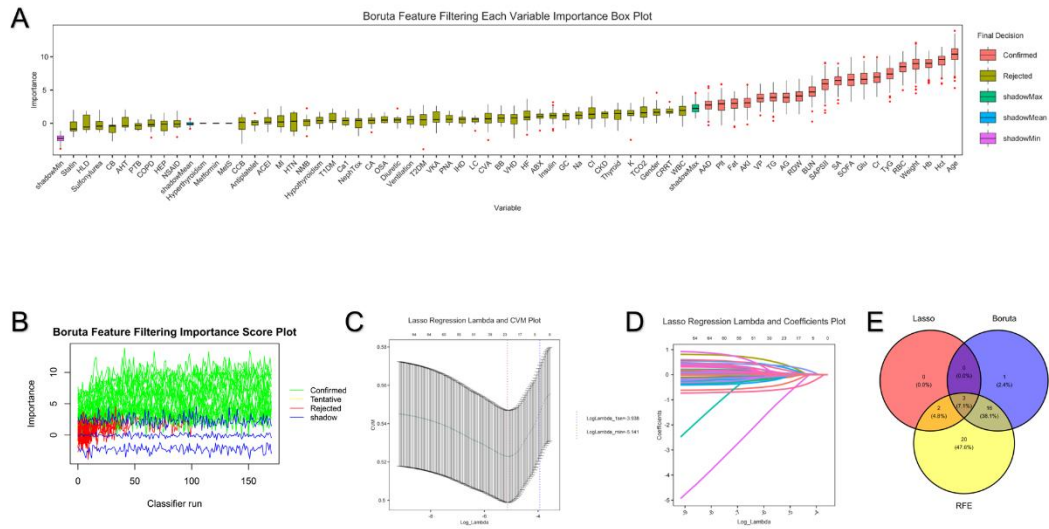


Supplementary Material

**Age-specific predictors of in-hospital mortality in critically ill patients with atrial
fibrillation: an interpretable machine-learning study**

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Supplementary Figure S1. Feature selection using Boruta, LASSO, and recursive feature elimination in the overall cohort.

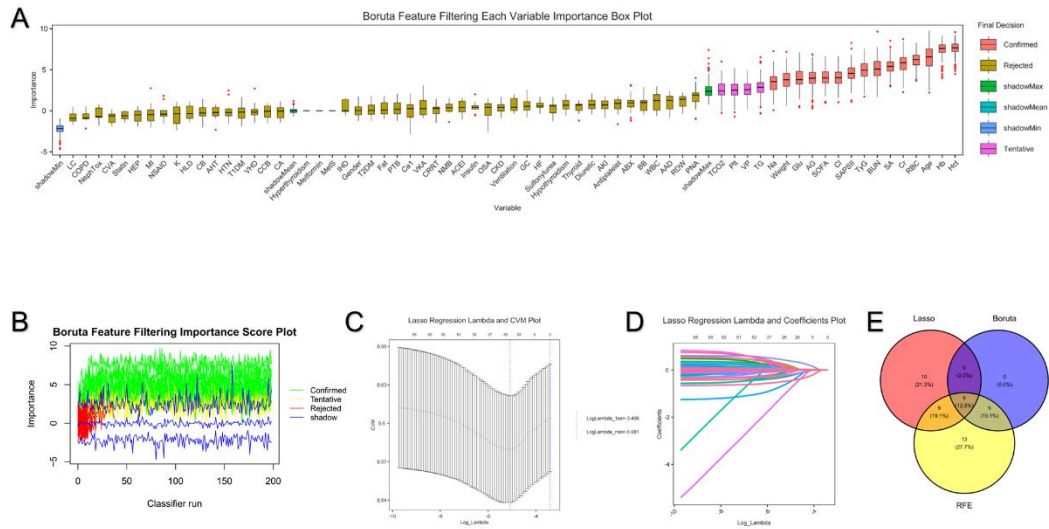
(A) Boruta feature importance plot showing the importance of candidate variables for model prediction, with variables classified as confirmed, tentative, or rejected.

(B) Boruta importance plot across multiple iterations, illustrating the stability of selected variables.

(C) Ten-fold cross-validation curve for the least absolute shrinkage and selection operator (LASSO) model, showing the relationship between the regularization parameter ($\log \lambda$) and the mean cross-validated error.

(D) LASSO coefficient profile showing the shrinkage of regression coefficients as the regularization parameter increased.

(E) Venn diagram showing the overlap among predictors selected by Boruta, LASSO, and recursive feature elimination (RFE).



Supplementary Figure S2. Feature selection using Boruta, LASSO, and recursive feature elimination in patients aged ≥ 65 years.

