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ORIGINAL ARTICLE

Machine Learning-Based Prediction of Intraoperative Red Blood Cell Transfusion in Aortic Valve Replacement Surgery

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SUMMARY

Background: **Blood shortage is a global challenge, impacting elective surgeries with high bleeding risk. Predicting intraoperative blood use, optimizing resource allocation, and ensuring safe elective surgery are vital. This study targets identifying key bleeding risk factors in Aortic Valve Replacement (AVR) through machine learning.**
Methods: **Data from 702 AVR patients were split into 70% training and 30% test sets. Thirteen models predicted RBC transfusion. SHapley Additive exPlanations (SHAP) analyzed risk factors.**
Results: **Logistic Regression excelled, with Area Under Curve (AUC) 0.872 and 81.0% accuracy on the test set. Notably, female gender, Hemoglobin (HGB) < 131.91 g/L, Hematocrit (HCT) < 0.41L/L, weight < 59.49 kg, age > 54.47 year, Mean Corpuscular Hemoglobin (MCH) < 29.15 pg, Total Protein (TP) > 69.7 g/L, FIB > 2.61 g/L, height < 160 cm, and type of operation is Surgical Aortic Valve Replacement (SAVR) were significant RBC transfusion predictors.**
Conclusions: **The study's model accurately forecasts AVR-related RBC transfusions. This informs pre-surgery blood preparations, reducing resource waste and aiding clinicians in optimizing patient care.**
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Supplementary Data

Table S1. Variable information and univariate analysis.

Variable name	All patients	Blood transfusion		p-value
	(n = 702)	No (n = 435)	Yes (n = 267)	
Gender				
Female	242 (34.47)	84 (34.71)	158 (65.29)	< 0.001
Male	460 (65.53)	351 (76.30)	109 (23.70)	
Ethnicity				
The Han nationality	666 (94.87)	410 (61.56)	256 (38.44)	0.391
Other ethnic groups	36 (5.13)	25 (69.44)	11 (30.56)	
Type of operation				
Surgical aortic valve replacement	679 (96.72)	413 (60.82)	266 (39.18)	0.002
Transcatheter aortic valve implantation	23 (3.28)	22 (95.65)	1 (4.35)	
Age (year)	55.3 (47.68, 64.24)	53.82 (47.38, 62.56)	60.22 (49.6, 65.55)	< 0.001 *
Body weight (kg)	61.21±11.76	64.0 (57.0, 70.12)	55.0 (50.0, 64.0)	< 0.001 *
Height (cm)	161.74 ± 10.24	165.0 (160.0, 170.0)	158.0 (152.0, 164.0)	< 0.001 *
New York Heart Association (NYHA)	3.0 (2.0, 3.0)	3.0 (2.0, 3.0)	3.0 (2.0, 3.0)	0.065 *
Body mass index (BMI, kg/m^2)	23.33 ± 3.13	23.44 (21.45, 25.88)	22.57 (20.63, 24.54)	< 0.001 *
Prothrombin time (PT, seconds)	12.1 ± 3.45	11.4 (10.9, 12.1)	11.6 (11.0, 12.3)	0.137 *
Activated partial thromboplastin time (APTT, seconds)	29.4 ± 4.62	28.5 (26.5, 31.0)	28.7 (26.5, 31.6)	0.612 *
Thrombin time (TT, seconds)	19.83 ± 1.43	20.0 (19.0, 20.9)	19.6 (18.7, 20.5)	0.001 *
Fibrinogen (FIB, g/L)	2.76 ± 0.78	2.55 (2.22, 2.98)	2.74 (2.36, 3.22)	0.001 *
Total bilirubin (TBIL, μmol/L)	13.4 (10.2, 18.1)	14.1 (10.45, 19.4)	12.3 (9.75, 15.9)	< 0.001 *
Direct Bilirubin (DBIL, μmol/L)	4.4 (3.3, 5.8)	4.5 (3.5, 6.1)	4.2 (3.1, 5.2)	0.001 *
Alanine aminotransferase (ALT, IU/L)	20.0 (14.0, 28.0)	21.0 (15.0, 28.0)	19.0 (13.0, 27.0)	0.009 *
Indirect bilirubin (IBIL, μmol/L)	8.8 (6.7, 12.4)	9.5 (6.9, 13.3)	8.3 (6.4, 11.1)	< 0.001 *
Total protein (TP, g/L)	70.48 ± 5.83	70.06 ± 5.77	71.15 ± 5.87	0.016
Albumin (ALB, g/L)	44.0 (41.4, 46.3)	44.2 (41.8, 46.4)	43.6 (40.75, 46.15)	0.033 *
Globulin (GLB, g/L)	26.45 (23.7, 29.2)	26.1 (23.2, 28.3)	27.3 (24.95, 30.6)	< 0.001 *
ALB/GLB (A/G)	1.67 (1.49, 1.88)	1.71 (1.52, 1.91)	1.63 (1.38, 1.78)	< 0.001 *
Creatinine (CREA, μmol/L)	73.0 (62.0, 84.0)	74.0 (65.5, 85.0)	68.0 (56.5, 83.0)	< 0.001 *
Uric acid (UA, μmol/L)	362.0 (292.0, 430.75)	381.0 (316.0, 447.0)	322.0 (267.5, 399.5)	< 0.001 *
Aspartate aminotransferase (AST, IU/L)	23.0 (19.0, 29.0)	23.0 (19.0, 29.0)	24.0 (20.0, 30.0)	0.053 *
Glucose (GLU, mmol/L)	5.06 (4.67, 5.59)	5.06 (4.7, 5.59)	5.05 (4.66, 5.62)	0.833 *
AST/ALT (A/A)	1.17 (0.93, 1.5)	1.1 (0.88, 1.38)	1.29 (1.04, 1.67)	< 0.001 *

