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Original Article */ Özgün Makale*

A comparison of robotically-assisted endoscopic versus sternotomy approach for myxoma excision: A single-center experience

Miksoma eksizyonunda robotik yardımlı endoskopik ve sternotomi yaklaşımlarının karşılaştırılması: Tek merkez deneyimi

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ABSTRACT

Background: In this study, we present our single-center experience in robotically-assisted endoscopic surgery versus conventional median sternotomy approach in patients undergoing cardiac myxoma excision.

Methods: Between January 2011 and September 2019, a total of 46 patients (24 males, 22 females; mean age 54.1±12.5 years; range, 25 to 79 years) who had a confirmed diagnosis of isolated cardiac myxoma were included in the study. The patients were divided into two groups as those undergoing robotic-assisted surgery (n=16) and those undergoing conventional median sternotomy (n=30). Clinical characteristics, operative, and postoperative outcomes were compared. Robotic approach to right or left-sided tumors and postoperative pain scores were also analyzed.

Results: There was no mortality or major complication. No conversion to sternotomy was needed in robotic procedures. The mean cardiopulmonary bypass and aortic cross-clamp times were significantly shorter in the median sternotomy group (p=0.001 for both). The mean ventilation time and the length of hospital stay were significantly shorter in robotic surgery than sternotomy group (p=0.043 and p=0.048, respectively). The mean amount of postoperative blood loss and transfusion rate were significantly lower in robotic surgery patients (p=0.001 and p=0.022, respectively). The mean postoperative pain scores were significantly lower in patients undergoing robotic surgery (p=0.022).

Conclusion: Robotic-assisted endoscopic surgery can be performed safely and effectively for cardiac myxoma excision with shorter hospital stay, less pain, and less amount of blood product use, as well as more favorable cosmetic results compared to conventional median sternotomy.

Keywords: Cardiac myxoma, excision, minimally invasive cardiac surgery, robotic surgery.

ÖZ

Amaç: Bu çalışmada, kardiyak miksoma eksizyonu yapılan hastalarda konvansiyonel medyan sternotomi yaklaşımına kıyasla robotik yardımlı endoskopik cerrahiye ilişkin tek merkez deneyimimiz sunuldu.

Çalışma planı: Ocak 2011 - Eylül 2019 tarihleri arasında izole kardiyak miksoma tanısı doğrulanmış olan toplam 46 hasta (24 erkek, 22 kadın; ort. yaş 54.1±12.5 yıl; dağılım, 25-79 yıl) bu çalışmaya alındı. Hastalar robotik yardımlı cerrahi yapılanlar (n=16) ve konvansiyonel medyan sternotomi yapılanlar (n=30) olmak üzere iki gruba ayrıldı. Klinik özellikler, cerrahi ve ameliyat sonrası sonuçlar karşılaştırıldı. Sağ veya sol-taraflı tümörlere robotik yaklaşım ve ameliyat sonrası ağrı skorları da incelendi.

Bulgular: Mortalite veya majör komplikasyon görülmedi. Robotik işlemlerde sternotomiye dönüş gerekmedi. Ortalama kardiyopulmoner baypas ve aortik kros klemp süreleri, medyan sternotomi grubunda anlamlı olarak daha kısaydı (her ikisi için p=0.001). Ortalama ventilasyon süresi ve hastanede kalış süresi, sternotomi grubuna kıyasla, robotik cerrahi grubunda anlamlı olarak daha kısaydı (sırasıyla p=0.043 ve p=0.048). Ameliyat sonrası ortalama kan kaybı miktarı ve transfüzyon oranı, robotik cerrahi hastalarında anlamlı olarak daha az idi (sırasıyla p=0.001 ve p=0.022). Ameliyat sonrası ortalama ağrı skorları, robotik cerrahi yapılan hastalarda anlamlı olarak daha düşüktü (p=0.022).

Sonuç: Konvansiyonel medyan sternotomiye kıyasla, robotik yardımlı endoskopik cerrahi, kardiyak miksoma eksizyonunda daha kısa hastanede kalış süresi, daha az ağrı ve daha az miktarda kan ürünü kullanımının yanı sıra, daha olumlu kozmetik sonuçlar ile birlikte, güvenle ve etkin olarak uygulanabilir.

Anahtar sözcükler: Kardiyak miksoma, eksizyon, minimal invaziv kardiyak cerrahi, robotik cerrahi.

