Original Article

The Role of High-Normal Potassium Levels in the Maintenance of Sinus Rhythm Following Cardiac Surgery in Patients with Persistent Atrial Fibrillation

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Highlights

- Potassium Optimization: Maintaining high-normal potassium levels (>4.4 mmol/L) during and after bypass significantly improves the restoration and maintenance of sinus rhythm.
- High Success Rates: 87% of patients achieved sinus rhythm post-surgery, with 71% remaining stable at 48 hours.
- Predictors of Failure: A larger left atrial diameter was identified as a primary reason for failed cardioversion and AF recurrence.
- Improved Recovery: Restoring sinus rhythm led to better hemodynamic stability and significantly reduced the duration of ICU stays.

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ABSTRACT

Atrial fibrillation (AF) is highly prevalent in patients undergoing cardiac surgery, and persistent AF poses significant challenges in postoperative rhythm management. This study investigated whether maintaining high-normal potassium levels (>4.4 mmol/L) during and after cardiopulmonary bypass (CPB) enhances SR restoration and stability in patients with persistent AF. A prospective observational study of 245 patients undergoing elective cardiac surgery was conducted, with potassium levels maintained above 4.5 mmol/L during CPB and supplemented postoperatively for 48 hours. Outcomes included SR conversion rates, hemodynamic parameters, and predictors of rhythm stability. Results showed that 87% of patients reverted to SR post-CPB, with 71% maintaining SR at 48 hours. Higher intraoperative potassium levels (mean, 4.54 vs 4.41 mmol/L; P=.02) significantly predicted successful cardioversion, whereas larger left atrial diameter (67.2 vs 53.8 mm; P<.001) correlated with AF persistence. Hemodynamic stability improved in patients with SR, with lower heart rates, higher mean arterial pressures, and reduced ICU stays (52.5 vs 58.8 h; P<.001). The study concludes that maintaining high-normal potassium levels during and after CPB facilitates SR restoration and short-term stability in patients with persistent AF, improving hemodynamics and reducing ICU dependency. Left atrial enlargement remains a key determinant of AF recurrence. These findings support perioperative potassium optimization as a feasible strategy to enhance postoperative outcomes, warranting further multicenter trials for validation.

Keywords: Atrial Fibrillation; Potassium; Rhythm; Cardiopulmonary Bypass

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RHYTHM
Research in Heart Yield and Translational Medicine

Introduction

Arrhythmias, especially atrial fibrillation (AF), are highly prevalent in patients undergoing cardiac surgery, affecting up to 90% of this population.

While most perioperative arrhythmias are transient, a minority can significantly worsen clinical outcomes.[1,2] The underlying causes are multifactorial, including myocardial handling, ischemia, electrolyte imbalances, and drug effects. AF is particularly frequent in left-sided valvular heart disease, in which left atrial (LA) dilation due to chronic pressure or volume overload is central to its pathogenesis. AF with rapid ventricular response impairs diastolic filling and cardiac output and increases the risk of thromboembolic events such as stroke.[3] Management typically includes rate control, antiarrhythmic drugs, and anticoagulation, but persistent AF often continues postoperatively despite these interventions.[4]

The perioperative period is characterized by significant fluid and electrolyte shifts, necessitating careful rhythm management to preserve cardiac output. Many antiarrhythmic agents are negatively inotropic, potentially exacerbating hypotension in the vulnerable postoperative state. Potassium, essential for myocardial excitability and resting membrane potential, is widely used to prevent arrhythmias, particularly ventricular tachycardias, in the intensive care unit after cardiac surgery.[5] Nonetheless, limited research exists on the role of potassium in actively restoring sinus rhythm (SR) in persistent AF following cardiac surgery.

Methods

This prospective observational study was conducted at our institute over 2 years from June 2022 through July 2024. After obtaining ethics committee approval and written informed consent, we enrolled 245 adult patients aged 18 to 70 years with persistent AF scheduled for elective cardiac surgery. Patients with severe heart dysfunction, kidney or liver problems, and emergency or redo surgeries were excluded. All participants underwent a thorough preoperative evaluation, including blood tests, ECG, chest radiograph, and echocardiography to confirm persistent AF.

Patient Selection and Surgical Protocol

Inclusion was strictly limited to patients undergoing elective on-pump cardiac surgery requiring cardiopulmonary bypass (CPB) and cardioplegia. This included isolated valve replacement, valve repair, and combined procedures involving coronary artery bypass grafting (CABG) with valve replacement or repair. Isolated CABG procedures and off-pump surgeries were excluded from this analysis. No concomitant Maze procedures or surgical AF ablations were performed in this cohort to avoid confounding the rhythm outcomes.