Table S1. Variable information and univariate analysis (continued).

Variable name	All patients	Blood transfusion		p-value
	(n = 702)	No (n = 435)	Yes (n = 267)	
Alkaline phosphatase (ALP, IU/L)	72.0 (59.0, 88.0)	71.0 (58.0, 84.5)	76.0 (61.0, 91.0)	0.009 *
Creatine kinase (CK, IU/L)	87.01 ± 63.97	78.0 (60.0, 104.5)	71.0 (51.0, 94.25)	0.001 *
Gamma-glutamyl transferase (GGT, IU/L)	22.0 (15.0, 38.75)	23.0 (16.0, 39.0)	21.0 (13.0, 36.5)	0.034 *
Lactate dehydrogenase (LDH, IU/L)	213.0 ± 69.17	193.0 (166.0, 224.5)	208.5 (180.75, 241.25)	< 0.001 *
Hydroxybutyrate dehydrogenase (HBDH, IU/L)	171.81 ± 60.53	155.0 (134.0, 181.0)	167.5 (143.0, 193.5)	< 0.001 *
Triglyceride (TG, mmol/L)	1.32 ± 0.77	1.17 (0.88, 1.67)	1.07 (0.82, 1.39)	0.002 *
Urea (UREA, mmol/L)	5.6 (4.5, 6.9)	5.6 (4.5, 6.85)	5.5 (4.6, 6.9)	0.981 *
Cholesterol (CHOL, mmol/L)	4.46 ± 1.0	4.48 (3.78, 5.17)	4.28 (3.67, 4.99)	0.066 *
High density lipoprotein cholesterol (HDL-C, mmol/L)	1.32 ± 0.4	1.25 (1.02, 1.51)	1.4 (1.07, 1.66)	< 0.001 *
Low-density lipoprotein cholesterol (LDL-C, mmol/L)	2.65 ± 0.82	2.65 (2.18, 3.24)	2.4 (1.93, 3.1)	0.001 *
Cystatin C (Cys-C, mg/L)	0.95 (0.85, 1.08)	0.94 (0.85, 1.07)	0.96 (0.85, 1.1)	0.415 *
Red blood cell (RBC, 10^{12}/L)	4.6 ± 0.6	4.7 (4.41, 5.09)	4.3 (4.01, 4.68)	< 0.001 *
Hemoglobin (HGB, g/L)	135.88 ± 18.06	143.0 (133.0, 152.0)	124.0 (115.5, 136.0)	< 0.001 *
Hematocrit (HCT, L/L)	0.41 ± 0.05	0.43 (0.41, 0.46)	0.38 (0.36, 0.42)	< 0.001 *
Mean corpuscular volume (MCV, fL)	90.19 ± 6.78	91.5 (88.28, 93.9)	90.8 (86.35, 93.75)	0.04 *
Mean corpuscular hemoglobin (MCH, pg)	29.65 ± 2.61	30.4 (29.2, 31.3)	29.6 (28.05, 30.8)	< 0.001 *
Mean corpuscular hemoglobin concentration (MCHC, g/L)	328.57 ± 11.91	331.0 (324.0, 338.0)	326.0 (317.0, 332.0)	< 0.001 *
Red cell distribution width-coefficient of variation (RDW-CV, %)	14.09 ± 1.48	13.6 (13.0, 14.32)	14.2 (13.4, 15.25)	< 0.001 *
Red cell distribution width-standard deviation (RDW-SD, fL)	46.13 ± 4.7	45.6 (43.2, 47.8)	46.6 (43.8, 49.35)	0.001 *
Platelet (PLT, 109/L)	169.19 ± 61.03	165.0 (129.0, 201.25)	159.0 (119.5, 204.0)	0.222 *
White blood cell (WBC, 109/L)	6.1 ± 2.0	5.84 (4.88, 6.99)	5.5 (4.62, 6.79)	0.022 *

*** - using the Mann-Whitney U test.**
Data are presented as mean ± SD, median (Q1, Q3), or n (%).