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Cardiac myxoma is the most common type of cardiac tumor in adults and surgical resection is recommended to prevent fatal complications such as systemic embolization and inflow or outflow obstruction.[1-3] The incidence of primary cardiac tumors varies between 0.001 and 0.3% based on autopsy studies.[1] More than half of benign cardiac tumors are reported as myxomas.[2,3] Conventional median sternotomy (MS) is accepted as the preferred standard approach for the resection of these tumors. On the other hand, robotic surgery (RS) has been used successfully in the management of mitral valve repair or replacement, coronary artery bypass grafting (CABG) and atrial septal defect closure.[3-9] The major advantages of robotically-assisted surgery include less pain, shorter hospital stay, less amount of postoperative blood loss, and early return to daily life. Robotic surgery has also favorable patient-reported outcomes which show the quality of surgical care in terms of body image, self-esteem, and cosmetic outcomes over the conventional approach in patients undergoing cardiac surgery.[8]

On the other hand, there are still few reports on robotically-assisted atrial myxoma excision due to the limited number of RS centers and high cost of the procedure. As a result, few reports contain institutional tutorials or small-sized initial experiences in the literature.[10-16]

The aim of this study was to present our single-center experience in robotically-assisted minimally invasive and conventional median sternotomy approaches for cardiac myxoma excision. We also aimed to review the literature on RS for myxoma excision.

PATIENTS AND METHODS

Between January 2011 and September 2019, a total of 72 patients with a primary diagnosis of a cardiac mass were operated in the cardiovascular surgery clinic of Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital. Patients were retrospectively analyzed using the hospital database. Nineteen patients whose pathology results were reported as thrombus, lipoma, fibroma, rhabdomyoma, hepatocellular carcinoma, or lymphoma were excluded. Seven patients were also excluded due to concomitant procedures including six CABG procedures and one aortic surgery due to aneurysm. Finally, a total of 46 patients (24 males, 22 females; mean age 54.1±12.5 years; range, 25 to 79 years) who had a confirmed diagnosis of isolated cardiac myxoma were included in the study. These patients were divided into two groups based on the technique preferred by the operating surgeon: RS group (n=16) and conventional MS group (n=30). Data including demographic characteristics, comorbidities, medical, and surgical histories, operative and laboratory findings, and postoperative outcomes were retrieved from the institutional database. A written informed consent was obtained from each patient. The study protocol was approved by the Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital Ethics Committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

All patients underwent physical examination, electrocardiography, biochemical tests, and chest X-ray preoperatively. Transthoracic and transesophageal echocardiography were applied for each patient and the location, size, contours, and obstruction status of the cardiac mass were evaluated. Coronary angiography was performed according to revascularization guidelines. Computed tomography or magnetic resonance imaging was used in selected cases where it was difficult to diagnose benign and malign cardiac tumors. Peripheral angiography was performed to assess the suitability of peripheral perfusion for cardiopulmonary bypass (CPB). Operative timing was based on the clinical status, hemodynamic instability, and size of the mass. The choice of surgical approach depended upon comorbidities, patient's preference, and surgical limitations. The patients with a right thoracic pathology, dense right pleural adhesions, chest trauma, or peripheral arterial disease were scheduled for MS procedure.

Robotic surgery technique

Da Vinci SI robotic surgery system (Intuitive Surgical Inc., Sunnyvale, CA USA) was used. External defibrillator patches were placed on the chest wall and the right internal jugular vein was cannulated percutaneously. After a 2-cm groin incision, the right femoral arterial and venous cannulations were performed. A service port (2-cm long) was opened on the anterior axillary line in the fourth intercostal space (Figure 1). The camera was inserted anteriorly in the same intercostal space. The arms were placed in the third and fifth intercostal spaces. The atrial retractor was inserted through the fifth intercostal space. During the operation, carbon dioxide (2-4 L/min) was insufflated into the operative field. After docking of robotic system, CPB was started and the lungs were deflated. Pericardium was opened and stay sutures were placed. A pericardial patch was prepared for

Figure 1. An intraoperative view showing set-up of robotically-assisted endoscopic surgery.

