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ORIGINAL RESEARCH

New-Onset Postoperative Atrial Fibrillation After Total Arch Repair Is Associated With Increased In-Hospital Mortality

Rui Zhao, MD*; Zhao Wang, MD*; Fangfang Cao, MD; Jian Song, MD; Shuya Fan, MD; Juntao Qiu, MD; Xiaohan Fan, MD; Cuntao Yu, MD

BACKGROUND: It is well established that postoperative atrial fibrillation (POAF) is associated with adverse postoperative outcomes after major cardiac operations. The purpose of this study was to investigate the incidence of new-onset POAF after successful total arch repair surgery and the association between POAF and in-hospital mortality.

METHODS AND RESULTS: All consecutive patients undergoing total arch repair from September 2012 to December 2019 in Fuwai hospital were enrolled (n=1280). Patients diagnosed with preoperative atrial fibrillation were excluded. POAF was diagnosed as the new-onset atrial fibrillation or flutter for more than 5 minutes based on continuous electrocardiogram monitoring. A logistic regression model was used to determine predictors of in-hospital mortality. Multivariable adjustment, inverse probability of treatment weighting, and propensity score matching were used to adjust for confounders. POAF was diagnosed in 32.3% (411/1271) of this cohort population. The occurrence of new-onset POAF was associated with age (odds ratio [OR], 1.05; 95% CI, 1.04–1.06; *P*<0.001), male sex (OR, 0.72; 95% CI, 0.52–0.98; *P*=0.035), and surgery duration (OR, 1.2; 95% CI, 1.12–1.28; *P*<0.001). The in-hospital mortality was significantly higher in patients with POAF than those without POAF (10.7% versus 2.4%, *P*<0.001). Inverse probability of treatment weighting and propensity score matching analyses confirmed the results. The increased in-hospital mortality in POAF group still existed among subgroup analysis based on different age, sex, hypertension, smoking, and hypokalemia, combined with cardiac surgery, and deep hypothermic circulatory arrest.

CONCLUSIONS: More careful attention should be given to POAF after total arch repair surgery. The incidence of POAF after total arch repair surgery was 32.3% and associated with increased in-hospital mortality. The elderly female patient who experienced longer operation duration was at highest risk for POAF.

Key Words: aortic disease ■ aortic dissection ■ arrhythmia ■ atrial fibrillation

In complex aortic arch diseases, total arch repair (TAR) surgery remains challenging and presents a high risk of mortality and complications.[1–3] Atrial fibrillation is a common arrhythmia occurring after aortic surgery, with reported prevalence of 10% to 52.7%.[4,5] Recently, studies have reported that postoperative atrial fibrillation (POAF) is associated with increased risk of mortality after cardiac surgery.[6] However, results are not consistent in patients with aortic arch surgery.[5,7,8] The present cohort study aimed to assess the prevalence of new-onset POAF and associated risk factors in patients undergoing TAR and the association between POAF and in-hospital mortality. The impact of POAF on in-hospital mortality was also evaluated by using multivariable adjustment, inverse probability of treatment weighting (IPTW), and propensity score matching (PSM).

Correspondence to: Xiaohan Fan, MD, or Cuntao Yu, MD, Fuwai Hospital, State Key Laboratory of Cardiovascular Disease, National Center for Cardiovascular Diseases, Chinese Academy of Medical Sciences and Peking Union Medical College, 167 Beilishi Rd, Beijing 100037, China. E-mail: fanxiaohan@fuwaihospital.org or cuntaoyu_fuwai@163.com

*R. Zhao and Z. Wang contributed equally.

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CLINICAL PERSPECTIVE

What Is New?

- This retrospective study showed that the incidence of postoperative atrial fibrillation after total arch repair surgery was not uncommon and associated with increased in-hospital mortality.
- The elderly female patient who experienced longer operation duration was at highest risk for postoperative atrial fibrillation.

What Are the Clinical Implications?

- These results suggest more careful attention should be given to postoperative atrial fibrillation after total arch repair.

Nonstandard Abbreviations and Acronyms

CPB	cardiopulmonary bypass
IPTW	inverse probability of treatment weighting
POAF	postoperative atrial fibrillation
PSM	propensity score matching
TAR	total arch repair

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Study Population and Design

This retrospective, observational cohort study consecutively enrolled patients undergoing TAR from September 18, 2012 to December 31, 2019 in Fuwai hospital. As shown in Figure 1, a total of 1280 patients undergoing TAR surgery were included. After exclusion of 9 patients with a history of paroxysmal or persistent atrial fibrillation or atrial flutter before surgery, 1271 patients were finally included in this study, of whom 1254 were diagnosed with aortic dissection, 12 with intramural hematoma, and 5 with aortic aneurysm. The informed consent on receiving TAR surgery was obtained from all patients. This study complies with the Declaration of Helsinki. The ethics committee had approved the research protocol, and the institutional review board allowed us to waive the requirement for obtaining informed consent to the study because the data are acquired for routine patient care and all data used for this study were acquired for clinical purposes and handled anonymously.

Data Collection and Clinical Variables Definition

Clinical data, surgical characteristics, and in-hospital outcomes were collected from electronic medical records. Continuous electrocardiogram monitoring was used to identify the cardiac rhythm. The occurrence of arrhythmia was evaluated by at least 1 physician and 1 electrophysiologist. POAF was defined as the occurrence of atrial fibrillation or atrial flutter lasting at least 5 minutes after surgery procedure according to the Society of Thoracic Surgeons National database definition (available at http://sts.org). [9]In-hospital mortality was defined as all-cause death during the hospitalization. Stroke was defined as a persistent central neurologic deficit (focal or generalized), as assessed by 1 neurologist. Reexploration was defined as reexploration for bleeding within the first 24 postoperative hours. Sepsis was defined as systemic vasodilation associated with evidence of infection. Acute kidney insufficiency was defined as serum creatinine increased by >1.5 times baseline values, glomerular filtration rate decrease by >25%, or urine output <0.5 mL/kg/h for 6 hours, and hepatic failure manifested as metabolic acidosis or increased lactate or prothrombin time, requiring general surgeon consultation according to the International Aortic Arch Surgery Study Group.[10] In our center, 2 TAR surgical modalities are mainly applied, namely frozen elephant trunk and hybrid TAR. The specific surgical methods have been introduced.[1]

Statistical Analysis

Continuous variables with normal distribution were expressed as mean±SD and compared using the *t* test. Nonnormally distributed continuous data were summarized as median (interquartile range) and compared using the Mann-Whitney test. Categorical variables were expressed as counts and composition ratio and were compared using the chi-square test or Fisher exact test as appropriate. A logistic regression model was used to determine predictors of in-hospital mortality based on the baseline characteristics. Univariate analysis evaluated possible perioperative predictors for in-hospital mortality. Identified univariate predictors were subjected to multivariate analysis to yield the best predictive model. Findings of *P* value less than 0.05 were considered significant.

