Predictor of Atrial Fibrillation Recurrence in Patients who Underwent a Tricuspid Valve Operation with Modified Cox Maze procedure

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Research

Keywords: tricuspid valve operation, maze, right atrium diameter, atrial fibrillation, structural heart disease

Posted Date: May 18th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-533155/v1

Version of Record: A version of this preprint was published at Echocardiography on February 14th, 2022. See the published version at https://doi.org/10.1111/echo.15315.

Abstract

Background Recurrence of any atrial arrhythmia after surgical ablation is known as a negative predictor of cardiovascular events and total mortality. However, there have been no focused studies for atrial fibrillation (AF) recurrence prediction in patients with significant tricuspid regurgitation (TR), and the risk-benefit estimation of surgical ablation in tricuspid valve (TV) surgery is not fully established.

Objectives In this study, we analyzed predictors of AF recurrence, safety, and efficacy of the modified Cox maze (CM) procedure in patients with AF undergoing TV operation.

Method We screened 421 patients who underwent a TV operation between 1994 and 2017. After excluding patients who did not undergo a maze operation, 158 patients were enrolled. Enrolled patients were divided by recurrence of AF.

We analyzed the difference between the AF recurrence group and no AF recurrence group, and AF recurrence factors in terms of clinical risk factors and echocardiographic risk factors. The hazard ratio (HR) and 95% confidence intervals (CIs) were presented using a Cox proportional hazard model.

ResultS Among 158 patients, AF recurred in 65 patients within 10 years. For AF prediction, age was most the important clinical factor and right atrium (RA) diameter was the most important echocardiographic parameters. In patients with a larger RA diameter over 49.2mm, the prevalence of AF recurrence was higher (HR 4.322, 95% CI [2.185-8.549], log rank p value < 0.001).

In clinical outcome, there was no significant difference between the AF recurrence group and the no recurrence group in terms of death, TR recurrence, heart failure and stroke. However, the risk of permanent pacemaker (PPM) insertion was higher in the AF recurrence group (HR 4.706, 95% CI [0.975-22.708], log rank p value 0.034) compared to the no recurrence group.

Conclusion Age and RA enlargement are key predictors of AF recurrence after TV operation with the CM procedure in patients with significant TR.

Introduction

Ablation of atrial fibrillation (AF) can reduce the risk of cardiovascular events compared to medical treatment, and recurrence of any atrial arrhythmia after ablation can be a predictor of cardiovascular events and total mortality [1]. The benefits of surgical ablation in structural heart disease (SHD are well recognized[2], and more than half of the patients with AF undergoing open-heart surgery have concomitant AF surgery these days[3]. Despite ablation, the risk of AF recurrence still remains, and AF recurrence can have negative effects on survival, heart failure exacerbation, and stroke risk [4].

AF recurrence risk estimation after ablation is not fully established yet. In catheter ablation, investigation of AF recurrence prediction is active due to high numbers of interventions and anticoagulation issues.

However, predictors of AF recurrence after surgical ablation are not as established as those of catheter ablation, and analysis of AF recurrence is usually conducted in patients who undergo general cardiac surgery or mitral valve surgery [5,6]. In particular, there is no concerted study for patients with significant tricuspid valve (TV) disease.

The Maze operation is controversial in patients with significant tricuspid regurgitation (TR) resulting from SHD due to concern of that AF may recur regardless of whether or not the Maze operation is performed. There is no established risk benefit estimation for Maze operation in TV surgery. Therefore, in this study, we analyzed predictors of AF recurrence after a modified Cox Maze (CM) procedure in patients with AF who underwent a TR operation and attempted to identify clear cutoffs for the benefits and safety of the CM procedure in TV surgery.

Methods

Study subject and data collection.

We retrospectively investigated 421 patients who underwent a TV operation between 1994 and 2017 at Samsung Medical Center in Seoul, South Korea. We enrolled 158 patients who had significant TR with AF who underwent TV repair or replacement and CM procedure. Patients who did not have the CM procedure, did not have a follow-up ECG after three months post-op, or had inadequate echocardiographic measurements were not included. Patients were divided by recurrence of AF within 10 years after the TV operation with CM procedure (**Figure 1**).

The primary endpoint was AF recurrence. We analyzed the difference between the AF recurrence group vs. no recurrence groups, and analyzed the AF recurrence factor in terms of clinical and echocardiographic risk factors. Secondary end points were clinical outcomes in the two groups, which included death, TR recurrence, heart failure (HF) admission, permanent pacemaker (PPM) insertion and stroke events. The median clinical outcome follow-up duration was 7.9 years.

The medical records of the enrolled patients were carefully reviewed by research coordinators. Mortality data for patients who were lost to follow-up were confirmed by National Death Records. The study protocol was approved and the requirement for informed consent of the individual patients was waived by the Institutional Review Board of Samsung Medical Center. This study was conducted according to the principles of the Declaration of Helsinki. (IRB No. 2020-12-054)

Surgical technique.

Detailed techniques of the cryo-maze procedure were described in our previous report[7]. The cryo-maze procedure was performed with an N2O-based cryoprobe or an argon-based cryoprobe according to surgeons' preference.

Usually, five lesions were created, including pulmonary vein isolation, mitral isthmus, posterior part of left atrium extending to the left atrial appendage to box the lesion, cavo-tricuspid-isthmus, and superior vena cava to inferior vena cava line. Ablation time was 180 seconds. After completion of this procedure, additional cardiac procedures including valve surgery, CABG, or ASD closures were performed. The opening left atrial appendage was internally obliterated without an excision using a running 3-0 monofilament suture.