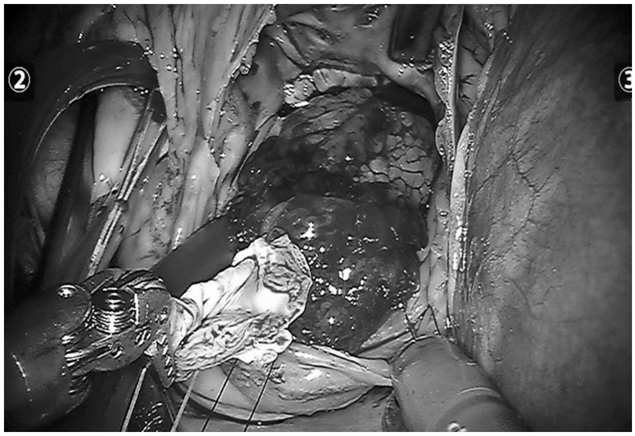

Figure 2. An endoscopic view showing resection of a left ventricular giant myxoma through right atriotomy incision. Note that Ti-cron™ suture is placed in tumor base and origin (on the fossa ovalis) and help patient-side surgeon during removal of mass.

septal reconstruction in case of a large resection of the interatrial septum. Antegrade cardioplegia needle was placed on the ascending aorta.[4,5,17] Aortic cross-clamp was inserted through the third intercostal space in the mid-axillary line. Diastolic arrest was established with isothermic blood cardioplegia.

Left atrial tumors were explored through a left atriotomy or right atriotomy using trans-septal incision (Figure 2). Bi-atriotomy was performed in some patients. The atrial wall as a tumor origin was completely resected to prevent recurrence. Septal defects or endocardial lacerations were repaired primarily or using a pericardial patch. A left atriotomy was performed in a patient with left ventricular tumor, which was easily exposed through the mitral valve orifice. Transesophageal echocardiography was performed for the diagnosis of a residual mass in the atrial cavity or residual interatrial shunting after repair of septal defects at the end of the procedures. A chest tube was placed in the right hemithorax. Femoral vessels and jugular vein were decannulated, and the skin incisions were closed.

Median sternotomy technique

Median sternotomy and central cannulation were performed. Operations were done at 32°C and blood cardioplegia was used. A left or right atriotomy incision was made according to the location of the tumors. Following resection of the tumors, primary suturing or pericardial patch reconstruction was done for intracardiac repair. The patients were weaned from CPB. The sternotomy incision was closed, after chest drains were placed. Transesophageal echocardiography was done to assess the presence of a residual tumor or a septal defect.

Postoperative pain scores and follow-up

All patients were given the same analgesic protocol including routine delivery of paracetamol 500 mg intravenously (q.i.d) and, if needed, additional delivery of tramadol of 1 mg/kg b.i.d. Postoperative pain scores of the patients were taken from the hospital records in the intensive care unit (ICU) and ward. In the follow-up sheets of the patients in the ICU and ward, the assessment of postoperative pain was made using the Visual Analog Scale (VAS)-Pain. The patients were asked to indicate the level of intensity of their pain within a scale of 1 (least pain) to 10 (worst pain). Maximum pain score during the hospital stay was used for the analysis of postoperative outcomes.

Transthoracic echocardiography was performed at postoperative Day 30 and subsequent follow-up visits. Each patient was given antiplatelet therapy (acetylsalicylic acid, 100 mg, once daily) during the first one year.

Statistical analysis

Statistical analysis was performed using the SPSS version 15.0 software (SPSS Inc., Chicago, IL, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency. Continuous data were evaluated for normality, and inter-groups comparisons were performed using either the Student's t-test or the Mann-Whitney U test for normally and non-normally distributed variables, respectively. The Fisher's exact test for 2×2 tables or Pearson's chi-square test was used to compare categorical data. A two-sided p value of <0.05 was considered statistically significant.

RESULTS

There was no significant difference between the groups in terms of age, sex, body mass index, initial symptoms, and demographic data (Table 1). Giant mobile tumors in the left atrium protruding into the left ventricle were diagnosed in eight patients (50%) in the RS group and in 20 patients (66.7%) in the MS group (p=0.27). Two of the patients in the MS group presented with congestive failure due to mitral inflow obstruction and were operated emergently. The mean preoperative EuroSCORE II values were 1.6±0.5 vs. 1.5±0.4, respectively (p=0.38). Preoperative hematocrit values were similar between the groups (36.4±5.6% [range, 29% to 48%] in the RS group vs. 34.6±4.3% [range, 30% to 44%] in the MS group; p=0.243).

