

Supplementary materials

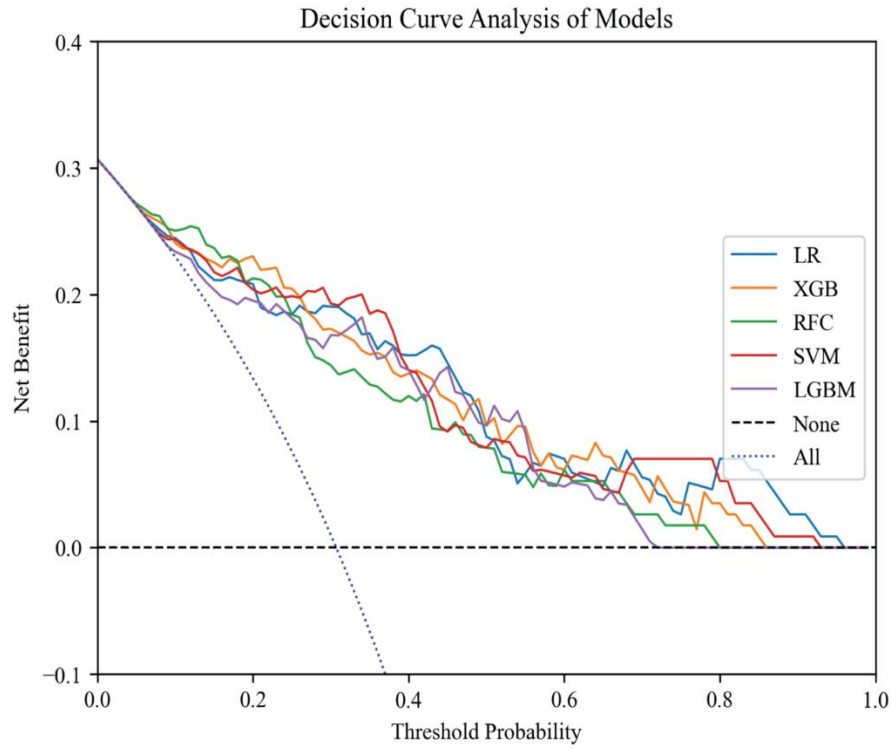


Figure S1. Decision curve analysis of the five models.

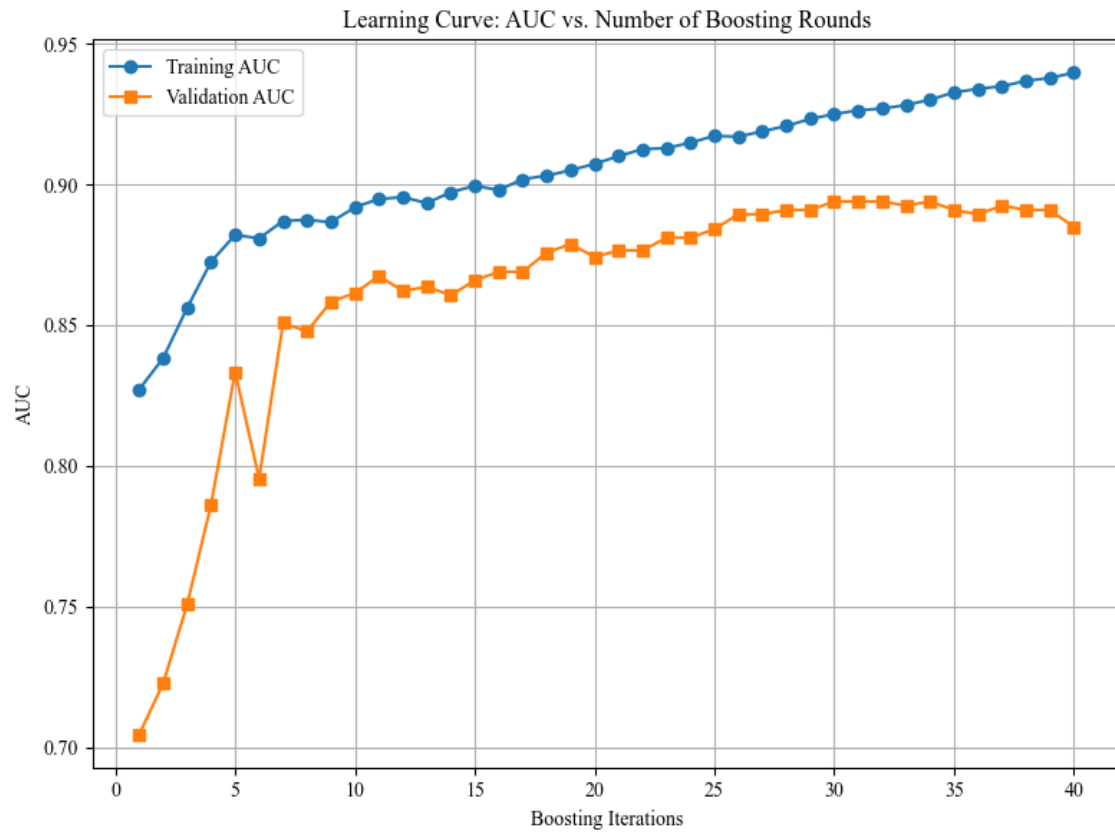


Figure S2. Learning curves: training and validation AUC over XGB iterations.