Definitions

AF recurrence was defined as restoration of AF rhythm at least one time in follow up electrocardiography (ECG) more than three months after the operation. Patients who never returned to sinus rhythm were counted in the AF recurrence group and recurrence day was set as zero.

Structural heart disease (SHD) in this study was defined as more than a moderate degree of valve disease, previous cardiac operation history, or congenital heart such as like atrial septal defects (ASD). Isolated TR without SHD indicates secondary TR caused by atrial fibrillation. Significant VHD indicates more than a moderate degree of valve disease.

Chronic kidney disease was defined as a glomerular filtration rate (GFR) <60 mL/min/1.73 m^2 over 3 months and a disease code in medical record. Coronary artery disease was defined as over 50% stenosis in at least one coronary artery on computed tomography (CT) angiography or coronary angiography. TR recurrence was defined as reappearance of more than a moderate degree of TR after restoration to a minimal or mild degree at early after surgery. Stroke was defined as a neurological deficit of abrupt onset caused by ischemia or hemorrhage within the brain.

Echocardiographic evaluation.

Two-dimensional echocardiography was performed using commercially available equipment (Vivid 7, GE Medical Systems, Milwaukee, WI; Acuson 512, Siemens Medical Solution, Mountain View, CA; or Sonos 5500, Philips Medical System, Andover, MA). End diastole was defined as the frame with the largest cavity area immediately before the onset of the QRS and end systole as the frame with the smallest cavity area. At rest, left ventricular end-diastolic dimension (LVEDD) and LV end-systolic dimension (LVESD) were obtained from parasternal views according to the American Society of Echocardiography (ASE) guidelines [8]. LV ejection fraction (EF) were calculated from two-dimensional recordings using the modified biplane Simpson's method. Relative wall thickness (RWT) and left ventricular mass (LVM) were calculated from linear dimensions using the ASE-recommended formula. Left atrial (LA) volume was assessed by the modified biplane area-length method and was indexed to body surface area. Early diastolic mitral inflow velocity (E) was measured using the pulsed wave Doppler method by placing the sample volume at the level of the mitral valve leaflet tips. Tissue Doppler-derived early diastolic mitral annular velocity (e') was measured from the septal corner of the mitral annulus in the apical four-chamber view. We calculated the E/e' ratio as an index of left ventricular filling pressure. LA diameter was measured in the apical 4 chamber view or parasternal long axis view at end systole phase and LA

diameter over 40mm was defined as LA enlargement (LAE). RA diameter was measure in a dedicated right heart view from an apical 4 chamber view that includes the entire RA and was not fore-shortened at the end ventricular systole phase from the inner edge to the inner edge at the mid-atrial level. Right ventricular (RV) diameter, Tricuspid annular plane systolic excursion (TAPSE), and TDI-derived tricuspid lateral annular systolic velocity (TV s') were also measured in a dedicated right heart view. A RA diameter over 45mm was defined as RA enlargement (RAE). Right ventricular systolic pressure (RVSP) was obtained by assumed RA pressure plus 4 * (maximal TR velocity)^2. RA pressure were assumed by Inferior vena cava (IVC) diameter and the presence of plethora. IVC diameter was measured at the junction of the hepatic vein approximately 3cm from the RA in a standard subcostal view at end expiration, perpendicular to the IVC long axis. Quantitative and qualitative measurements of TR severity were performed according to American Society of Echocardiography guidelines.

Statistical analysis.

Continuous variables are presented as mean ± standard deviation or median [interquartile range (IQR)]. Differences between the AF recurrence group and no AF recurrence group were evaluated using student t-test or Mann Whitney U test. Categorical variables were compared between groups using the Chi-square test or Fisher's exact test and are presented as numbers and relative frequencies (%).

Clinical factors were considered for old age (age over 60), Sex, DM, HTN, CKD, Stroke Hx, CAD, previous cardiac operation history, and TV operation method (TV repair or replacement). We also examined echo parameters including LVEF, LAVI, RAD, LVEDD, RVSP, E/e', TR grade, and ASD closure. The univariable and multivariable Cox proportional hazard model was applied to estimate the hazard ratio (HR) and 95% confidence interval (CI) for AF recurrence. The survival curves were extracted using the Kaplan-Meier method. Variance inflation factors (VIF) of clinical factors ranged from 1.055 to 1.374. The VIFs of echo parameters ranged from 1.069 to 1.725. For clinical factors and echo parameters, the final multivariable regression model was determined by backward variable selection method with criteria of p-value<0.05. The C index or concordance C was considered an overall measure of discrimination in survival analysis, and we tested whether there was a difference between two correlated overall C indices. Cut-off values were determined by the slope and intercept value of a generalized linear model.

All p-values were two-sided, and p-values <0.05 were considered statistically significant. Statistical analyses were performed using R Statistical Software (version 3.6.0; R Foundation for Statistical Computing, Vienna, Austria) and SPSS statistics 20 (SPSS Inc., Chicago, IL).

Results

PredictorS of AF recurrence.

Among 158 patients who underwent TVR or TV repair with CM procedure, 136 patients (86.1%) of them had SHD and the remainder (n=22) had isolated TR without SHD. 134 patients (84.8%) of them had a TR repair and the remaining 24 patients (15.2%) had a TV replacement. 11 (7.0%) patients had an ASD

closure and 8 (5.1%) patients had a concomitant CABG. 65 of 158 patients (41.1%) had recurrent AF within 10 years while 93 patients (58.9%) maintained sinus rhythm without evidence of AF recurrence on follow up ECG.