On the day of surgery, standard anesthesia protocols were followed, and intraoperative monitoring included arterial and central venous lines. During CPB, potassium levels were closely monitored and maintained above 4.4 mmol/L through supplementation. At the end of surgery, if patients did not spontaneously revert to SR, up to 3 synchronized electrical shocks were delivered to restore normal rhythm. After surgery, potassium infusion was continued for 48 hours to keep levels in the high-normal range, and patients were monitored in the ICU for heart rhythm, hemodynamic status, and complications.

Data collected included patient demographics, potassium levels, LA size, number of shocks needed, heart rate, blood pressure, central venous pressure, inotropic support, time to extubation, ICU stay, and rhythm status at various time points.

Statistical Analysis

All data were collected in a structured proforma and entered into a Microsoft Excel sheet. Data were analyzed with the statistical package SPSS, version 26.0. Continuous data were reported as mean (standard deviation [SD]) or median, whereas categorical data were reported as number (percentage). Categorical data were compared using the χ^2 test; parametric data were compared using the independent t test. Multivariate regression models identified predictors of SR restoration, adjusted for the use of perioperative rhythm-modifying agents (eg, β-blockers and amiodarone) to account for their influence as confounders. A *P* value of less than .05 was considered statistically significant.

Results

In this study of 245 patients with persistent AF undergoing cardiac surgery, the results showed a high rate of successful conversion to SR immediately after coming off CPB. Specifically, 215 patients (87%) reverted to SR post-CPB, while 30 remained in AF. At 24 hours postoperatively, 193 patients were still in SR, and by 48 hours, 176 patients (71%) maintained SR, indicating some recurrence of AF over time (Table 1). The mean age of the cohort was 47.2 years. Statistical analysis revealed that patients who maintained SR had substantially higher potassium levels during CPB (mean, 4.54 mmol/L) compared with those who remained in AF (mean, 4.41 mmol/L); this difference was statistically significant (P=.02) (Table 3). Multivariate regression confirmed that a potassium level above 4.4 mmol/L during CPB was a significant positive predictor for successful cardioversion to SR (β=0.1023; P=.01), whereas a larger LA diameter was a strong negative predictor (β=−0.0164; P<.001), meaning patients with larger atria were less likely to revert to or maintain SR (Table 2).

In terms of hemodynamics, patients who achieved and maintained SR had lower heart rates and higher mean arterial pressures after surgery compared with those who remained in AF. Immediately after CPB, the SR group had a heart rate of 77 bpm and a mean arterial pressure of 76 mm Hg, while the AF group had a heart rate of 81.7 bpm and a mean arterial pressure of 69 mm Hg; both differences were statistically significant. Central venous pressure was consistently lower in the SR group at all measured time points, reflecting better cardiac function. The LA diameter was substantially larger in the AF group (mean, 67.2 mm) than in the SR group (mean, 53.8 mm), with a strong statistical association (P<.001). The need for inotropic support was higher in the AF group, and these patients also had a longer ICU stay (mean, 58.8 h) compared with those in SR (mean, 52.5 h; P<.001). No significant difference in overall mortality was observed between the groups. Most patients required only 1 electrical shock to restore SR, although some required 2 or 3, and approximately 25% reverted without any shock. The duration of CPB did not differ significantly between groups (Table 2).

Table 1. Surgical distribution and Cardioversion

Type of surgical procedure	Total (n=245)	Conversion to SR	Persistent AF
Isolated Valve Replacement / Repair	185	162	23
Combined (Valve+ CABG)	60	53	7
Total	245	215	30

Table 2. Variables in patients with atrial fibrillation and sinus rhythm during and postoperative CPB.

	AF	SR	p-value
During CPB			
Potassium	4.41 ± 0.25	4.54 ± 0.3	0.0223
Post CPB			
Heart rate	81.67 ± 3.28	77 ± 3.57	0.01
MAP	69 ± 3.57	76 ± 4.51	0.0024
CVP	6.45 ± 1.46	3.72 ± 1.79	<0.0001
Potassium	4.08 ± 0.17	4.17 ± 0.29	0.0933
Urine Output	84.14 ± 17.53	85.98 ± 16.85	0.5834
LA Diameter	67.24 ± 10.49	53.81 ± 7.65	<0.0001
Inotropic Requirement	5.8 ± 0.6	5.6 ± 0.5	0.04
Time of Discharge from ICU	58.76 ± 12.15	52.45 ± 9.35	<0.0001

Table 3. Multivariate Regression based on Rhythm outcome.