Moreover, IPTW, PSM, and subgroup analysis were performed as sensitivity analysis. PSM was performed between POAF group and non-POAF group. We used a multivariable logistic regression model to estimate propensity scores, with POAF as the dependent variable and the following factors as covariates: age, sex, body mass index, Marfan syndrome, family history of coronary artery disease, hypertension, hyperlipidemia,

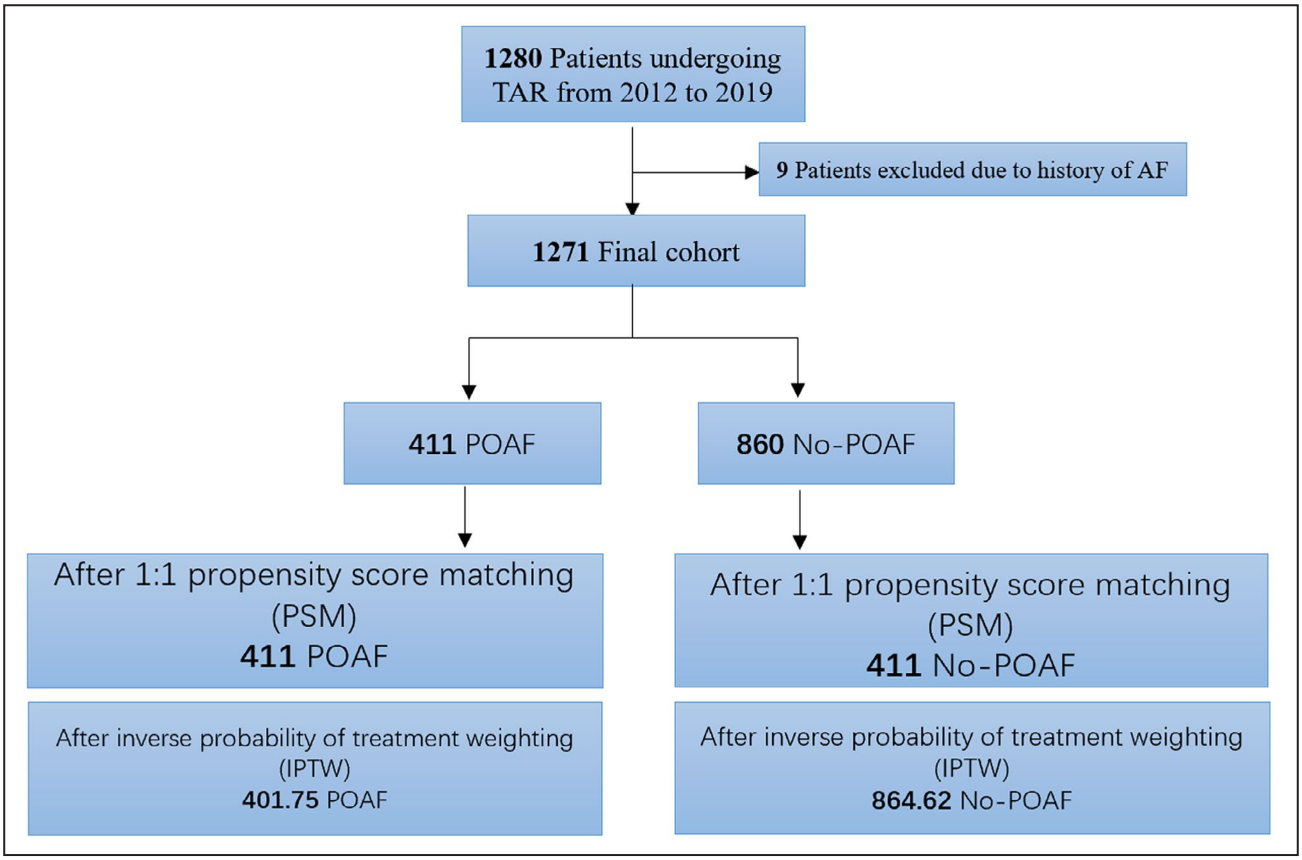

Figure 1. Study design: summary of inclusion and exclusion criteria.
AF indicates atrial fibrillation; IPTW, inverse probability of treatment weighting; POAF, postoperative atrial fibrillation; PSM, propensity score matching; and TAR, total arch repair.

diabetes mellitus, chronic obstructive pulmonary disease, chronic kidney disease, current smoker, hemoglobin, white blood cell, platelets, left ventricular ejection fraction, hypokalemia, left atrial diameter, surgery type, surgery time, cardiopulmonary bypass (CPB) time, cross-clamp time, deep hypothermic circulatory arrest time, minimum operating temperature, standard Euro-score. PSM was performed using the nearest neighbor matching algorithm and a 1:1 ratio. IPTW was performed by using the same covariates in PSM. Standardized difference less than 0.1 indicated good balance after PSM and IPTW. All analyses were performed by R 4.0.4 and SPSS Statistics Version 25 (IBM Corp., Armonk, NY).

RESULTS

The Occurrence and Associated Risk Factors of POAF

A total of 411 (32.3%) patients was diagnosed as POAF in this cohort population. The demographic, surgical, and preoperative characteristics were presented in Table 1. Patients with POAF were older (53.66±10.86 versus 47.97±11.15, *P*<0.001), and suffered longer surgery time, CPB time, and cross-clamp time. Most other clinical characteristics did not differ significantly. Advanced age (odds ratio [OR], 1.05; 95% CI, 1.04–1.06; *P*<0.001), male sex (OR, 0.72; 95% CI, 0.52–0.98; *P*=0.035), and longer operation time (OR, 1.2; 95% CI, 1.12–1.28; *P*<0.001) were the risk factors associated with POAF by multivariate logistic regression analysis (Table 2).