Table S1. Optimal hyperparameters for each model.

Classifier models	Hyper-parameter	Optimal value
LR	C	0.1
	Penalty	L2
	Solver	liblinear
	Class weight	balanced
XGB	N estimators	30
	Learning rate	0.09
	Max depth	3
	Gamma	0
	Min child weight	5
	Colsample bytree	1
RFC	N estimators	65
	Max depth	3
	Min samples leaf	2
	Min samples split	2
	Class weight	balanced
SVM	Kernel	linear
	C	0.5
	Gamma	0.05

LGBM	Class weight	balanced
	num_leaves	10
	learning_rate	0.01
	max_depth	15
	class_weight	balanced

LR: logistic regression; XGB: extreme gradient boosting; RFC: random forest classifier; SVM: support vector machine; LGBM: light gradient boosting machine.

Table S2. Clinical characteristics of the patients based on hemodynamic characteristics and echocardiographic parameters.

Variables		Total (<i>n</i> = 378)	Non-LCOS (<i>n</i> = 257)	LCOS (<i>n</i> = 121)	<i>p</i>-value
Hemodynamic variables					
MAP_65_time, (IQR)	median	165.00 (125.00, 220.00)	160.00 (120.00, 210.00)	190.00 (140.00, 235.00)	0.004
MAP_60_time, (IQR)	median	120.00 (85.00, 165.00)	110.00 (80.00, 150.00)	135.00 (100.00, 185.00)	0.002
MAP_55_time, (IQR)	median	80.00 (50.00, 118.75)	75.00 (45.00, 105.00)	90.00 (60.00, 140.00)	0.008
MAP_50_time, (IQR)	median	45.00 (25.00, 74.29)	45.00 (25.00, 65.00)	50.00 (25.00, 80.00)	0.138
cvp_12_time, median (IQR)		30.00 (5.00, 75.00)	25.00 (5.00, 70.00)	35.00 (10.00, 85.00)	0.125
cvp_16_time, median (IQR)		5.00 (0.00, 15.00)	0.00 (0.00, 15.00)	5.00 (0.00, 20.00)	0.008
cvp_20_time, median (IQR)		0.00 (0.00, 5.00)	0.00 (0.00, 5.00)	0.00 (0.00, 5.44)	0.018

AUT_65, median (IQR)	1,815.00 2,680.00)	(1,266.25, 1,740.00	(1,230.00, 2,495.00)	2,015.00 2,915.00)	(1,520.00, 0.011
AUT_60, median (IQR)	1,105.00 1,735.00)	(711.25, 1,070.00	(680.00, 1,575.00)	1,215.00 (800.00, 1,940.00)	0.031
AUT_55, median (IQR)	607.50 (340.00, 976.25)	560.00 (335.00, 905.00)	650.00 (360.00, 1,175.00)	0.13	
AUT_50, median (IQR)	272.50 (130.00, 476.25)	265.00 (120.00, 460.00)	285.00 (140.00, 523.70)	0.406	
AUT_cvp_12, median (IQR)	95.00 (10.00, 313.75)	80.00 (5.00, 245.00)	150.00 (20.00, 380.00)	0.016	
AUT_cvp_16, median (IQR)	5.00 (0.00, 88.75)	0.00 (0.00, 70.00)	10.00 (0.00, 190.00)	0.006	
AUT_cvp_20, median (IQR)	0.00 (0.00, 20.00)	0.00 (0.00, 15.00)	0.00 (0.00, 45.05)	0.03	
TWA_MAP_65, median (IQR)	11.25 (9.64, 13.15)	11.27 (9.60, 13.06)	11.22 (9.72, 13.32)	0.439	
TWA_MAP_60, median (IQR)	9.59 (7.78, 11.24)	9.77 (7.88, 10.94)	9.38 (7.63, 11.61)	0.938	