	Coefficient	OR	t-stat	p-value	95%CI (LL, UL)
Intercept	1.75	5.75	11.07	0.00	(1.44,2.06)
CPB Time	0.00	1.00	-0.27	0.786	(-0.01,0.01)
LA Diameter	-0.02	0.98	-8.06	0.000	(-0.02, -0.01)
Age	0.00	1.00	-0.20	0.843	(-0.01,0.01)
Sex	-0.01	0.99	-0.35	0.728	(-0.09,0.06)
Potassium >4.4	0.10	0.10	2.57	0.011	(0.02,0.18)

Discussion

Maintaining potassium levels above 4.4 mmol/L during CPB was associated with enhanced electrical cardioversion success and short-term SR maintenance in patients with persistent AF. Typically, a decline in potassium levels is observed during CPB, which may be attributed to dilutional effects, but the use of a cardioplegia solution with high potassium content and the administration of a hotshot of warm hyperkalemic cardioplegia at the conclusion of the surgical procedure may help sustain potassium levels in the bloodstream. This finding chimes with that of Sultan et al,[6] in which K+/Mg+ pretreatment increased cardioversion efficacy by stabilizing myocardial membrane potential and reducing automaticity. Hypokalemia (<3.9 mmol/L) was strongly associated with failed cardioversion and AF recurrence, corroborating the findings of Tatarintseva et al[7] and Colin et al,[8] who identified hypokalemia as a modifiable arrhythmia risk factor. Continuous postoperative potassium infusion (target, 4-4.5 mmol/L) ensured stable levels without adverse events, supporting the findings of Richard et al[9] on infusion safety.[10] The protective mechanism involves the role of potassium in prolonging refractory periods and suppressing ectopic activity, particularly in Purkinje fibers, as noted by Satoskar et al.[11]

This study also highlights the critical role of LA size in predicting rhythm outcomes. Larger LA diameter was a strong negative predictor for successful cardioversion and maintenance of SR, with patients who persisted in AF having a mean LA diameter of 67.2 mm compared with 53.8 mm in those who achieved SR ($P < .001$). Linear regression analysis further confirmed that an increase in LA diameter significantly reduced the success rate of cardioversion, and a weak inverse correlation was observed between LA diameter and maintenance of SR, suggesting increased recurrence of AF in patients with larger LA. These findings are consistent with the meta-analysis by Dipesh Raniga et al,[12] which showed that higher LA volume index was a significant predictor of AF recurrence after cardioversion; with Baris Akdemir et al,[13] who demonstrated that lower LA volume index before cardioversion was associated with both immediate and long-term maintenance of SR; and with Wilfred Umeojiako et al,[14] who showed that patients with LA diameter of 4 cm or smaller had superior SR maintenance (20.4% vs 6.2% at 12 months).

Restoration of SR was associated with improved hemodynamic parameters, including lower heart rate, higher mean arterial pressure, and reduced central venous pressure, compared with patients who remained in AF. These findings are consistent with those of Sofia Klavebäck et al,[15] who found that successful cardioversion led to a significant reduction in heart rate and an increase in cardiac output, which correlates with improved symptom severity and quality of life. William Shapiro et al[16] also found that conversion to SR improved cardiac output and pressure-stroke work relationships, especially during exercise. In the current study, patients in SR required less inotropic support and had shorter ICU stays, highlighting the clinical benefits of restoring and maintaining SR after cardiac surgery.

Limitations

Despite these benefits, the study acknowledges several limitations. It was a single-center, observational design, which may limit the generalizability of the findings. There was no long-term follow-up beyond 48 hours and no control group for antiarrhythmic drug use.

Conclusions

Maintaining potassium in the high-normal range above 4.4 mmol/L during and after CPB facilitates successful cardioversion in patients with persistent AF, contributing to improved hemodynamics and significant improvement in postoperative recovery. Although this strategy may not be effective for a longer period, SR can be maintained in the initial 48 hours, when hemodynamic instability is more likely. Avoidance of antiarrhythmic drugs in the perioperative period is feasible. LA dilatation is a major factor for failure of cardioversion and recurrence of AF. Further large multicenter randomized clinical trials are required to confirm these findings and their application in the general population.

Declarations:

Ethical Approval

(EC/Approval/03/C_Anae13/06/2022)

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Conflict of Interest

The authors report no conflict of interest.

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