BMC Cardiovascular Disorders

RESEARCH

Open Access

Blood transfusion in percutaneous left atrial appendage occlusion: a nationwide analysis of incidence, predictors, and outcomes

Binbin Tian[1†], Chunbo Chen[2†], Chengzhao Huang[1†], Qiuqiang Chen[1], Junfen Cheng[3], Haiqiang Wu[4], Jian Wang[5], Junde Mo[1*], Guorong Zhong[1*] and Xiaozhuo Chen[1*]

Abstract

Background Patients with atrial fibrillation (AF) may benefit from PLAAO, a method proven to reduce the risk of stroke. However, the risk of requiring blood transfusion during the perioperative period has not been adequately evaluated.

Objectives Using a comprehensive nationwide database, this study aimed to evaluate the frequency of transfusion events, identify contributing factors, and assess clinical outcomes in individuals who underwent PLAAO.

Methods A retrospective evaluation of 61,445 PLAAO procedures, documented in the Nationwide Inpatient Sample database from 2015 to 2019, was conducted. The analysis compared patient characteristics, underlying conditions, medical complications, institutional features, and clinical results between groups requiring and not requiring transfusion support. A multivariable logistic regression model was used to identify key predictors of blood transfusion.

Results Transfusion support was necessary in 1.8% of procedures (1,090/61,445), with a decrease from 5.0% in 2015 to 1.7% by 2019. Independent factors associated with an increased need for transfusion included female sex, pre-existing conditions (chronic blood loss anemia, coagulopathy, fluid and electrolyte disorders, metastatic cancer, other neurological disorders, and peripheral vascular disorders), and complications (hemorrhage/seroma/hematoma, postoperative shock, urinary tract infections, gastrointestinal bleeding, acute heart failure, dialysis). Protective factors included elective admission and hospital location in the Midwest/North central, South, or West regions. The transfusion group experienced significantly poorer outcomes, with higher mortality (3.2% vs. 0.1%, $P<0.05$), longer hospitalizations (median 3 vs. 1 day, $P<0.05$), and greater hospital expenses (median $159,635 vs. $101,953, $P<0.05$).

Conclusion Patients undergoing PLAAO who require blood transfusion face significantly higher risks of death, extended hospital stays, and increased healthcare expenses. A thorough pre-procedure risk assessment could improve patient selection and minimize transfusion requirements.

†Binbin Tian, Chunbo Chen and Chengzhao Huang contributed equally to this work.

*Correspondence:
Junde Mo
13828292748@139.com
Guorong Zhong
13828292946@163.com
Xiaozhuo Chen
13802828074@163.com
Full list of author information is available at the end of the article

Keywords Percutaneous left atrial appendage occlusion, Blood transfusion, Risk factors, Outcomes, Nationwide inpatient sample

Background

PLAAO serves as a critical therapeutic option for stroke prevention in patients with atrial fibrillation (AF), particularly when conventional anticoagulation therapy is unsuitable or poses excessive risks [1–5]. Despite its efficacy in preventing thromboembolism, this interventional procedure carries certain risks, including significant bleeding concerns. Current data indicate that approximately 5% of individuals undergoing PLAAO require blood product support [1].

While the administration of red blood cells (RBCs) is crucial for maintaining adequate tissue oxygenation, it can lead to several complications. These adverse events include acute pulmonary compromise, volume overload, thrombotic complications, and altered immune responses [6, 7]. Additionally, the administration of blood transfusion is associated with increased healthcare utilization, higher costs, a greater likelihood of in-hospital complications, and elevated mortality rates [6, 7]. Understanding the prevalence and predictors of transfusion requirements following PLAAO procedures is essential for developing preventive strategies and optimizing patient outcomes. To our knowledge, there have been no large-scale, cross-sectional studies specifically investigating the incidence of transfusion and the associated risk factors in the PLAAO patient population.

Our investigation aims to address this knowledge gap by analyzing a nationwide database to determine the frequency of and risk factors associated with blood transfusion in patients undergoing PLAAO. We hypothesize that specific patient demographics, comorbidities, and perioperative complications significantly increase the likelihood of blood transfusion in PLAAO procedures and correlate with adverse outcomes.

Methods

Data source

Data for our study was obtained from the Healthcare Cost and Utilization Project's Nationwide Inpatient Sample (NIS), the largest all-payer hospitalization database in the United States. This resource accounts for approximately one-fifth of annual hospital discharge records from over 1,000 medical facilities across the nation [8]. The database includes comprehensive details on patient characteristics, hospital attributes such as location, capacity, and academic status, and financial metrics. As the research involved publicly accessible, de-identified data, an ethics committee review was not required.

Data collection

The investigation analyzed NIS entries from 2015 to 2019. PLAAO procedures were identified using the ICD-10-CM procedural classification 02L73DK. Cases involving transfusion were detected through specific diagnostic codes within the ICD-10-CM system. The study population excluded individuals younger than 18 years and those with missing data including death, age, gender, elective admission, LOS, race, type of insurance, bed size of hospital and total charge (Fig. 1).

Subjects were categorized into two groups based on their perioperative transfusion requirements. Our analysis compared population characteristics, institutional features, and clinical outcomes between these groups, including hospitalization duration, expenditures, and mortality rates. Pre-existing conditions and medical complications were documented using ICD-10-CM diagnostic classifications (Table 1). The complications encompassed included cardiac arrest, hemorrhage/seroma/hematoma, stroke, postoperative shock, acute myocardial infarction, deep vein thrombosis, continuous trauma ventilation, postoperative delirium, convulsion, urinary tract infections, gastrointestinal bleeding, thrombocytopenia, sepsis, dialysis, and acute heart failure (Table 1).

