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Clinical Research

Surgical Outcomes of Cardiac Myxoma Resection Through Right Mini-Thoracotomy

Changwon Shin, M.D., Min Ho Ju, M.D., Chee-Hoon Lee, M.D., Mi Hee Lim, M.D., Ph.D., Hyung Gon Je, M.D., Ph.D.

Department of Thoracic and Cardiovascular Surgery, Pusan National University Yangsan Hospital, Medical Research Institute, Pusan National University School of Medicine, Yangsan, Korea

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Corresponding author
Hyung Gon Je
Tel 82-55-360-2127
Fax 82-55-360-2157
E-mail jehg7332@gmail.com
ORCID
https://orcid.org/0000-0003-4713-2898

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Background: With recent advances in cardiac surgery through minimal access, mini-thoracotomy has emerged as an excellent alternative for cardiac myxoma resection. This study analyzed the surgical results of this approach, focusing on postoperative cerebral embolism and tumor recurrence.
Methods: We retrospectively reviewed 64 patients (mean age, 56.0±12.1 years; 40 women) who underwent myxoma resection through mini-thoracotomy from October 2008 to July 2020. We conducted femoral cannulation and antegrade cardioplegic arrest in all patients. Patient characteristics and perioperative data, including brain diffusion-weighted magnetic resonance imaging (DWI) findings, were collected. Medium-term echocardiographic follow-up was performed.
Results: Thirteen patients (20.3%) had a history of preoperative stroke, and 7 (11.7%) had dyspnea with New York Heart Association functional class III or IV. Sixty-one cases (95.3%) had myxomas in the left atrium. The mean cardiopulmonary bypass and cardiac ischemic times were 69.0±28.6 and 34.1±15.0 minutes, respectively. Sternotomy conversion was not performed in any case, and 50 patients (78.1%) were extubated in the operating room. No early mortality or postoperative clinical stroke occurred. Postoperative DWI was performed in 32 (53%) patients, and 7 (22%) showed silent cerebral embolisms. One patient underwent reoperation for tumor recurrence during the study period; in that patient, a genetic study confirmed the Carney complex.
Conclusion: Mini-thoracotomy for cardiac myxoma resection showed acceptable clinical and neurological outcomes. In the medium-term echocardiographic follow-up, reliable resection was proven, with few recurrences. This approach is a promising alternative for cardiac myxoma resection.

Keywords: Minimally invasive surgical procedures, Thoracotomy, Myxoma, Embolism, Carney complex

Introduction

Cardiac myxoma is the most common type of benign heart tumor in adults [1-3], and the conventional surgical approach is median sternotomy. However, this approach has unsatisfactory cosmetic outcomes, risk of sternal infection, and other possible complications [4,5]. With recent advances in surgical techniques, minimally invasive cardiac surgery (MICS) has emerged as an alternative to conventional methods [6-9]. Nevertheless, there are still several concerns regarding this approach [10]. The first is cerebral embolism during MICS due to tumor fragmentation and retrograde perfusion following femoral cannulation. Second, tumor recurrence is associated with incomplete resection due to the limited exposure of the tumor. There are limited data on the incidence of cerebral embolism and recurrence following myxoma resection with the mini-thoracotomy approach. In this study, we analyzed the surgical results of this approach, focusing on postoperative cerebral embolism diagnosed using brain diffusion-weighted magnetic resonance imaging (DWI) and medium-term follow-up of tumor recurrence.

