Concomitant Cox - Maze IV Procedure for Atrial Fibrillation During Cardiac Surgery at Hanoi Heart Hospital: A Single Center Experience in 123 Consecutive Patients

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ABSTRACT:

Introduction: This study aimed to investigate the outcomes of the Cox-Maze IV procedure (CMP-IV) in Hanoi Heart Hospital for management of atrial fibrillation during other cardiac surgeries, including in minimally invasive cases.

Methods: This was a retrospective cohort study on patients who underwent open heart surgery combined with CMP-IV for atrial fibrillation from January 2022 to September 2023.

Results: 123 consecutive patients aged 58.4 ± 9.1 years, 55.3% was femalewere included in the study. The cardiopulmonary bypass time was 122.7 ± 15.2 mins, aortic cross-clamp time was 95.4 ± 12.4 mins, and the ablation time of the Cox-Maze IV was18.1 ± 2.0 mins. 32.5% of patients required temporary pacing upon weaning off bypass. Two patients (1.6%) required reopen of the chest for valve-related complications. During six months of follow-up, there was no mortality, postoperative complications were stroke (7.2%), and pacemaker implantation (4.1%). Sinus rhythm restoration was achieved in 84.6% of patients at hospital discharge, 74.8% at three-month, and 66.7% at six-month follow-up.

Conclusion: CMP-IV was effective and safe for management of atrial fibrillation during cardiac surgery, with sinus rhythm restoration rate of 74.8% at three-month and 66.7% at six-month after surgery.

Keywords: *Atrial fibrillation; Cox-Maze IV procedure; Cardiac surgery*

1. Introduction

The incidences of heart failure, stroke, and decreased survival are elevated in patients with preoperative atrial fibrillation (AF). The 10-year survival rate of individuals with preoperative AF undergoing coronary artery bypass graft (CABG) surgery was reported 24% lower compared to those without AF (1). Patients with AF undergoing aortic valve replacement (AVR) surgery presented with increased postoperative risks of interventions associated with arrhythmia, congestive heart failure, stroke, and perioperative death, as compared to those without AF (2). Therefore, the International Society of Minimally Invasive Cardiothoracic Surgery recommended concomitant Cox-Maze procedure for AF during cardiac surgery (3). The introduction of the Cox – Maze procedure in 1987 is considered the "gold

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Received date: *16/07/2025* ***Revised:*** *07/08/2025*
Accepted: *12/08/2025*

standard" for the surgical treatment of AF. While medical management remains essential to patient care, the Cox – Maze III procedure has emerged as a highly effective surgical treatment for this condition. However, this traditional approach has been associated with longer operative times and more invasive surgical techniques. The development of the Cox – Maze IV procedure (CMP-IV), which utilizes linear lines of ablation using monopolar radiofrequency, has significantly shortened operative times and allowed for a minimally invasive approach. When combined with open-heart surgery, particularly valve repair or replacement, the CMP-IV procedure restores sinus rhythm in approximately 60–80% of cases (4). This study evaluated the early outcomes of cardiac surgery combined with the Cox – Maze IV procedure for management of atrial fibrillation.

2. Methods

This is a retrospective cohort study on patients who underwent cardiac surgery combined with CMP-IV for AF treatment from January 2022 to September 2023 at Hanoi Heart Hospital. Electrocardiograms or 24-hour Holter monitorings were obtained. All patients were followed-up for six months.

2.1. Procedure

Cardiac surgery combined with CMP-IV was performed under cardiopulmonary bypass, using either median sternotomy or minimally invasive via right thoracotomy. CMP-IV was conducted using a monopolar radiofrequency device (Medtronic Cardioblate system (Medtronic, Inc.)), and left atrial appendage closure was performed in all patients. Additionally, left atrial volume reduction was performed in most patients. Following the CMP-IV, the surgeon proceeded with cardiovascular surgeries.

