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Minimally invasive approaches to primary cardiac tumors: A systematic review and meta-analysis

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Abstract

Objective: Cardiac tumors are rare conditions. The vast majority of them are benign yet they may lead to serious complications. Complete surgical resection is the gold standard treatment and should be performed as soon as the diagnosis is made. Median sternotomy (MS) is the standard approach and provides excellent early outcomes and durable results at follow-up. However, minimally invasive (MI) is gaining popularity and its role in the treatment of cardiac tumors needs further clarification.

Methods: A systematic literature review identified 12 candidate studies; of these, 11 met the meta-analysis criteria. We analyzed outcomes of 653 subjects (294 MI and 359 MS) with random effects modeling. Each study was assessed for heterogeneity. The primary endpoints were mortality at follow-up and tumor relapse. Secondary endpoints included relevant intraoperative and postoperative outcomes; tumor size was also considered.

Results: There were no significant between-group differences in terms of late mortality (incidence rate ratio [IRR]: MI vs. MS, 0.98 [95% confidence interval [CI]: 0.25–3.82], $p = .98$). Few relapses (IRR: 1.13; CI: 0.26–4.88; $p = .87$) and redo surgery (IRR: 1.92; 95% CI: 0.39–9.53; $p = .42$) were observed in both groups; MI approach resulted in prolonged operation time but that did not influence the clinical outcomes. Tumor size did not significantly differ between groups.

Conclusion: Both MI and MS are associated with excellent early and late outcomes with acceptable survival rate and low incidence of recurrences. This study confirms that cardiac tumor may be approached safely and radically with a MI approach.

1 | INTRODUCTION

Primary cardiac tumors are rare entities.[1] Approximately 75% are benign with nearly 50% being myxoma.[2,3] Surgery should be performed soon after diagnosis. The long-term prognosis of benign tumors is excellent,[1] but complete removal of the mass is mandatory. Cardiac tumors should be excised with a margin of normal tissue to reduce the potential for recurrence. While recurrence rates of benign cardiac tumors are low, relapse is likely the consequence of inadequate excision of the tumor.[4] Additionally, cardiac chambers should be irrigated and suctioned to prevent embolization of fragments. If a defect is created, it should be closed primarily or with a

Abbreviations: CC, cross clamp; CI, confidence interval; CPB, cardiopulmonary bypass; IRR, incidence rate ratio; LoS, length of hospital stay; MI, minimally invasive; MS, median sternotomy.

patch. Median sternotomy (MS) is the common approach for cardiac tumor since it provides excellent exposure. This traditional approach is associated with excellent early and late clinical outcomes and remains the gold standard treatment for primary cardiac tumors.[1]

Minimally invasive (MI) surgery has emerged as an alternative method to MS. Nevertheless, a main criticism of the MI approach is that, given the limited exposure of the surgical field and the surrounding structures, complete and durable eradication of the cardiac tumor may be compromised compared to the MS approach.

Therefore, the aim of this pairwise meta-analysis was to investigate whether MI may achieve the same early and late outcomes as MS surgery in the context of primary cardiac masses.

2 | METHODS

2.1 | Search strategy

Ethical and internal review board approval was not required for this analysis as no human or animal subjects were involved and no individual patient data was used; need for patients' consent was waived. Data will be available on request.

The meta-analysis was performed in accordance with the preferred reporting items for systematic reviews and meta-analyses statement[5] and the meta-analysis of observational studies in epidemiology guidelines.[6] We performed a search of the PubMed, Google Scholar, Ovid MEDLINE, and Ovid EMBASE databases for studies on minimal access surgery. Searches were performed during September of 2019 and used the following search terms: (a) "minimally invasive cardiac tumor" (Title/Abstract); (b) "cardiac tumor" (Title/Abstract); (c) "cardiac myxomas" (Title/Abstract); (d) "benign cardiac tumor" (Title/Abstract); (e) "primary cardiac tumor" (Title/Abstract); and (f) "valve tumors" (Title/Abstract).

2.2 | Study selection and inclusion criteria

Articles reporting early and late outcomes for MI and MS procedures were included. Studies were excluded from the analysis if: data was in a non-extractable format; data was duplicated; or the research was performed in an animal model. Two assessors (MM, MR) independently reviewed the titles and abstracts of potentially eligible studies and selected studies that met the inclusion or exclusion criteria for full-text retrieval and further examination. Any disagreement was resolved by discussion with a third author (MG). Inter-rater agreement was assessed using Cohen's κ coefficient. Librarians were not involved in the research.