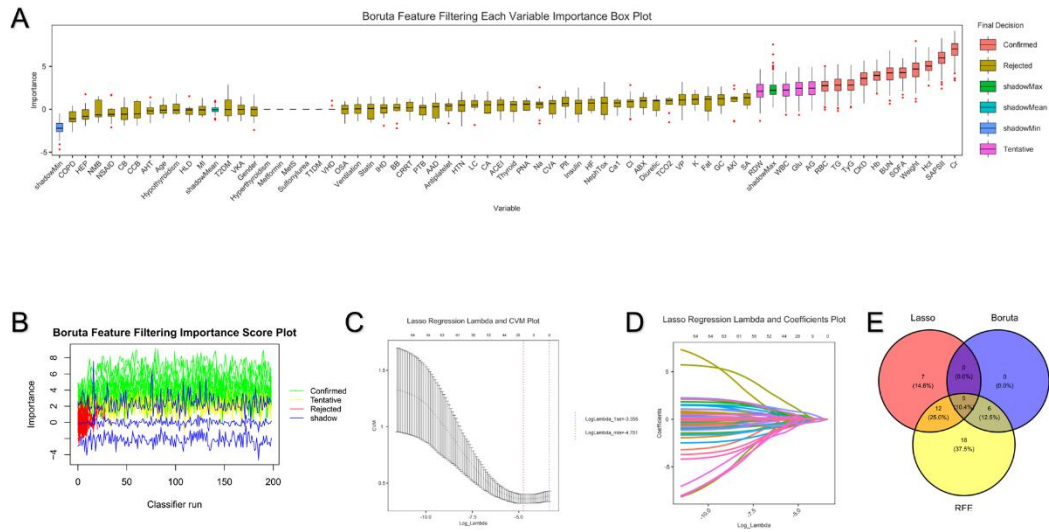
(A) Boruta feature importance box plot showing the importance of candidate variables for model prediction, with variables classified as confirmed, tentative, or rejected according to the Boruta algorithm.

(B) Boruta importance score plot across repeated classifier runs, illustrating the stability of confirmed, tentative, rejected, and shadow features.

(C) Ten-fold cross-validation curve for the least absolute shrinkage and selection operator (LASSO) model, showing the relationship between the regularization parameter ($\log \lambda$) and the mean cross-validated error.

(D) LASSO coefficient profile showing the shrinkage of regression coefficients as the regularization parameter increased.

(E) Venn diagram showing the overlap among predictors selected by Boruta, LASSO, and recursive feature elimination (RFE).



Supplementary Figure S3. Feature selection using Boruta, LASSO, and recursive feature elimination in patients aged <65 years.

(A) Boruta feature importance box plot showing the relative importance of candidate variables, with features classified as confirmed, tentative, or rejected.

(B) Boruta importance score plot across repeated classifier runs, demonstrating the stability of selected variables.

(C) Ten-fold cross-validation curve for the least absolute shrinkage and selection operator (LASSO) model, showing the relationship between the regularization parameter ($\log \lambda$) and the mean cross-validated error.

(D) LASSO coefficient profile showing the shrinkage of regression coefficients with increasing regularization.

(E) Venn diagram showing the overlap among predictors selected by Boruta, LASSO, and recursive feature elimination (RFE).

Supplementary Table S1. Baseline characteristics of the overall and age-stratified MIMIC-IV cohorts