2.2. Postoperative Care

All patients were managed according to our hospital protocols. Anticoagulants i.e. warfarin or acenocoumarol were administered in the early postoperative period for most patients. For those experiencing postoperative atrial tachycardia, cardioversion with electrical shock or amiodarone was administered as needed. Temporary epicardial pacing was used for bradycardia, and permanent pacing was indicated in patients with sinus node dysfunction or atrioventricular block. Patient follow-up was scheduled monthly after discharge in accordance with hospital protocols. Recurrence of AF was defined as any episode of AF, atrial flutter, or atrial tachycardia longer than 30 seconds.

2.3. Ethics

This study was approved by the Institutional Review Board of Hanoi Heart Hospital. The study adhered to the principles of the Helsinki Declaration for biomedical research.

2.4. Statistical analysis

Statistical analysis were performed using SPSS software. All p-values were two sided, and a p-value < 0.05 was considered significant.

3. Results

3.1. Patient characteristics

The study included 123 eligible patients with characteristics shown in Table 1. The mean age was 58.4 ± 9.1 years (range 25–76), female was 55.3%. A history of stroke was noted in 13% of patients. Palpitations were reported in 80.5% of patients, and 66.7% presented with NYHA class III. The types of cardiac surgery included

mitral valve replacement (61.0%), mitral valve repair (17.9%), atrial septal defect closure (3.2%), and coronary artery bypass grafting (2.4%). The average cardiopulmonary bypass time was 122.7 ± 15.2 minutes (range 89–162 minutes), with an average aortic cross-clamp time of 95.4 ± 12.4 minutes (range 59–128 minutes). The Cox-Maze procedure had an ablation duration of 18.1 ± 2.0 minutes (range 12–22 minutes), with 81.3% of cases using 25W ablation. 37.4% of patients required electrical cardioversion due to ventricular fibrillation, tachycardia, or atrial fibrillation.

3.2. Surgical outcomes

Table 2 showed postoperative heart rhythm. Early postoperative sinus rhythm or junctional rhythm was achieved in 82.1% of patients. 86.2% of patients had sinus or junctional rhythm at discharge. Sinus rhythm was restored in 48.8% of patients by the end of the surgery, increasing to 65% during the recovery phase. Sinus rhythm was reported in 84.6%, 74.8% and 66.7% of patients at discharge, 3-month and 6-month, respectively. Postoperative arrhythmias occurred in 38.2% of cases, including AF, tachycardia, and ventricular fibrillation. In the early postoperative period, 17.1% of patients developed junctional rhythm, 17.1% had AF, and 0.8% experienced third-degree atrioventricular block (AV block). Temporary pacemaker implantation was required in one patient at discharge, with five patients (4.1%) requiring permanent pacemaker implantation by six months postoperatively.

Table 3 showed the echocardiographic characteristics before and after the operation. Left atrial diameter were reduced from 52.6 ± 7.7 mm (range 35–79 mm) preoperatively, to 42.4 ± 6.2 mm (range 28–69 mm) before discharge, 41.3 ± 5.6 mm (range 31–58 mm) at three months, and 38.5 ± 5.1 mm (range 29–57 mm) at six months postoperatively. Pulmonary artery pressure decreased from 41.2 ± 12.6 mmHg (range 21–90 mmHg) preoperatively to 30.6 ± 8.1 mmHg (range 20–62 mmHg) at discharge, 29.2 ± 6.6 mmHg (range 20–55 mmHg) at three months, and 28.5 ± 7.4 mmHg (range 19–64 mmHg) at six months. Preoperatively, 14.6% of patients had left atrial thrombus. Pericardial effusion was present in 16.3% of patients preoperatively, increasing to 56.1% at discharge and decreasing to 26.8% at three months and 3.3% at six months postoperatively.

3.3. Safety

Table 4 showed the laboratory test results before and after the operation. Postoperative heart failure was associated with increased NT-proBNP levels from 1552.1 ± 1426.4 pg/mL to 4147.5 ± 4244.4 pg/mL. CK-MB rose from 15.7 ± 4.0 U/L to 52.1 ± 36.4 U/L, and high-sensitivity Troponin T increased from 13.8 ± 5.3 ng/L to 2483.9 ± 1763.7 ng/L. C-reactive protein (CRP) levels increased from 2.0 ± 1.7 mg/L to 130.5 ± 73.0 mg/L. A decline in renal function was observed, with the estimated glomerular filtration rate (eGFR) decreasing from 67.7 ± 21.6 mL/min/1.73 m^2 to 52.7 ± 18.7 mL/min/1.73 m^2.