Operative data are shown in Table 2. There was no procedure-related mortality. No surgical conversion to thoracotomy or sternotomy incision was needed in the

Table 1. Baseline demographic and clinical characteristics of patients

	Robotic surgery (n=16)				Median sternotomy (n=30)				
	n	%	Mean±SD	Min-Max	n	%	Mean±SD	Min-Max	*p*
Age (year)			53.2±11.4				54.7±13.2		0.715
Sex	5	31.3			17	56.7			0.100
Female									
Body mass index (kg/m²)			23.8±2.3				24.3±2.7		0.480
Initial symptom and diagnosis									
Incidental	6	37.5			8	26.7			0.447
Palpitation	2	12.5			1	3.3			0.230
Shortness of breath	6	37.5			20	66.7			0.057
Cerebrovascular event (TIA)	2	12.5			1	3.3			0.230
Peripheral embolization	0	0			0	0			-
Giant intracardiac tumor	8	50			20	66.7			0.270
NYHA functional class			1.3±0.5				1.5±0.8		0.398
Ejection fraction (%)			61.5±2.3				58.7±5.5		0.056
Pulmonary artery pressure (mmHg)			32.3±4.8				37.7±11.5		0.079
Hematocrit level (%)			36.4±5.6	29-48			34.6±4.3	30-44	0.243
Co-morbidities									
Hypertension	6	37.5			15	50			0.481
Diabetes mellitus	2	12.5			7	23.3			0.378
Ischemic heart disease	3	18.8			6	2.0			0.919
COPD	1	6.3			6	20			0.216
Atrial fibrillation	2	12.5			0	0			-
Congestive heart failure	0	0			2	6.7			-
Chronic renal failure	0	0			1	3.3			-
Peripheral artery disease	0	0			3	10			-
Previous cardiothoracic surgery	0				0				-
Chest wall deformity	0				0				-
Surgical timing									
Emergent	0	0			2	6.7			-
Elective	16	100			28	93.3			0.267

SD: Standard deviation; Min: Minimum; Max: Maximum; TIA: Transient ischemic attack; NYHA: New York Heart Association functional class; COPD: Chronic obstructive pulmonary disease.

Table 2. Operative data

	Robotic surgery (n=16)			Median sternotomy (n=30)			
	n	%	Mean±SD	n	%	Mean±SD	*p*
Surgical conversion to sternotomy			0			-	-
Cardiopulmonary bypass time (min)			107.8±52.7			58.3±26.8	0.001
Aortic clamping time (min)			59.7±29.3			29.4±12.2	0.001
Maximum diameter of the mass (mm)			37.3±16.6			44.0±15.5	0.179
Tumor location and origin							
Left atrium, septum	14	87.5		24	80		0.523
Left atrium, free wall	0	0		4	13.3		0.126
Right atrium, septum	1	6.3		2	6.7		0.958
Left ventricle, mid-septum	1	6.3		0	0		0.166
Right ventricle	0	0		0	0		-
Surgical approach to left-sided tumors							
Left atriotomy	3	18.8		2	6.7		0.210
Right atriotomy (Trans-septal incision)	12	75		28	93.3		0.079
Biatriotomy	1	6.3		0	0		0.166
Ventriculotomy	0	0		0	0		-
Surgical approach to right atrial tumors							
Right atriotomy	1	6.3		2	6.7		0.958
Interatrial septum reconstruction							
Pericardial patch	9	56.3		9	30		0.082
Primary repair	7	43.8		20	66.7		0.133
Left atrial wall reconstruction							
Pericardial patch	6	37.5		8	26.6		0.092

SD: Standard deviation.

Table 3. Postoperative data

	Robotic surgery (n=16)			Median sternotomy (n=30)			
	n	%	Mean±SD	n	%	Mean±SD	*p*
Mortality			0			0	
Ventilation time (h)			5.8±1.4			12.5±4.7	0.043
Intensive care unit stay (day)			1.2±0.4			1.3±0.8	0.411
Hospital stay (day)			4.3±0.4			6±2.4	0.048
Inotropic usage	0	0		2	6.7		0.291
Pain score			2.5±0.6			4.2±0.9	0.022
Drainage (mL)			110±48.3			240±99.4	0.001
Blood transfusion	5	31.3		20	66.7		0.022
Erythrocyte suspension replacement (unit)			0.6±0.9			1.8±1.7	0.014
Postoperative exploration	0	0		0	0		-
Cardiac tamponade	0	0		0	0		-
Postoperative rhythm							
Atrial fibrillation	1	6.3		3	10		0.667
Atrioventricular block (2nd degree)	0	0		1	3.3		0.460
Neurological complication	0	0		0	0		-
Surgical wound infection	0	0		0	0		-
Recurrence	0	0		0	0		-

SD: Standard deviation.