Table 1A. Overall MIMIC-IV cohort

Section	Variable	Overall (n=3449)	Training Cohort (n=2414)	Internal Testing Cohort(n=1035)	P value
General information					
	Male sex	2053 (59.52%)	1440 (59.60%)	613 (59.34%)	0.910
	Age, years	74.00 (65.00–82.00)	74.00 (65.00–82.00)	73.00 (65.00–81.00)	0.140
	Weight, kg	81.00 (67.90–98.10)	80.70 (67.60–97.62)	82.00 (68.80–99.80)	0.219
Comorbidities					
	Valvular Heart Disease	81 (2.35%)	52 (2.15%)	29 (2.81%)	0.269
	Hypertension	1291 (37.43%)	906 (37.50%)	385 (37.27%)	0.908
	Cerebrovascular Accident	447 (12.96%)	313 (12.96%)	134 (12.97%)	1.000
	Heart Failure	1635 (47.41%)	1153 (47.72%)	482 (46.66%)	0.577
	Myocardial Infarction	488 (14.15%)	355 (14.69%)	133 (12.88%)	0.166
	Ischemic Heart Disease	1524 (44.19%)	1077 (44.58%)	447 (43.27%)	0.501
	Hyperthyroidism	10 (0.29%)	7 (0.29%)	3 (0.29%)	1.000
	Hypothyroidism	554 (16.06%)	378 (15.65%)	176 (17.04%)	0.312
	Metabolic Syndrome	0 (0.00%)	0 (0.00%)	0 (0.00%)	1.000
	Obesity	483 (14.00%)	329 (13.62%)	154 (14.91%)	0.335
	Type 2 Diabetes Mellitus	1174 (34.04%)	828 (34.27%)	346 (33.49%)	0.666
	Type 1 Diabetes Mellitus	29 (0.84%)	20 (0.83%)	9 (0.87%)	0.842
	Hyperlipidemia	1580 (45.81%)	1106 (45.78%)	474 (45.89%)	0.970
	Obstructive Sleep Apnea	415 (12.03%)	281 (11.63%)	134 (12.97%)	0.278
	Chronic Bronchitis	396 (11.48%)	282 (11.67%)	114 (11.04%)	0.641
	Chronic Obstructive Pulmonary Disease	586 (16.99%)	417 (17.26%)	169 (16.36%)	0.553
	Pneumonia	1225 (35.52%)	852 (35.26%)	373 (36.11%)	0.641
	Pulmonary Tuberculosis	77 (2.23%)	48 (1.99%)	29 (2.81%)	0.166
	Acute Kidney Injury	1823 (52.86%)	1286 (53.23%)	537 (51.98%)	0.503
	Chronic Kidney Disease	959 (27.81%)	670 (27.73%)	289 (27.98%)	0.901
	Liver Cirrhosis	251 (7.28%)	176 (7.28%)	75 (7.26%)	1.000
	Hepatitis	145 (4.20%)	99 (4.10%)	46 (4.45%)	0.644
	Cancer	567 (16.44%)	405 (16.76%)	162 (15.68%)	0.452
Treatment/ Medication					
	Antiarrhythmic agents	927 (26.88%)	628 (25.99%)	299 (28.94%)	0.078
	Diuretics	553 (16.03%)	400 (16.56%)	153 (14.81%)	0.206
	Calcium Channel Blocker	432 (12.53%)	298 (12.33%)	134 (12.97%)	0.613
	Angiotensin-Converting Enzyme Inhibitor	995 (28.85%)	701 (29.01%)	294 (28.46%)	0.774
	Beta Blocker	2847 (82.55%)	1998 (82.70%)	849 (82.19%)	0.732

Table 1A (Continued)

Section	Variable	Overall (n=3449)	Training Cohort (n=2414)	Internal Testing Cohort(n=1035)	P value
	Antiplatelet agents	981 (28.44%)	695 (28.77%)	286 (27.69%)	0.537
	Vitamin K Antagonist	914 (26.50%)	646 (26.74%)	268 (25.94%)	0.643
	Vasopressor	2119 (61.44%)	1466 (60.68%)	653 (63.21%)	0.169
	Antihypertensive drugs	2879 (83.47%)	2024 (83.77%)	855 (82.77%)	0.484
	Insulin	2442 (70.80%)	1713 (70.90%)	729 (70.57%)	0.870
	Sulfonylureas	134 (3.89%)	88 (3.64%)	46 (4.45%)	0.290
	Metformin	0 (0.00%)	0 (0.00%)	0 (0.00%)	1.000
	Statins	686 (19.89%)	461 (19.08%)	225 (21.78%)	0.070
	Nonsteroidal Anti-Inflammatory Drug	112 (3.25%)	82 (3.39%)	30 (2.90%)	0.529
	Thyroid medication	224 (6.49%)	149 (6.17%)	75 (7.26%)	0.229
	Neuromuscular Blocker	251 (7.28%)	177 (7.33%)	74 (7.16%)	0.886
	Sedative and analgesic agents	2255 (65.38%)	1578 (65.31%)	677 (65.54%)	0.907
	Nephrotoxic drugs	3002 (87.04%)	2105 (87.13%)	897 (86.83%)	0.825
	Glucocorticoids	1056 (30.62%)	724 (29.97%)	332 (32.14%)	0.211
	Antibiotics	2899 (84.05%)	2031 (84.06%)	868 (84.03%)	1.000
	Continuous Renal Replacement Therapy	437 (12.67%)	303 (12.54%)	134 (12.97%)	0.738
	Mechanical Ventilation	2854 (82.75%)	1997 (82.66%)	857 (82.96%)	0.844
ICU physiological score					
	Sequential Organ Failure Assessment	5.00 (3.00–8.00)	5.00 (3.00–8.00)	5.00 (3.00–8.00)	0.836
	Simplified Acute Physiology Score II	40.00 (32.00–50.00)	41.00 (32.00–50.00)	40.00 (32.00–50.00)	0.208
Laboratory Indicators					
	Hematocrit, %	33.20 (28.30–38.30)	33.20 (28.37–38.32)	33.00 (28.10–38.20)	0.601
	Hemoglobin, g/dL	10.70 (9.10–12.50)	10.80 (9.10–12.50)	10.70 (9.00–12.40)	0.533
	Red cell distribution width, %	14.80 (13.70–16.60)	14.70 (13.70–16.60)	14.80 (13.80–16.40)	0.800
	Red blood cell count, $\times 10^{12}/L$	3.60 (3.10–4.20)	3.60 (3.10–4.20)	3.60 (3.10–4.20)	0.518
	White blood cell count, $\times 10^9/L$	11.00 (8.10–15.80)	10.90 (8.10–15.80)	11.00 (7.90–15.70)	0.798
	Platelet count, $\times 10^9/L$	193.00 (139.00–263.00)	193.00 (139.00–264.00)	194.00 (139.00–262.00)	0.913
	Anion gap, mmol/L	14.00 (12.00–17.00)	14.00 (12.00–17.00)	14.00 (12.00–17.00)	0.852
	Calcium, mg/dL	8.40 (7.90–8.90)	8.40 (7.90–8.90)	8.40 (7.90–8.90)	0.831
	Chloride, mmol/L	103.00 (99.00–107.00)	103.00 (99.00–107.00)	103.00 (99.00–107.00)	0.157
	Potassium, mmol/L	4.20 (3.80–4.60)	4.20 (3.80–4.70)	4.10 (3.70–4.60)	0.161