Table 5 showed the postoperative interventions and complications. A total of 40 cases (32.5%) required short-term temporary pacing postoperatively, while 28 cases (22.8%) received amiodarone infusion. Vasopressors and inotropic agents were used in 87 cases (70.7%), and an intra-aortic balloon pump (IABP) was used in 5 cases (4.1%). Acute renal failure

requiring dialysis occurred in 2 cases (1.6%). There were 9 cases with postoperative new stroke (7.2%). Two cases (1.6%) required reoperation due to valve-related structural complications. Respiratory infections, including pneumonia, were reported in 26 cases (21.1%). No mortality was recorded during the postoperative period or up to 6 months of follow-up.

Table 1: Clinical and surgical characteristics

Characteristics		**Patients (n =123)**	
		n	**%**
Gender	Male	55	44.7
	Female	68	55.3
Age (year) $\overline{X}$ ± SD		58.4 ± 9.1 (25 – 76)	
History of stroke		16	13.0
Palpitations		99	80.5
NYHA classification	II	41	33.3
	III	82	66.7
Types of Cardiac Surgery	Mitral valve replacement	75	61.0
	Mitral valve repair	22	17.9
	Aortic valve replacement	19	15.5
	Atrial septal defect (ASD) closure	4	3.2
	Coronary artery bypass grafting (CABG)	3	2.4
Cardiopulmonary bypass time (minutes):	Cardiopulmonary bypass time	122.7 ± 15.2 (89 – 162)	
	Aortic cross-clamp time	95.4 ± 12.4 (59 – 128)	
Cox – Maze IV procedure	25W ablation	100	81.3
	35W ablation	23	18.7
	Maze ablation duration (minutes)	18.1 ± 2.0 (12 – 22)	
Postoperative electrical cardioversion	No	77	62.6
	Yes	46	37.4

Table 2. Postoperative Heart rhythm

Characteristics		Patients (n =123)	
		n	%
Immediate postoperative	Sinus rhythm	60	48.8
	Junctional rhythm	16	13.0
	Atrial fibrillation (AF), ventricular tachycardia (VT), ventricular fibrillation (VF)	47	38.2
Early postoperative	Sinus rhythm	80	65.0
	Junctional rhythm	21	17.1
	AF, atrial tachycardia	21	17.1
	Third-degree atrioventricular block (AV block)	1	0.8
At Discharge	Sinus rhythm	104	84.6
	Junctional rhythm	2	1.6
	Atrial fibrillation	16	13.0
	Temporary pacemaker	1	0.8
3-month	Sinus rhythm	92	74.8
	Atrial fibrillation	28	22.8
	Pacemaker	3	2.4
6-month	Sinus rhythm	82	66.7
	Atrial fibrillation	36	29.3
	Pacemaker	5	4.1

Table 3. Perioperative echocardiography

Characteristics	**Before surgery** (n=123)	**Discharge** (n=123)	**Postoperative 3-month** (n=123)	**Postoperative 6-month** (n=123)	**p**
Pericardial effusion	20 (16,3)	69 (56.1)	33 (26.8)	4 (3.3)	--
Left atrial thrombus	18 (14.6)	0	0	0	--
Left atrial diameter (mm)	52.6 ± 7.7 (35-79)	42.4 ± 6.2 (28-69)	41.3 ± 5.6 (31-58)	38.5 ± 5.1 (29-57)	<0.05
Left ventricular ejection fraction (LVEF, %)	60.3 ± 9.0 (35-81)	61.9 ± 9.9 (30-83)	63.9 ± 9.0 (36-85)	64.3 ± 8.4 (42-83)	<0.05
Left ventricular end-diastolic diameter (mm)	48.3 ± 8.5 (30-70)	46.8 ± 5.9 (34-61)	45.3 ± 5.0 (32-57)	45.5 ± 5.4 (31-60)	<0.05
Pulmonary artery pressure (mmHg)	41.2 ± 12.6 (21-90)	30.6 ± 8.1 (20-62)	29.2 ± 6.6 (20-55)	28.5 ± 7.4 (19-64)	<0.05