RS group. However, there was a significant difference in CPB (107.8±52.7 vs. 58.3±26.8 min, respectively; p=0.001) and cross-clamp times (59.7±29.3 vs. 29.4±12.2 min, respectively; p=0.001) between the RS and MS groups. Most tumors in the RS and MS groups were located in the left atrium (n=14, 87.5% vs. n=28, 93.3%, respectively; p>0.05). A right atrial tumor was diagnosed in one patient (6.3%) in the RS group and in two patients (6.7%) in the MS group (p=0.958). Only one patient presented with a left ventricular myxoma and operated using the robotic technique through the left atriotomy. In both groups, the surgical approach to the left atrial tumors was mostly trans-septal approach using a right atriotomy incision (75% vs. 93.3%, respectively; p=0.079). The left atriotomy was performed in three patients (18.8%) in the RS group and in two patients (6.7%) in the MS group (p=0.210). The bi-atriotomy incision was done in the RS group due to the difficult exposure in one patient (6.3%). Following resection of the tumors, interatrial septum reconstruction was made using a pericardial patch in nine patients (56.3%) in the RS group and in nine (30%) in the MS group (p=0.082). In the other patients, the interatrial septum was repaired primarily. Left atrial wall reconstruction was needed in six patients (37.5%) in the RS group.

Postoperative data are presented in Table 3. The mean ventilation time (5.8±1.4 vs. 12.5±4.7 h, respectively; p=0.043) and hospital length of stay (4.3±0.4 vs. 6±2.4 days, respectively; p=0.048) were significantly shorter in the RS group. However, the mean length of the ICU stay was similar between the groups (p=0.411). The mean amount of blood loss and blood transfusion were significantly lower in the RS patients (110±48.3 vs. 240±99.4 mL, respectively; p=0.001 and 5 [31.3%] vs. 20 [66.7%] patients, respectively; p=0.022). There was no neurological event, pulmonary dysfunction, infection or renal complication postoperatively. The mean maximum VAS-pain scores were significantly lower in the patients undergoing RS (2.5±0.6 vs. 4.2±0.9, respectively; p=0.022).

The mean follow-up was 7.1±7.0 (range, 1 to 26) months in the RS group and 20.1±21.3 (range, 1 to 84) months in the MS group. No tumor recurrence was observed in either group during follow-up (p=0.023).

DISCUSSION

Minimally invasive RS for cardiac myxoma excision provide cosmetic superiority for the patients with a better postoperative quality of life, causes less pain, and requires less blood product use.[10-12] Thus, the patients can return to normal daily life within a shorter rehabilitation period. In the literature, the number of available data on robotic cardiac myxoma excision, other than coronary revascularization and mitral valve procedures, is limited and these data mostly depend on case series (Table 4).[10-16] The first series on robotic cardiac myxoma operations with RS was performed by Murphy et al.[15] in 2005. In 2008, Gao et al.[14] published a case series of 10 patients with a cardiac myxoma who underwent RS. The same author published another series of 19 patients in 2010.[13] These studies present only the feasibility and safety of RS for myxoma excision. Later on, only three studies were published which compared the RS approach versus sternotomy approach.[10-12] In all these studies, the results of less than 150 cases were reported. These studies concluded that the excision of cardiac myxoma by the RS method was safe, effective, and reasonable with favorable cosmetic results, early return to daily life, and improved postoperative quality of life. Moreover, Moss et al.[12] concluded that RS might be associated with a lower incidence of perioperative blood transfusion, as well as shorter ventilation time and shorter length of ICU and hospital stay.

In previous studies of myxoma excision comparing the RS and MS approaches, cross-clamp and CPB times were reported to be longer in RS.[10-12] In our study, the mean cross-clamp and CPB times were found to be significantly longer in patients undergoing RS. However, this difference did not have a negative effect on the clinical outcomes. Similar to a previous study,[12] we observed a significantly less amount of postoperative bleeding and blood product use which may have provided an uneventful postoperative rehabilitation period. The mean postoperative pain scores of the patients undergoing RS were also found to be significantly lower. Additionally, there was no surgical conversion in our experience, indicating the feasibility of the robotic technique.