Methods

Between October 2008 and September 2020, 72 benign cardiac tumor resections were performed at Pusan National University Yangsan Hospital. After excluding non-myxomatous benign tumors in 4 cases, 68 operations for myxoma were included. Four patients who underwent surgery using the median sternotomy approach were excluded to investigate the surgical outcomes of myxoma resection through mini-thoracotomy. Median sternotomy was combined with aortic valve replacement (n=2) or emergent surgery with concomitant mitral or tricuspid valve repair (n=2). Four surgeons operated during the study period, and 3 of them routinely checked DWI to detect acute cerebral embolism preoperatively and postoperatively. Postoperative DWI was performed regardless of neurological symptoms. Acute cerebral embolism within 2 weeks was confirmed as a lesion with high signal intensity on brain DWI. We only counted newly developed embolic lesions based on comparisons of magnetic resonance imaging (MRI) before and after surgery. Whenever preoperative embolic infarction was detected on brain MRI, a neurology consultation was performed. With a multidisciplinary discussion including cardiology and neurology, myxoma resection was conducted without delay even in cases of preoperative cerebral embolism. We considered the possibility of hemorrhagic transformation to be very low because most of the cerebral embolisms were small and scattered, and the possibility of mycotic aneurysm formation, as in infective endocarditis, was deemed to be very low in myxoma cases. After confirming the absence of hemorrhagic transformation on brain MRI, myxoma resection surgery was performed as soon as possible to minimize further embolization. Postoperative transthoracic echocardiography (TTE) was performed in all patients who underwent mini-thoracotomy before discharge. The study was approved by the institutional review board of Pusan National University Yangsan Hospital, and the requirement for individual consent was waived (IRB approval no., 05-2022-171).

Continuous variables with normal and non-normal distributions were expressed as mean±standard deviation and median and interquartile range, respectively.

Surgical procedure

Under general anesthesia, a single-lumen endotracheal tube with a bronchial blocker or a double-lumen endotracheal tube was inserted for single-lung ventilation. The patients were placed on their left side in a supine position at a 30° angle, with the right arm slightly flexed to expose the mid-axillary line. After confirming the appropriateness of the femoral vessels using bedside sonography, right mini-thoracotomy was performed along the fourth intercostal space. Femoral artery and vein cannulation was performed via a semi-open technique with a 2-cm skin incision or the Seldinger technique. We have used a ProGlide (Abbott Vascular Inc., Santa Clara, CA, USA) perclosure device for percutaneous femoral artery cannulation since September 2017. After cardiopulmonary bypass (CPB), the pericardium was opened longitudinally 3 cm anterior to the phrenic nerve. After transthoracic aortic cross-clamping through the third intercostal space, cardioplegic arrest was induced along with antegrade cardioplegia. After the left of right atriotomy was approached along the located mass—such that every myxoma in the left atrium was resected with left atriotomy—a tagging suture on the hard tissue of the mass attached to the septum was applied to pull the mass without manipulation of the fragile mass. We believed that this method might minimize tumor fragmentation. Not only did it facilitate the cutting of the stalk of the mass, but it also allowed the mass to be removed in 1 piece without fracturing the myxoma. Depending on the depth of the tumor stalk, endocardial or transmural resection was performed. After removing the myxoma, we checked the feeding vessel and controlled it using electrocautery. After weaning from CPB, we routinely evaluated the intraoperative transesophageal echocardiogram to determine the presence of a residual mass, interatrial shunt, and coronary-to-atrial fistula.

Clinical and echocardiographic follow-up

Follow-up echocardiography was scheduled 1 year postoperatively, and an evaluation every 2 years to confirm the recurrence of cardiac myxoma was recommended. We presumed the presence of the Carney complex (CNC) based on each patient's premedical history and postoperative clinical follow-up. The diagnosis of the CNC was confirmed if 1 of the following factors was present: (1) a patient presenting with 2 or more major criteria; (2) identification of a pathogenic variant in the protein kinase A-type I-alpha regulatory subunit (PRKAR1A); and (3) one major criterion was met and a first-degree relative had the CNC or an inactivating mutation of PRKAR1A. The major criteria included spotty skin pigmentation with typical distribution, cardiac or noncardiac myxoma, primary pigmented nodular adrenocortical disease, acromegaly due to growth hormone-producing adenoma, a large cell calcify-

ing Sertoli cell tumor, thyroid carcinoma or multiple hypoechoic nodules on thyroid ultrasonography in a young patient, psammomatous melanotic schwannoma, blue nevus, and breast ductal adenoma [11]. The presence of the CNC was confirmed by consultation with the genetics department or a thorough review of the patient's past medical history.