Clinical Outcomes

As shown in, Table 3 demonstrates the postoperative complications and clinical outcomes. Patients with POAF had higher in-hospital mortality (10.7% versus 2.4%, *P*<0.001), longer length of stay (14 [11, 20] versus 12 [9, 17] days, *P*<0.001), and higher incidence of complications including pulmonary infection, acute kidney insufficiency, and acute hepatic failure. The unadjusted OR for in-hospital mortality of POAF group versus non-POAF group derived by logistic regression was 4.79 (95% CI, 2.81–8.17; *P*<0.001). After adjusting for covariates including age, sex, hyperlipidemia, chronic kidney disease, platelet, deep hypothermic circulatory arrest, surgery time, CPB time, perioperative stroke, sepsis, pulmonary

Table 1. Characteristics of 1271 Patients Undergoing TAR Surgery from 2012 to 2019

Variable	Non-POAF	POAF	
No. of patients	n=860	n=411	*P* Value
Age, y	47.97±11.15	53.66±10.86	<0.001
Male sex, n (%)	658 (76.5)	279 (67.9)	0.001
Body mass index, kg/m^2	25.84 (23.40–28.40)	25.97 (23.69–28.08)	0.474
Marfan syndrome, n (%)	37 (4.3)	5 (1.2)	0.007
Aortic family history, n (%)	24 (2.8)	7 (1.7)	0.326
Hypertension, n (%)	679 (79.0)	341 (83.0)	0.108
Hyperlipidemia, n (%)	208 (24.2)	111 (27.0)	0.31
Diabetes mellitus, n (%)	31 (3.6)	13 (3.2)	0.811
Chronic obstructive pulmonary disease, n (%)	7 (0.8)	4 (1.0)	>.99
Chronic kidney disease, n (%)	20 (2.3)	17 (4.1)	0.106
Current smoker, n (%)	357 (41.5)	165 (40.1)	0.688
Hemoglobin, g/L	136.00 (123.75–147.00)	133.00 (120.00–145.00)	0.009
White blood cell, ×10^9	11.03 (8.48–13.62)	10.88 (8.57–13.82)	0.968
Platelet, ×10^9	181.00 (147.00–228.00)	167.00 (137.00–210.00)	<0.001
Left ventricular ejection fraction, %	60.00 (59.00–62.00)	60.00 (58.00–62.00)	0.798
Hypokalemia, n (%)	114 (13.3)	49 (11.9)	0.565
Left atrial diameter, mm	35.00 (32.00–38.00)	35.00 (32.00–38.00)	0.625
Combined with cardiac surgery, n (%)	316 (36.7)	164 (39.9)	0.306
DHCA, n (%)	746 (86.7)	334 (81.3)	0.013
Surgery time, h	6.25 (5.42–7.50)	6.75 (5.82–8.03)	<0.001
Cardiopulmonary bypass time, min	168.00 (140.00–200.00)	186.00 (143.50–227.00)	<0.001
Cross-clamp time, min	97.00 (79.00–119.00)	104.00 (81.00–131.00)	0.002
DHCA time, min	18.00 (13.00–22.00)	18.00 (10.00–23.00)	0.751
Minimum operating temperature, °C	23.92 (19.40–25.51)	24.08 (18.90–26.24)	0.771
Euro-score	7.00 (5.00–8.00)	7.00 (4.00–8.00)	0.128

DHCA indicates deep hypothermic circulatory arrest; POAF, postoperative atrial fibrillation; and TAR, total arch repair.

infection, acute kidney insufficiency, acute hepatic failure, and reexploration, POAF was still an independent risk factor of in-hospital mortality (OR, 2.53; 95% CI, 1.39–4.70; *P*=0.003). Detail of logistic regression for primary outcomes are shown in Table 4.

PSM, Propensity Score Weighting, and Subgroup Analysis

To control for baseline differences and corroborate the result, we matched 411 patients with POAF and 411 without it. After PSM, POAF group showed higher

Table 2. Univariate and Multivariate Risk Factors for AF

	Univariate analysis			Multivariate analysis		
Risk factor	OR	95% CI	*P* Value	OR	95% CI	*P* Value
Age, y	1.05	1.04–1.06	<0.001	1.05	1.05–1.03	<0.001
Male sex	0.65	0.5–0.84	0.001	0.72	0.52–0.98	0.035
Marfan syndrome	0.27	0.11–0.70	0.007	0.5	0.19–1.31	0.181
Hemoglobin, g/L	0.99	0.99–1.00	0.012	1.00	0.99–1.01	0.716
Platelet, ×10^9	1.0	1.0–1.0	0.004	1	1–1.00	0.131
Deep hypothermic circulatory arrest	0.66	0.48–0.91	0.011	1.28	0.86–1.91	0.088
Surgery time, h	1.18	1.11–1.26	<0.001	1.17	1.12–1.28	<0.001
Cardiopulmonary bypass time, min	1.00	1.00–1.01	<0.001	1.00	1.00–1.00	0.259
Cross clamp time, min	1.00	1.00–1.01	0.003	1.00	1.00–1.00	0.319

AF indicates atrial fibrillation; and OR, odds ratio.

Table 3. Clinical Outcomes and Postoperative Complications

Variable	No-POAF	POAF	
No. of patients	n=860	n=411	*P* Value
In-hospital mortality, n (%)	21 (2.4)	44 (10.7)	<0.001
Expenses, yuan	168704.60 (147621.22–225067.13)	230767.92 (177005.94–310158.41)	<0.001
Hospital length of stay, d	12 (9–17)	14 (11–20)	<0.001
Intensive care unit time, h	72.00 (48.00–120.00)	144.00 (96.00–264.00)	<0.001
Mechanical ventilation time, h	16.23 (9.54–33.96)	34.22 (12.71–91.47)	<0.001
Perioperative stroke, n (%)	27 (3.1)	27 (6.6)	0.007
Sepsis, n (%)	4 (0.5)	16 (3.9)	<0.001
Pulmonary infection, n (%)	31 (3.6)	43 (10.5)	<0.001
Acute kidney injury, n (%)	201 (23.4)	186 (45.3)	<0.001
Acute hepatic failure, n (%)	10 (1.2)	32 (7.8)	<0.001
Re-exploration, n (%)	21 (2.4)	31 (7.5)	<0.001

POAF indicates postoperative atrial fibrillation.

in-hospital mortality than non-POAF group (OR, 1.08; 95% CI, 1.05–1.19; *P*<0.001). Decreased sample size after PSM might weak the statistical power and not all covariates were well balanced. To overcome this sample size limitation, we further performed propensity score weighting by IPTW method using the same covariates in PSM. After IPTW, the standardized differences of almost all the covariates were <10%, indicating covariates were well balanced (Figure 2). As shown in Table 4, weighted logistic regression still showed significant higher in-hospital mortality in diffuse POAF group (OR, 1.04; 95% CI, 1.03–1.08; *P*<0.001). Detailed characteristics of the study cohort after PSM and IPTW were shown in Tables S1–S4. Subgroup analyses defined by age, sex, hypertension, smoking, and hypokalemia, combined with cardiac surgery, and deep hypothermic circulatory arrest between POAF group and non-POAF group were performed (Figure 3). The trend toward increased risk of in-hospital mortality in POAF group was consistently obtained among all subgroups and no significant interaction effect was found.