Table 1A (Continued)

Section	Variable	Overall (n=3449)	Training Cohort (n=2414)	Internal Testing Cohort(n=1035)	P value
		138.00 (135.00–141.00)	138.00 (135.00–141.00)	139.00 (135.00–142.00)	0.439
	Sodium, mmol/L				
	Creatinine, mg/dL	1.10 (0.80–1.80)	1.10 (0.80–1.80)	1.10 (0.80–1.80)	0.490
	Blood urea nitrogen, mg/dL	24.00 (16.00–41.00)	24.00 (16.00–41.00)	24.00 (16.00–41.00)	0.721
	Total carbon dioxide, mmol/L	25.00 (21.00–28.00)	25.00 (21.00–28.00)	25.00 (22.00–28.00)	0.475
	Triglycerides, mg/dL	117.00 (81.00–176.00)	117.00 (80.00–177.00)	116.00 (82.00–175.00)	0.823
	Glucose, mmol/L	7.30 (5.90–9.60)	7.30 (5.90–9.50)	7.40 (6.10–9.60)	0.489

Table 1B. Patients aged ≥65 years

Section	Variable	Overall (n=2635)	Training Cohort (n=1844)	Internal Testing Cohort(n=791)	P value
General information					
	Male sex	1465 (55.60%)	1043 (56.53%)	422 (53.42%)	0.146
	Age, years	78.00 (71.00–84.00)	78.00 (71.00–84.00)	78.00 (71.25–85.00)	0.261
	Weight, kg	78.70 (66.25–94.10)	79.10 (66.50–94.40)	77.65 (65.35–93.57)	0.112
Comorbidities					
	Valvular Heart Disease	53 (2.01%)	34 (1.84%)	19 (2.41%)	0.364
	Hypertension	1040 (39.47%)	710 (38.48%)	330 (41.77%)	0.117
	Cerebrovascular Accident	392 (14.88%)	273 (14.80%)	119 (15.06%)	0.858
	Heart Failure	1279 (48.54%)	899 (48.73%)	380 (48.10%)	0.799
	Myocardial Infarction	381 (14.46%)	260 (14.09%)	121 (15.32%)	0.432
	Ischemic Heart Disease	1220 (46.30%)	868 (47.05%)	352 (44.56%)	0.250
	Hyperthyroidism	9 (0.34%)	5 (0.27%)	4 (0.51%)	0.466
	Hypothyroidism	464 (17.61%)	308 (16.69%)	156 (19.75%)	0.065
	Metabolic Syndrome	0 (0.00%)	0 (0.00%)	0 (0.00%)	1.000
	Obesity	303 (11.50%)	214 (11.60%)	89 (11.27%)	0.842
	Type 2 Diabetes Mellitus	913 (34.65%)	653 (35.39%)	260 (32.91%)	0.228
	Type 1 Diabetes Mellitus	11 (0.42%)	8 (0.43%)	3 (0.38%)	1.000
	Hyperlipidemia	1304 (49.49%)	903 (48.94%)	401 (50.76%)	0.395
	Obstructive Sleep Apnea	288 (10.93%)	193 (10.46%)	95 (12.03%)	0.247
	Chronic Bronchitis	324 (12.30%)	243 (13.17%)	81 (10.25%)	0.038
	Chronic Obstructive Pulmonary Disease	479 (18.18%)	356 (19.30%)	123 (15.57%)	0.024
	Pneumonia	930 (35.29%)	664 (35.99%)	266 (33.67%)	0.266
	Pulmonary Tuberculosis	57 (2.16%)	38 (2.06%)	19 (2.41%)	0.562
	Acute Kidney Injury	1376 (52.22%)	978 (53.01%)	398 (50.38%)	0.217
	Chronic Kidney Disease	801 (30.40%)	563 (30.51%)	238 (30.13%)	0.853

Table 1B (Continued)