Results

The mean age was 56.4±12.0 years, and 41 patients (64.1%) were women. Myxoma resection by emergency or urgent means was performed in 12 cases (18.8%). We conducted emergent or urgent myxoma resection in cases of a hypermobile mass observed on TTE because of the high risk of acute systemic embolism, and in cases of hemodynamically significant functional mitral stenosis resulting from the myxoma itself.

Preoperatively, 44 patients (68.7%) underwent brain DWI, of whom 5 patients had acute embolic infarctions and 8 had chronic embolic infarctions. The mean European System for Cardiac Operative Risk Evaluation II of these patients was 1.3±0.9, and the left ventricular ejection fraction was 62.8%±4.9% on preoperative echocardiography (Table 1).

The most common location of the mass was the left atrium (n=62, 96.9%); however, some tumors developed in the right atrium (n=2, 3.1%). Transmural tumor excision was performed in 46 patients (71.9%), inducing iatrogenic atrial septal defect repair. Conversion to sternotomy was not performed in any case. The mean CPB time was 69.0±28.6 minutes, and the cardiac ischemic time was 34.1±15.0 minutes (Table 2).

There were no early deaths or reoperations due to bleeding. Eighteen patients (28.1%) received transfusion. Red blood cell transfusion, fresh frozen plasma transfusion, and platelet transfusion were performed in 16, 4, and 1 patients, respectively. Postoperative arrhythmias were identified, including 7 cases (10.9%) of atrial fibrillation and 2 cases (3.1%) of junctional rhythm. Most of the postoperative arrhythmia were temporary and converted to sinus rhythms without specific treatment. Only 2 patients who developed atrial fibrillation needed amiodarone infusion for sinus rhythm conversion. Patients with a junctional rhythm needed inotropic support such as dobutamine. One of them remained in a junctional rhythm at the time of discharge, and sinus rhythm restoration was noted at an outpatient clinic visit. At discharge, none of the patients had arrhythmia, and anticoagulants were not required.

Table 1. Preoperative patient characteristics (N=64)

Characteristic	Value
Age (yr)	56.4±12.0
Female sex	41 (64.1)
Body surface area (m^2)	1.7±0.2
Hypertension	21 (32.8)
Diabetes mellitus	13 (20.4)
Dyslipidemia	38 (59.4)
Chronic kidney disease stage ≥3	9 (14.1)
Prior stroke	13 (20.3)
Current smoker	14 (21.9)
NYHA functional class III or IV	7 (11.0)
EuroSCORE II (%)	1.3±0.9
Left ventricular ejection fraction (%)	62.8±4.9
Emergency or urgency	12 (18.8)

Values are presented as mean±standard deviation or number (%).
NYHA, New York Heart Association; EuroSCORE, European System for Cardiac Operative Risk Evaluation.

Table 2. Operative details (N=64)

Variable	Value
Tumor location	
Right atrium	2 (3.1)
Left atrium	62 (96.9)
Largest tumor diameter (cm)	3.6±1.6
Transmural resection and iatrogenic ASD repair	46 (71.9)
Concomitant surgery	
Mitral valve repair	2 (3.1)
Surgical ablation for atrial fibrillation	2 (3.1)
Cardiopulmonary bypass time (min)	69.0±28.6
Cardiac ischemic time (min)	34.1±15.0

Values are presented as number (%) or mean±standard deviation.
ASD, atrial septal defect.

Table 3. Early clinical outcomes (N=64)

Variable	Value
Early death	0
Sternotomy conversion	0
Early complications	
Stroke	0
Need for mechanical circulatory support	0
New-onset dialysis	0
Transfusion requirement	18 (28.1)
Atrial fibrillation	7 (10.9)
Junctional rhythm	2 (3.1)
Extubation in the operating room	50 (78.1)
Requiring re-intubation	0
Ventilation time >24 hr	2 (3.1)
Intensive care unit stay (hr)	23 (21–25)
Hospital stays (day)	4 (3–5)

Values are presented as number (%) or median (interquartile range).