DISCUSSION

Our analysis results revealed that the incidence of POAF after TAR surgery was 32.3% and significant risk of in-hospital mortality in POAF group than non-POAF group. The higher mortality was consistent in propensity score matched cohort, propensity score weighted analysis, and subgroup analysis.

Although the literature is replete with studies of the effect of POAF after cardiac surgery, the data are sparse in the arena of aortic arch surgery. Only a handful of studies have examined this topic. Matsuura et al found a 52.7% incidence of POAF after TAR surgery (N=459) and the survival rate was not different between the patients with or without POAF.[5] In another review of patients with TAR surgery requiring deep hypothermic circulatory arrest (N=144) found that POAF is common but does not independently increase mortality.[8] These are the only 2 studies dedicated to the evaluation of POAF after TAR. TAR surgery is one of the most challenging operations in the field of cardiac surgery. But strangely, adverse effects of new-onset POAF after other cardiac surgery have been increasingly recognized. Mariscalco and Engström studied 1832 patients undergoing isolated coronary artery bypass graft surgery and reported that POAF occurred in 31% of the study subjects and was associated with increased long-term mortality.[11] Blanco et al found that POAF after revascularization of abdominal aorta and its branches was associated with increased inpatient mortality and 1-year mortality.[12] According to the American Association for Thoracic Surgery guideline

Table 4. Summary of Clinical Outcomes and OR for POAF Group

	Sample size		In-hospital mortality		
Type analysis	No-POAF	POAF	No. (%)	OR (95% CI)	*P* Value
Unadjusted	860	411	21 vs 44 (2.4% vs 10.7%)	4.79 (2.81–8.17)	<0.001
Matched	411	411	12 vs 44 (2.9% vs 10.7%)	1.08 (1.05–1.19)	<0.001
Weighted	864.62	401.75	30.9 vs 35.1 (3.6% vs 8.7%)	1.04 (1.03–1.08)	<0.001
Multivariable	860	411	21 vs 44 (2.4% vs 10.7%)	2.53 (1.39–4.70)	0.003

OR indicates odds ratio; and POAF, postoperative atrial fibrillation.

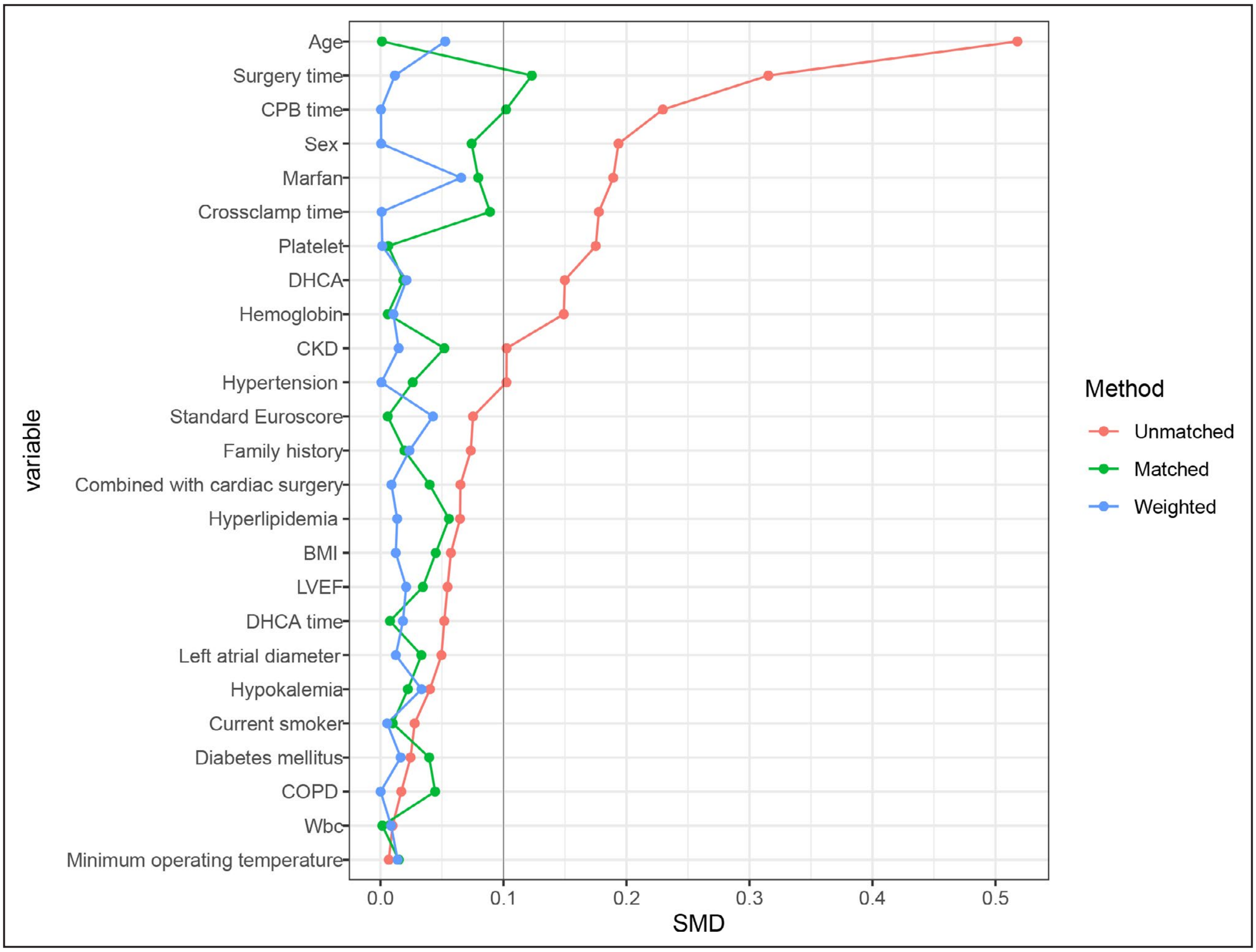

Figure 2. Covariate balance in the study cohort.
BMI indicates body mass index; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CPB, cardiopulmonary bypass; DHCA, deep hypothermic circulatory arrest; LVEF, left ventricular ejection fraction; SMD, standardized mean difference; and WBC, white blood cell.