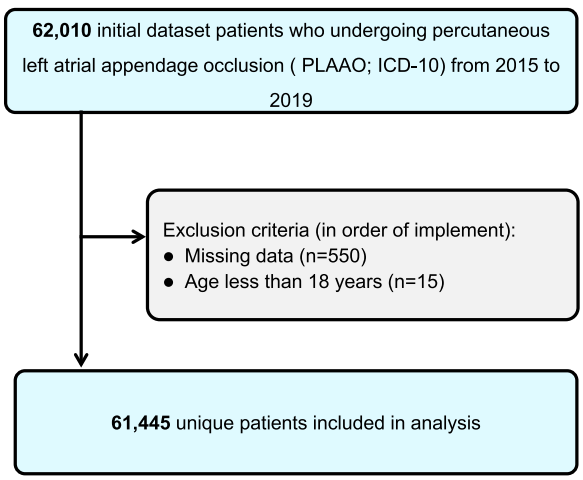

Fig. 1 Inclusion/exclusion process of PLAAO

Table 1 Variables used in binary logistic regression analysis

Variables Categories	Specific Variables
Patient demographics	Age (≤80 years and > 80 years), sex (male and female), race (White, Black, Hispanic, Asian or Pacific Islander, Native American and Other)
Hospital characteristics	Type of admission (non-elective, elective), bed size of hospital (small, medium, large), teaching status of hospital (nonteaching, teaching), location of hospital (rural, urban), location of the hospital (northeast, Midwest or north central, south, west)
Comorbidities	AIDS, alcohol abuse,deficiency anemia, rheumatoid diseases, chronic blood loss anemia, congestive,heart failure, chronic pulmonary disease, coagulopathy, depression, diabetes (uncomplicated), diabetes (with chronic complications), drug abuse, hypertension, hypothyroidism, liver disease, lymphoma, fluid and electrolyte disorders,metastatic cancer, neurological disorders, obesity, paralysis, peripheral,vascular disorders, psychoses, pulmonary circulation disorders, renal failure,solid tumor without metastasis, peptic ulcer disease, valvular disease and weight loss
Complications	cardiac arrest, hemorrhage/seroma/hematoma, stroke, postoperative shock, acute myocardial, infarction, deep vein thrombosis, continuous trauma ventilation, postoperative delirium, convulsion, urinary tract infections, gastrointestinal bleeding,thrombocytopenia, sepsis, dialysis, acute heart failure

AIDS Acquired immunodeficiency syndrome

Data analysis

Statistical evaluation was performed using SPSS software (version 25.0). Independent t-tests assessed continuous variables, and chi-square analysis was used for categorical data comparisons. To identify predictors of transfusion requirements, multivariable logistic regression was employed, incorporating patient attributes, facility characteristics, and clinical variables (Table 1). This analysis produced odds ratios with associated 95% confidence intervals, considering $p < 0.05$ as statistically significant [9]. To ensure nationally representative findings, appropriate survey weights, stratification variables, and cluster adjustments were implemented, accounting for the NIS's complex sampling methodology [5]. The risk assessment model was determined by studying the risk factors that occur in patients with PLAAO.

Results

Transfusion Frequency in PLAAO Interventions

A review of 61,445 PLAAO interventions from 2015 to 2019 indicated that blood transfusion was required in 1,090 cases, representing 1.8% of procedures. The annual transfusion rate decreased steadily from 5.0% in 2015 to 1.7% by 2019 (Fig. 2).

Patient demographics and hospital characteristics

Statistical analysis revealed significant variations in demographic and clinical parameters between patients who received transfusions and those who did not. Although the median age for both groups was 77 years, age distribution patterns differed significantly ($P = 0.016$). Women constituted a higher proportion of the transfusion recipients (51.4% compared to 41.5% in non-recipients, $P = 0.004$). Elective admissions were less common among transfusion recipients (71.6% vs. 92.2%, $P < 0.001$) (Table 2).

Clinical outcomes associated with blood transfusion

Transfusion recipients experienced less favorable health outcomes. Mortality rates during hospitalization were significantly higher in this group (3.2% compared to 0.1%, $P < 0.001$). These individuals also required longer hospital stays (median duration 3 days vs. 1 day, $P < 0.001$) and incurred higher healthcare costs

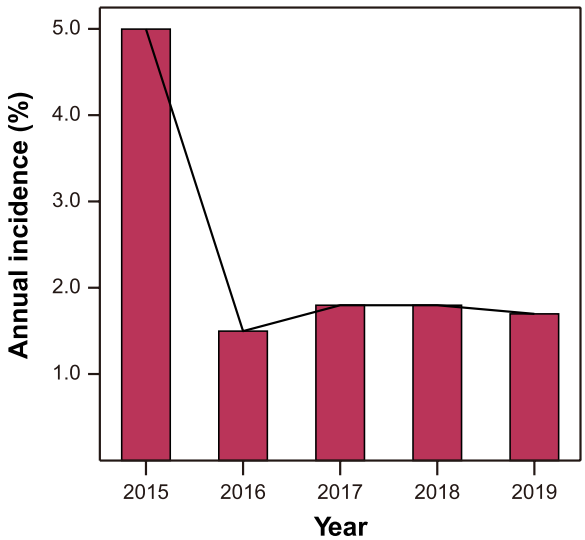

Fig. 2 Annual incidence of blood transfusion in PLAAO

($159,635 vs. $101,953, $P < 0.001$) (Table 2).