Table 4. Perioperative Laboratory test results

	Before operation (n=123)	**12 to 24 hours postoperation** (n=123)	**p**
Na^+ (mmol/L)	135.4 ± 3.0	133.8 ± 3.0	0.001
K^+ (mmol/L)	4.1 ± 0.3	4.1 ± 0.4	0.056
CK (U/L)	101.9 ± 49.3	1217.4 ± 581.2	0.009
CK-MB (U/L)	15.7 ± 4.0	52.1 ± 36.4	0.801
Troponoin Ths (ng/L)	13.8 ± 5.3	2483.9 ± 1763.7	0.009
NT-proBnP (pg/mL)	1552.1 ± 1426.4	4147.5 ± 4244.4	0.000
CRP (mg/L)	2.0 ± 1.7	130.5 ± 73.0	0.000
Creatinin (µmol/L)	80.1 ± 17.6	106.0 ± 31.1	0.000
eGFR (mL/phút/1,73m^2)	67.7 ± 21.6	52.7 ± 18.7	0.000

Table 5. Postoperative interventions and complications

Characteristics		Patients (n =123)	
		n	%
Intravenous amiodarone administration		28	22.8
Short-term temporary pacing		40	32.5
Inotropic and vasopressor support		87	70.7
Intra-aortic balloon pump (IABP)		5	4.1
Acute renal failure requiring dialysis		2	1.6
Postoperative respiratory tract infections		26	21.1
Reoperations	Hemostasis	8	6.5
	Valve repair/replacement	2	1.6
New stroke	30-day postoperative period	3	2.4
	During 3-month	3	2.4
	During 6-month	3	2.4
	Total	9	7.2
Mortality (During 6-month)		0	0
Hospital length of stay (days)		24.6 ± 10.3 (10 – 70)	
Postoperative length of stay (days)		14.0 ± 5.8 (6 – 41)	

4. Discussion

Atrial fibrillation is a known risk factor for thrombus formation, and thromboembolic stroke. In our study, 13% of patients had a history of stroke, similar to the 12% reported by Weimar et al. (5). During the perioperative period, 2.4% (3 cases) of patients experienced a stroke, with the notable finding that two of these three patients had sinus rhythm postoperatively and had preoperative left atrial thrombus. The occurrence of perioperative stroke in these cases is likely related to the dislodgment of thrombi during surgery. During the 3- to 6-month follow-up period, 4.8% of patients experienced transient ischemic strokes (TIAs) with detectable lesions on MRI, though none of these cases had permenant neurological deficits. All patients who experienced these events had recurrent atrial fibrillation after surgery. No intracardiac thrombi were detected at discharge and 3- and 6-month follow-ups. Despite left atrial appendage closure, left atrial volume reduction, and adequate anticoagulation, patients remain at risk for cerebrovascular embolic events if AF recurs. Following the 2012 recommendations of the Heart Rhythm Society, all patients undergoing surgery for other cardiac conditions who present with preoperative symptomatic AF should undergo concomitant AF treatment (6). However, caution should be noted in cases with severe

preoperative cardiac dysfunction, recent acute myocardial infarction, or markedly enlarged left atrial dimensions (7). Our cohort presented with a wide spectrum of heart failure severity and the sequelae of concomitant AF. It is estimated that approximately one-third of patients with mitral valve disease undergoing surgery do not receive concomitant atrial fibrillation treatment (8). Despite the acceptance of its efficacy and the issuance of a Class IA recommendation (9), the number of patients receiving this procedure in Vietnam remains limited. In our view, this is primarily due to the lack of experience and commitment among surgeons and the financial constraints faced by patients. The CMP-IV represents an improvement over the traditional Cox – Maze procedure, which involves a complex cut-and-sew technique and carries higher risks of complications such as bleeding and heart failure (10). Therefore, combining the CMP-IV with open-heart surgery does not significantly prolong the overall duration of the operation. The CMP-IV is technically simpler and more time-efficient than percutaneous radiofrequency catheter ablation for atrial fibrillation.

