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Impact of aortic root rotation angle on new-onset first-degree atrioventricular block following mitral valve surgery

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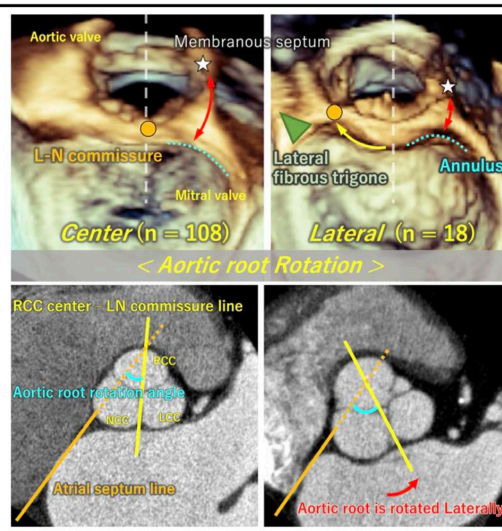
Summary

In a total of 126 patients with normal ECG undergoing isolated mitral valve surgery, we analyzed the impact of aortic root anatomical variations (*center* or *lateral rotation*) diagnosed by preoperative 3D-TEE and the root rotation angle measured by cardiac CT on postoperative AVB. *Lateral rotation* and a larger rotation angle were significant risk factors for new-onset AVB.



Legend: ECG, electrocardiogram; 3D-TEE, three-dimensional transesophageal echocardiography; CT, computed tomography; AVB, atrioventricular block

Abstract

OBJECTIVES: This study aimed to classify anatomical variations in aortic root rotation using preoperative three-dimensional transoesophageal echocardiography (3D-TEE), validate these findings with cardiac computed tomography (CT) in patients undergoing mitral valve surgery and evaluate the clinical impact on postoperative atrioventricular conduction disorders.

METHODS: A total of 126 patients with normal electrocardiograms who underwent isolated mitral valve surgery were included. Anatomical variation was diagnosed using 3D-TEE, and aortic root rotation angle was measured using cardiac CT. New-onset postoperative atrioventricular block (AVB) and bundle branch block were analysed.

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RESULTS: Variations of aortic root rotation were classified by 3D-TEE into two categories: 'center rotation' (normal) (85.7%, $n = 108/126$), where the commissure of the left and non-coronary aortic leaflet was located at center of the anterior mitral leaflet, and 'lateral rotation' (14.3%, $n = 18/126$), rotated to the lateral trigone side. The aortic root rotation angle, where the interatrial septum was defined as a reference, measured by cardiac CT strongly correlated with 3D-TEE findings ('center rotation' vs 'lateral rotation': 51.6° vs 64.6°, $P < 0.001$). The incidence of new-onset conduction disorder, all presenting with first-degree AVB, was significantly higher in the 'lateral rotation' than in the 'center rotation' (38.9% [$n = 7/18$] vs 5.6% [$n = 6/108$], $P < 0.001$). Aortic root rotation angles were identified as significant risk factors for postoperative first-degree AVB (odds ratio, 1.05; 95% confidential interval, 1.01–1.09; $P = 0.027$), with cutoff values of 58.7° predicting persistent new-onset AVB.

CONCLUSIONS: Aortic root rotation angle measured by cardiac CT validated 3D-TEE diagnosis of 'lateral rotation' of the aortic root. 'Lateral rotation' and larger aortic root rotation angles were significant risk factors for postoperative first-degree AVB following mitral valve surgery.

Keywords: mitral valve surgery • three-dimensional transesophageal echocardiography • cardiac computed tomography • aortic root rotation position • atrioventricular conduction disorder

ABBREVIATIONS

3D-TEE	Three-dimensional transoesophageal echocardiography
AVB	Atrioventricular block
BBB	Bundle branch block
CI	Confidential interval
CT	Computed tomography
ECGs	Electrocardiograms
OR	Odds ratio
PAF	Paroxysmal atrial fibrillation

INTRODUCTION

Valvular heart disease, particularly mitral valve disease, is a global public health concern, with an increasing incidence with age [1–3]. Surgical interventions, repair and replacement are the standard treatments for mitral valve disease, providing good short- and long-term outcomes [4–6]. However, sutures in mitral valve surgery can damage the bundle of His, potentially causing atrioventricular conduction disorders [7]. Little is known about these anatomical risk factors.

A detailed preoperative imaging of the mitral valve anatomy is crucial for preventing postoperative complications. Three-dimensional transesophageal echocardiography (3D-TEE) is essential for mitral valve surgery, providing real-time, high-quality images to investigate mitral leaflet motion and detailed cardiac anatomies in almost all patients undergoing the procedure [8, 9].