In baseline characteristics analysis, the AF recurrence group were older (age over 60) and had a larger RAD. There was no significant difference in sex, DM, HTN, CKD, stroke history, coronary artery disease, previous cardiac operation history, concomitant procedure, or surgical information between the AF recurrence group and the no recurrence group. With respect to echocardiographic parameters, there were no significant differences between the AF recurrence group and the no recurrence group except for RAD. LAD, LAVI, and LVEF were not significantly different between two groups. In addition, the proportion of patients with significant valve disease such as more than a moderate degree of mitral stenosis (MS), mitral regurgitation (MR), aortic stenosis (AS), aortic regurgitation (AR), and isolated TR were also not significant different between the two groups (**Table 1**).

In a multivariable Cox regression model among clinical factors (**Table 2-1**), old age was the only significant risk factor for AF recurrence. Among echocardiographic parameters, LAVI, RAD, and RVSP were important risk factors for AF recurrence in the multivariable model **(Table 2-2).** The C-index value for AF recurrence within 10 years of old age (defined as age over 60) was 57.9%. When we combined the prediction value of old age and echocardiographic parameters, which were both significant in multivariable Cox regression, only RAD had an additive value to the C index, at 67.7% (p value = 0.003, when compared to the C-index of old age alone, which was 57.9%). (**Figure 2**)

The AUC value of solitary RAD was 66.5%. The cut-off value for RAD was 49.2mm, and AF recurred more than 4 times in patients with RAD over 49.2mm (HR 4.322, 95% CI [2.185-8.549], p value < 0.001). (**Figure 3**) When comparing the AUC value of solitary echocardiographic parameters for AF recurrence prediction, RAD showed superior predictive value over LAVI. (p value = 0.036, **Supplemental Figure 1**)

Comparing right heart-related echocardiographic parameters between the AF recurrence group and the no AF recurrence group, only IVC diameter showed a significant difference. The IVC diameter was higher in the AF recurrence group, although the RV dysfunction incidence estimated by TAPSE and TV s' did not differ significantly. Differences of RV size and TV annulus size were also insignificant. (**Table 3**)

In subgroup analysis with left-sided valve disease, the group with more than a moderate degree of MS showed unique baseline characteristics and significance of hazard ratio for AF recurrence according to RAD diameter. (**Supplemental Table 1,2**). In the MS group, the baseline RA diameter was not significantly different between the two groups (no AF recurrence group 50.9 ± 7.3 mm vs. AF recurrence group 54.1 ± 6.0 mm, p value = 0.077). However, LAVI did show a significant difference (no AF recurrence group 103.8 ± 44.0 mm vs AF recurrence group 137.9 ± 66.6 mm, p value = 0.036) in this subgroup, although no other group showed a significant difference in LAVI between the AF recurrence and no recurrence groups. RA diameter was not predictor for AF recurrence (HR 1.052, 95% CI [0.998-1.109], p value < 0.061) in the MS group, even though all other subgroups showed significance in AF prediction according to RA diameter. In the MS group, LAVI seems more important than RA diameter.

In subgroup analysis of SHD (n=136,86.1%) and isolated TR (n=22,13.9%), although RAD could predict AF recurrence in SHD (HR 1.052, 95% CI [1.028-1.076], p value < 0.001), RAD did not correlate with AF recurrence in the isolated TR group (HR 1.009, 95% CI [0.959-1.062], p value < 0.724). The interaction p-value of RA diameter and the presence of isolated TR for AF recurrence was insignificant at 0.098. The RA diameter of the AF recurrence group (65.5±14.1mm) was numerically higher than that of the no recurrence group (60.8±8.8mm) in patients with isolated TR, but there was no significant difference (p value = 0.353).

Clinical outcome.

Long term, TR recurrence, HF admission, ischemic stroke, and hemorrhagic stroke showed no correlation with AF recurrence. Instead, the possibility of PPM insertion within the same period happened more frequently in the AF recurrence group. In patients who had recurrent AF within 10 years, 7 patients (15.1%) had a PPM insertion, while only 2 patients (3.5%) who maintained sinus rhythm needed PPM insertion. In the Cox proportional hazard model, the hazard ratio for PPM insertion in the AF recurrence group was 4.706 (95% CI [0.975-22.708], log rank p value = 0.034) (**Table 4**, **Figure 4**).

Discussion

In this study, we investigated predictors of AF recurrence and the safety and efficacy of a modified Cox maze procedure in patients with AF who underwent a TV operation. The major findings of this study were as follows: (1) RA enlargement is key predictor of AF recurrence after a TV operation with CM procedure in patients with significant TR; (2) AF recurred more than 4 times more commonly in patients with RAD over 49.2mm; and (3) risk of PPM insertion was higher in the AF recurrence group.

Predictors of AF recurrence

AF recurrence analysis based on echocardiographic parameters has been well-studied recently. Risk models like the APPLE score [9] and MB-LATER score [10] consist of clinical risk factors and echocardiographic parameters, and show superiority over the $CHADS^2$ and CHA^2DS^2-VASc scores. These new risk prediction models use LA diameter as a scoring factor. LA diameter, LAVI, and LA strain [11-14] are well known for AF recurrence prediction in both lone AF and AF in SHD. This is also in line with the fact that pulmonary vein isolation is the most recommend strategy in AF [15,16]. Beside LAVI, RA area [13], AF duration [13,17] and size of F wave [17] are known for predicting AF recurrence. In this study, suppression of AF recurrence after the CM procedure with TV surgery was up to baseline RAD and age. The relationship between RAD in AF occurrence was observed in mitral valve surgery[13], catheter ablation[18] and hypertrophic cardiomyopathy[19]. However, there are few studies that directly compare RAD with other echocardiographic parameters like LAD, LAVI or RVSP. In this study, LAVI had less discriminative value than RAD. 81% patients had left-sided valve disease and the average LAVI was 107ml/m^2, which is 3 times higher than the upper limit of normal. This suggests that there was no definite discriminative value in LAVI since LA dilatation had already progressed.