Section	Variable	Overall	Training Cohort	Internal Testing	P value
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	(n=2635)	(n=1844)	Cohort(n=791)	
Liver Cirrhosis	138 (5.24%)	98 (5.31%)	40 (5.06%)	0.849
Hepatitis	71 (2.69%)	51 (2.76%)	20 (2.53%)	0.794
Cancer	503 (19.09%)	342 (18.54%)	161 (20.38%)	0.279
Treatment/ Medication				
Antiarrhythmic agents	639 (24.25%)	457 (24.77%)	182 (23.04%)	0.347
Diuretics	450 (17.08%)	317 (17.18%)	133 (16.84%)	0.865
Calcium Channel Blocker	331 (12.56%)	235 (12.74%)	96 (12.15%)	0.701
Angiotensin-Converting Enzyme Inhibitor	749 (28.43%)	510 (27.64%)	239 (30.25%)	0.187
Beta Blocker	2183 (82.85%)	1535 (83.20%)	648 (82.03%)	0.464
Antiplatelet agents	759 (28.80%)	555 (30.08%)	204 (25.82%)	0.027
Vitamin K Antagonist	702 (26.64%)	498 (26.99%)	204 (25.82%)	0.564
Vasopressor	1533 (58.18%)	1078 (58.43%)	455 (57.59%)	0.698
Antihypertensive drugs	2197 (83.38%)	1532 (83.04%)	665 (84.18%)	0.493
Insulin	1875 (71.16%)	1307 (70.84%)	568 (71.90%)	0.606
Sulfonylureas	101 (3.83%)	67 (3.63%)	34 (4.30%)	0.438
Metformin	0 (0.00%)	0 (0.00%)	0 (0.00%)	1.000
Statins	572 (21.71%)	406 (22.01%)	166 (21.01%)	0.606
Nonsteroidal Anti-Inflammatory Drug	67 (2.54%)	45 (2.44%)	22 (2.78%)	0.591
Thyroid medication	184 (6.98%)	127 (6.88%)	57 (7.22%)	0.740
Neuromuscular Blocker	159 (6.03%)	121 (6.56%)	38 (4.81%)	0.090
Sedative and analgesic agents	1630 (61.86%)	1147 (62.17%)	483 (61.14%)	0.630
Nephrotoxic drugs	2281 (86.57%)	1598 (86.61%)	683 (86.46%)	0.901
Glucocorticoids	769 (29.18%)	550 (29.81%)	219 (27.72%)	0.283
Antibiotics	2171 (82.39%)	1532 (83.04%)	639 (80.89%)	0.199
Continuous Renal Replacement Therapy	280 (10.63%)	206 (11.17%)	74 (9.37%)	0.190
Mechanical Ventilation	2165 (82.16%)	1537 (83.31%)	628 (79.49%)	0.023
ICU physiological score				
Sequential Organ Failure Assessment	5.00 (3.00–8.00)	5.00 (3.00–8.00)	5.00 (3.00–8.00)	0.836
Simplified Acute Physiology Score II	40.00 (32.00–50.00)	41.00 (32.00–50.00)	40.00 (32.00–50.00)	0.208
Laboratory Indicators				
Hematocrit, %	33.20 (28.40 – 38.05)	33.20 (28.40 – 37.80)	33.10 (28.50 – 38.48)	0.894
Hemoglobin, g/dL	10.70 (9.10 – 12.40)	10.70 (9.10 – 12.40)	10.70 (9.20 – 12.40)	0.644

Table 1B (Continued)

Section	Variable	Overall (n=2635)	Training Cohort (n=1844)	Internal Testing Cohort(n=791)	P value
	Red cell distribution width, %	14.80 (13.70 - 16.40)	14.80 (13.80 - 16.40)	14.70 (13.60 - 16.40)	0.364
	Red blood cell count, ×10 ¹² /L	3.60 (3.10 - 4.20)	3.60 (3.10 - 4.20)	3.60 (3.10 - 4.20)	0.796
	White blood cell count, ×10 ⁹ /L	10.90 (8.10 - 15.40)	10.90 (8.00 - 15.40)	11.00 (8.20 - 15.10)	0.785
	Platelet count, ×10 ⁹ /L	196.00 (143.00 - 264.00)	194.00 (141.00 - 260.00)	199.50 (147.25 - 271.75)	0.166
	Anion gap, mmol/L	14.00 (12.00 - 17.00)	15.00 (12.00 - 17.00)	14.00 (12.00 - 16.00)	0.047
	Calcium, mg/dL	8.40 (7.90 - 8.90)	8.40 (7.90 - 8.90)	8.40 (7.90 - 8.90)	0.632
	Chloride, mmol/L	103.00 (99.00 - 107.00)	103.00 (99.00 - 107.00)	103.00 (100.00 - 107.00)	0.948
	Potassium, mmol/L	4.10 (3.80 - 4.60)	4.10 (3.70 - 4.60)	4.20 (3.80 - 4.60)	0.894
	Sodium, mmol/L	139.00 (136.00 - 141.00)	139.00 (136.00 - 141.00)	138.00 (135.00 - 141.00)	0.443
	Creatinine, mg/dL	1.10 (0.80 - 1.70)	1.20 (0.80 - 1.80)	1.10 (0.80 - 1.70)	0.176
	Blood urea nitrogen, mg/dL	25.00 (17.00 - 41.00)	26.00 (18.00 - 43.00)	24.00 (16.00 - 37.75)	0.009
	Total carbon dioxide, mmol/L	25.00 (22.00 - 28.00)	25.00 (22.00 - 28.00)	25.00 (22.00 - 28.00)	0.798
	Triglycerides, mg/dL	112.00 (79.00 - 166.00)	111.00 (79.00 - 164.00)	114.00 (79.00 - 169.00)	0.515
	Glucose, mmol/L	166.00 (79.00 - 166.00)	164.00 (79.00 - 164.00)	169.00 (79.00 - 169.00)	0.027

