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Clinical Research

Impact of Interatrial Septal Reconstruction on Atrial Tachyarrhythmia after Surgical Resection of Myxoma

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Background: Complete surgical excision is the only curative treatment for primary cardiac tumors. For wide excision, interatrial septal reconstruction (ISR) is commonly performed. We hypothesized that ISR may increase the risk of postoperative atrial tachyarrhythmia (AT) after surgical resection of cardiac myxoma.

Methods: After excluding patients with a history of cardiac surgery and concomitant procedures unrelated to tumor resection and those with AT or permanent pacemakers, we finally enrolled 272 adult patients who underwent benign cardiac tumor surgery from 1995 to 2021 at our institution. They were divided into the ISR (n=184) and non-ISR (n=88) groups. The primary outcome was postoperative new-onset AT.

Results: The study cohort predominantly consisted of women (66.2%), with a mean age of 57.2±13.6 years. The incidence of postoperative new-onset AT was 15.4%. No 30-day mortality or recurrence was observed. The cardiopulmonary bypass time and aortic cross-clamping time were significantly longer in the ISR group than in the non-ISR group (p<0.001). The median duration of hospital stay of all patients was 6.0 days (interquartile range, 5.0–7.0 days), and no significant difference was observed between the 2 groups (p=0.329). ISR was not an independent predictor of new-onset AT (p=0.248). Male sex and hypertension were found to be independent predictors of new-onset AT.

Conclusion: ISR was not a significant predictor of postoperative new-onset AT. ISR might be a feasible and safe procedure for surgical resection of cardiac myxoma and should be considered if needed.

Keywords: Benign cardiac tumor, Interatrial septal reconstruction, Atrial tachyarrhythmia

Introduction

Primary cardiac tumors have been reported to be rare, with an incidence of approximately 0.2%, and 75% of these tumors are considered benign [1]. Myxoma is the most common benign cardiac neoplasm and can arise in any cavity of the heart [1,2]. Complete surgical excision is the only curative treatment for primary cardiac tumors, and the surgical outcomes are acceptable [1,2-4]. The interatrial septum is the most common site of origin of benign cardiac tumors, particularly myxoma [3]. If the interatrial septum is left in place, there is a possibility of recurrence even if the stalk is completely resected [4]. If the resected interatrial septum is closed directly, the tension will increase. For complete resection, wide excision and reconstruction of the interatrial septum have been widely adopted [4,5]. However, interatrial septal reconstruction (ISR) is somewhat challenging with a minimally invasive approach, including thoracoscopic and robotic surgery. Furthermore, ISR can increase both the surgical time, with a concomitant increase in suture lines and materials, and the risk of postoperative atrial tachyarrhythmia (AT) [6-8].

Several reports have demonstrated that the interatrial septum plays an important role in interatrial conduction, and it might activate interatrial reentry and stimulation of AT [9-12]. Quah et al. [9] demonstrated that the interatrial septum is one of the main pathways of biatrial electrical

propagation, and López-Candales et al. [10] reported that fibrosis or fatty infiltration of the interatrial septum might be associated with AT. Kharbanda et al. [11] demonstrated that conduction disorders at the interatrial septum might facilitate interatrial block, which could be related to the development of AT. Power et al. [12] reported that interatrial septal conduction block might be an independent risk factor for AT, major cardiac and cerebrovascular events such as stroke, and mortality.

However, only a few studies have reported on the incidence of AT and other adverse outcomes according to whether ISR was performed for cardiac myxoma [13]. Hence, we reviewed our experience of surgery for cardiac myxoma.

Methods

Study patients

We analyzed 332 adult patients (≥18 years old) who underwent benign cardiac tumor surgery at Samsung Medical Center from 1995 to 2021. Patients with a history of cardiac surgery (n=8), those who underwent concomitant procedures unrelated to tumor resection (e.g., coronary artery bypass grafting, atrial septal defect repair, and Bentall operation) (n=32), those with AT (n=15), those with a permanent pacemaker (n=2), and those who underwent procedures including aortotomy (n=3) were excluded from this study. The final cohort of this study consisted of 272 patients (Fig. 1).