Similarly, ventilation time and length of hospital stay are expected to be shorter in patients undergoing RS.[10-12] In our study, these parameters were significantly lower in patients who underwent RS. However, the length of ICU stay was similar between the groups due to our clinical protocol. Per protocol, all patients were extubated in the ICU and stayed one night routinely.

The feasibility of robotic myxoma excision should be evaluated in each patient with a detailed assessment of medical history, echocardiography and angiography results. The operation should be planned considering the size, location, and removability of the mass. The tumor can be reached through a left atriotomy, right

Table 4. Literature review on robotically-assisted atrial myxomas excision

Author	Article type / patient group	Outcomes	Key results	Comments
Moss et al.[12]	Original article /retrospective, multicenter Robotic surgery (n=30) versus sternotomy incision (n=39)	Mechanical ventilation time ICU length of stay Hospital length of stay Perioperative blood transfusion	Significantly shorter in robotic surgery Shorter ICU stay (16.3 fewer hours; p=0.11) in robotic surgery Hospital LOS (1.1 fewer days; p=0.17) in robotic surgery Decreased blood transfusions (adjusted odds ratio, 0.33; CI: 0.09-1,20; p=0.09)	Comparison with sternotomy Robotic surgery may be associated with a lower incidence of perioperative blood transfusion as well as shorter ventilation time, and shorter ICU and hospital LOS.
Yang et al.[11]	Original article/robotic surgery (n=49) versus sternotomy incision (n=44)	Mortality Conversion Re-exploration CPB time Ventilation time ICU time Hospitalization time Postoperative atrial fibrillation QoL postoperatively, at day 30 and 6 months The degree of pain Time to return to work	No mortality No conversion No re-exploration 79.7±16.5 in robotic group vs 68.6±27.8 min, p=0.03 7.1±2.1 h vs. 8.4±3.0 h, p=0.00 2.7±1.0 days vs. 4.1±3.6 days, p=0.04 6.2±1.3 days vs. 8.7±1.9 days, p=0.04 2 (4.1%) vs. 8 (18.2%) patients, p=0.04 better in the robotically assisted group (p<0.05) less pain in the robotic patients after 0.9±0.1 vs 3.3±0.4 months	Comparison with conventional sternotomy The level of restoration of normal QoL within 30 days after atrial myxoma surgery is excellent with the robotically assisted approach
Kesävuori et al.[10]	Original article/robotic (n=9) versus sternotomy incision (n=18)	CPB time Cross-clamp time Ventilation time Hospitalization time Clinical follow-up time Recurrence HRQoL results	124±30 vs. 54±21 min, <0.001 67±21 vs. 34±15 min, <0.001 14.6±5.0 vs. 9.0±3.0 h, <0.001 5.8±1.0 vs. 7.0±1.6 days, 0.023 8.0±6.9 vs. 18.2±21.1 months No recurrence No significant difference in any of the eight measured RAND-36 scales	Limited comparison with conventional sternotomy Robotic surgery: Short hospital stay, effective, safe technique/quality of life is similar to conventional surgery
Schilling et al.[16]	Original article/retrospective design robotic resection (n=16) versus full sternotomy incision (n=29)	In-hospital mortality Conversion to full sternotomy Bleeding requiring reoperation Postoperative renal failure Blood products administered CPB time ACC time Total hospital length of stay	0/16 (0%) vs 0/29 (0%), P=NA No conversion No exploration 0/16 (0%) vs. 3/29 (10%), p=0.54 2/16 (13%) vs 7/29 (26%), p=0.30 91.3±45.2 vs. 96.8±42.1 min, p=0.68 49.4±37.6 vs. 52.1±39.6 min, p=0.82 3.6±0.8 vs 6.2±5.1 days, p=0.05	Comparison with conventional sternotomy Robotic surgery had similar postoperative outcomes and shorter total hospital length of stay
Gao et al.[13]	Original article/19 robotic surgery patients	Operative mortality Stroke Other complications Follow-up Recurrence	No death No stroke None 1-18 months, and 100% complete None	Robotic surgery is safe, feasible and efficacious. Excellent surgical and cosmetic outcomes No comparison with standard approach
Murphy et al.[15]	Case series/3 patients underwent excision of left atrial myxomas	In-hospital mortality Conversion to full sternotomy Mean CPB time Mean ACC time Hospital length of stay Postoperative complication	No mortality No conversion 103±40 min 64±2 min 4 days No complication	Endoscopic excision of atrial myxomas with the da Vinci robotic system is feasible