Safety and Efficacy of modified Cox Maze procedure in TR operation

The pathophysiology of AF is reentry and atrial ectopic activity. Ablation for arrhythmia targets rhythm control by isolation of focal atrial ectopic activity. Concomitant surgical ablation of AF is recommended with level of evidence grade I in open surgical ablation and level II evidence in closed surgical ablation [16]. However, the beneficial effect of the maze procedure in TV surgery has not been discussed. In this study, the success rate of the CM procedure in TV surgery was 58.9% (93/158) without mortality. The cut-off value of RAD for AF recurrence was 49.3mm and the PPM insertion rate was higher in the AF recurrence group. When deciding whether to perform a CM procedure in patients with more than a moderate degree of TR and AF, RAD could be an important factor for decision making based on this study's result.

Progression of TR is related to bi-atrial enlargement and tricuspid annulus dilatation [20-22]. In this study, most patients with moderate TR have RA enlargement (96.8%) and RAD was the most important echocardiographic parameter for predicting AF recurrence. LA enlargement was also present in 96.8% of patients. The difference in IVC tended to be associated with RAD. The AF recurrence group had a larger IVC diameter, which could be explained by assumption that elevated RA pressure due to TR jet flow contributes to RA enlargement and IVC dilatation [23] at the same time. RA enlargement made by a significant TR jet could lead to right atrial pathophysiological damage, and this change could contribute to AF recurrence after ablation.

Atrial enlargement is a feature in patients with SHD and in senescence. It is known that atrial myocardial structure relating to sinus node dysfunction (SND) is primarily in the right atrium [24]. This finding is in line with the fact that AF recurrence group, which has more RAD, eventually need more permanent pacemaker than the no AF recurrence group.

In the MS group with more than moderate TR, LAVI was still the most discriminative factor. LA enlargement and subsequent LA remodeling and fibrosis is major pathophysiology of AF in the MS group [25]. It seems that RA enlargement in the MS group is subsequent change after LA enlargement and tricuspid annulus deformation.

In subgroup analysis of isolated TR, RAD was not a statistically significant factor predicting AF recurrence. Considering that even LAVI ,which is a known predictor of AF recurrence in lone AF, was not significant indicator of AF recurrence (HR 1.000, 95% CI [0.983-1.018], p value < 0.969) in the isolated TR group, irrelevance of RAD could come from small number of patients with isolated TR (n=22, 13.9%) .

Limitations

The study has several limitations that need to be addressed. First, this is single center study, so center characteristics could be reflected here. However, a relatively long follow-up duration after surgery (median 7.9 years) is strength of this study. We need external validation moving forward. Second, RAD could be affected by volume status, but there was no measurable value that reflects volume status of patients in

our data. We should assume that all patients have euvolemic volume status before surgery. Third, because of the limitations of a retrospective study, we could not identify the value of the RA volume index (RAVI). Since RA size has fewer clinical implications than LA size, RAVI was not included in routine protocol. We could include RAVI measurements in a prospective study later. Fourth, there was a limitation in subgroup analysis in patients with isolated TR (n = 22) due to the relatively small number of patients. Although we could not reach valuable conclusions in the isolated TR subgroup, it is meaningful that AF recurrence factors are analyzed in end-stage structural heart disease accompanied by significant TR, and this differs from the common-sense view that LA size is most important among echocardiographic parameters in AF recurrence prediction.

Conclusion

RA enlargement is key predictor of AF recurrence after a modified Cox Maze procedure in patients with significant TR. We can use RA size in clinical risk prediction models to create a risk-benefit estimation of the CM procedure in patients with significant TR and AF.

Perspectives

Clinical COMPETENCY in patIENT care and medical knowlege: In patients with significant TR and AF, a CM procedure at the appropriate time determined by RA diameter could reduce AF recurrence.

TRANSLATIONAL OUTLOOK: Future prospective studies are warranted to determine the AF recurrence prediction power of RAVI measured at euvolemic status in patients with significant TR and AF after TV surgery and CM procedure.

Abbreviations

Atrial fibrillation = AF

Left atrium volume index = LAVI

Modified Cox maze = CM

Mitral valve stenosis = MS

Right atrium diameter = RAD

tricuspid valve = TV

Tricuspid valve regurgitation = TR

Declarations

Conflict of Interest Statement

None of the authors have any conflicts of interest to declare.

Acknowledgments and Funding Sources

None

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Table

Table 1 Baseline Clinical Characteristics Between No AF Recurrence Group and AF Recurrence Group

Variable	No AF recurrence (n = 93)	AF recurrence (n = 65)	p value
Demographics			
Age over 60	39 (41.9%)	38 (58.5%)	**0.041**
Sex (female)	61 (65.6%)	40 (61.5%)	0.602
Cardiovascular risk factors			
DM	12 (12.9%)	8 (12.3%)	0.912
HTN	20 (21.5%)	14 (21.5%)	0.996
CKD	6 (6.5%)	1 (1.5%)	0.241
Stroke Hx.	9 (9.7%)	8 (12.3%)	0.600
CAD	2 (2.2%)	3 (4.6%)	0.403
Previous cardiac op	8 (8.6%)	5 (7.7%)	0.838
Echocardiographic parameters			
LVEF (%)	55.8 ±9.8	56.6 ±8.2	0.759
LAD (mm)	57.3 ± 9.8	59.1 ± 10.7	0.266
LAVI (mL/m^2)	98.2 ± 47.9	120.9 ± 88.7	0.316
LAE	92 (98.9%)	60 (92.3%)	0.082
RAD (mm)	51.7 ± 8.6	58.6 ± 11.5	**<0.001**
RAE	89 (95.7%)	64 (98.5%)	0.649
LVEDD (mm)	52.1 ± 9.0	51.9 ± 9.6	0.843
LVESD (mm)	34.6 ± 7.3	34.9 ± 8.5	0.822
LVMI (g/m^2)	109.1 ± 42.0	114.6 ± 48.9	0.755
RVSP (mmHg)	47.8 ± 17.5	52.3 ± 18.4	0.119
E (m/sec)	1.64 ± 0.55	1.53 ± 0.61	0.244
e' (m/sec)	0.087 ± 0.082	0.084 ± 0.027	0.779
E/e'	22.9 ± 12.0	20.6 ± 14.9	0.089
DT (msec)	438.0 ± 277.4	440.0 ± 336.5	0.708
Significant MS	37 (39.8%)	24 (36.9%)	0.716
Significant MR	44 (47.3%)	32 (49.2%)	0.812
Significant AS	11 (11.8%)	5 (7.7%)	0.396