Clear and high-resolution images of the heart can be obtained with recent advancements in cardiac imaging technologies, such as TEE and computed tomography (CT), revealing its detailed anatomy. Cardiac CT has revealed significant variations in aortic root rotation [10–15], suggesting 'lateral rotation', where the aortic root to the lateral fibrous trigone side shortens the distance between the membranous septum and mitral annulus [10, 14]. These variations are reflected in the location of the atrioventricular conduction system, but their clinical significance is not fully understood.

This study aimed to classify the anatomical variation in the 'lateral rotation' of the aortic root using preoperative 3D-TEE in patients undergoing mitral valve surgery. To evaluate the diagnostic validity of 3D-TEE, the rotational angle of the aortic root was measured using cardiac CT, and its consistency with 3D-TEE findings was investigated. Their clinical influence on postoperative atrioventricular conduction disorders associated with mitral valve surgery was analysed.

MATERIALS AND METHODS

Study population

This single-centre, retrospective study included 857 consecutive mitral valve surgeries at Osaka University Hospital between 2012 and 2023. Among them, a total of 252 patients with normal electrocardiograms (ECGs) and no history of arrhythmia, including paroxysmal atrial fibrillation (PAF), underwent first-time elective isolated mitral valve surgery via the right-sided left atrial approach. Patients who had concomitant surgery or mitral valve surgery via a transseptal approach, as well as those with a history of cardiac disease, including cardiothoracic surgery and percutaneous intervention, were excluded. Finally, 126 patients who underwent both preoperative 3D-TEE and cardiac CT images were included in the final analysis (Supplementary Fig. S1). Postoperative ECG follow-up was conducted 1 week and 3 months after surgery (Supplementary Fig. S1). All ECG diagnoses, including right bundle branch block (BBB) and left BBB, followed established guidelines, with a PR interval of 200 ms or more considered indicative of a first-degree atrioventricular block (AVB) [16]. The diagnoses were determined by at least two cardiovascular specialists who blindly reviewed the ECGs. Postoperative conduction disorders were defined as those occurring immediately after surgery, excluding those that developed after discharge.

Ethical statement

This study was conducted in accordance with the principles of the Declaration of Helsinki. The Clinical Research Ethics Committee of Osaka University Hospital approved the study, and the data were released (approval number: 23121(T6), approval date: 1 August 2023). Written informed consent was obtained from all the patients.

Definition of diagnosis in 3D-TEE and measurement in cardiac CT

Diagnosis using 3D-TEE was performed using an X8-2t probe (Philips Medical Systems) with the EPIQ ultrasound machine (Philips Medical Systems) and analysed using the QLAB software packages (Philips, Best, Netherlands). As shown in Fig. 1, the

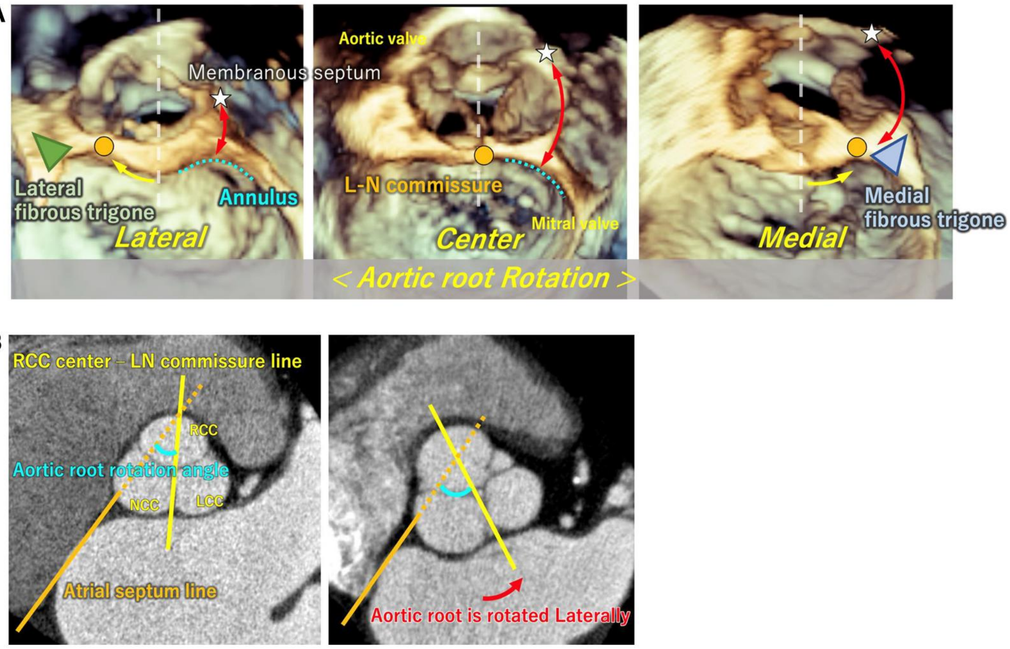

Figure 1: Definitions of aorto-mitral positional anatomy diagnosed by 3D-TEE (**A**), and aortic root rotation angle measured by cardiac CT (**B**). 3D-TEE: three-dimensional transoesophageal echocardiography; CT: computed tomography; LCC: left coronary cusp; LN: left non-coronary; NCC: non-coronary cusp; RCC: right coronary cusp