Table 1C. Patients aged <65 years

Section	Variable	Overall (n=814)	Training Cohort (n=570)	Internal Testing Cohort(n=244)	P value
General information					
	Male sex	588 (72.24%)	410 (71.80%)	178 (73.25%)	0.732
	Age, years	58.00 (53.00-62.00)	58.00 (53.00-62.00)	58.00 (52.00-62.00)	0.930
	Weight, kg	91.90 (75.00-111.00)	93.00 (76.00-112.50)	87.90 (73.60-109.70)	0.093
Comorbidities					
	Valvular Heart Disease	28 (3.44%)	20 (3.50%)	8 (3.29%)	1.000
	Hypertension	251 (30.84%)	184 (32.22%)	67 (27.57%)	0.214
	Cerebrovascular Accident	55 (6.76%)	39 (6.83%)	16 (6.58%)	1.000
	Heart Failure	356 (43.73%)	237 (41.51%)	119 (48.97%)	0.054
	Myocardial Infarction	107 (13.14%)	79 (13.84%)	28 (11.52%)	0.428
	Ischemic Heart Disease	304 (37.35%)	204 (35.73%)	100 (41.15%)	0.154
	Hyperthyroidism	1 (0.12%)	1 (0.18%)	0 (0.00%)	1.000
	Hypothyroidism	90 (11.06%)	71 (12.43%)	19 (7.82%)	0.066
	Metabolic Syndrome	0 (0.00%)	0 (0.00%)	0 (0.00%)	1.000
	Obesity	180 (22.11%)	131 (22.94%)	49 (20.16%)	0.407

Table 1C (Continued)

Section	Variable	Overall (n=814)	Training Cohort (n=570)	Internal Testing Cohort(n=244)	P value
	Type 2 Diabetes Mellitus	261 (32.06%)	175 (30.65%)	86 (35.39%)	0.190
	Type 1 Diabetes Mellitus	18 (2.21%)	16 (2.80%)	2 (0.82%)	0.115
	Hyperlipidemia	276 (33.91%)	194 (33.98%)	82 (33.74%)	1.000
	Obstructive Sleep Apnea	127 (15.60%)	93 (16.29%)	34 (13.99%)	0.460
	Chronic Bronchitis	72 (8.85%)	46 (8.06%)	26 (10.70%)	0.227
	Chronic Obstructive Pulmonary Disease	107 (13.14%)	73 (12.78%)	34 (13.99%)	0.651
	Pneumonia	295 (36.24%)	212 (37.13%)	83 (34.16%)	0.427
	Pulmonary Tuberculosis	20 (2.46%)	18 (3.15%)	2 (0.82%)	0.050
	Acute Kidney Injury	447 (54.91%)	320 (56.04%)	127 (52.26%)	0.356
	Chronic Kidney Disease	158 (19.41%)	114 (19.96%)	44 (18.11%)	0.563
	Liver Cirrhosis	113 (13.88%)	86 (15.06%)	27 (11.11%)	0.150
	Hepatitis	74 (9.09%)	55 (9.63%)	19 (7.82%)	0.505
	Cancer	64 (7.86%)	45 (7.88%)	19 (7.82%)	1.000
Treatment/ Medication					
	Antiarrhythmic agents	288 (35.38%)	204 (35.73%)	84 (34.57%)	0.810
	Diuretics	103 (12.65%)	72 (12.61%)	31 (12.76%)	1.000
	Calcium Channel Blocker	101 (12.41%)	69 (12.08%)	32 (13.17%)	0.728
	Angiotensin-Converting Enzyme Inhibitor	246 (30.22%)	185 (32.40%)	61 (25.10%)	0.045
	Beta Blocker	664 (81.57%)	467 (81.79%)	197 (81.07%)	0.844
	Antiplatelet agents	222 (27.27%)	165 (28.90%)	57 (23.46%)	0.122
	Vitamin K Antagonist	212 (26.04%)	150 (26.27%)	62 (25.51%)	0.862
	Vasopressor	586 (71.99%)	401 (70.23%)	185 (76.13%)	0.089
	Antihypertensive drugs	682 (83.78%)	479 (83.89%)	203 (83.54%)	0.917
	Insulin	567 (69.66%)	387 (67.78%)	180 (74.07%)	0.080
	Sulfonylureas	33 (4.05%)	24 (4.20%)	9 (3.70%)	0.847
	Metformin	0 (0.00%)	0 (0.00%)	0 (0.00%)	1.000
	Statins	114 (14.00%)	76 (13.31%)	38 (15.64%)	0.379
	Nonsteroidal Anti-Inflammatory Drug	45 (5.53%)	34 (5.95%)	11 (4.53%)	0.504
	Thyroid medication	40 (4.91%)	29 (5.08%)	11 (4.53%)	0.860
	Neuromuscular Blocker	92 (11.30%)	69 (12.08%)	23 (9.47%)	0.333
	Sedative and analgesic agents	625 (76.78%)	431 (75.48%)	194 (79.84%)	0.204
	Nephrotoxic drugs	721 (88.57%)	506 (88.62%)	215 (88.48%)	1.000
	Glucocorticoids	287 (35.26%)	200 (35.03%)	87 (35.80%)	0.873
	Antibiotics	728 (89.43%)	510 (89.32%)	218 (89.71%)	0.902
	Continuous Renal Replacement Therapy	157 (19.29%)	105 (18.39%)	52 (21.40%)	0.332