Significant AR	17 (18.3%)	10 (15.4%)	0.634
Severe TR	57 (61.3%)	48 (73.8%)	0.168
Isolated TR	11 (11.8%)	11 (16.9%)	0.363
Concomitant procedure			
ASD closure	4 (4.3%)	7 (10.8%)	0.202
CABG	2 (2.2%)	6 (9.2%)	0.065
AVR	19 (20.4%)	13 (20.0%)	0.947
MVR	55 (59.1%)	45 (69.2%)	0.195
DVR	18 (19.4%)	12 (18.5%)	0.888
TVR	14 (15.1%)	10 (15.4%)	0.955
Surgical information			
EuroScore	5.2 ± 2.1	5.5 ± 2.1	0.278
pump time	149.0 [122.0-189.5]	154.0 [120.0-208.0]	0.458
ACC time	115.0 [97.0-152.0]	117.0 [93.5-155.5]	0.690

Data are presented as mean ± standard deviation or n (%) except pump time and ACC time, pump time and ACC time are presented as median [25 percentile – 75 percentiles].

Statistical significance was defined as $p<0.05$ by student t-test or Mann Whitney U test (continuous variables) or the Chi-square test or fisher's exact test (categorical variables). The values in bold indicate statistical significance ($p<0.05$).

ACC = aortic cross clamping; AR = aortic regurgitation; AS = aortic stenosis; ASD = atrial septal defect; AVR = aortic valve replacement; CABG = coronary artery bypass graft surgery; CAD = coronary artery disease; CKD = chronic kidney disease; DM = diabetes mellitus; DT = deceleration time; DVR(AVR and MVR) = double valve replacement; E = early diastolic mitral inflow velocity; e' = early diastolic mitral annular tissue velocity; HTN = hypertension; LAD = left atrium diameter; LAE = left atrium enlargement; LAVI = left atrium volume index; LVEDD = left ventricular end diastolic diameter; LVEF = left ventricular ejection fraction; LVESD = left ventricular end systolic diameter; LVMI = left ventricular mass index; RAE = right atrium enlargement; RAD = right atrium diameter; RVSP = right ventricular systolic pressure; MR = mitral regurgitation; MS = mitral stenosis; MVR = mitral valve replacement; TR = tricuspid regurgitation; TV = tricuspid valve; TVR = tricuspid valve replacement.

Table 2-1 Clinical Risk Factor for AF Recurrence

Variable	Univariable Analysis			Multivariable Analysis		
	HR	95% CI	p value	HR	95% CI	p value
Age over 60	2.299	1.380-3.828	0.001	2.299	1.380-3.828	0.001
Male Sex	0.811	0.491-1.339	0.412			
DM	1.145	0.545-2.404	0.721			
HTN	1.241	0.682-2.258	0.480			
CKD	0.310	0.043-2.235	0.245			
Stroke Hx.	1.281	0.610-2.691	0.514			
CAD	2.239	0.696-7.203	0.176			
Previous cardiac op	1.014	0.407-2.526	0.976			
TV operation method	1.193	0.607-2.346	0.608			

CI = confidence interval; HR = hazard ratio; other abbreviations are listed in **Table 1**.

Table 2-2 Echocardiographic Risk Factor for AF Recurrence

Variable	Univariable Analysis			Multivariable Analysis		
	HR	95% CI	p value	HR	95% CI	p value
LVEF (%)	1.003	0.976-1.030	0.850			
LAVI (ml/m^2)	1.003	1.000-1.007	0.033	1.003	1.000-1.007	0.043
RAD (mm)	1.044	1.023-1.064	<0.001	1.063	1.035-1.091	<0.001
LVEDD (mm)	0.997	0.971-1.022	0.793			
RVSP (mmHg)	1.015	1.001-1.030	0.035	1.020	1.004-1.037	0.017
E/e'	0.992	0.968-1.017	0.532			
TR grade	1.537	0.883-2.674	0.129			
ASD	1.692	0.771-3.713	0.190			

CI = confidence interval; HR = hazard ratio; other abbreviations are listed in **Table 1**.

Table 3 Right Heart-related Echocardiographic Parameters Comparison Between No AF Recurrence Group and AF Recurrence Group

Variable	No AF recurrence (n = 93)	AF recurrence (n = 65)	p value
TAPSE (mm)	15.0 ± 3.6	16.7 ± 5.1	0.271
TV S' (m/s)	0.093 ± 0.023	0.090 ± 0.020	0.736
TV annulus (mm)	40.8 ± 7.3	42.4 ± 7.9	0.531
IVC diameter (mm)	24.5 ± 4.8	27.3 ± 5.8	**0.008**
RV basal diameter (mm)	47.5 ± 8.1	51.0 ± 10.1	0.106
RV mid diameter(mm)	40.1 ± 6.1	44.9 ± 10.4	0.115
RV dilatation	40 (43.0%)	37 (57.8%)	0.068
RV dysfunction	18 (19.4%)	11 (17.2%)	0.831

Data are presented as mean ± standard deviation or n (%).