surgeon's view of the mitral valve simultaneously visualized the aortic valve, allowing the rotational position of the aortic root to be diagnosed independently by two or more cardiovascular specialists in a blinded manner. The diagnosis of aortic root rotation was defined as normal when the commissure between the left and non-coronary aortic valve leaflets was located at the center of the anterior mitral leaflet ('center rotation'), 'lateral rotation' when it was clearly recognized to have rotated towards the lateral fibrous trigone side and 'medial rotation' when rotated to the medial trigone side (Fig. 1). The measurement method in cardiac CT was performed in the horizontal cross-section of the aortic valve, which is consistent with previously reported methods [10–13]. The angle formed by the line connecting the center of the right coronary cusp and the commissure between the left and non-coronary aortic valve leaflets and the line of the atrial septum was defined as the aortic root rotation angle (Fig. 1).

Endpoints

Anatomical variation of the aortic root rotation was diagnosed utilizing preoperative 3D-TEE. To validate the diagnosis, we assessed the consistency with the aortic root rotation angle measured by preoperative cardiac CT. We then identified new-onset postoperative atrioventricular conduction disorders (including AVB and BBB), analysed whether 'lateral rotation' of the aortic root was a risk factor, and examined its relationship with the aortic root rotation angle.

Statistical analysis

Categorical variables were presented as percentages (%), whereas continuous variables were expressed as median with interquartile range. To compare the two groups, Fisher's exact test was used for categorical variables, and the Wilcoxon rank-sum test was used for continuous variables. Univariable analyses using a logistic regression model were performed to identify the risk factors for new-onset and persistent postoperative conduction disorders at each 1 week and 3 months after the surgery. Statistical significance was set at $P < 0.05$. All statistical analyses were performed using JMP® Pro (version 17.1.0, SAS Institute Inc., Cary, NC, USA).

RESULTS

Background and surgical characteristics of study population

Table 1 shows the patient backgrounds. The median age was 62.8 years, and 73% of the patients were male. No preoperative antiarrhythmic medication was administered to 77% of the patients, and almost all patients were diagnosed with degenerative mitral regurgitation (90.5%). The operative data and postoperative medications are presented in Table 1. The minimally invasive cardiac surgery was performed in 57.1% of the patients, all of which were right thoracotomies, without the use of robotic assistance. Among the myocardial protection methods, 46.7% of patients received only antegrade cardioplegia, while the remaining 53.3% received both antegrade and retrograde cardioplegia. A full prosthetic ring was used in 76.3% of the cases underwent mitral valve plasty, and a partial ring was used in the remaining patients (23.7%). All rings, whether full or partial, were semi-rigid. Among the postoperative antiarrhythmic medications, 50.8% of patients received beta-blockers, whereas 49.2% of patients did not receive any antiarrhythmic medication.

Validation of 3D-TEE diagnosis with cardiac CT measurements

The diagnosis of 3D-TEE and cardiac CT for all patients was made by two or more cardiovascular specialists based on the defined criteria and then verified separately to ensure that each diagnosis

Table 1: Baseline characteristics and operative data

Variable	All patients ($n = 126$)	
Baseline characteristics		
Age (years)	62.8	[52.0–70.6]
Male	93	(73.8)
BMI (kg/m^2)	22.6	[19.7–24.7]
Diabetes	15	(11.9)
Dialysis	3	(2.4)
Hypertension	45	(35.7)
Peripheral artery disease	2	(1.6)
Cerebrovascular disease	10	(7.9)
NYHA ≥ III	17	(13.5)
Elective	122	(96.8)
Preoperative antiarrhythmic medication		
Non	97	(77.0)
Beta-blocker	29	(23.0)
Preoperative transthoracic echocardiography		
LVDd (mm)	57.0	[53.0–61.0]
LVDs (mm)	34.0	[30.0–39.0]
LVEF (%)	68.0	[63.0–74.0]
LAD (mm)	46.0	[42.0–51.0]
MR ≥ moderate	122	(96.8)
Carpentier 1	4	(3.2)
Carpentier 2	114	(90.5)
Carpentier 3a	2	(1.6)
Carpentier 3b	6	(4.8)
Mitral stenosis	1	(0.8)
Active infective endocarditis	6	(4.8)
Intraoperative myocardial protection		
CPB time (min)	179.0	[139.8–231.8]
Cross clamp time (min)	122.5	[96.8–154.5]
Antegrade cardioplegia only	57	(46.7)
Operative procedures		
Median approach	54	(42.9)
Mitral valve plasty[a]	118	(93.6)
Full prosthetic ring	90	(76.3)
Prosthetic ring size (mm)	30.0	[30.0–32.0]
Mitral valve replacement[b]	8	(6.4)
Bioprosthesis	7	(87.5)
Prosthetic valve size	28.0	[25.5–29.0]
Postoperative antiarrhythmic medication		
Non	62	(49.2)
Beta-blocker	64	(50.8)
Amiodarone	1	(0.8)
Digitalis	1	(0.8)