Table 1C (Continued)

Section	Variable	Overall (n=814)	Training Cohort (n=570)	Internal Testing Cohort(n=244)	P value
ICU physiological score	Mechanical Ventilation	689 (84.64%)	478 (83.71%)	211 (86.83%)	0.289
	Sequential Organ Failure Assessment	6.00 (3.00–10.00)	6.00 (3.00–9.00)	6.00 (3.00–10.00)	0.211
	Simplified Acute Physiology Score II	35.00 (27.00–47.00)	36.00 (27.00–47.00)	35.00 (27.00–47.00)	0.842
Laboratory Indicators	Hematocrit, %	33.20 (27.50–38.77)	33.40 (27.85–38.85)	32.80 (26.95–38.70)	0.262
	Hemoglobin, g/dL	10.70 (8.90–12.78)	10.80 (9.15–12.80)	10.50 (8.60–12.65)	0.192
	Red cell distribution width, %	14.80 (13.70–17.00)	14.80 (13.60–17.00)	14.70 (13.80–17.00)	0.703
	Red blood cell count, ×10 ¹² /L	3.70 (3.00–4.30)	3.70 (3.10–4.30)	3.60 (3.00–4.30)	0.412
	White blood cell count, ×10 ⁹ /L	11.15 (7.90–17.00)	11.10 (7.80–17.40)	11.20 (8.05–16.50)	0.652
	Platelet count, ×10 ⁹ /L	186.00 (120.00–260.75)	188.00 (123.50–266.00)	177.00 (115.00–253.50)	0.202
	Anion gap, mmol/L	15.00 (12.00–18.00)	15.00 (12.00–17.00)	15.00 (11.00–18.00)	0.725
	Calcium, mg/dL	8.30 (7.80–8.80)	8.30 (7.80–8.80)	8.30 (7.80–8.90)	0.985
	Chloride, mmol/L	102.00 (97.25–106.00)	102.00 (98.00–106.00)	102.00 (97.00–106.50)	0.885
	Potassium, mmol/L	4.20 (3.80–4.70)	4.20 (3.80–4.70)	4.10 (3.70–4.60)	0.329
	Sodium, mmol/L	137.00 (134.00–141.00)	137.00 (133.00–141.00)	138.00 (134.00–141.00)	0.267
	Creatinine, mg/dL	1.15 (0.80–2.10)	1.10 (0.80–2.10)	1.20 (0.80–2.10)	0.865
	Blood urea nitrogen, mg/dL	22.00 (14.00–40.00)	22.00 (14.00–40.00)	22.00 (14.00–39.50)	0.944
	Total carbon dioxide, mmol/L	24.00 (21.00–28.00)	24.00 (21.00–28.00)	26.00 (22.00–28.00)	0.004
	Triglycerides, mg/dL	135.00 (90.00–219.50)	134.00 (90.00–223.50)	142.00 (90.00–211.00)	0.568
	Glucose, mmol/L	7.30 (5.90–9.97)	7.20 (6.00–10.20)	7.30 (5.90–9.80)	0.900

Continuous variables are presented as median (interquartile range), and categorical variables are presented as n (%). P values compare the training and internal testing cohorts within the overall cohort and each age subgroup. Continuous variables were analyzed using the two-sided Wilcoxon rank-sum test, and categorical variables were analyzed using the two-sided Fisher's exact test for 2 × 2 tables. For categorical variables, n denotes the number of positive cases.