Risk Factors for Blood Transfusion

Multiple regression analysis identified several predictors of the need for transfusion: female sex (Fig. 3, Table 3), chronic blood loss anemia, coagulopathy, fluid

Table 2 Patient characteristics and outcomes after percutaneous left atrial appendage occlusion (PLAAO) (2015–2019)

Characteristics	Transfusion	No transfusion	P
Total (*n* = count)	1,090	60,355	
Total incidence (%)	1.8%		
Age (median, years)	77(72,84)	77 (71,82)	0.016
Age group (%)			
18–70	19.3	22.2	0.051
71–80	41.7	46.6	
≥ 80	39.0	31.3	
Gender (%)			
Male	48.6	58.5	0.004
Female	51.4	41.5	
Race (%)			
White	78.9	84.7	0.093
Black	7.3	4.0	
Hispanic	6.9	4.8	
Asian or Pacific Islander	1.8	1.4	
Native American	0	0.3	
Other	5.0	4.7	
LOS (median, d)	3 (1–7.25)	1 (1–1)	< 0.001
TOTCHG (median, $)	159,635 (102,284.5–217,376.5)	101,953 (75,461–146,175)	< 0.001
Bed size of hospital (%)			
Small	6.4	10.6	0.053
Medium	20.2	22.9	
Large	73.4	66.4	
Elective admission (%)	71.6	92.2	< 0.001
Type of hospital (teaching %)	85.3	88.5	0.144
Location of hospital (urban, %)	96.8	98.1	0.151
Region of hospital (%)			
Northeast	30.7	16.5	< 0.001
Midwest or North Central	11.9	22.1	
South	41.7	39.2	
West	15.6	22.2	
Died (%)	3.2	0.1	< 0.001

LOS Length of stay, TOTCHE: Total charge

and electrolyte disorders, metastatic cancer, other neurological disorders, and peripheral vascular disorders (Fig. 4).

Protective factors included elective admission and hospital locations in the Midwest/North Central, South, or West regions (Fig. 3, Table 3).

Factors Associated with Blood Transfusions during PLAAO

The requirement for blood transfusion was strongly correlated with various postoperative complications: hemorrhage/seroma/hematoma, postoperative shock, urinary tract infections, gastrointestinal bleeding, acute heart failure, and dialysis (Fig. 5). Hosmer–Lemeshow goodness of fit test shows that the model works well ($p = 0.651$).

The VIF of all variables is less than 5, and the correlation between these variables can be considered negligible.

Discussion

The management of atrial fibrillation has evolved considerably in recent years, with oral anticoagulant therapy for patients with stroke risk factors and surgical treatments (ablation/PLAAO) offering alternatives for those unsuitable for or intolerant to pharmacological approaches [10]. Patients with nonvalvular AF can be treated with PLAAO to reduce the risk of cardiogenic stroke, but the probability of postoperative massive bleeding is higher

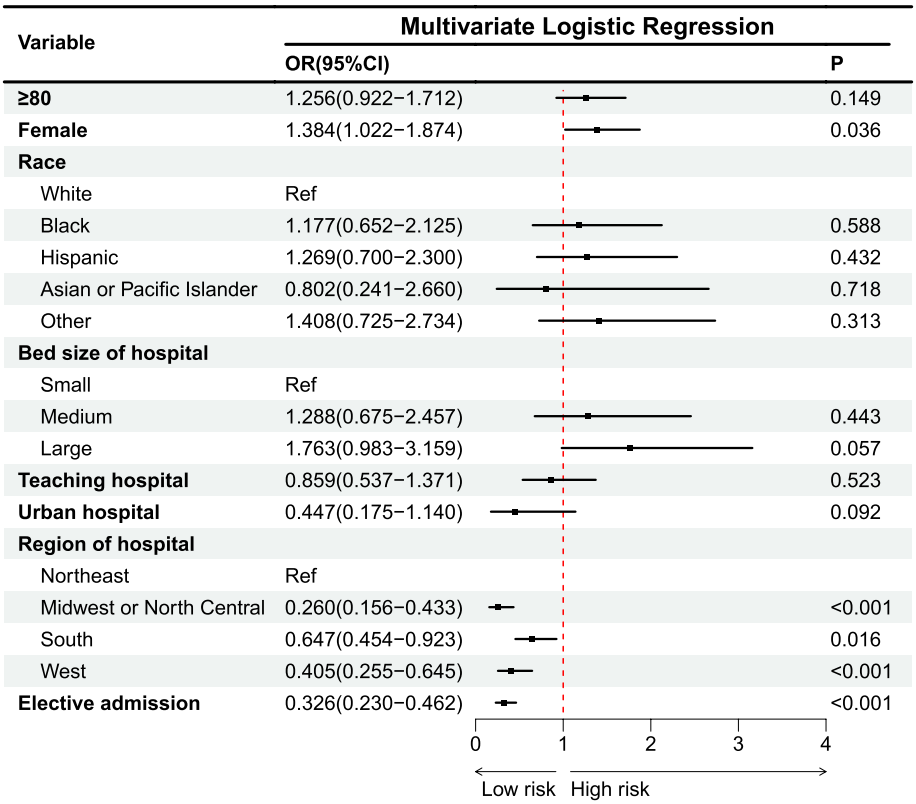

Fig. 3 Risk factors associated with blood transfusion in PLAAO

Table 3 Risk factors associated with transfusion in PLAAO

Variable	Multivariate Logistic Regression		
	OR	95% CI	P
≥80	1.256	0.922–1.712	0.149
Female	1.384	1.022–1.874	0.036
Race			
White	Ref	——	——
Black	1.177	0.652–2.125	0.588
Hispanic	1.269	0.700–2.300	0.432
Asian or Pacific Islander	0.802	0.241–2.660	0.718
Other	1.408	0.725–2.734	0.313
Bed size of hospital			
Small	Ref	——	——
Medium	1.288	0.675–2.457	0.443
Large	1.763	0.983–3.159	0.057
Teaching hospital	0.859	0.537–1.371	0.523
Urban hospital	0.447	0.175–1.140	0.092
Region of hospital			
Northeast	Ref	——	——
Midwest or North Central	0.260	0.156–0.433	< 0.001
South	0.647	0.454–0.923	0.016
West	0.405	0.255–0.645	< 0.001
Elective admission	0.326	0.230–0.462	< 0.001

AIDS Acquired immunodeficiency syndrome, *OR* Odds ratio, *CI* Confidence interval