[a]Mitral valve plasty, $N = 118$.
[b]Mitral valve replacement, $n = 8$.
Data are presented as n (%) or median [interquartile range].
BMI: body mass index; CPB: cardiopulmonary bypass; LAD: left atrium diameter; LVDd: left ventricular end-diastolic diameter; LVDs: left ventricular end-systolic diameter; LVEF: left ventricular ejection fraction; NYHA: New York Heart Association functional classification; TR: tricuspid regurgitation; TRPG: tricuspid regurgitation pressure gradient.

was correct. All patients had tricuspid aortic valves, and there were no patients with bicuspid valves. According to the 3D-TEE classification, 108/126 cases (85.7%) were clearly diagnosed with ‘center rotation’ and 18/126 cases (14.3%) with ‘lateral rotation’ (Table 2). ‘Medial rotation’ was not observed. The association between 3D-TEE classification and aortic root rotation angle measured by CT was examined. The aortic root rotation angle measured by preoperative CT was 51.6° in the ‘center rotation’ group and 64.6° in the ‘lateral rotation’ group ($P < 0.001$) with a cutoff value of 59.3° or more indicates ‘lateral rotation’. This suggests a strong association between the aortic root rotation angle measured using cardiac CT and 3D-TEE diagnosis (Fig. 2).

Table 2: Aorto-mitral positional anatomy classification based on 3D-TEE and new-onset postoperative conduction disorders

Anatomy/classification	One-week after surgery ($n = 126$)	
Aorto-mitral positional anatomy classified by 3D-TEE		
Aortic root rotation		
Center rotation	108	(85.7)
Lateral rotation	18	(14.3)
Medial rotation	0	(0.0)
Postoperative atrioventricular conduction disorders		
New AVB or BBB	13	(10.3)
New AVB		
First degree AVB	13	(10.3)
Second degree AVB	0	(0.0)
Third degree AVB	0	(0.0)
New BBB (including LBBB/RBBB)		
LBBB	0	(0.0)
RBBB	1	(0.8)
Anatomy/classification	**Three-month follow-up ($n = 122$)**	
Persistence of conduction disorders	6	(4.9)
AVB		
First degree AVB	6	(4.9)
Second degree AVB	0	(0.0)
Third degree AVB	0	(0.0)
BBB (including LBBB/RBBB)		
LBBB	0	(0.0)
RBBB	1	(0.8)

Data are presented as n (%) or median [interquartile range].
3D-TEE: three-dimensional transoesophageal echocardiography; AVB: atrioventricular block; BBB: bundle branch block; LBBB: left bundle branch block; RBBB: right bundle branch block.

‘Lateral rotation’ and aortic root rotation angle: risk of new-onset atrioventricular conduction disorders after mitral valve surgery

New-onset postoperative atrioventricular conduction disorders occurred in 10.3% ($n = 13/126$) of patients, all presenting with first-degree AVB, including right BBB in one patient. Six of these patients had persistent first-degree AVB 3 months postoperatively (Table 2). In the association between aortic root rotation classified by preoperative 3D-TEE and postoperative first-degree AVB, the ‘lateral rotation’ group was significantly more frequent than the ‘center rotation’ group (38.9% $n = 7/18$ vs 5.6% $n = 6/108$, $P < 0.001$: Fig. 3A). The relationship between the aortic root rotation angle and the occurrence of postoperative conduction disorder revealed that patients with new-onset first-degree AVB had a significantly larger aortic root rotation angle than patients without AVB (60.6° vs 52.2°, $P = 0.004$), with a cutoff value of 55.4° or more suggesting that a first-degree AVB may develop at 1 week postoperatively (Fig. 3A). In the 3-month follow-up, ‘lateral rotation’ had a significantly higher incidence of persistent first-degree AVB than ‘center rotation’ ($n = 5/17$ vs $n = 1/105$, $P < 0.001$; Fig. 3B). Additionally, the rotation angle was significantly larger in patients whose first-degree AVB persisting for 3 months after surgery (60.0° vs 52.7°, $P = 0.032$), with a cutoff value of 58.7° or more suggesting that new-onset first-degree AVB is likely to persist at 3 months postoperatively (Fig. 3B). Univariable analysis revealed that ‘lateral rotation’ (odds ratio [OR], 10.82; 95% confidential interval [CI], 3.08–37.96; $P < 0.001$) and large aortic root rotation angles (OR, 1.05; 95% CI, 1.01–1.09; $P = 0.027$) were identified as significant risk factors for