Abbreviations: MIMIC-IV, Medical Information Mart for Intensive Care IV.

Supplementary Table S2. Performance of the nine machine learning models in the external validation cohort of the overall study population

Model	AUC	Threshold	Accuracy	Sensitivity	Specificity	Precision	F1 score
Logistic regression	0.655	0.560	0.745	0.469	0.759	0.089	0.149
SVM	0.650	0.498	0.467	0.786	0.451	0.067	0.123
GBM	0.644	0.564	0.731	0.490	0.743	0.087	0.148
Neural network	0.633	0.530	0.550	0.694	0.543	0.071	0.128
KNN	0.557	0.500	0.636	0.469	0.645	0.062	0.110
XGBoost	0.659	0.500	0.627	0.633	0.627	0.078	0.139
AdaBoost	0.618	0.500	0.722	0.449	0.736	0.078	0.133
LightGBM	0.588	0.328	0.564	0.612	0.562	0.065	0.118
CatBoost	0.693	0.620	0.553	0.755	0.543	0.076	0.139

Nine machine learning models were evaluated using the final predictors selected in the overall cohort, including age, body weight, and red cell distribution width. Model performance was assessed in the external validation cohort from MIMIC-III. The classification threshold for each model represents the probability cutoff used to calculate threshold-dependent metrics. AUC is threshold-independent; accuracy, sensitivity, specificity, precision, and F1 score are threshold-dependent metrics.

Abbreviations: AUC, area under the receiver operating characteristic curve; F1, F1 score; GBM, gradient boosting machine; KNN, k-nearest neighbors; ML, machine learning; RDW, red cell distribution width; SVM, support vector machine.

Supplementary Table S3. Performance of the nine machine learning models in the external validation cohort of patients aged ≥ 65 years

Model	AUC	Threshold	Accuracy	Sensitivity	Specificity	Precision	F1 score
Logistic regression	0.642	0.461	0.492	0.738	0.479	0.070	0.128
SVM	0.649	0.515	0.497	0.750	0.484	0.072	0.131
GBM	0.627	0.487	0.604	0.625	0.602	0.077	0.138
Neural network	0.619	0.381	0.344	0.875	0.316	0.064	0.119
KNN	0.553	0.500	0.612	0.487	0.618	0.064	0.113
XGBoost	0.633	0.500	0.726	0.550	0.736	0.100	0.169
AdaBoost	0.627	0.750	0.803	0.400	0.825	0.108	0.171
LightGBM	0.607	0.242	0.479	0.738	0.465	0.069	0.125
CatBoost	0.652	0.636	0.832	0.400	0.855	0.129	0.195

Nine machine learning models were evaluated in the external validation cohort of patients aged ≥ 65 years. The classification threshold for each model represents the probability cutoff used to calculate threshold-dependent metrics. AUC is threshold-independent; accuracy, sensitivity, specificity, precision, and F1 score are threshold-dependent metrics.

Abbreviations: AUC, area under the receiver operating characteristic curve; F1, F1 score; GBM, gradient boosting machine; KNN, k-nearest neighbors; SVM, support vector machine; XGBoost, extreme gradient boosting; LightGBM, light gradient boosting machine.

Supplementary Table S4. Performance of the nine machine learning models in the external validation cohort of patients aged <65 years

Model	AUC	Threshold	Accuracy	Sensitivity	Specificity	Precision	F1 score
Logistic regression	0.766	0.324	0.496	0.944	0.478	0.066	0.124
SVM	0.771	0.527	0.680	0.833	0.674	0.091	0.164
GBM	0.756	0.372	0.594	0.889	0.583	0.077	0.142
Neural network	0.735	0.584	0.646	0.833	0.639	0.083	0.151
KNN	0.572	0.500	0.638	0.500	0.643	0.052	0.094
XGBoost	0.762	0.501	0.826	0.667	0.833	0.135	0.224
AdaBoost	0.690	0.234	0.552	0.833	0.541	0.066	0.123
LightGBM	0.646	0.958	0.644	0.667	0.643	0.068	0.124
CatBoost	0.784	0.623	0.642	0.889	0.633	0.086	0.158

Nine machine learning models were evaluated in the external validation cohort of patients aged <65 years. The classification threshold for each model represents the probability cutoff used to calculate threshold-dependent metrics. AUC is threshold-independent; accuracy, sensitivity, specificity, precision, and F1 score are threshold-dependent metrics.

Abbreviations: AUC, area under the receiver operating characteristic curve; F1, F1 score; GBM, gradient boosting machine; KNN, k-nearest neighbors; SVM, support vector machine; XGBoost, extreme gradient boosting; LightGBM, light gradient boosting machine.