Comorbidities	Univariate Analysis			Multivariate Logistic Regression	
	No transfusion	Transfusion	P	OR(95%CI)	P
Preoperative comorbidities					
Acquired immune deficiency syndrome	50 (0.1%)	0 (0%)	0.671	0.930(0.742−1.167)	0.531
Alcohol abuse	695 (1.2%)	20(1.8%)	0.351	0.912(0.263−3.164)	0.885
Deficiency anemia	1930 (3.2%)	60 (5.5%)	0.057	1.047(0.540−2.028)	0.893
Rheumatoid arthritis/collagen vascular diseases	1500 (2.5%)	40 (3.7%)	0.268	1.067(0.483−2.358)	0.872
Chronic blood loss anemia	1030 (1.7%)	85 (7.8%)	<0.001	3.723(2.102−6.595)	<0.001
Congestive heart failure	20,505 (34.0%)	580 (53.2%)	<0.001	1.275(0.912−1.783)	0.156
Chronic pulmonary disease	13,100 (21.7%)	295 (27.1%)	0.058	1.051(0.746−1.480)	0.777
Coagulopathy	2425 (4.0%)	245 (22.5%)	<0.001	4.817(2.801−8.284)	<0.001
Depression	4665 (7.7%)	100 (9.2%)	0.429	0.943(0.558−1.592)	0.826
Diabetes, uncomplicated	11530 (19.1%)	175 (16.1%)	0.256	1.066(0.702−1.618)	0.765
Diabetes with chronic complications	9840 (16.3%)	255 (23.4%)	0.005	0.849(0.566−1.275)	0.430
Drug abuse	115 (0.2%)	15 (1.4%)	<0.001	4.522(0.984−20.780)	0.052
Hypertension	52285 (86.6%)	975 (89.4%)	0.225	1.273(0.753−2.152)	0.367
Hypothyroidism	10,685 (17.7%)	230 (21.1%)	0.193	0.987(0.680−1.433)	0.946
Liver disease	1730 (2.9%)	90 (8.3%)	<0.001	1.479(0.813−2.690)	0.200
Lymphoma	300 (0.5%)	10 (0.9%)	0.385	0.666(0.090−4.929)	0.691
Fluid and electrolyte disorders	2,270 (3.8%)	205 (18.8%)	<0.001	2.307(1.472−3.615)	<0.001
Metastatic cancer	195 (0.3%)	20 (1.8%)	<0.001	3.632(1.113−11.853)	0.033
Other neurological disorders	515 (0.9%)	65 (6.0%)	<0.001	2.501(1.054−5.937)	0.038
Obesity	10305 (17.1%)	150 (13.8%)	0.197	0.652(0.421−1.010)	0.055
Paralysis	315 (0.5%)	10 (0.9%)	0.425	0.512(0.092−2.858)	0.446
Peripheral vascular disorders	6310(10.5%)	220(20.2%)	<0.001	1.728(1.178−2.537)	0.005
Psychoses	515 (0.9%)	15 (1.4%)	0.408	0.856(0.212−3.452)	0.827
Pulmonary circulation disorders	3735 (6.2%)	125 (11.5%)	0.001	1.189(0.740−1.910)	0.474
Renal failure	13525 (22.4%)	415 (38.1%)	<0.001	1.439(0.995−2.082)	0.053
Solid tumor without metastasis	1020 (1.7%)	55 (5.0%)	<0.001	1.854(0.903−3.807)	0.092
Peptic ulcer disease excluding bleeding	465(0.8%)	5(0.5%)	<0.001	0.582(0.079−4.312)	0.597
Valvular disease	12530 (20.8%)	370 (33.9%)	<0.001	1.248(0.894−1.741)	0.193
Weight loss	245 (0.4%)	15 (1.4%)	0.029	0.540(0.135−2.168)	0.385

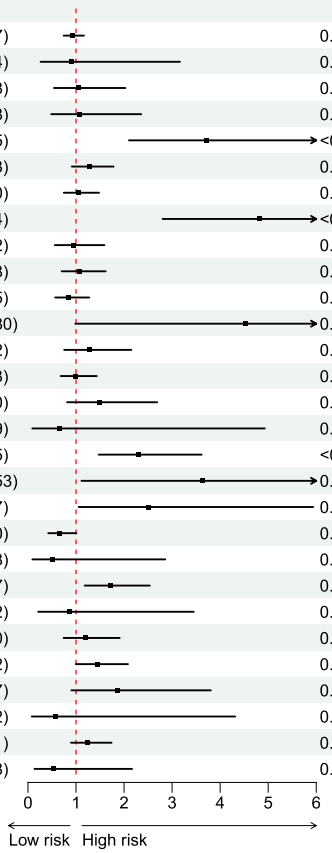

Fig. 4 Relationship between blood transfusion and preoperative comorbidities

Complications	Univariate Analysis			Multivariate Logistic Regression	
	No transfusion	Transfusion	P	OR(95%CI)	P
Medical complications					
Cardiac arrest	75 (0.1%)	20 (1.8%)	<0.001	3.659(0.862−15.533)	0.079
Hemorrhage/seroma/hematoma	210 (0.3%)	75 (6.9%)	<0.001	14.754(6.931−31.407)	<0.001
Stroke	1625 (2.7%)	40 (3.7%)	0.378	1.088(0.503−2.353)	0.830
Postoperative Shock	45 (0.1%)	30 (2.8%)	<0.001	13.148(3.498−49.423)	<0.001
acute myocardial infarction	120 (0.2%)	15 (1.4%)	<0.001	1.000(0.175−5.713)	1.000
Deep vein thrombosis	65 (0.1%)	10 (0.9%)	0.001	0.277(0.007−10.425)	0.488
Continuous trauma Ventilation	460 (0.8%)	35 (3.2%)	<0.001	1.540(0.610−3.886)	0.361
Postoperative Delirium	135 (0.2%)	25 (2.3%)	<0.001	1.680(0.428−6.594)	0.457
Convulsion	145 (0.2%)	5 (0.5%)	0.517	1.998(0.214−18.628)	0.543
UTIs	510 (0.8%)	60 (5.5%)	<0.001	3.289(1.473−7.346)	0.004
Gastrointestinal bleeding	1220 (2.0%)	95 (8.7%)	<0.001	2.777(1.560−4.942)	0.001
Thrombocytopenia	1415 (2.3%)	135 (12.4%)	<0.001	0.853(0.426−1.708)	0.654
Sepsis	95 (0.2%)	20 (1.8%)	<0.001	0.843(0.212−3.356)	0.809
Dialysis	785 (1.3%)	60 (5.5%)	<0.001	2.267(1.084−4.741)	0.030
Acute heart failure	1465 (2.4%)	160 (14.7%)	<0.001	2.528(1.519−4.209)	<0.001