TWA_MAP_55, median (IQR)	8.00 (6.20, 9.49)	8.03 (6.47, 9.67)	7.75 (6.00, 9.18)	0.223
TWA_MAP_50, median (IQR)	6.32 (4.69, 7.99)	6.38 (4.67, 8.00)	6.25 (4.75, 7.94)	0.773
TWA_cvp_12, median (IQR)	2.46 (1.00, 4.63)	2.14 (1.00, 4.10)	2.73 (1.50, 5.79)	0.005
TWA_cvp_16, median (IQR)	1.00 (0.00, 3.82)	0.00 (0.00, 3.60)	1.25 (0.00, 5.00)	0.012
TWA_cvp_20, median (IQR)	0.00 (0.00, 2.00)	0.00 (0.00, 1.67)	0.00 (0.00, 3.00)	0.072
Echocardiographic parameters				
EF, median (IQR)	60.00 (50.00, 63.06)	62.00 (57.50, 64.00)	50.00 (40.00, 58.00)	<0.001
LVDs, median (IQR)	38.00 (34.00, 44.00)	36.00 (33.00, 40.00)	44.50 (39.31, 51.00)	<0.001
LVDd, median (IQR)	55.72 (51.19, 61.00)	54.00 (50.00, 58.00)	60.00 (55.80, 65.62)	<0.001
LVPW, median (IQR)	10.00 (9.00, 11.00)	10.00 (9.00, 11.00)	9.00 (9.00, 10.07)	<0.001
AOD, median (IQR)	35.00 (32.00, 37.92)	35.00 (32.00, 38.00)	35.00 (32.00, 37.19)	0.718

LA, median (IQR)	47.00 (43.00, 51.00)	46.00 (43.00, 50.34)	49.00 (44.00, 53.00)	0.003
FS, median (IQR)	32.02 (26.00, 35.00)	33.21 (30.31, 35.00)	26.00 (20.00, 31.00)	<0.001

Males and patients with LCOS are represented as numbers (%), and other variables are represented as median (interquartile range). MAP: mean arterial pressure; IQR: interquartile range; CVP: central venous pressure; AUT: area under the curve for blood pressure below the threshold; AUT-CVP: area under the curve for central venous pressure above the threshold; TWA-MAP: time weighted area under the curve for mean arterial pressure below the threshold; TWA-CVP: time weighted area under the curve for central venous pressure above the threshold; EF: ejection fraction; LCOS: low cardiac output syndrome; LVDs: left ventricular systolic diameter; LVDd: left ventricular diastolic diameter; LVPW: left ventricular posterior wall thickness; AOD: aortic diameter; LA: left atrium; FS: fractional shortening.

Table S3. Evaluation metrics for the lactate feature-exclusion models in the training cohort.

Train	AUROC	AUPRC	Brier score	Sensitivity	Specificity	PPV	NPV	Accuracy	Precision	Recall	F1-value
LR	0.839	0.735	0.152	0.826	0.719	0.587	0.895	0.754	0.587	0.826	0.686
XGB	0.922	0.874	0.112	0.849	0.831	0.709	0.919	0.837	0.709	0.849	0.772
RFC	0.912	0.859	0.139	0.872	0.764	0.641	0.925	0.799	0.641	0.872	0.739
SVM	0.839	0.734	0.153	0.791	0.725	0.581	0.878	0.746	0.581	0.791	0.670
LGBM	0.932	0.878	0.121	0.942	0.764	0.659	0.965	0.822	0.659	0.942	0.775

AUROC: area under the receiver operating characteristic curve; AUPRC: area under the precision-recall curve; PPV: positive predictive value; NPV: negative predictive value; LR: logistic regression; XGB: extreme gradient boosting; RFC: random forest classifier; SVM: support vector machine; LGBM: light gradient boosting machine.

Table S4. Evaluation metrics for the lactate feature-exclusion models in the test cohort.

Test	AUROC	AUPRC	Brier score	Sensitivity	Specificity	PPV	NPV	Accuracy	Precision	Recall	F1-value
LR	0.830	0.729	0.149	0.800	0.709	0.549	0.889	0.737	0.549	0.800	0.651
XGB	0.842	0.692	0.146	0.771	0.759	0.587	0.882	0.763	0.587	0.771	0.667
RFC	0.830	0.701	0.163	0.829	0.696	0.547	0.902	0.737	0.547	0.829	0.659
SVM	0.833	0.719	0.149	0.829	0.696	0.547	0.902	0.737	0.547	0.829	0.659
LGBM	0.838	0.701	0.152	0.800	0.646	0.500	0.879	0.693	0.500	0.800	0.615

AUROC: area under the receiver operating characteristic curve; AUPRC: area under the precision-recall curve; PPV: positive predictive value; NPV: negative predictive value; LR: logistic regression; XGB: extreme gradient boosting; RFC: random forest classifier; SVM: support vector machine; LGBM: light gradient boosting machine.

Table S5. Regularization details.

Parameter	Set value	Regularization effect
Max_depth	3	Limit the depth of each tree to prevent the trees from becoming overly complex, thereby reducing model variance.
Min_child_weight	5	The minimum sum of sample weights required for node splitting. The higher the value, the more conservative it is, which helps prevent overfitting.
Gamma	0	The minimum loss reduction required for node splitting. The default value is 0, but it can still be used in conjunction with other parameters to control complexity.
Colsample_bytree	1	Set the sampling ratio; 1 indicates the use of all features (due to the small sample size, dimensionality reduction was not performed).
Learning_rate	0.09	The learning rate is low, requiring more iterations, but each tree's contribution is small, which helps prevent overfitting.
n_estimators	30	The number of iterations is determined through cross-validation to prevent excessive rounds from leading to overfitting.