Data collection

The baseline characteristics of the patients, including echocardiography findings, operative data, and postoperative outcomes, were obtained from their medical records. A database from Statistics Korea was used to confirm the mortality data using a unique personal identification number for each patient. At our institution, preoperative transthoracic echocardiography is routinely performed. The final diagnosis was confirmed through a permanent biopsy of the resected tumor via cardiac surgery. In postoperative care, changes in the electrocardiogram were checked in real-time through telemonitoring until discharge. After hospital discharge, periodic surveillance of chest X-ray examinations, laboratory tests, electrocardiography, and echocardiography, was performed at the outpatient clinic.

This study was approved by the Institutional Review Board of Samsung Medical Center (Seoul, Korea), which waived the requirement for informed patient consent due to the retrospective nature of this study (IRB approval no., 2022-07-111).

Surgical technique

ISR was defined as patch repair of an interatrial septal defect using a bovine or autologous pericardial patch. Of the 272 patients included in this study, 184 underwent benign cardiac tumor resection with ISR, and these patients were defined as the ISR group. In 183 patients, surgery was performed using a median sternotomy approach, and the remaining 1 patient underwent video-assisted minimally invasive surgery via right anterior thoracotomy. Although we prefer median sternotomy for highly mobile or fragile tumors, the choice of the surgical approach was decided through discussion with the patient. The left and/or right atriotomy and septectomy were performed depending on the location of the tumor. ISR was favored when the mass formed a broad stalk in the interatrial septum. When the tumor was attached to the valve structure or the chamber

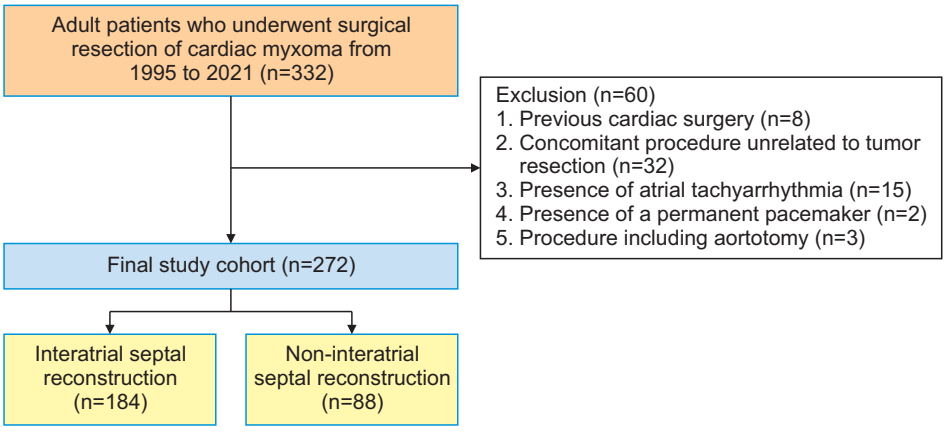

Fig. 1. Flow diagram of patients included in this study.

size increased because of the size of the tumor and there was an abnormality in the valve function, a concomitant valve procedure was performed. The interatrial septum was excised, including the main tumor, to achieve a clear resection margin. ISR was performed with patch closure via continuous monofilament polypropylene sutures. The interatrial septum was preserved when the tumor was not attached to it. In cases of a minimally invasive approach, including thoracoscopic or robotic surgery, the endocardium of the tumor origin was excised. If there was a defect, such as a small iatrogenic atrial septal defect, the endocardium of the tumor origin was directly closed, and these patients were classified as belonging to the non-ISR group.

Definition and study endpoints

Postoperative new-onset AT was defined as a complication that occurred after surgery and persisted for more than 12 hours during hospitalization or after hospital discharge. The primary outcome was the occurrence of postoperative new-onset AT. The secondary outcomes were early complications, such as 30-day mortality, stroke, and reoperation due to bleeding or pericardial effusion.