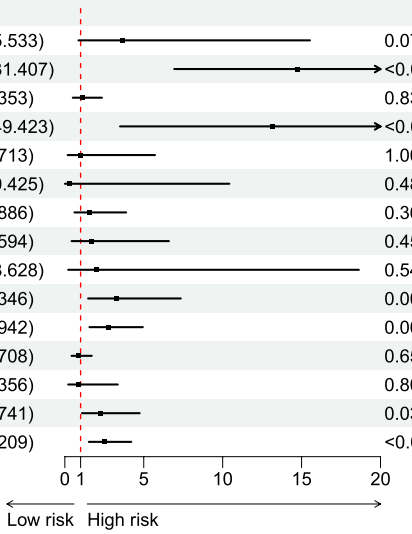

Fig. 5 Relationship between blood transfusion and postoperative complications

[11]. This study provides a comprehensive evaluation of blood transfusion frequency and its determinants following PLAAO procedures. Our research identified multiple significant predictors of transfusion requirements, including patient sex, underlying health conditions, hospital setting, medical complications. Earlier research exploring transfusion risk factors in this context was predominantly published as brief letter, lacking sufficient statistical power due to limited participant numbers [1]. Understanding these factors is crucial for developing targeted prevention strategies.

The observed downward trend in transfusion requirements from 2015 (5%) to 2019 (1.7%) (Fig. 2) can be attributed to several advancements: improved operative techniques, device improvements, adoption of conservative transfusion strategies, enhanced blood conservation methods, and improved adherence to transfusion guidelines [1, 12–15].Our analysis revealed an aggregate transfusion rate of 1.8%, markedly lower than the previously reported rate of 5% [1]. This reduction is likely due to two key factors. First, variation in data sources exist between studies, as previous investigations utilized multi-institutional registries with relatively small cohorts of 396 participants [1, 16]. Second, the temporal gap in data collection reflects ongoing improvements in surgical approaches and clinical practices [17]. Future prospects indicate potential for further reductions in transfusion frequency through enhanced blood management protocols and increased focus on high-risk patient populations [15].

Our study demonstrated that being female is a significant independent predictor of requiring blood transfusions during the perioperative period (Fig. 3 and Table 3). Clinical data strongly supports this gender-specific risk pattern [18–20]. The increased transfusion requirements among female patients can be attributed to their higher susceptibility to complications and generally less favorable clinical outcomes [18, 20]. Studies have shown that women tend to experience greater age-related thickening and stiffness of blood vessels as they age than men, which puts women at higher risk for bleeding [21]. Furthermore, the correlation between gender and transfusion needs seems partly rooted in basic physiological differences: women's normal hemoglobin ranges are characteristically lower than men's, yet current practice rarely incorporates sex-specific adjustments to transfusion threshold values [19, 20].

Our study corroborates existing findings that blood transfusions are associated with prolonged hospital stays, increased healthcare costs, and elevated mortality rates (Table 2). Notably, each unit of blood transfused is associated with an approximate direct cost of $2,500 to the hospital, aside from contributing to a higher frequency of perioperative complications [22–27]. Research by Murphy and colleagues highlights a significantly higher mortality risk, six times greater within 30 days in patients undergoing cardiac surgery who received transfusions compared to their non-transfused counterparts [25].

Elective admissions are associated with lower requirements for blood transfusions, likely due to superior preoperative patient health and adequate preparation time [23]. Supporting this, Long and colleagues found that emergency admissions considerably elevate the probability of needing perioperative blood transfusions in the surgical treatment of colorectal cancer liver metastases, as evidenced by their analysis of U.S. NIS data [28]. The proportion of patients undergoing PLAAO among elective admissions was significantly higher at Northeast Hospital compared to other regions, potentially identifying Northeast Hospital as a risk factor in this cohort (Fig. 6). Geographic disparities in U.S. transfusion rates reflect variability in healthcare technology access, institutional protocols, socioeconomic disparities, and guideline adherence across healthcare facilities [17, 29, 30].

The identification of preoperative risk factors is essential in reducing the necessity for blood transfusions during surgical procedures [23]. Schiergens and colleagues highlighted key predictors, such as female gender, existing anemia, and significant operative blood loss, corroborating our research [28]. Our research identified correlations between medical conditions and transfusion requirements, particularly in patients with anemia, coagulopathies, and electrolyte imbalances, due to compromised hemoglobin levels [17, 23, 26, 31]. The transfusion further alters coagulation dynamics, resulting in dilutional phenomena and consumption coagulopathy, which, coupled with diminished platelet counts, may worsen outcomes for those with existing clotting abnormalities [32]. Munting and associates have also noted that insufficient preoperative hemoglobin levels can necessitate the deferral of surgeries while interventions are applied to improve hemoglobin concentrations [33].