IVC = inferior vena cava; RV = right ventricle; TAPSE = Tricuspid annular plane systolic excursion; other abbreviations are listed in **Table 1**.

Statistical significance was defined as p<0.05 by student t-test or Mann Whitney U test (continuous variables) or Chi-square test or fisher's exact test (categorical variables). The values in bold indicate statistical significance (p<0.05).

Table 4 Comparison of 10 Years Clinical Outcomes Between No AF Recurrence Group and AF Recurrence Group

	No AF recurrence (n = 93)	AF recurrence (n = 65)	Univariable Analysis			Log-rank
			HR	95% CI	p value	p value
All death	15 (26.7%)	13 (23.5%)	1.106	0.525-2.334	0.791	0.791
TR recurrence	9 (11.0%)	8 (14.6%)	1.277	0.492-3.313	0.615	0.614
Heart failure admission	6 (7.0%)	7 (12.3%)	1.635	0.549-4.870	0.377	0.373
PPM insertion	2 (3.5%)	7 (15.1%)	4.706	0.975-22.708	0.054	0.034
Ischemic stroke	0 (0.0%)	0 (0.0%)	0.607	0.054-6.791	0.686	0.683
Hemorrhage stroke	1 (1.6%)	3 (7.0%)	1.899	0.425-8.498	0.401	0.393

Values are n (%). Cumulative incidence of events was presented as Kaplan-Meier estimates.

AF = atrial fibrillation; CI = confidence interval; HR = hazard ratio; PPM = permanent pacemaker; TR = tricuspid regurgitation.