Statistical analysis

The baseline and clinical characteristics of the cohort are presented as means±standard deviations, medians with interquartile ranges (IQRs), or frequencies and proportions. The chi-square test and Fisher exact test were used to compare categorical variables between the ISR and non-ISR groups. The Wilcoxon rank-sum test was performed to compare continuous variables with skewed distributions. All tests were 2-tailed. To obtain hazard ratios (HRs) and 95% confidence intervals (CIs) to investigate the impact of ISR on the occurrence of postoperative new-onset AT, Cox proportional hazards regression modeling was used. The risk factors considered in the analyses included ISR, female sex, age, body mass index, comorbidities (hypertension, diabetes mellitus, chronic kidney disease, dyslipidemia, stroke, and history of percutaneous coronary intervention), echocardiographic parameters including left ventricular ejection fraction, surgical details (cardiopulmonary bypass time, aortic cross-clamping time, and concomitant valve surgery), pathology, tumor size, and tumor location. Variables with ISR and p-values of less than 0.1 in the univariable analyses were entered into the multivariable analysis. A p-value of less than 0.05 was used to denote statistical significance. The statistical analysis was performed using IBM SPSS ver. 27.0 (IBM Corp., Armonk, NY, USA).

Results

Baseline characteristics and preoperative echocardiography findings

The baseline characteristics of the patients included in this study are presented in Table 1. The study cohort predominantly consisted of women (66.2%), with a mean age of 57.2±13.6 years. The most common comorbidities were hypertension (28.7%) and stroke (14.7%). On preoperative electrocardiography, right bundle branch block was observed in the ISR group only; however, the difference between the ISR and non-ISR groups was not statistically significant (p=0.119). On preoperative echocardiography, no significant differences in parameters such as the left ventricular ejection fraction, left ventricular dimension (systolic and diastolic), and left atrial diameter were observed between the ISR and non-ISR groups.

Operative data and postoperative outcomes

The operative data and postoperative outcomes are summarized in Table 2. The minimally invasive approach was performed in 16 patients (5.9%). The robotic approach was applied in 11 patients, and 5 patients underwent thoracoscopic surgery. The cardiopulmonary bypass time and aortic cross-clamping time were significantly longer in the ISR group than in the non-ISR group (p<0.001). Concomitant valve surgery was more frequently performed in the non-ISR group than in the ISR group (p=0.002). Mitral annuloplasty and tricuspid annuloplasty were the most commonly performed concomitant valve procedures. The tumor size had no significant difference between the 2 groups (p=0.256). The most common site for benign cardiac tumors was the left atrium (92.3%).

The incidence of postoperative new-onset AT was 15.4% (n=42) and was highest on postoperative days 2–3 (6 patients on postoperative day 2 and 11 patients on postoperative day 3). No significant difference in the incidence of postoperative new-onset AT was observed between the ISR and non-ISR groups (p=0.860). The frequency of postoperative new-onset AT is summarized in Fig. 2.

There was no 30-day mortality. One patient in the ISR group had postoperative new-onset stroke. The patient recovered without any neurological sequela at 3 months of follow-up. The median duration of hospital stay of all patients was 6.0 days (IQR, 5.0–7.0 days), and no significant