The restoration of sinus rhythm after the CMP-IV procedure was 66.7% at six months. Weimar et al, reported that the success rate of the CMP-IV in 90%, with 82-84% of patients free from AF and antiarrhythmic medications after 6 to 24 months. However, the recurrence of AF remains a significant concern following the Cox-Maze procedure, with 80% AF, 10% atrial flutter, and 10% atrial tachycardia (5). The failure of the Cox – Maze procedure can be attributed to multiple factors, such as increased left atrial diameter, early postoperative atrial tachycardia within the first month, and incomplete isolation of the left atrium (11). A preoperative left atrial diameter greater than 80 mm has been reported to be associated with a 50% risk of AF recurrence postoperatively (11). In our study, the preoperative left atrial diameter was reduced in size through surgery, and left atrial appendage closure was performed in combination with CMP-IV to minimize the risk of postoperative AF recurrence. Especially, the type of AF and its duration before surgery were not associated with a higher rate of AF recurrence (11). The mechanism of AF recurrence was in the presence of triggers and sustaining factors. The failure of CMP-IV is incomplete transmural lesions at specific ablation sites. The lesions created during CMP-IV must effectively block electrical conduction, requiring complete transmural ablation. Even a single incomplete site or small gap can result in arrhythmias by allowing slow conduction of electrical impulses, which increases the likelihood of reentry circuits. Lesions must originate and terminate in non-conductive tissue to block abnormal electrical transmission (12).

The primary goal of CMP-IV is to terminate AF and restore normal sinus rhythm. and to prevent a fearful complication of stroke. Restoration of sinus rhythm improves hemodynamic function, re-establishes atrial contraction, enhances heart failure outcomes, and eliminates the risk of thromboembolism formation. Left atrial appendage closure or isolation is essential, as the majority of strokes caused by thromboembolism in AF patients originate from this structure. The removal or exclusion of the left atrial appendage significantly

reduces the risk of stroke or systemic embolism, as shown in a previous study (13).

Postoperatively, 38.2% of patients experienced arrhythmias. Permanent pacemaker implantation was required in 1 patient at discharge, increasing to 5 patients (4.1%) during the 6-month follow-up. Permanent pacemaker implantation is a recognized complication of Cox – Maze procedures, with reported rates of 6.9% to 11% within the first 30 days after the procedure (14), (15). The reasons for permanent pacemaker implantation in these patients were sinus node dysfunction, bradycardia during AF, and slow junctional rhythm. Permanent pacemaker implantation is indicated for patients with irreversible sinus node dysfunction (10), which is likely a pre-existing condition and not directly caused by CMP-IV. The incidence of sinus node dysfunction increases with patient age and the duration of AF prior to surgery (15).

Postoperative medical management and intensive care play a crucial role in the success of cardiac surgery in general, helping to prevent and address postoperative complications, including those related to arrhythmias following the procedure. No deaths were recorded during the postoperative period or within six months of follow-up. The main complications were pneumonia (28 cases - 19.2%). This result was in line with other study showed that the incidence of postoperative pneumonia is approximately 20% (5).

A limitation of this study was that 24-hour Holter monitoring was only performed before discharge, while follow-up assessments at subsequent visits were conducted using standard 12-lead electrocardiograms. This may cause underestimation of the rate of procedural failure.

5. Conclusion

Concomitant CMP-IV procedure during cardiac surgery was effective for atrial fibrillation treatment, with a **sinus rhythm restoration rate of** 74.8% at three months and 66.7% at six months after surgery. This approach was safe, with no mortality and a low rate of complications.

Disclosure statement

The authors declare no conflict of interest.

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