ICU: Intensive care unit; LOS: Length of stay; CI: Confidence interval; CPB: Cardiopulmonary bypass; QOL: Quality of life; HRQoL: Health-related quality of life; SD: Standard deviation; ACC: Aortic cross-clamp.

atriotomy or bi-atriotomy incisions. In a study where RS was performed, a left atriotomy incision was used to remove the myxoma in the left atrium.[13] However, if the surgeon would excise the tumor, its pedicle, and its origin completely, this incision may cause a catastrophe during RS and a large septal defect may cause massive blood return to the left atrium. Thus, both caval occlusions should be established before resection of the septal tissue. According to our experience in RS, the left atriotomy incision can be used for small tumors in the left atrium and for those located in the left ventricle.

Based on our experience, 93.3% of the tumors were in the left atrium. We preferred the transseptal route following the right atriotomy incision to excise the tumor in the left atrium, its pedicle, and originating atrial wall to prevent recurrence. This approach is simple, feasible, and safe during RS. The tumors can be removed completely and as a whole single mass without multiple small pieces. However, the location of the tumor origin, its base on the interatrial wall, and pedicle of the tumor should be defined through preoperative echocardiography. This helps us where the entry point to the left atrium or septostomy incision is made to avoid unnecessary cutting through the tumor. Technically, a 4/0 prolene suture is put through the right atrial side of the tumor base, and interatrial septum is incised around the tumor base along the tumor-free area. When the tumor is separated from the septal wall, the tumor is taken outside the chest through service port using an endobag by the patient-side surgeon. The procedure is, then, completed with reconstruction of the interatrial wall. Therefore, we recommend the right atriotomy incision for robotic resection of large tumors in the left atrium.

Although biatriotomy technique can be considered the most appropriate method, it is very likely to cause the development of arrhythmia in the postoperative period.[18] In our study, biatriotomy was performed in only one patient and, in this case, adequate exposure could not be reached via left atriotomy due to the small left atrium and we switched to the right atriotomy. When a left atriotomy is done, complete resection of the tumors from the atrial septum may be difficult. The complete removal of the tumor as a single piece, transfer outside the chest and closure of the septal defect or intracardiac reconstructions may be challenging with robotic instruments. This approach also prolongs the CPB time.

There are several important points to be considered in cardiac myxoma surgery, including removing the tumor entirety without violating its capsule, leaving no residual tumor tissue, and closing the defects after the excision. Reconstructive procedures can be necessary to ensure endocardial continuity. Performing these procedures can be more challenging with RS. In our study, during resection of these tumors, the base or origin of the tumor and tumor-free atrial wall around the tumor base were widely resected to prevent tumor recurrence. The whole base of the tumor was resected as large as possible with a tumor-free septal or atrial wall around the tumor base. We attempted to leave a healthy tissue behind after resection of the tumors. Also, in some cases, surgical reconstruction of the left atrial wall with pericardial patch was needed, if the integrity of the endocardium was disrupted during resection. Therefore, we performed reconstruction to the left atrial wall in 14 patients with a large tumor base, while only four of them had an isolated tumor originated from the left atrial wall. On the other hand, in small atrial myxomas with a narrow origin from the interatrial septum, resection of tumor was performed with a limited excision of septal tissue around its base. There was enough tissue left to closure the septum primarily, and we did not need to repair with pericardial patch. Thus, 18 of 41 patients with myxomas originating from the atrial septum underwent pericardial patch repair after excision of the tumors. The other cases underwent primary closure of the septal defects. We had no difficulty in any of these stages, and the tumors were removed from the cardiac cavity.