Our study revealed that metastatic cancer significantly predicts the need for blood transfusions during surgical procedures (Fig. 4), affirming the hypothesis that patients in poor health are more susceptible to surgical blood loss [23]. Additionally, the study identified risk factors like peripheral vascular and neurological disorders. Huang et al. note surgical stress increases transfusion needs in patients with circulatory disorders [16]. Clinical data also shows that the blood transfusion correlates with a higher occurrence of infections, respiratory complications, blood-borne infections, and adverse cardiac outcomes [7]. These results highlight the critical need for early detection of patients at high risk for transfusions,

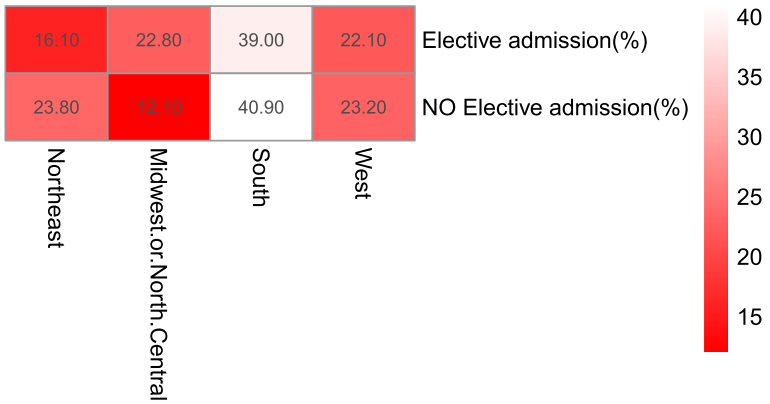

Fig. 6 Geographic differences of institutional-level factor

promoting prompt participation in PBM programs to lessen dependency on transfusions [34].

Moreover, our study links post-PLAAO blood transfusions to acute heart failure, due to blood rheology changes affecting circulatory volume and cardiac stress, consistent with previous transfusion-related findings. [15, 23]. Our research also identified a significant association between UTIs and transfusions post-PLAAO (Fig. 5). The implicated mechanism, Transfusion-Related Immune Modulation (TRIM), temporarily diminishes immune function, compromising the body's defenses [22, 26, 28, 35, 36]. Furthermore, infections following surgery activate immune-mediated coagulation pathways, complicating the clinical environment by reducing blood volume and simultaneously increasing transfusion requirements [16]. Meta-analytical studies by Hill and associates have shown that transfusion recipients are over three times more likely to develop systemic infections post-surgery [32]. Our research confirms blood transfusion's link to complications (hemorrhage/seroma/hematoma, postoperative shock, gastrointestinal bleeding). Studies attribute these to reduced hemoglobin and increased bleeding susceptibility [17]. Additionally, our study revealed transfusion needs correlate with dialysis procedures, possibly due to enhanced red blood cell breakdown or compromised production in dialysis patients [37].

The study identified the risk factors for blood transfusion in PLAAO patients, and clinicians adopted more precise anticoagulation strategies based on the patient's risk factors. Studies have shown that different anticoagulation strategies help improve patient outcomes [38].

Limitation

This study presents several inherent limitations that merit attention. The reliance on administrative datasets introduces notable constraints, especially in terms of accessing detailed clinical metrics like specific measurements of blood loss, perioperative hemoglobin levels, and precise quantities of blood products used. Additionally, our dataset does not include details on the management of medications prior to procedures, particularly concerning protocols for anticoagulation and antiplatelet therapies, which are critical factors influencing bleeding outcomes. Due to the observational nature of this study, we are limited to identifying associations, not establishing causality. While the substantial size of our cohort provides robust statistical power, we must recognize that variations in coding practices over time and potential coding inaccuracies could influence the interpretation of our results. Our analysis was confined to inpatient data, precluding us from assessing complications or outcomes that occurred post-discharge and outpatient procedures. However, the broad scope of our patient base and the inclusion of multiple institutions still allow us to offer valuable perspectives on transfusion needs and related risk factors during left atrial appendage closure procedures.

Conclusion

Our research shows blood transfusion rates in PLAAO procedures decreased from 5.0% to 1.7% between 2015–2019. Female patients and those with pre-existing conditions showed higher transfusion risks. Major complications included hemorrhage, shock, UTIs, gastrointestinal bleeding, heart failure, and dialysis requirement. Transfusion recipients experienced extended hospitalizations, increased complications, higher costs, and elevated mortality. These findings emphasize the importance of thorough pre-procedural risk assessment and optimization strategies to improve PLAAO outcomes.

Abbreviations

AF	Atrial Fibrillation
PLAAO	Percutaneous Left Atrial Appendage Occlusion
RBC	Red Blood Cell
NIS	Nationwide Inpatient Sample

ICD-10-CM	International Classification of Diseases, Tenth Revision, Clinical Modification
PBM	Patient Blood Management
TRIM	Transfusion-Related Immune Modulation
UTIs	Urinary Tract Infections

Acknowledgements
Not applicable.

Clinical trial number
Not applicable.

Authors' contributions
BT, CC, and CH were involved in the study design, data collection and analysis, result interpretation, as well as drafting and revising the manuscript. QC, HW and JC participated in the study design, result interpretation, and critical review of the manuscript. JW was responsible for data collection, analysis, and manuscript review. XC, JM and GZ contributed to designing the study, interpreting the results, and providing critical revisions. All authors have read and approved the final version of the manuscript.

Funding
1.National Natural Science Foundation of China (82172162 to Chunbo Chen).
2.National Natural Science Foundation of China (82,472,211 to Chunbo Chen).
3.Major Program of Summit Project, Guangdong Province High-level Hospital Construction Project of Guangdong Provincial People's Hospital, Guangdong Academy of Medical Sciences (DFJH2020028 to Chunbo Chen).

Data availability
This study is based on data provided by Nationwide Inpatient Sample (NIS) database, part of the Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality. The NIS database is a large publicly available full-payer inpatient care database in the United States and the direct web link to the database is https://www.ahrq.gov/data/hcup/index.html.Therefore, individual or grouped data cannot be shared by the authors.