Fifty patients (78.1%) were extubated in the operating room. Only 2 patients (3.1%) required prolonged ventilation for over 24 hours. Fifty-nine patients (92.1%) were transferred to the general ward from the intensive care unit on the day after surgery, and 46 patients (71.8%) were discharged within 5 days of admission (Table 3).

Incidence of postoperative cerebral embolism

There were no newly developed symptomatic strokes in the study population. To check for asymptomatic cerebral embolism after MICS myxoma resection, we routinely performed brain DWI during the early postoperative hospitalization regardless of neurological symptoms in 35 patients (54.7%). Among these patients, silent cerebral embolism was confirmed in 9 (25.7%) (Fig. 1). Most patients had only 1 or 2 new embolic lesions, and no embolism location was predominant (Table 4).

Incidence of tumor recurrence

The median echocardiographic follow-up duration was 24.8 months (interquartile range, 9.9–38.5 months), and the clinical follow-up duration was 36.7 months (interquartile range, 13.4–81.8 months). In this study, only 1 patient experienced tumor recurrence. A 51-year-old woman underwent endocardial resection during the first cardiac myxoma resection in July 2011. She did not have preoperative and postoperative MRI results because she underwent surgery performed by the surgeon who did not check MRI

Table 4. Preoperative and postoperative DWI findings (N=64)

Variable	Value
Preoperative DWI evaluation	44 (68.7)
Acute infarction (<14 day)	5/44 (11.3)
Postoperative DWI evaluation	35 (54.7)
Silent cerebral embolism	9/35 (25.7)
No. of embolisms	
1	3/9 (33.3)
2	3/9 (33.3)
4	2/9 (22.2)
11	1/9 (11.1)
Lesion location	
Anterior	3/9 (33.3)
Posterior	3/9 (33.3)
Both (anterior+posterior)	3/9 (33.3)
Left	2/9 (22.2)
Right	1/9 (11.1)
Both (left+right)	6/9 (66.7)

Values are presented as number (%) or median (interquartile range).
DWI, diffusion-weighted magnetic resonance imaging.

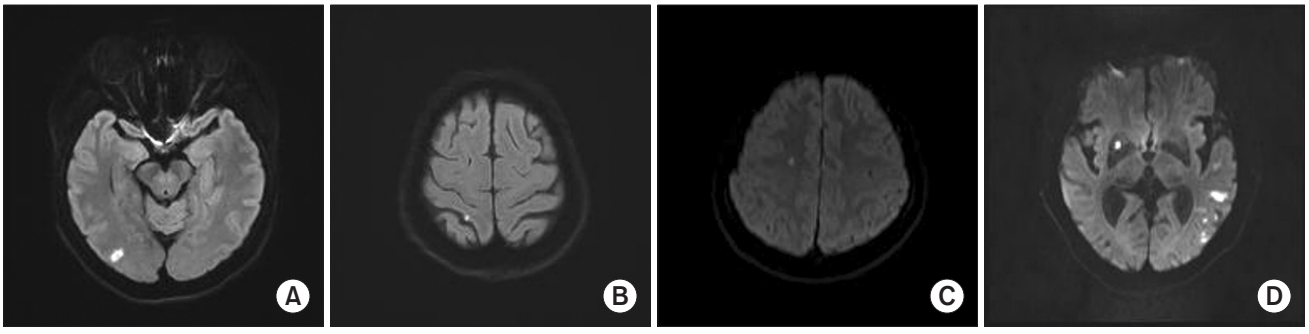

Fig. 1. Embolic infarction at the right parietal lobe (A), right occipital lobe (B), and right middle cerebral artery territory (C) and multiple infarctions in the left middle cerebral artery territory and right basal ganglia (D).