Figures

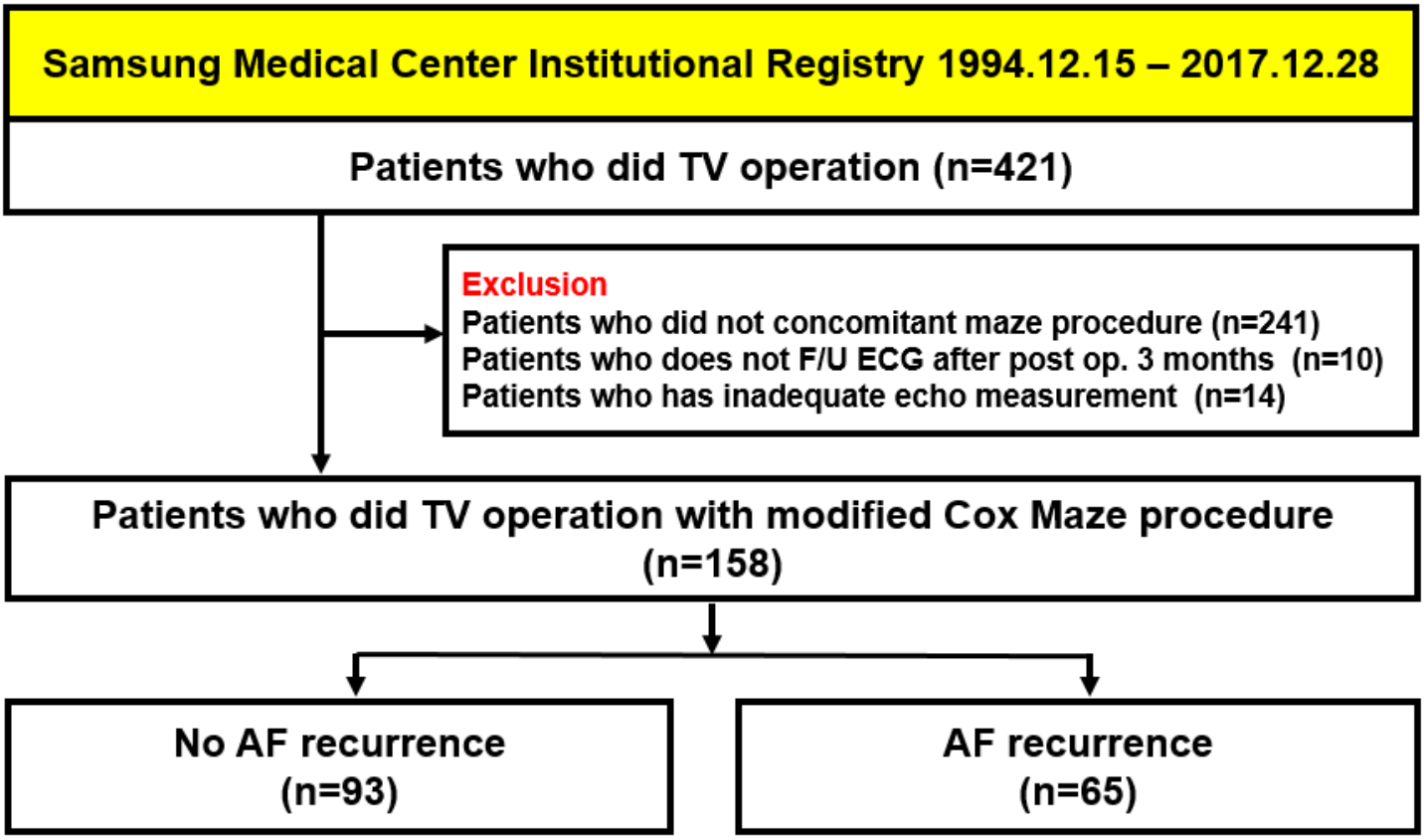

Figure 1

Study flow chart

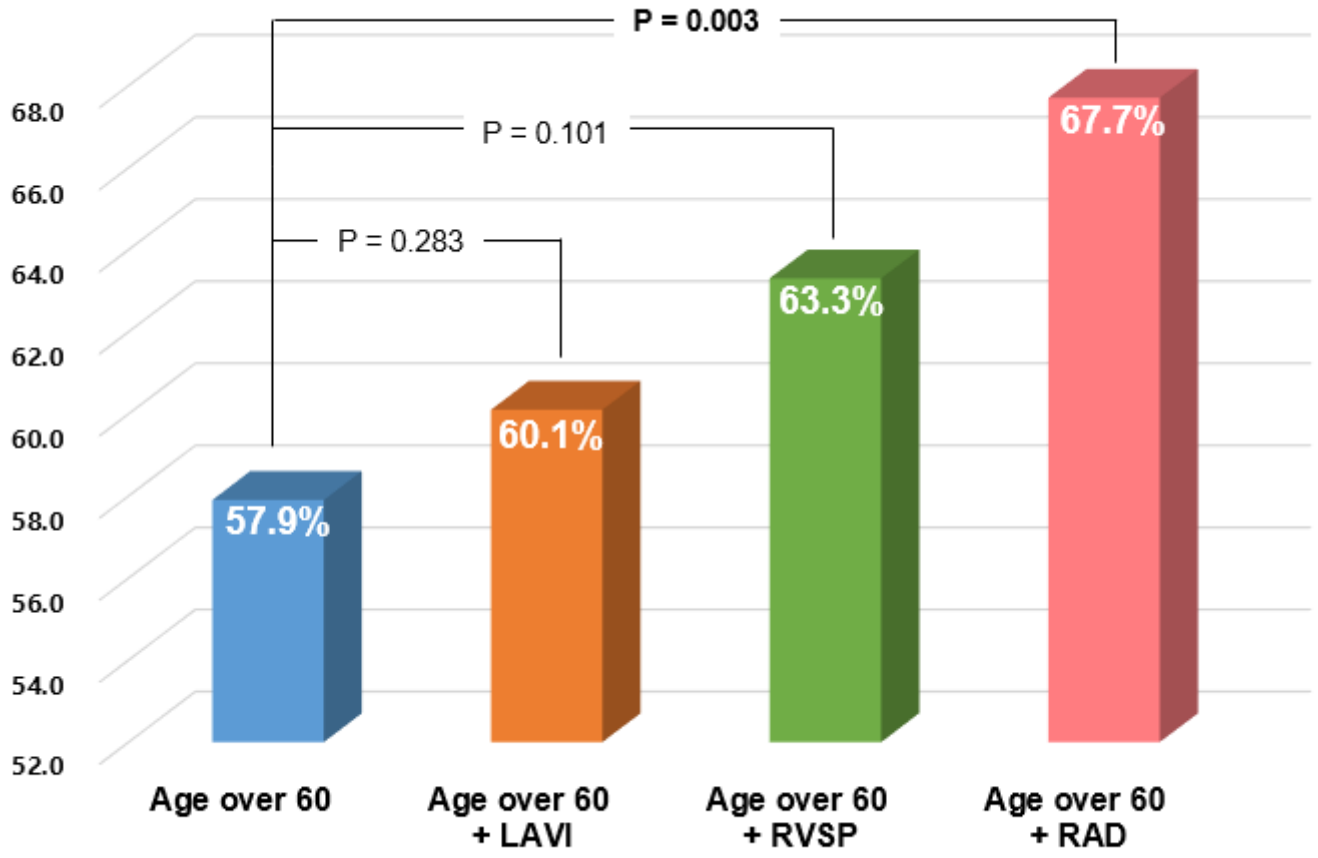

Figure 2

C index comparison for AF recurrence

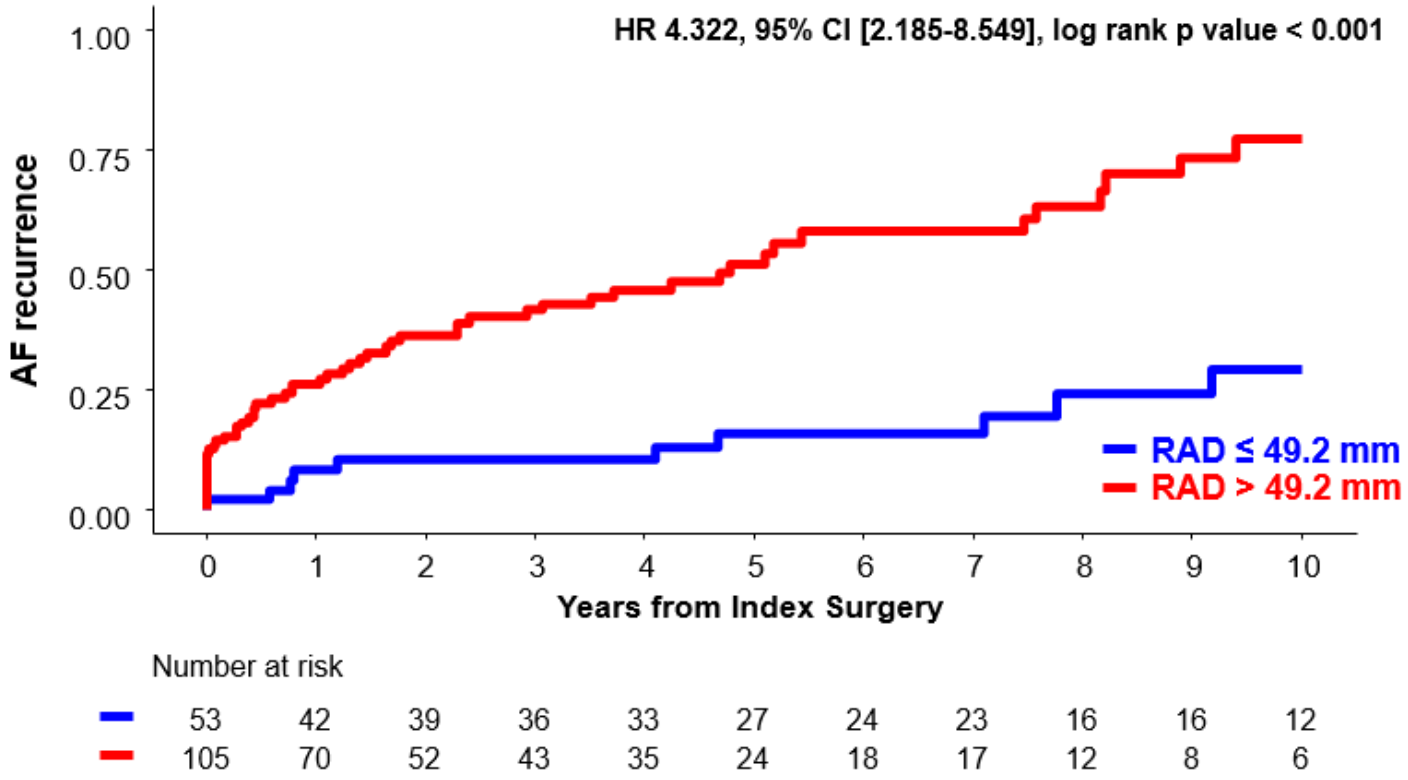

Figure 3