Declarations

Ethics approval and consent to participate
Human Ethics and Consent to Participate declarations: not applicable. This article does not contain any studies with human participants or animals performed by any of the authors. This observational study was deemed exempt by the Institutional Review Board of Central People's Hospital of Zhanjiang because it used deidentified publicly available data.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Present Address: Department of Critical Care Medicine, Central People's Hospital of Zhanjiang, Zhanjiang 524045, Guangdong, China. [2]Present Address: Department of Critical Care Medicine, Shenzhen People's Hospital, The Second Clinical Medical College of Jinan University, The First Affiliated Hospital of South University of Science and Technology, Shenzhen 518020, China. [3]Department of Respiration, The Second Affiliated Hospital of Guangdong Medical University, Zhanjiang, Guangdong 524002, China. [4]Department of Neurosurgery II, Central People's Hospital of Zhanjiang, Zhanjiang, Guangdong 524045, China. [5]Division of Orthopaedic Surgery, Department of Orthopaedics, Nanfang Hospital, Southern Medical University, Guangzhou, Guangdong 510515, China.

Received: 10 December 2024 Accepted: 12 March 2025
Published online: 22 April 2025

References

1. Parodi G, Sanna GD, Stolcova M, Pastormerlo LE, Forteleoni A, Maiani S, Koni E, Meucci F, Talanas G, Di Mario C, et al. Hemoglobin trajectories and blood transfusions associated with percutaneous left atrial appendage occlusion. JACC Cardiovasc Interv. 2020;13(3):397–9.
2. Halperin JL, Rothman KJ. Initial antithrombotic therapy after percutaneous left atrial appendage occlusion: shifting approaches to a moving target. J Am Coll Cardiol. 2023;82(18):1774–6.
3. Reinhardt SW, Gibson DN, Hsu JC, Kapadia SR, Yeh RW, Price MJ, Piccini JP, Nair DG, Christen T, Allocco DJ, et al. Anticoagulation alone vs anticoagulation plus aspirin or DAPT following left atrial appendage occlusion. J Am Coll Cardiol. 2024;84(10):889–900.
4. Aarnink EW, Ince H, Kische S, Pokushalov E, Schmitz T, Schmidt B, Gori T, Meincke F, Protopopov AV, Betts T, et al. Incidence and predictors of 2-year mortality following percutaneous left atrial appendage occlusion in the EWOLUTION trial. Europace. 2024;26(7):euae188. https://doi.org/10.1093/europace/euae188.
5. Messele LF, Khan MZ, Darden D, Agarwal S, Krishan S, Pasupula DK, Ul Abideen Asad Z, Balla S, Singh GD, Srivatsa UN, et al. Outcomes of percutaneous left atrial appendage occlusion device implantation in atrial fibrillation patients based on underlying stroke risk. Europace. 2023;25(4):1415–22.
6. Coz Yataco AO, Soghier I, Hébert PC, Belley-Cote E, Disselkamp M, Flynn D, Halvorson K, Iaccarino JM, Lim W, Lindenmeyer CC, et al. Red blood cell transfusion in critically ill adults: an American College of Chest Physicians clinical practice guideline. Chest. 2024;167(2):477–89.
7. Morris FJD, Åhman R, Craswell A, Didriksson H, Jonsson C, Gisselgård M, Andersson HA, Fung YL, Chew MS. Effect of perioperative blood transfusion on preoperative haemoglobin levels as a risk factor for long-term outcomes in patients undergoing major noncardiac surgery: a prospective multicentre observational study. Br J Anaesth. 2024;133(6):1183–91.
8. Swanson J, Ailes EC, Cragan JD, Grosse SD, Tanner JP, Kirby RS, Waitzman NJ, Reefhuis J, Salemi JL. Inpatient Hospitalization Costs Associated with Birth Defects Among Persons Aged <65 Years - United States, 2019. MMWR Morb Mortal Wkly Rep. 2023;72(27):739–45.
9. Mao X, Liang C, Li X, Shi D, Yang Q, Xie H, Liang F, Cui Y. The impact of long-term aspirin use on the patients undergoing shoulder arthroplasty. J Orthop Surg Res. 2023;18(1):894.
10. Lip GYH, Tse HF, Lane DA. Atrial fibrillation. Lancet. 2012;379(9816):648–61.
11. Shrestha B, Poudel B, Poudel D, Diaz Fraga J. National Yearly Trend of Utilization and Procedural Complication of the Watchman Device in the United States. Cureus. 2022;14(6): e25567.
12. Goel R, Zhu X, Patel EU, Crowe EP, Ness PM, Katz LM, Bloch EM, Tobian AAR. Blood transfusion trends in the United States: national inpatient sample, 2015 to 2018. Blood Adv. 2021;5(20):4179–84.
13. Nazir S, Ahuja KR, Kolte D, Isogai T, Michihata N, Saad AM, Ramanathan PK, Krishnaswamy A, Wazni OM, Saliba WI, et al. Association of hospital procedural volume with outcomes of percutaneous left atrial appendage occlusion. JACC Cardiovasc Interv. 2021;14(5):554–61.
14. Gofus J, Zacek P, Shahin Y, Medilek K, Haman L, Vojacek J. Left atrial appendage occlusion: Percutaneous and surgical approaches in everyday practice. Kardiol Pol. 2024;82(3):267–75.
15. Jeschke E, Citak M, Halder AM, Heller KD, Niethard FU, Schräder P, Zacher J, Leicht H, Malzahn J, Günster C, et al. Blood transfusion and venous thromboembolism trends and risk factors in primary and aseptic revision total hip and knee arthroplasties: a nationwide investigation of 736,061 cases. Orthopaed Traumatol Surg Res OTSR. 2022;108(1):102987.
16. Huang Y, Wang Z, Yang Q, Xie H, Wu J, Chen K. Incidence and risk factors of blood transfusion after total knee arthroplasty: A retrospective nationwide inpatient sample database study. Heliyon. 2024;10(14): e34406.
17. Chen C, Zhu B, Wang Y, Zhao Y, Chen G, Peng Y, Peng Y, Wang X, Xie H, Zhou Y, et al. Incidence and risk factor of blood transfusion after abdominal radical hysterectomy for cervical cancer: a 10-year retrospective study of the US nationwide inpatient sample. BMC Cancer. 2024;24(1):1454.
18. Koettnitz J, Migliorini F, Peterlein CD, Götze C. Same-gender differences in perioperative complications and transfusion management for lower limb arthroplasty. BMC Musculoskelet Disord. 2023;24(1):653.
19. Dai CQ, Wang LH, Zhu YQ, Xu GH, Shan JB, Huang WC, Wei LH, Zhou FL, Li Y. Risk factors of perioperative blood transfusion in elderly patients with femoral intertrochanteric fracture. Medicine. 2020;99(15): e19726.