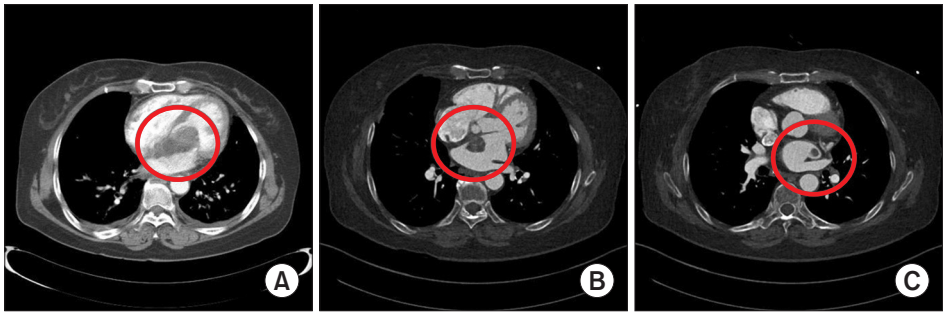

Fig. 2. Recurrence of cardiac myxoma. (A) In 2011, a 6.5-cm myxoma was attached at the interatrial septum (red circle). In 2021, two myxomas (2.8 cm and 1.5 cm) recurred at the interatrial septum (B, red circle) and left atrial appendage (C, red circle).

Table 5. Clinical features of patients with confirmed Carney complex

No.	Age (yr)	Sex	Clinical features	Echocardiogram follow-up duration (mo)	Recurrence
1	51	Female	Lentigines, thyroid nodules, adrenal incidentaloma, benign breast mass	122.3	Yes
2	47	Female	Thyroid cancer	91.7	No
3	61	Female	Pituitary adenoma	12.3	No
4	24	Male	Adrenal adenoma, PRKAR1A mutation	12.1	No
5	28	Female	Breast adenoma	24.9	No

PRKAR1A, cAMP-dependent protein kinase type I-alpha regulatory subunit.

routinely. Cardiac myxoma recurred after 9 years. It is judged that metachronous occurrence likely occurred since the location of cardiac myxoma on computed tomography was different and about 9 years had passed since the first surgery. She met 3 major criteria for the CNC: cardiac myxoma, skin pigmentation, and breast cancer. Moreover, genetic testing confirmed the presence of the CNC. Myxoma recurred 10 years after the initial surgery at the left atrium appendage (Fig. 2). With clinical suspicion applied to every patient in this study, we identified 5 patients (7.8%) who satisfied the criteria for a clinical diagnosis of the CNC (Table 5). However, because some patients refused a genetic analysis for the CNC, the number of CNC patients might have been underestimated.

Discussion

The conventional approach for cardiac myxoma resection is median sternotomy. Studies comparing thoracotomy and sternotomy showed no significant difference in overall early surgical outcomes, including CPB time, cardiac ischemic time, hospital stay, and wound-related problems [6-9]. MICS has recently emerged as a promising alternative. However, domestic data on cardiac myxoma resection via mini-thoracotomy are limited. Our study included more than 60 patients and analyzed their basic perioperative data, DWI results, and medium-term TTE evaluation results. The most important findings of this study are as follows: first, early operative outcomes were excellent; second, the incidence of newly developed cerebral embolism was acceptable; and third, tumor recurrence in the medium-term follow-up was very low after cardiac myxoma resection through mini-thoracotomy.

In our study, the comprehensive postoperative outcomes were satisfactory. The CPB time and cardiac ischemic time were acceptable compared to the outcomes of other surgical approaches [12,13]. In most studies on minimally invasive approaches for myxoma resection, the median sternotomy conversion rate has been reported to be 0% [6,8,9]. Fortunately, none of the 64 patients in this study underwent conversion to median sternotomy. Lee et al. [8] found that the thoracotomy group showed a shorter postoperative intubation time than the median sternotomy group. In our study, 78.1% of patients were extubated in the operating room, and 97% were extubated within 24 hours postoperatively. Prolonged postoperative ventilation is associated with a higher risk of nosocomial pneumonia. These results demonstrated that early extubation effectively reduced the pulmonary complication rate. The median durations of intensive care unit stay and hospital stay were 23 hours and 4 days, respectively, which are comparable to or even shorter than those in previous studies [6,14].