Table 1. Baseline characteristics of the entire cohort

Characteristic	Total (n=272)	ISR (n=184)	Non-ISR (n=88)	p-value
Female sex	180 (66.2)	122 (66.3)	58 (65.9)	0.949
Age (yr)	57.2±13.6	59.0±12.1	56.8±12.2	0.159
Body mass index (kg/m^2)	24.0±3.2	23.8±3.3	23.9±3.4	0.813
Past history				
Hypertension	78 (28.7)	53 (28.8)	25 (28.4)	0.946
Diabetes mellitus	37 (13.6)	24 (13.0)	13 (14.8)	0.697
Chronic kidney disease	2 (0.7)	1 (0.5)	1 (1.1)	0.592
Dyslipidemia	39 (14.3)	27 (14.7)	12 (13.6)	0.819
Stroke	40 (14.7)	28 (15.2)	12 (13.6)	0.731
Percutaneous coronary intervention	5 (1.8)	5 (2.7)	0	0.119
Abnormal electrocardiogram				
Sinus tachycardia	7 (2.6)	3 (1.6)	4 (4.5)	0.155
Sinus bradycardia	24 (8.8)	16 (8.7)	8 (9.1)	0.914
Atrioventricular block	8 (2.9)	4 (2.2)	4 (4.5)	0.279
Right bundle branch block	5 (1.8)	5 (2.7)	0	0.119
Left anterior fascicular block	2 (0.7)	1 (0.5)	1 (1.1)	0.592
Left ventricular ejection fraction (%)	64.0 (60.5–68.5)	64.5 (61.0–69.0)	64.0 (59.0–67.0)	0.303
Left ventricular dimension (systolic) (mm)	29.0 (26.9–31.0)	29.0 (26.7–31.0)	29.0 (26.0–31.8)	0.583
Left ventricular dimension (diastolic) (mm)	49.0 (46.0–52.0)	49.0 (46.0–52.0)	49.0 (45.0–51.5)	0.306
Left atrial diameter (mm)	39.0 (35.0–44.0)	39.2 (35.0–44.0)	39.2 (35.0–44.0)	0.664
Left atrial volume index (mL/m^2)	35.8 (29.0–48.0)	37.2 (29.6–48.8)	31.8 (27.4–47.5)	0.097
Average E/e′	10.3 (7.7–14.9)	11.4 (8.1–16.6)	9.7 (6.9–13.6)	0.077
TR velocity (maximum) (mm Hg)	29.1 (23.9–36.0)	28.2 (23.9–35.0)	26.2 (22.8–33.3)	0.126

Values are presented as number (%) for categorical variables and mean±standard deviation or median (interquartile range) for continuous variables. The Wilcoxon rank-sum test was performed for continuous variables with skewed distributions. The chi-square test and the Fisher exact test were used to compare categorical variables (ISR vs. non-ISR). Statistically significant differences were determined using 2-sided tests. A p-value of less than 0.05 indicated statistical significance.
ISR, interatrial septal reconstruction; TR, tricuspid regurgitation.

difference was observed between the ISR and non-ISR groups (p=0.329).

Predictors of postoperative new-onset atrial tachyarrhythmia

The baseline characteristics and early outcomes classified according to the presence of AT are shown in Supplementary Table 1. The proportion of women was significantly lower in the AT group than in the non-AT group (p=0.021). Patients in the AT group were significantly older than those in the non-AT group (p=0.005). The prevalence of hypertension was significantly higher in the AT group than in the non-AT group (p<0.001). Regarding early outcomes, postoperative pericardial effusion was significantly higher in the AT group than in the non-AT group (p=0.002).

The results of Cox proportional hazards regression modeling for univariable and multivariable analyses of postoperative new-onset AT are summarized in Table 3. After adjusting for ISR and variables with p-values of less than 0.1 in the univariable analyses, hypertension (HR, 3.496; 95% CI, 1.835–6.657) was found to be an independent predictor of postoperative new-onset AT. Furthermore, female sex (HR, 0.510; 95% CI, 0.275–0.944) was a significant predictor of a lower incidence of postoperative new-onset AT. ISR was not an independent predictor of postoperative new-onset AT (p=0.248; HR, 0.669; 95% CI, 0.339–1.322).

Discussion

The main findings of this study were as follows: (1) the incidence of postoperative new-onset AT was 15.4%, (2) ISR was not an independent predictor of postoperative new-onset AT, (3) male sex and hypertension were independent predictors of postoperative new-onset AT, and (4) although ISR increased the cardiopulmonary bypass and aortic cross-clamping time, the duration of postoperative hospitalization between the ISR and non-ISR was similar.