20. Song K, Pan P, Yao Y, Jiang T, Jiang Q. The incidence and risk factors for allogenic blood transfusion in total knee and hip arthroplasty. J Orthop Surg Res. 2019;14(1):273.
21. Martin WH, Ogawa T, Kohrt WM, Malley MT, Korte E, Kieffer PS, Schechtman KB. Effects of aging, gender, and physical training on peripheral vascular function. Circulation. 1991;84(2):654–64.
22. Sun RC, Button AM, Smith BJ, Leblond RF, Howe JR, Mezhir JJ. A comprehensive assessment of transfusion in elective pancreatectomy: risk factors and complications. J Gastrointest Surg : Off J Soc Surg Alimentary Tract. 2013;17(4):627–35.
23. Li X, Xie H, Liu S, Wang J, Shi Z, Yao Q, Yang Q, Li Q, Bao L. Analysis of the incidence and risk factors of blood transfusion in total knee revision: a retrospective nationwide inpatient sample database study. BMC Musculoskelet Disord. 2024;25(1):225.
24. Chen LY, Wang JQ, Zhao YM, Feng YZ. Construction and validation of a nomogram for blood transfusion after open reduction and internal fixation (ORIF) of proximal humeral fractures in the elderly: a cross-sectional study. BMC Musculoskelet Disord. 2024;25(1):530.
25. Murphy GJ, Reeves BC, Rogers CA, Rizvi SI, Culliford L, Angelini GD. Increased mortality, postoperative morbidity, and cost after red blood cell transfusion in patients having cardiac surgery. Circulation. 2007;116(22):2544–52.
26. Cao X, Liu X, Zhang X, Zhang K, Chen C, Yang Q, Wang J, Li X, Wei L. Risk factors for perioperative blood transfusion in patients undergoing total laparoscopic hysterectomy. BMC Womens Health. 2024;24(1):65.
27. Mistry JB, Gwam CU, Naziri Q, Pivec R, Abraham R, Mont MA, Delanois RE. Are Allogeneic Transfusions Decreasing in Total Knee Arthroplasty Patients? National Inpatient Sample 2009–2013. J Arthroplasty. 2018;33(6):1705–12.
28. Long B, Xiao ZN, Shang LH, Pan BY, Chai J. Impact of perioperative transfusion in patients undergoing resection of colorectal cancer liver metastases: A population-based study. World J Clin Cases. 2019;7(10):1093–102.
29. Mumo E, Agutu NO, Moturi AK, Cherono A, Muchiri SK, Snow RW, Alegana VA. Geographic accessibility and hospital competition for emergency blood transfusion services in Bungoma, Western Kenya. Int J Health Geogr. 2023;22(1): 6.
30. Daichman S, Ostrovsky D, Dreiher J, Pikovsky O. Does training make a difference? Proficiency training in transfusion guidelines and its effect on red blood cell administration. Transfusion. 2022;62(5):1121–7.
31. Viola J, Gomez MM, Restrepo C, Maltenfort MG, Parvizi J. Preoperative anemia increases postoperative complications and mortality following total joint arthroplasty. J Arthroplasty. 2015;30(5):846–8.
32. Turan A, Yang D, Bonilla A, Shiba A, Sessler DI, Saager L, Kurz A. Morbidity and mortality after massive transfusion in patients undergoing noncardiac surgery. Can J Anaesth. 2013;60(8):761–70.
33. Munting KE, Klein AA. Optimisation of pre-operative anaemia in patients before elective major surgery - why, who, when and how? Anaesthesia. 2019;74(Suppl 1):49–57.
34. Guo J, He Q, Li Y. Development and validation of machine learning models to predict perioperative transfusion risk for hip fractures in the elderly. Ann Med. 2024;56(1): 2357225.
35. Abreu A, Máximo J, Almeida C, Lourenço A, Leite-Moreira A. The additive effects of anaemia and transfusion on long-term survival after coronary artery bypass surgery. Eur J Cardiothorac Surg. 2024;65(3):403.
36. Boer C, Meesters MI, Milojevic M, Benedetto U, Bolliger D, von Heymann C, Jeppsson A, Koster A, Osnabrugge RL, Ranucci M, et al. 2017 EACTS/EACTA Guidelines on patient blood management for adult cardiac surgery. J Cardiothorac Vasc Anesth. 2018;32(1):88–120.
37. Vashistha T, Streja E, Molnar MZ, Rhee CM, Moradi H, Soohoo M, Kovesdy CP, Kalantar-Zadeh K. Red cell distribution width and mortality in hemodialysis patients. Am J Kidney Dis. 2016;68(1):110–21.
38. Mohanty S, Torlapati PG, La Fazia VM, Kurt M, Gianni C, MacDonald B, Mayedo A, Allison J, Bassiouny M, Gallinghouse GJ, et al. Best anticoagulation strategy with and without appendage occlusion for stroke prophylaxis in postablation atrial fibrillation patients with cardiac amyloidosis. J Cardiovasc Electrophysiol. 2024;35(7):1422–8.

Publisher's Note