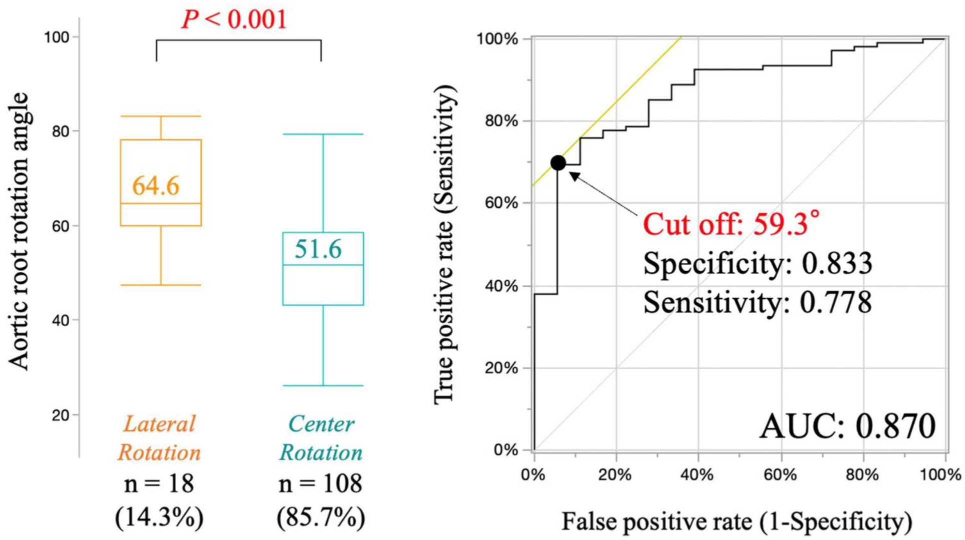

Figure 2: Relationship between the aortic root rotation angle and the anatomical variation of aortic root rotation diagnosed by 3D-TEE. 3D-TEE: three-dimensional transoesophageal echocardiography

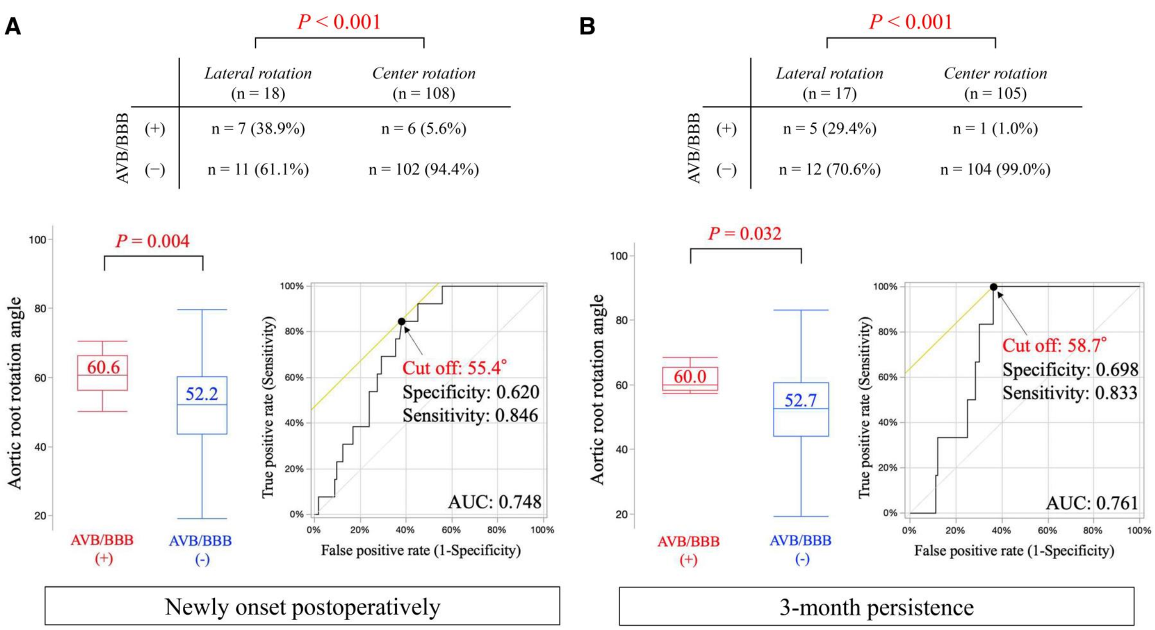

Figure 3: Incidence of atrioventricular conduction disorders in patients with anatomical variation of aortic root rotation, and differences in aortic root rotation angle between with or without new-onset conduction disorders, including cutoff values for event occurrence at postoperative period (**A**) and three-month follow-up (**B**)