for prevention and management of perioperative atrial fibrillation and flutter for thoracic surgical procedures, the incidence of POAF was more than 15% after some high-risk thoracic procedures and POAF was associated with increased mortality.[13] Even in noncardiac surgery, POAF was not uncommon and also associated with increased mortality and cost.[14] As for cardiac surgery, a recent meta-analysis of 239 018 patients showed that POAF occurred in 25.5% of patients and was associated with significantly higher rates of early mortality (OR, 1.74; *P*<0.001).[6] In another review, POAF occurred in around 35% of cardiac surgery cases and had been identified a 2-fold increase in all-cause 30-day and 6-month mortality.[15] However, our findings revealed that the onset of POAF after TAR was nearly identical to this review and also associated with increased in-hospital mortality. As our sample size is larger, the results are different from those of the previous 2 studies. Also, this adverse association between POAF and outcomes results in higher cost of care. In our study, the propensity score matching and IPTW analyses resulted in a substantially lower OR for POAF than the original analysis (OR, 1.08 or 1.04 versus 2.53). These results indicate that some clinical factors may have an impact on both the in-hospital mortality and the occurrence of POAF, such as age, the operation time, chronic obstructive pulmonary disease, and so on. The PSM and IPTW analyses could strip off the influence of other clinical factors and then demonstrate the impact of POAF alone on clinical outcomes.

Therefore, the current research results increasingly emphasize the need to pay attention to the risk factor of POAF. In the current study, increasing age, female sex, and longer surgery time were the strongest factors associated with POAF. Advanced age is the most reported and widely accepted risk factor for POAF.[5,8,16,17] Surgical trauma, ischemia from the CPB, and circulatory arrest during TAR surgery lead to oxidative stress

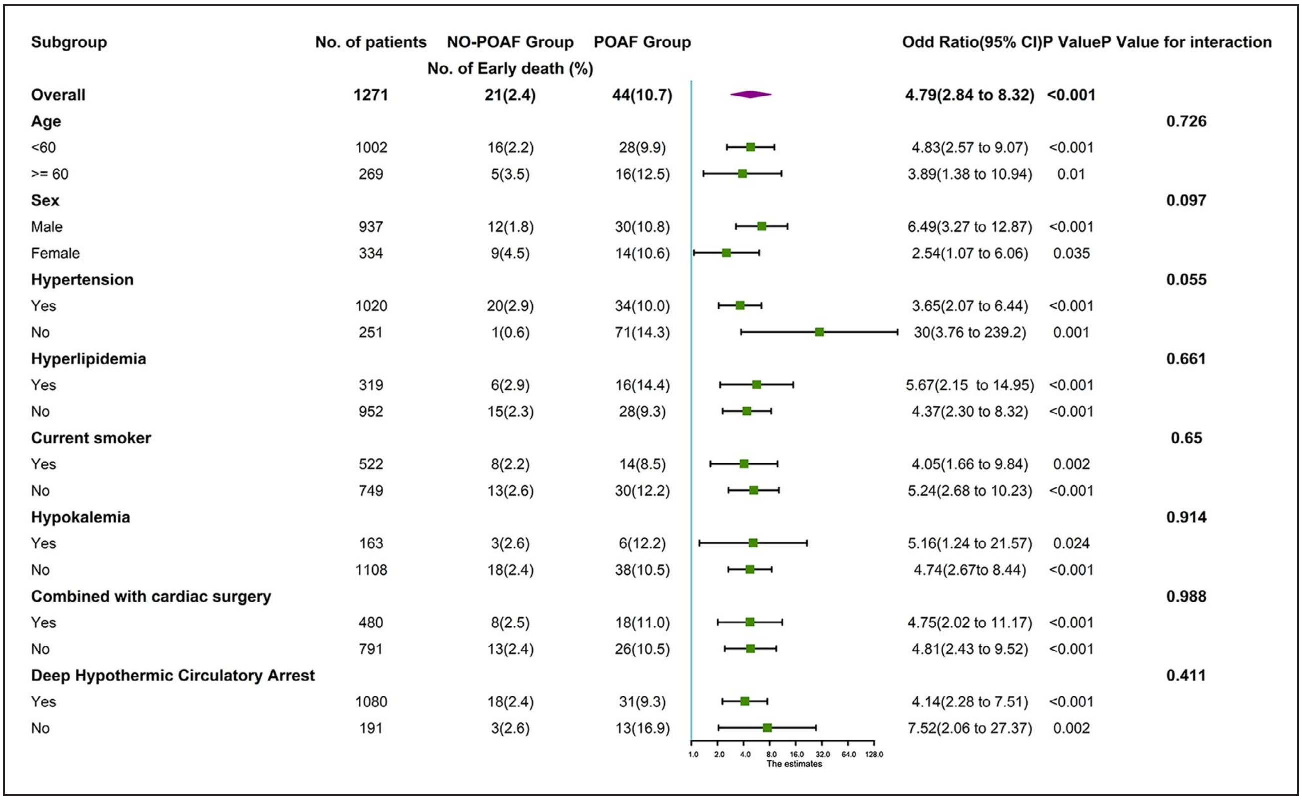

Figure 3. In-hospital mortality of POAF in subgroup analysis.
The pooled odds ratio (OR) presented graphically as a purple diamond, where the center of the diamond is the overall estimate and the width of the diamond is the overall confidence. The OR of each subgroup is presented in green squares and 95% CI is presented by a horizontal black line. POAF indicates postoperative atrial fibrillation.

and the production of proinflammatory molecules, and the aging process leads to a loss of myocardial fibers, increased fibrosis and collagen deposition in the atria, particularly near the sinoatrial node, which alters atrial electrical properties.[18] Therefore, age-related physiological changes are a "setup" for POAF. However, in our subgroup analysis, POAF was associated with mortality in all age groups; thus we must pay enough attention to POAF, regardless of the patient's age. Another risk factor associated with POAF in our study was the female sex. There are conflicting data as to whether or not sex plays a role in the association of various risk factors and the development of atrial fibrillation.[19] Men develop postoperative atrial fibrillation at higher rates than do women.[20] But many studies had showed that women had higher 30-day mortality than men after acute aortic repair, a sex difference that remained after age adjustment.[21]TAR surgery is a very challenging procedure, and many patients undergo a long-time surgical procedure. Some studies have shown that CPB and aortic cross-clamp duration have consistently been associated with POAF in coronary artery bypass graft surgery.[20,22] But we did not find this in our study, even when we did a subgroup analysis of surgery with combined cardiac surgery. But both of these factors are involved in the operation time. Longer surgery duration may result in more severe ischemia and inflammation, which are related to the mechanism of POAF.