Cardiac myxomas present with early and delayed neurological symptoms [15]. Desousa et al. [16] demonstrated that cardiac myxomas showed preoperative neurologic symptoms and underwent cerebral embolization [17]. Moreover, Lee et al. [18] reported that 18.6% of 59 patients with myxomas had an embolism with signs of brain infarction preoperatively. In this study, 13 patients (20.3%) had a preoperative stroke, and 5 of them were confirmed to have had an acute stroke. However, there have been few studies on the incidence of newly developed cerebral embolisms after myxoma resection. A literature search performed by the authors found no publications on the incidence of cerebral embolism after MICS myxoma resection. Minimally invasive mitral valve surgery has been shown to have a higher incidence of stroke after thoracotomy than conventional surgery [10]. Myxoma resection through mini-thoracotomy also poses a concern regarding postoperative cerebral embolism. Embolic events related to neurologic complications can be caused by femoral cannulation with retrograde perfusion. Grossi et al. [19] reported that retrograde arterial perfusion was associated with an increased risk of stroke in minimally invasive mitral valve repair. However, Saadat et al. [20] reported a low incidence of embolic infarction in MICS in the femoral cannulation

group. Subclinical cerebral embolism detected by DWI showed significant variability in its postoperative prevalence in the procedural surgical group. Furthermore, tumor fragmentation during MICS can cause embolic infarctions. It is difficult to determine whether new-onset cerebral embolism is due to peripheral cannulation or tumor fragmentation. As there were no cases of clinical stroke in this study, and only 25.7% of patients showed subclinical cerebral embolism, we infer that our mini-thoracotomy approach did not increase the incidence of cerebral embolism.

Another problem with myxoma resection through MICS is recurrence due to incomplete tumor resection. Shah et al. [21] reported that the rates of freedom from tumor recurrence were 92.3%, 91.0%, and 85.6% at 10, 20, and 30 years, respectively. In our study, only 1 case of recurrence was observed, in a patient diagnosed with the CNC (Fig. 2). The CNC, initially reported by Carney et al. [22], is a rare autosomal dominant syndrome characterized by pigmented skin lesions, familial cardiac myxoma, and endocrine neoplasms of the adrenocortical, thyroid, or testicular systems. Because cardiac myxomas in patients with the CNC have a higher risk of recurrence than sporadic cardiac myxomas [23], extensive resection, including the stalk with the adjacent endocardium, is advised [24]. As many studies have stated, the recurrence rate of cardiac myxoma was low. However, patients with the CNC need close follow-up because this condition is characterized by cardiac myxoma and some reported that cardiac myxomas in patients with the CNC have a higher risk of recurrence than sporadic cardiac myxomas. Periodic TTE during long-term follow-up, genetic counseling, and family education are highly recommended.

This study has some limitations. It included a small number of patients and was conducted at a single center. Moreover, long-term TTE is necessary to evaluate tumor recurrence. Since most myxoma resections were performed using the MICS approach at our center, we were unable to compare MICS with median sternotomy, which is also a limitation.

In conclusion, cardiac myxoma resection through right mini-thoracotomy can be a promising alternative based on its medium-term surgical outcomes and the low incidence of postoperative cerebral embolism and tumor recurrence.

Article information

ORCID

Changwon Shin: https://orcid.org/0000-0003-2135-6287
Min Ho Ju: https://orcid.org/0000-0001-7839-8598
Chee-Hoon Lee: https://orcid.org/0000-0002-0456-225X
Mi Hee Lim: https://orcid.org/0000-0002-0167-7836
Hyung Gon Je: https://orcid.org/0000-0003-4713-2898

Author contributions

Conceptualization: HGJ. Data curation: MHL, HGJ, MHJ, CHL. Formal analysis: MHJ, CHL. Funding acquisition: HGJ. Methodology: CHL, MHJ. Project administration: HGJ. Visualization: CS, MHJ, CHL. Writing–original draft: CS. Writing–review & editing: HGJ. Final approval of the manuscript: HGJ.

Conflict of interest

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

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