postoperative first-degree AVB. These were also identified as risk factors for persistence of first-degree AVB over 3 months ('lateral rotation': OR, 43.33; 95% CI, 4.67–402.44; $P < 0.001$; aortic root rotation angle: OR, 1.05; 95% CI, 1.00–1.10; $P = 0.038$) (Table 3). The use of a full prosthetic ring for annuloplasty had a tendency to contribute to the occurrence of first-degree AVB in 1 week after the surgery (OR, 3.04; 95% CI, 0.85–10.87; $P = 0.087$) and at 3-month persistence (OR, 7.39; 95% CI, 0.67–48.41; $P = 0.067$) (Table 3), but these were not statistically significant.

To investigate the homogeneous cohort, patients with Carpentier type 2 mitral regurgitation who underwent mitral valve plasty ($n = 111$) were analysed. The results were similar to the total cohort analysis (Supplementary Table S1, Figs S2 and S3).

Patient follow-up and incidence of postoperative cardiac events

The study analysed the frequency of postoperative cardiac events (Fig. 4). Among six patients with persistent new-onset first-degree AVB, five were available for follow-up ECGs over 1 year postoperatively. All five of these patients had residual first-degree AVB over 1 year, with none having recovered to a normal ECG. Patients with persistent first-degree AVB for 3 months after surgery had a significantly higher incidence of new-onset PAF, which was diagnosed when it occurred intermittently during hospitalization after surgery and/or detected by follow-up ECG, and required outpatient treatment with oral

Table 3: Risk analysis for postoperative new-onset atrioventricular conduction disorders

Variable	One-week after the surgery			Three-month follow-up		
	Odds ratio (95% CI)		*P* value	Odds ratio (95% CI)		*P* value
Baseline characteristics and echocardiography						
Age (year)	1.02	(0.98–1.07)	0.337	1.04	(0.97–1.11)	0.262
Male	4.74	(0.59–37.97)	0.143	1.82	(0.28–35.64)	0.568
Body mass index (kg/m^2)	1.09	(0.93–1.28)	0.277	1.00	(0.79–1.28	0.974
Diabetes	1.70	(0.20–14.07)	0.602	1.58	(0.17–14.64)	0.685
Dialysis		Unconverged[c]			Unconverged[c]	
Hypertension	1.63	(0.51–5.17)	0.410	1.89	(0.35–9.48)	0.472
Peripheral artery disease		Unconverged[c]			Unconverged[c]	
Cerebrovascular disease	2.39	(0.45–12.67)	0.307	2.37	(0.25–22.61)	0.451
LVDd (mm)	1.05	(0.95–1.15)	0.341	1.06	(0.93–1.21)	0.365
LVEF (%)	0.99	(0.93–1.06)	0.878	0.98	(0.90–1.06)	0.541
LAD (mm)	1.01	(0.94–1.09)	0.807	1.01	(0.91–1.13)	0.838
Carpentier 3 (vs 1 and 2)		Unconverged[c]			Unconverged[c]	
Mitral stenosis		Unconverged[c]			Unconverged[c]	
Active infective endocarditis	1.80	(0.19–16.72)	0.605		Unconverged[c]	
Elective (vs emergent)	0.33	(0.03–3.40)	0.349		Unconverged[c]	
Aorto-mitral rotation						
'Lateral rotation' (vs 'centre rotation')	10.82	(3.08–37.96)	**<0.001**	43.33	(4.67–402.44)	**<0.001**
Rotation angle (degree)	1.05	(1.01–1.09)	**0.027**	1.05	(1.00–1.10)	**0.038**
Operative procedures						
Cross clamp time (min)	1.00	(0.99–1.01)	0.694	1.00	(0.99–1.02)	0.894
Antegrade cardioplegia only	1.38	(0.43–4.36)	0.587	1.68	(0.27–10.58)	0.579
Full prosthetic ring (vs partial ring)[a]	3.04	(0.85–10.87)	0.087	7.39	(0.67–48.41)	0.067
Mitral valve replacement (vs mitral valve plasty)[b]	3.24	(0.58–18.04)	0.179		Unconverged[c]	
Postoperative antiarrhythmic medication						
Beta-blocker	2.37	(0.69–8.15)	0.170	2.00	(0.35–11.35)	0.434
Amiodarone		Unconverged[c]			Unconverged[c]	
Digitalis		Unconverged[c]			Unconverged[c]	

Values in bold indicate statistically significant.

[a]Mitral valve plasty, $n = 118$.

[b]Mitral valve replacement, $N = 8$.

[c]Calculation was not possible because there were no events.

CI: confidential interval; LAD: left atrium diameter; LVDs: left ventricular end-systolic diameter; LVEF: left ventricular ejection fraction.