In addition, we also included some factors that might be related to POAF in our study. The most recent preoperative serum potassium was recorded, but hypokalemia (a serum potassium level below 3.5 mmol/L) was not associated with the occurrence of POAF. Even if hypokalemia leads to cellular hyperpolarization, higher resting potential, increased automaticity and excitability, and ventricular arrhythmias, recent data call into question the widely held assumption that hypokalemia contributes to POAF.[15,23,24] We also included postoperative organ damage such as renal insufficiency, liver failure, and pulmonary infection, but they did not cover up the influence of POAF after TAR on prognosis.

As the Augoustides et al[8] have mentioned in previous studies 15 years ago, despite advances in the conduct of TAR, there remains a substantial risk of perioperative organ damage. These entities most likely obscure the effects of POAF on outcome;

perhaps, with continuing advances, outcomes will continue to improve, and the effects of POAF will become apparent, as has happened for coronary artery bypass surgery. The association of advanced age, female sex, and prolonged surgery duration with POAF indicated that elderly female patients with complicated aortic disease should be concerned about prophylactic measures to prevent the occurrence of POAF. Our study also raised a concern about POAF: whether taking measures to prevent the occurrence of POAF before or during surgery procedure could be useful to reduce in-hospital mortality. The potential benefit of prophylactic preventing POAF should be investigated in future studies.

This study has some limitations. First of all, a large proportion of these patients were diagnosed with aortic dissection, and many preoperative outcomes were missing because of the urgency of the condition, that is why we did not review preoperative serum magnesium levels. Second, because of the limitation of the database, we did not get the specific time of POAF, nor did we know the sequence of POAF and other complications. Therefore, we included only preoperative and intraoperative factors in the risk factor analysis of POAF. Finally, our study design could not determine the definite association between POAF and the increased mortality because this was a retrospective study. In our study, we observed an increased occurrence of stroke in the POAF group (3.3% versus 6.6%, P=0.007). And stroke was an independent risk factor for increased in-hospital mortality. In addition, anticoagulation therapy might increase the risk of bleeding, which affect the clinical outcomes in patients with POAF. POAF may also worsen heart failure because of uncontrolled tachycardia or irregular rhythm. Therefore, future long-term follow-up data might be helpful to determine whether POAF is a marker or a main cause of increased in-hospital mortality.

CONCLUSIONS

We have reported that the incidence of POAF after TAR surgery was 32.3% and associated with increased in-hospital mortality. In addition, the elderly female patient who experienced longer operation duration was at highest risk for POAF. Therefore, more careful attention should be given to treat patients with POAF.

ARTICLE INFORMATION

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Affiliations

Department of Vascular Surgery (R.Z., F.C., J.S., S.F., J.Q., C.Y.) and Cardiac Arrhythmia Center (Z.W., X.F.), Fuwai Hospital, State Key Laboratory of Cardiovascular Disease, National Center for Cardiovascular Diseases, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China.

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Disclosures

None.

Supplementary Material

Tables S1–S4

REFERENCES

1. Zhang L, Yu C, Yang X, Sun X, Qiu J, Jiang W, Wang D. Hybrid and frozen elephant trunk for total arch replacement in debakey type i dissection. *J Thorac Cardiovasc Surg*. 2019;158:1285–1292. DOI: 10.1016/j.jtcvs.2019.01.020.
2. Sun X, Guo H, Liu Y, Li Y. The aortic balloon occlusion technique in total arch replacement with frozen elephant trunk. *Europ J Cardio-Thorac Surg*. 2019;55:1219–1221. DOI: 10.1093/ejcts/ezy369.
3. Wu J, Qiu J, Qiu J, Dai L, Ma M, Zhang L, Yu C. A new graft for total arch replacement with frozen elephant trunk in type a dissection. *Semin Thorac Cardiovasc Surg*. 2020;32:840–842. DOI: 10.1053/j.semtcvs.2020.02.022.
4. Valentine RJ, Rosen SF, Cigarroa JE, Jackson MR, Modrall JG, Clagett GP. The clinical course of new-onset atrial fibrillation after elective aortic operations. *J Am Coll Surg*. 2001;193:499–504. DOI: 10.1016/s1072-7515(01)01028-6.
5. Matsuura K, Ogino H, Matsuda H, Minatoya K, Sasaki H, Kada A, Yagihara T, Kitamura S. Prediction and incidence of atrial fibrillation after aortic arch repair. *The Annals of thoracic surgery*. 2006;81:514–518. DOI: 10.1016/j.athoracsur.2005.07.052.
6. Woldendorp K, Farag J, Khadra S, Black D, Robinson B, Bannon P. Postoperative atrial fibrillation after cardiac surgery: a meta-analysis. *Ann Thoracic Surg*. 2020. DOI: 10.1016/j.athoracsur.2020.10.055.
7. Burrage PS, Low YH, Campbell NG, O'Brien B. New-onset atrial fibrillation in adult patients after cardiac surgery. *Curr Anesthesiol Rep*. 2019;9:174–193. DOI: 10.1007/s40140-019-00321-4.
8. Augoustides JG, Szeto W, Ochroch EA, Cowie D, Weiner J, Gambone AJ, Pinchasik D, Bavaria JE. Atrial fibrillation after aortic arch repair requiring deep hypothermic circulatory arrest: Incidence, clinical outcome, and clinical predictors. *J Cardiothorac Vasc Anesth*. 2007;21:388–392. DOI: 10.1053/j.jvca.2006.11.024.
9. Arakawa M, Miyata H, Uchida N, Motomura N, Katayama A, Tamura K, Sueda T, Takamoto S. Postoperative atrial fibrillation after thoracic aortic surgery. *Ann Thorac Sur*. 2015;99:103–108. DOI: 10.1016/j.athoracsur.2014.08.019.
10. Yan TD, Tian DH, LeMaire SA, Hughes GC, Chen EP, Misfeld M, Griepp RB, Kazui T, Bannon PG, Coselli JS, et al. Standardizing clinical end points in aortic arch surgery: a consensus statement from the international aortic arch surgery study group. *Circulation*. 2014;129:1610–1616. DOI: 10.1161/CIRCULATIONAHA.113.006421.
11. Mariscalco G, Engström KG. Postoperative atrial fibrillation is associated with late mortality after coronary surgery, but not after valvular surgery. *Ann Thorac Sur*. 2009;88:1871–1876. DOI: 10.1016/j.athoracsur.2009.07.074.
12. Blanco BA, Kothari AN, Halandras PM, Blackwell RH, Graunke DM, Kuo PC, Cho JS. Transient atrial fibrillation after open abdominal aortic revascularization surgery is associated with increased length of stay, mortality, and readmission rates. *J Vasc Surg*. 2017;66:413–422. DOI: 10.1016/j.jvs.2016.11.036.
13. Frendl G, Sodickson AC, Chung MK, Waldo AL, Gersh BJ, Tisdale JE, Calkins H, Aranki S, Kaneko T, Cassivi S, et al. 2014 aats guidelines for the prevention and management of perioperative atrial fibrillation