Comparison of AF recurrence according to RA enlargement

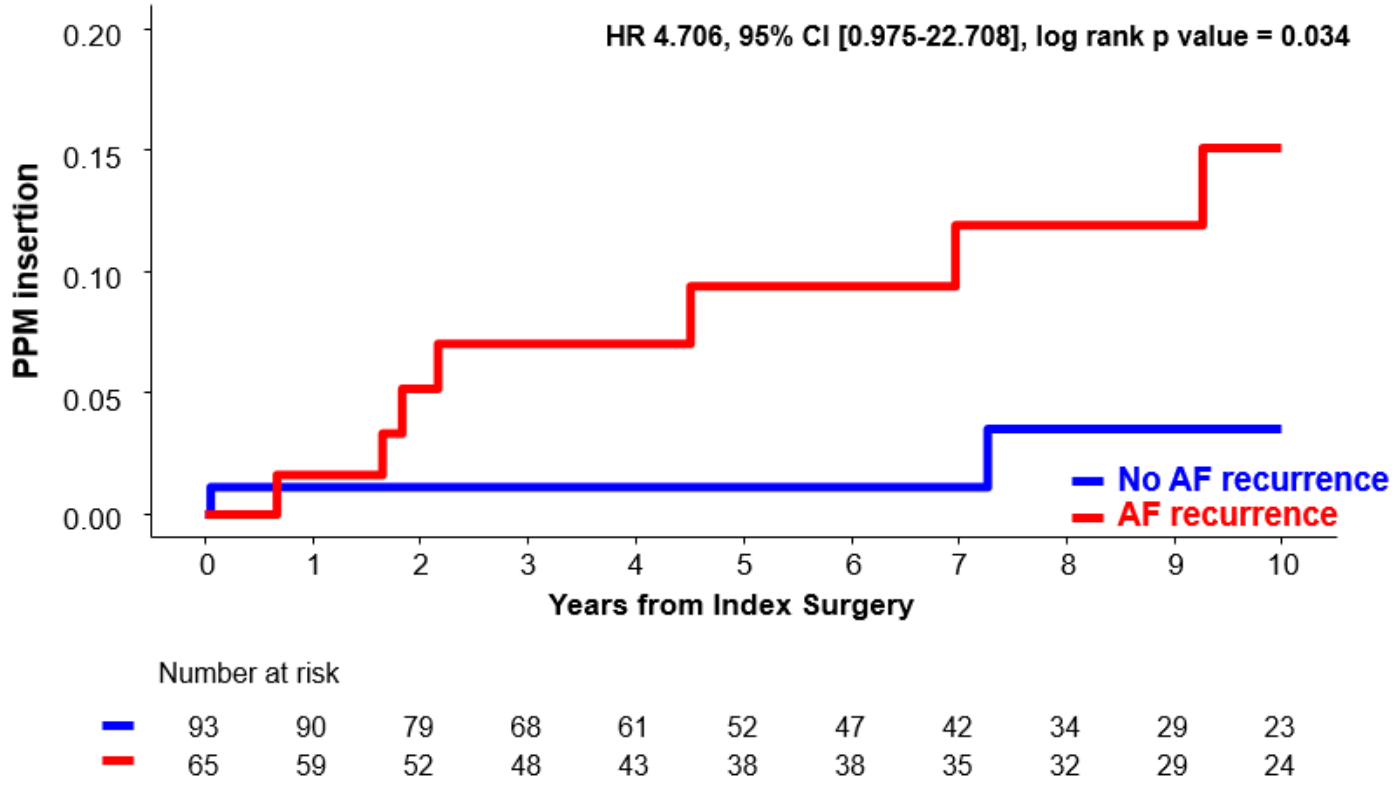

Figure 4

Incidence of PPM insertion according to AF recurrence

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementarytable.docx
- Sup.1.png