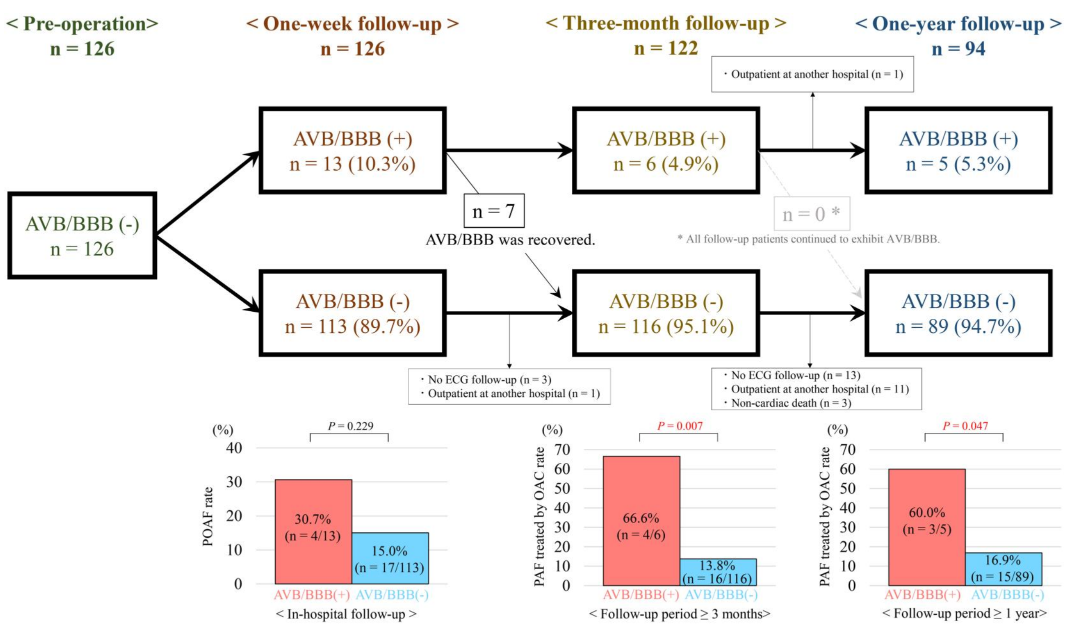

Figure 4: Patients' follow-up chart. Relationship between persistent conduction disorder and postoperative atrial fibrillation. AVB: atrioventricular block; BBB: bundle branch block; OAC: oral anticoagulants; PAF: paroxysmal atrial fibrillation; POAF: postoperative atrial fibrillation

anticoagulants. At 1 year postoperatively, the frequency of PAF requiring oral anticoagulant treatment was also significantly higher in patients with residual first-degree AVB (Fig. 4).

DISCUSSION

This study's results contribute significantly to this field. First, 3D-TEE, a crucial examination in mitral valve surgery, was effective in diagnosing 'lateral rotation'. Second, the 3D-TEE diagnosis was significantly correlated with the aortic root rotation angle measured by preoperative cardiac CT, indicating that the 3D-TEE-based diagnosis is highly valid. Moreover, 'lateral rotation' and larger aortic root rotation angle were identified as a significant risk factor for first-degree AVB after mitral valve surgery. Finally, the cut-off value was defined as an aortic root rotation angle of $\sim 60^{\circ}$, with greater angles being diagnosed as lateral rotation, and the frequency of postoperative AVB increasing and persisting for more than 3 months, and the frequency of PAF was significantly higher in patients with residual AVB.

This study provides new information indicating that 'lateral rotation' and the associated aortic root rotation angle may be involved in first-degree AVB following mitral valve surgery. Aortic root rotation is now recognized as a variation in cardiac anatomy [10–15]. In the context of aortic root surgery, potential anatomical changes around the aortic root have been discussed, with associated complications including intraoperative right atrial injury and tricuspid valve injury [11, 13]. Although 'lateral rotation' has been suggested to change the distance between the membranous septum and mitral annulus, potentially indicating a change in the location of the conduction system [10, 14], few reports have examined a relationship to atrioventricular conduction disorders. We found that diagnosing 'lateral rotation' using 3D-TEE might be associated with postoperative conduction disorders [17]. However, a major issue was the subjective nature of the echocardiographic diagnosis. To address this, we performed an objective evaluation using cardiac CT simultaneously and demonstrated 3D-TEE's diagnostic validity. This study first reported that the occurrence of first-degree AVB following mitral valve surgery can be objectively predicted by the aortic root rotation angle calculated from preoperative CT. When either modality identifies a large aortic root rotation angle ('lateral rotation'), the potential for first-degree AVB after mitral valve surgery should be considered.