and flutter for thoracic surgical procedures. *J Thorac Cardiovasc Surg*. 2014;148:e153–e193. DOI: 10.1016/j.jtcvs.2014.06.036.
14. Bhave PD, Goldman LE, Vittinghoff E, Maselli J, Auerbach A. Incidence, predictors, and outcomes associated with postoperative atrial fibrillation after major noncardiac surgery. *Am Heart J*. 2012;164:918–924. DOI: 10.1016/j.ahj.2012.09.004.
15. Greenberg JW, Lancaster TS, Schuessler RB, Melby SJ. Postoperative atrial fibrillation following cardiac surgery: a persistent complication. *Eur J Cardiothorac Surg*. 2017;52:665–672. DOI: 10.1093/ejcts/ezx039.
16. Mitchell LB. Canadian cardiovascular society atrial fibrillation guidelines 2010: Prevention and treatment of atrial fibrillation following cardiac surgery. *Can J Cardiol*. 2011;27:91–97. DOI: 10.1016/j.cjca.2010.11.005.
17. Shen J, Lall S, Zheng V, Buckley P, Damiano RJ, Schuessler RB. The persistent problem of new-onset postoperative atrial fibrillation: A single-institution experience over two decades. *J Thorac Cardiovasc Surg*. 2011;141:559–570. DOI: 10.1016/j.jtcvs.2010.03.011.
18. Echahidi N, Pibarot P, O'Hara G, Mathieu P. Mechanisms, prevention, and treatment of atrial fibrillation after cardiac surgery. *J Am Coll Cardiol*. 2008;51:793–801. DOI: 10.1016/j.jacc.2007.10.043.
19. Westerman S, Wenger N. Gender differences in atrial fibrillation: A review of epidemiology, management, and outcomes. *Curr Cardiol Rev*. 2019;15:136–144. DOI: 10.2174/1573403X15666181205110624.
20. Mathew JP, Parks R, Savino JS, Friedman AS, Koch C, Mangano DT, Browner WS. Atrial fibrillation following coronary artery bypass graft surgery: predictors, outcomes, and resource utilization. Multicenter study of perioperative ischemia research group. *JAMA*. 1996;276:300–306. DOI: 10.1001/jama.1996.03540040044031.
21. Smedberg C, Steuer J, Leander K, Hultgren R. Sex differences and temporal trends in aortic dissection: a population-based study of incidence, treatment strategies, and outcome in Swedish patients during 15 years. *Eur Heart J*. 2020;41:2430–2438. DOI: 10.1093/eurheartj/ehaa446.
22. Villareal RP, Hariharan R, Liu BC, Kar B, Lee V-V, Elayda M, Lopez JA, Rasekh A, Wilson JM, Massumi A. Postoperative atrial fibrillation and mortality after coronary artery bypass surgery. *J Am Coll Cardiol*. 2004;43:742–748. DOI: 10.1016/j.jacc.2003.11.023.
23. Svagzdiene M, Sirvinskas E. Changes in serum electrolyte levels and their influence on the incidence of atrial fibrillation after coronary artery bypass grafting surgery. *Medicina (Kaunas)*. 2006;42:208–214.
24. Auer J, Weber T, Berent R, Lamm G, Eber B. Serum potassium level and risk of postoperative atrial fibrillation in patients undergoing cardiac surgery. *J Am Coll Cardiol*. 2004;44:938–939. DOI: 10.1016/j.jacc.2004.05.035.

SUPPLEMENTAL MATERIAL

Table S1. Baseline Characteristics after propensity score matched.

Variable	**No-POAF**	**POAF**	***P* value**
No. of patients	**N=411**	**N=411**	
Age, y	53.65±9.95	53.66±10.86	0.987
Male sex, n (%)	293(71.3)	279(67.9)	0.324
BMI (kg/m^2)	26.12[24.19,28.72]	25.97[23.69,28.08]	0.271
Marfan syndrome, n (%)	2(0.5)	5(1.2)	0.448
Aortic family history, n (%)	6(1.5)	7(1.7)	1
Hypertension, n (%)	345(83.9)	341(83.0)	0.778
Hyperlipidemia, n (%)	101(24.6)	111(27.0)	0.473
Diabetes mellitus, n (%)	16(3.9)	13(3.2)	0.705
COPD, n (%)	6(1.5)	4(1.0)	0.75
CKD, n (%)	13(3.2)	17(4.1)	0.577
Current smoker, n (%)	163(39.7)	165(40.1)	0.943
Hemoglobin, g/L	133.00[122.00,144.00]	133.00[120.00,145.00]	0.978
WBC,$\times 10^9$	11.13[8.77,13.38]	10.88[8.57,13.82]	0.803
Platelet, $\times 10^9$	172.00[139.00,207.00]	167.00[137.00,210.00]	0.526
LVEF, %	60.00[59.00,62.00]	60.00[58.00,62.00]	0.791
Hypokalemia, n (%)	52(12.7)	49(11.9)	0.832
LAD, mm	35.00[32.00,38.00]	35.00[32.00,38.00]	0.58
Combined with cardiac surgery, n (%)	156(38.0)	164(39.9)	0.617