As mentioned above, several previous publications have reported the association between the interatrial septum and AT [9-12]. Although the interatrial septal conduction

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Table 2. Operative data and postoperative outcomes

Variable	Total (n=272)	ISR (n=184)	Non-ISR (n=88)	p-value
Surgical details				
Minimally invasive approach	16 (5.9)	1 (0.5)	15 (17.0)	<0.001
CPB time (min)	78.0 (62.3–98.0)	81.0 (68.3–100.0)	70.0 (50.3–94.8)	<0.001
ACC time (min)	54.0 (39.0–70.0)	60.5 (47.3–76.8)	40.5 (28.0–52.8)	<0.001
Concomitant valve surgery	27 (9.9)	11 (6.0)	16 (18.2)	0.002
Atriotomy				
Right atriotomy	131 (48.2)	83 (45.1)	48 (54.5)	0.155
Left atriotomy	29 (10.7)	8 (4.3)	21 (23.9)	<0.001
Right and left atriotomy	112 (41.2)	93 (50.5)	19 (21.6)	<0.001
Tumor size (cm)	3.5 (2.0–5.0)	3.7 (2.0–5.0)	3.1 (1.6–5.0)	0.256
Location				
Left atrium	250 (92.3)	172 (93.5)	78 (88.6)	0.233
Right atrium	17 (6.3)	10 (5.4)	7 (8.0)	0.594
Others	5 (1.8)	2 (1.1)	3 (3.4)	0.333
Early outcome				
Atrial tachyarrhythmia	42 (15.4)	29 (15.8)	13 (14.8)	0.860
Reoperation for bleeding	1 (0.4)	1 (0.5)	0	0.488
Pericardial effusion	5 (1.8)	4 (2.2)	1 (1.1)	0.673
Stroke	1 (0.4)	1 (0.5)	0	0.488
30-Day mortality	0	0	0	>0.999
Length of hospital stay (day)	6.0 (5.0–7.0)	6.0 (5.0–8.0)	6.0 (5.0–7.0)	0.329

Values are presented as number (%) for categorical variables and median (interquartile range) for continuous variables. The Wilcoxon rank-sum test was performed for continuous variables with skewed distributions. The chi-square test and the Fisher exact test were used to compare categorical variables (ISR vs. non-ISR). Statistically significant differences were determined using 2-sided tests. A p-value of less than 0.05 indicated statistical significance.
ISR, interatrial septal reconstruction; CPB, cardiopulmonary bypass; ACC, aortic cross-clamping.

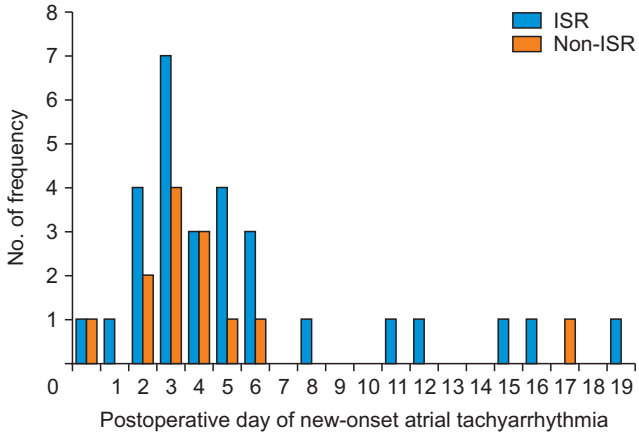

Fig. 2. The frequency of postoperative new-onset atrial tachyarrhythmia. ISR, interatrial septal reconstruction.

block could increase the risk of postoperative new-onset AT, we decided on the surgical method with complete resection of cardiac myxoma as the top priority. Debate continues regarding the ideal route of access to tumors in the left atrium [5,14]. At our institution, if the tumor is small and has a narrow stalk, a transseptal approach via right atriotomy was used to resect the tumor. This approach is performed with a simple incision, which allows for good exposure of the left atrium via the interatrial septum. Furthermore, it allows for easy access to the fossa ovalis, where most tumors are attached. It is also the preferred approach in patients with a heart located deep in the chest or small left atrium. Several studies have reported favorable long-term outcomes using the transseptal approach [14,15]. Meanwhile, the biatrial approach is used in cases where exposure is limited for complete tumor resection because of the very large size of the tumor attached to the interatrial septum. Furthermore, in tumors with a broad base, the biatrial approach rather than the transseptal approach enables the complete resection of the tumor with visualization of the correct resection margin. Multiple reports have advocated this approach and demonstrated a low recurrence rate [4,5].