In this study, all atrioventricular conduction disorders observed after mitral valve surgery were first-degree AVB, with no instances of severe AVB requiring permanent pacemaker implantation. Generally, almost all cases of AVB that occur after cardiac surgery are transient; however, those that persist beyond 6–8 weeks postoperatively are considered irreversible [18]. This study revealed that no patient with residual first-degree AVB 3 months postoperatively showed recovery to normal ECGs, suggesting that the condition was irreversible. The Framingham study identified first-degree AVB as an independent risk factor for atrial fibrillation, heart failure, permanent pacemaker implantation and mortality [19]. First-degree AVB occurring after cardiac surgery has been reported as a risk factor for pacemaker implantation [20, 21]. However, no specific reports address its impact, particularly after mitral valve surgery. The study found that patients with first-degree AVB persisting beyond 3 months had a higher frequency of PAF, suggesting first-degree AVB after mitral valve surgery may be a risk factor. Given the small number of events and lack of long-term follow-up data, further analysis is needed.

The question at hand is the identification of measures to prevent postoperative first-degree AVB in patients with 'lateral rotation' undergoing mitral valve surgery. It is paramount to ensure optimal mitral valve surgery in all cases, even in patients with anatomical variations. Risk analysis suggested that the use of full prosthetic rings, compared to partial rings, may be associated with an increased risk of developing first-degree AVB. Therefore, in patients diagnosed with high-risk anatomy, using a partial ring for annuloplasty may reduce the incidence of postoperative first-degree AVB, and it may also be important to avoid placing a deep suture around the medial trigone of the mitral annulus. Additionally, recent reports suggested that intraoperative conduction mapping using fibre-optic confocal microscopy and electrophysiological mapping may help prevent conduction disorders during cardiac surgery [22, 23]. Considering that first-degree AVB following mitral valve surgery is a risk factor for the occurrence of PAF, left atrial appendage resection or closure, along with postoperative anticoagulants for stroke prevention, may become effective, even in patients maintaining sinus rhythm with the large aortic root rotation angle. Attention should focus on the occurrence of first-degree AVB, and long-term follow-up should be considered with the potential development of PAF. In this study, postoperative 3D-TEE and cardiac CT could not be performed to assess changes in the aortic root rotation angle after mitral prosthesis or ring implantation. Further investigations may still identify preventive methods by evaluating postoperative changes in aortic root anatomy using cardiac CT and 3D-TEE.

Limitations

This study has a few limitations. First, this was a single-centre, retrospective study with a small sample size. In this study, 'medial rotation' was not observed because preoperative cardiac CT was not performed. Therefore, analysis of 'medial rotation' was not possible. Second, a lack of long-term follow-up data exists. Postoperative 3D-TEE and cardiac CT were not conducted to assess the change of aortic root rotation angle after mitral prosthesis or ring implantation. Further investigation may still reveal preventive measures by evaluating cardiac CT and 3D-TEE for postoperative changes in aortic root anatomy. Third, the number of patients who underwent both 'lateral rotation' and postoperative AVB was limited, resulting in multivariable analysis not being possible due to the small number of events. Future multicentre prospective observational studies are needed to explore the anatomical implications of aortic root rotation and postoperative AVB after mitral valve surgery. Nevertheless, a new diagnostic approach using cardiac CT validates a large aortic root rotation angle as a risk factor for AVB and its association with PAF, providing new insights into local anatomy.

CONCLUSION

The diagnosis of 'lateral rotation' in aortic root was clearly detectable using 3D-TEE, and its consistency with the aortic root rotation angle measured using cardiac CT confirmed the validity of this diagnostic approach. In cases of 'lateral rotation' with a large aortic root rotation angle, it may be important to avoid placing a deep suture around the medial trigone of the mitral annulus, and the risk of first-degree AVB increases following mitral valve surgery, necessitating long-term careful monitoring for cardiac events, especially PAF.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *ICVTS* online.

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CONFLICT OF INTEREST

None declared.

DATA AVAILABILITY

The authors declare that all data are available within the article.

ETHICS APPROVAL

Osaka University Hospital Clinical Research Ethics Committee approved this study and publication of data (approval number: 23121(T6), approval date: 1 August 2023).

Author contributions

Kazuma Handa: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing—original draft; Writing—review & editing. **Masashi Kawamura:** Conceptualization; Data curation; Investigation; Methodology; Supervision; Validation; Writing—original draft; Writing—review & editing. **Daisuke Yoshioka:** Supervision. **Shunsuke Saito:** Supervision. **Takuji Kawamura:** Supervision. **Ai Kawamura:** Supervision. **Yusuke Misumi:** Supervision. **Sho Komukai:** Formal analysis; Supervision; Validation. **Tetsuhisa Kitamura:** Formal analysis; Supervision; Validation. **Shigeru Miyagawa:** Supervision

Reviewer information

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