DHCA, n (%)	331(80.5)	334(81.3)	0.859
Surgery time, h	6.67[5.73,7.77]	6.75[5.82,8.03]	0.216
CPB time, min	178.00[144.50,210.50]	186.00[143.50,227.00]	0.082
Cross-clamp time, min	100.00[81.00,122.00]	104.00[81.00,131.00]	0.147
DHCA time, min	17.00[10.00,23.00]	18.00[10.00,23.00]	0.54
Minimum operating temperature,℃	24.00[19.05,26.29]	24.08[18.90,26.24]	0.866
Euro-score	7.00[5.00,8.00]	7.00[4.00,8.00]	0.743

BMI, body mass index; COPD, chronic obstructive pulmonary disease; CKD, chronic kidney disease; WBC, white blood cell; LVEF, left ventricular ejection fraction; LAD, Left Atrial Diameter; DHCA, deep hypothermic circulatory arrest; CPB, cardiopulmonary bypass

Table S2. Clinical outcomes and postoperative complications after propensity score matched.

Variable	**No-POAF**	**POAF**	***P* value**
No. of patients	**N=411**	**N=411**	
In-hospital mortality, n (%)	12 (2.9)	44 (10.7)	<0.001
Expenses, yuan	180477.35 [151588.71, 251201.10]	230767.92 [177005.94, 310158.41]	<0.001
Hospital LOS, d	13 [10, 17]	14.00 [11, 20]	<0.001
ICU time, hour	96.00 [48.00, 120.00]	144.00 [96.00, 264.00]	<0.001
Mechanical ventilation time, h	17.92 [10.17, 38.92]	34.22 [12.71, 91.47]	<0.001
Perioperative stroke, n (%)	17(4.1)	27(6.6)	0.163
Sepsis, n (%)	3(0.7)	16(3.9)	0.005
Pulmonary infection, n (%)	20(4.9)	43(10.5)	0.004
AKI, n (%)	102(24.8)	186(45.3)	<0.001
AHF, n (%)	7(1.7)	32(7.8)	<0.001
Re-exploration, n (%)	10(2.4)	31(7.5)	0.001

LOS, length of stay; ICU, Intensive Care Unit; AKI, acute kidney injury; AHF, acute hepatic failure

Table S3. Baseline Characteristics after propensity score weighted.

Variable	**No-POAF**	**POAF**	***P* value**
No. of patients	**N= 864.62**	**N= 401.75**	
Age, y	49.84±11.26	50.43 ±11.07	0.429
Male sex, n (%)	641.8(74.2)	298.1(74.2)	0.993
BMI (kg/m^2)	25.95[23.44,28.41]	26.09[23.65,28.02]	0.755
Marfan syndrome, n (%)	28.2(3.3)	8.8(2.2)	0.427
Aortic family history, n (%)	21.0(2.4)	8.4(2.1)	0.74
Hypertension, n (%)	692.4(80.1)	321.6(80.0)	0.991
Hyperlipidemia, n (%)	213.5(24.7)	96.9(24.1)	0.83
Diabetes mellitus, n (%)	29.0(3.4)	12.3(3.1)	0.79
COPD, n (%)	7.6(0.9)	3.5(0.9)	0.999
CKD, n (%)	25.5(2.9)	12.9(3.2)	0.812
Current smoker, n (%)	355.4(41.1)	166.2(41.4)	0.933
Hemoglobin, g/L	135.00[122.90,147.00]	136.00[122.00,147.00]	0.641
WBC,$\times 10^9$	11.11[8.51,13.63]	10.90[8.62,13.90]	0.99
Platelet, $\times 10^9$	179.00[144.00,222.00]	171.00[139.00,217.95]	0.356
LVEF, %	60.00[59.00,62.00]	60.00[58.00,63.00]	0.323
Hypokalemia, n (%)	112.4(13.0)	47.8(11.9)	0.6
LAD, mm	35.00[32.00,38.00]	35.00[32.00,38.00]	0.95
Combined with cardiac surgery, n (%)	330.4(38.2)	151.8(37.8)	0.891

DHCA, n (%)	734.2(84.9)	338.1(84.2)	0.731
Surgery time, h	6.50[5.50,7.67]	6.53[5.58,7.67]	0.51
CPB time, min	172.00[141.00,205.00]	176.00[137.00,216.00]	0.452
Cross-clamp time, min	99.00[81.00,122.00]	100.00[79.00,124.93]	0.676
DHCA time, min	18.00[12.00,22.00]	17.45[12.00,22.00]	0.9
Minimum operating temperature,℃	23.94[19.20,25.60]	24.15[19.29,25.66]	0.709
Euro-score	7.00[5.00,8.00]	7.00[5.00,8.00]	0.601

BMI, body mass index; COPD, chronic obstructive pulmonary disease; CKD, chronic kidney disease; WBC, white blood cell; LVEF, left ventricular ejection fraction; LAD, Left Atrial Diameter; DHCA, deep hypothermic circulatory arrest; CPB, cardiopulmonary bypass

Table S4. Clinical outcomes and postoperative complications after propensity score weighted.

Variable	No-POAF	POAF	*P* value
No. of patients	**N= 864.62**	**N= 401.75**	
In-hospital mortality, n (%)	30.9 (3.6)	35.1 (8.7)	0.001
Expenses, yuan	172267.65 [149068.35, 234074.12]	219410.48 [170047.05, 292173.38]	<0.001
Hospital LOS, d	12 [9, 17]	14 [10, 20]	<0.001
ICU time, hour	72.00 [48.00, 120.00]	120.00 [72.00, 240.00]	<0.001
Mechanical ventilation time, h	17.58 [10.04, 36.39]	25.34 [12.57, 79.41]	<0.001
Perioperative stroke, n (%)	30.0(3.5)	26.5(6.6)	0.021
Sepsis, n (%)	4.4(0.5)	14.9(3.7)	<0.001
Pulmonary infection, n (%)	37.6(4.4)	36.5(9.1)	0.002
AKI, n (%)	218.5(25.3)	172.5(42.9)	<0.001
AHF, n (%)	12.8(1.5)	29.4(7.3)	<0.001
Re-exploration, n (%)	21.6(2.5)	31.8(7.9)	<0.001

LOS, length of stay; ICU, Intensive Care Unit; AKI, acute kidney injury; AHF, acute hepatic failure