Postoperative AT is a frequent complication after cardiac surgery [7,8]. The production of pro-inflammatory molecules due to the prolonged use of cardiopulmonary bypass, electrolyte imbalance, and local inflammation caused by pericardial disruption contributes to the development of postoperative AT, although the precise mechanism of postoperative AT has not yet been established [16-18]. The inci-

Table 3. Predictors of postoperative new-onset atrial tachyarrhythmia

Variable	Univariable	Multivariable	
	p-value	p-value	HR (95% CI)
Interatrial septum reconstruction	0.375	0.248	0.669 (0.339–1.322)
Female	0.015	0.032	0.510 (0.275–0.944)
Age	0.024	0.172	1.023 (0.990–1.058)
Hypertension	<0.001	<0.001	3.496 (1.835–6.657)
Diabetes mellitus	0.237		
Chronic kidney disease	0.758		
Stroke	0.033	0.070	2.018 (0.945–4.311)
Percutaneous coronary intervention	0.649		
Left ventricular ejection fraction	0.862		
Left ventricular dimension (systolic)	0.334		
Left ventricular dimension (diastolic)	0.208		
Left atrial diameter	0.167		
Left atrial volume index	0.870		
Average E/e'	0.666		
TR velocity (maximum)	0.479		
CPB time	0.863		
ACC time	0.754		
Concomitant valve surgery	0.140		
Tumor size	0.529		
Location			
Left atrium	0.249		
Right atrium	0.343		

HRs and 95% CIs were calculated using Cox proportional hazards regression modeling. Variables with interatrial septum reconstruction and p-values of less than 0.1 in the univariable analyses were entered into the multivariable analysis.
HR, hazard ratio; CI, confidence interval; TR, tricuspid regurgitation; CPB, cardiopulmonary bypass; ACC, aortic cross-clamping.

dence of postoperative AT after cardiac surgery, reaching up to 50%, depends on the type of surgery and patients' baseline characteristics [7,19]. However, previous studies have mainly focused on AT after cardiac surgery, including coronary artery bypass grafting [7,8].

In our cohort, which excluded patients with AT or permanent pacemakers and solely focused on postoperative new-onset AT, the incidence of postoperative new-onset AT was 15.4% and was highest on postoperative days 2–3. This result was consistent with those reported in previous studies [20,21]. Although this early onset of postoperative AT was once considered benign and transient, several studies have reported the relationship between this event and increased morbidity, such as postoperative stroke and respiratory tract infection, and long-term mortality [22-25]. In our study, patients with postoperative new-onset AT tended to experience high rates of other complications, such as postoperative pericardial effusion. A possible explanation may be that mediastinal blood or effusion within the pericardial space might contribute to a highly proinflammatory and prooxidant status that could trigger AT [26].

Several studies have examined the risk factors for the occurrence of AT after cardiac surgery [22,27,28]. Several studies reported that hypertension was an independent predictor of postoperative AT [29,30], and our results were consistent with those of previous studies that examined other types of cardiac surgery. Studies have reported inconsistent results have been reported regarding the influence of sex on the occurrence of postoperative AT [20,21]. However, these investigations also mainly focused on AT after nonspecific cardiac surgery.

This study has several limitations. First, this was a retrospective, single-center study. Therefore, a risk of selection bias might be present. Second, we did not record the heart rhythm continuously in general wards unless the patient was symptomatic or arrhythmia occurred in the intensive care unit. For this reason, we might have missed intermittent AT events and underestimated the incidence of postoperative new-onset AT. Third, it was difficult for each patient to have a constant range of ISR.

In conclusion, ISR was not a significant predictor of postoperative new-onset AT. ISR might be a feasible and safe procedure for surgical resection of cardiac myxoma and should be considered if needed.

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Conflict of interest

No potential conflict of interest relevant to this article was reported.

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Supplementary materials

Supplementary materials can be found via https://doi.org/10.5090/jcs.22.112. **Supplementary Table 1**. Baseline characteristics and early outcomes classified according to the presence of postoperative atrial tachyarrhythmia.

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