In cardiac surgery, a delicate hemostasis is essential for an uneventful postoperative course. Regarding postoperative bleeding in RS, there are several potential sites that include port places, aortic puncture site for cardioplegia needle, and atriotomy incision. In conventional cases using MS incision, hemorrhage can be related to sternotomy incision, puncture sites of sternal wires, jugular area, mediastinal vessels, central artery and veins, pericardial incision, cannulation sites, and atriotomy incision. Review of the literature reveals that blood loss and blood product use in RS is less than conventional procedures.[4,5,9] In our study, the amount of postoperative blood loss and blood product use in the RS group were significantly less than MS cases. In addition, no postoperative exploration was needed in either group. However, the blood transfusion rate was 31.3% in the RS group and 66.7% in the MS group. The mean blood product use was 0.6 U and 1.8 U, respectively. Based on these findings, we can speculate that there can be two reasons for this situation. First, the lowest value of preoperative hematocrit level in both groups was about 29 to 30% and blood products was given due to hemodilution. Second, blood loss occurred to the surgical field during surgery. In RS, we observed that blood loss to the field was very low. In other words, when atriotomy was done, the cavity was almost completely aspirated to the pump sucker. Therefore, the reason for less blood product use in the RS group might be hemodilution in some patients with a low preoperative hematocrit value. In MS cases, blood transfusion can be necessary due to a low preoperative hematocrit value, as well as blood loss to the surgical field before and after CPB.

In closed-chest procedures including video-assisted surgery or RS, the transfer of the tumor to the outside the chest cavity through a small working port is an issue to be solved. In the market, laparoscopy endobags are available for tissue extraction. However, in our experience, a home-made endobag was prepared using latex gloves to transfer very large masses outside the chest cavity through a service port of 2 to 3 cm in diameter. The masses were placed in the endobag in the thoracic cavity and, then, taken out from the service port. Thus, the skin incision did not need to be expanded. Thus, the breakup of the tumor into small pieces in the chest cavity or iatrogenic embolization to the atrium could be prevented.

Furthermore, robotic-assisted cardiac surgery provides many advantages for patients, as well as cardiac surgeons. The absence of a sternotomy incision provides patients to have less postoperative pain, excellent cosmetic results, and early return to normal daily life.[4-16] Also, the atrial retractor arm of the robotic system provides comfort and convenience to the cardiac surgeon with its easy manipulation and technological features of the three-dimensional camera. The da Vinci surgical robotic system can easily transfer the surgeon's wrist movements to the arms of the device. Tremor filtration also provides an improved surgical precision in tight spaces. Thus, the intracardiac mass can be easily reached and can be removed entirely.

On the other hand, the RS approach has certain disadvantages. One of them is the necessity of a well-trained and experienced patient-side surgeon to assist the console surgeon. Some surgeons believe that RS can be done easily with anyone on the patient-side. However, this is not safe for the patient and for the feasibility of robotic procedures. Another disadvantage is its high cost. However, in a study, no significant difference was found in the total cost between open surgery and RS, when the contribution of faster return to normal daily life to the economy was considered.[19] Also, we recently showed that the outcomes of RS could be comparable to transcatheter procedures.[20] This finding indicates that RS is a reasonable alternative to percutaneous procedures.

In our routine RS protocol, we do not have any strong exclusion criteria for robotic procedures. Concomitant morbidities such as peripheral artery disease, coronary disease or moderate-to-severe aortic regurgitation can be considered as major limitations. In particular, intensive pleural adhesions may complicate the procedure during pleural dissection. In some patients, there may be a difficulty in cannulation of the right internal jugular vein or femoral vessels. The use of ultrasound probe for venous access and transesophageal echocardiography for cannulations is a must in RS procedures to prevent unexpected complications. As the team establishes cannulation and robotic docking uneventfully, we believe that there would be no more risks for a conversion to sternotomy. The literature reports confirm us that most conversions in RS have been seen before docking of the system.[21]

In Turkey, RS is also used by experienced centers in complex cases, and case series are published.[4-9] According to the distributor and proctors, active RS program should include more than 50 to 100 cases per year. Currently, there are only three centers in Turkey using RS technique routinely in cardiac surgery. Of note, this is a chance for young surgeons and our community. All young surgeons, residents, and trainees should be encouraged and educated in minimally invasive techniques. Future symposiums, courses and congress would also increase the application of RS by more surgeons. We believe that RS would be preferred more widely in the near future.

This is a short-term, retrospective study with a small sample size. Therefore, further large-scale, long-term, prospective studies are needed comparing RS with endoscopic mini-thoracotomy procedures.

In conclusion, robotic surgery is a feasible and safe alternative approach for patients undergoing excision of cardiac myxomas. The robotic surgery approach causes less pain, requires less blood product use, and provides excellent cosmetic results. We believe that, when the cost problem is solved, robotic surgery would be the most preferred method of minimally invasive cardiac surgery in the future.

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