2.3 | Outcomes

Primary outcomes were both late mortality and tumor relapse at last follow-up. Secondary outcomes were: cardiopulmonary bypass (CPB) and cross clamp (CC) times, tumor size, re-exploration for bleeding, renal failure, respiratory failure, neurological complications (transient ischemic attack and stroke), in-hospital mortality, re-do surgery at follow-up and total length of stay (LOS). Need for conversion to sternotomy was also recorded in the MI group as a safety endpoint.

TABLE 1 Criteria for quality assessment

Quality checklist
Selection
1. Assignment for treatment—any criteria reported? (If yes, 1-star)
2. How representative was the "reference" group (MI) in comparison to the "alternative" group (MS); (If yes, 1 star, no star if the patients were selected or selection of group was not described)
Comparability
Comparability variables: (1) age; (2) gender; (3) renal function; (4) extracardiac arteriopathy; (5) poor mobility; (6) previous cardiac surgery; (7) chronic lung disease; (8) active endocarditis; (9) urgency; (10) DM; (11) NYHA; (12) CCS IV; (13) LV function; (14) recent coronary syndrome; (15) pulmonary hypertension; (16) urgency; (17) BSA; (18) tumor type (histology/location); (19) tumor size.
3. Groups comparable for 1, 2, 3, 4, 5, 6, 7, 8, 9 (If yes, 1-star was assigned for each of these. No star was assigned if the groups differed)
4. Groups comparable for 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 (If yes, 1-star was assigned for each of these. No star was assigned if the two groups differed).
Outcome assessment
6. Clearly defined outcome of interest (If yes, 1-star).
7. Follow-up (1-star if described).

Note: Comparability are based on the EuroSCORE II risk-factors and tumor type (histology/location) and size.

Abbreviations: BSA, body surface area; CCS, Canadian Cardiovascular Society; IDDM, insulin dependent diabetes mellitus; MI, minimally invasive; MS, median sternotomy; NYHA, New York Heart Association.

2.4 | Quality scoring

Modified Newcastle–Ottawa scale was used for quality assessment of each study. Studies attaining equal/greater than the median score of 10 (out of a maximum 19) were defined to have "higher matching quality."[6] Modified Newcastle–Ottawa scoring criteria are shown in Table 1 and quality scoring results are reported in Table S1.

2.5 | Heterogeneity and publication bias

Inter-study heterogeneity was explored using the χ^2-statistic, but the I^2 value was calculated to quantify the degree of heterogeneity across trials that could not be attributable to chance alone. If heterogeneity was significant ($I^2 > 75\%$), three strategies were used to assess data validity and heterogeneity: (1) a subgroup analysis of higher quality studies (quality score ≥10); (2) funnel plots to evaluate publication bias

(i.e., funnel asymmetry) with Egger's test; and (3) a meta-regression to assess the effects of covariates on the primary outcome of interest.

A domain-based evaluation of risk of bias was performed in accordance with the guidelines outlined in the Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.08 as previously described.[7] Three authors (MM, MG, GN) subjectively reviewed all studies included in this review and assigned a value of "critical," "serious," "moderate" or "low" to the following questions: (Domain 1) Was the allocation sequence adequately generated? (D2) Was allocation adequately concealed? (D3) Was the treatment adequately classified? (D4) Were data affected by deviation from intended intervention? (D5) Were incomplete outcome data sufficiently assessed? (D6) Are reports in the study free of the suggestion of selecting outcome measures or (D7) of selective outcome reporting?; "Risk of bias" plots were performed using package "plotvis" R-project, following the Review Manager Version 5.3 layout (The Cochrane Collaboration, Software Update).

2.6 | Statistical analysis

Measurement data are reported as the mean ± standard deviation. The analysis used a random effects model (inverse-variance method). For short term categorical outcomes, risk difference with 95% confidence interval (CI) were used, as many studies have zero events in both sides. For continuous outcomes, standardized mean difference (SMD) and 95% CI were used. For late outcomes, incidence rate ratio and 95% CI were estimated from the total number of events observed within a treatment group out of the total person-time of follow-up for that treatment group.[8] Meta-regression was used to assess the effect of sample size, age, gender, chronic obstructive pulmonary disease, New York Heart Association (NYHA), previous stroke or transient ischemic attack (TIA) and redo surgery on the primary outcomes and secondary outcome (perioperative mortality).

Hypothesis testing for equivalence was set at the two-tailed 0.05 level. Analyses and data modeling were performed with R-project (version 3.3.3 R project for Statistical Computing), following packages were used: "metafor," "stats," and "graphics" for data visualization.

3 | RESULTS

3.1 | Study characteristics

Our research revealed 11 studies fulfilling these inclusion criteria,[9–19] producing a pooled data set of 653 patients of whom 294 underwent MI and 359 underwent MS cardiac tumor excision (Table 3) (Figure 1).

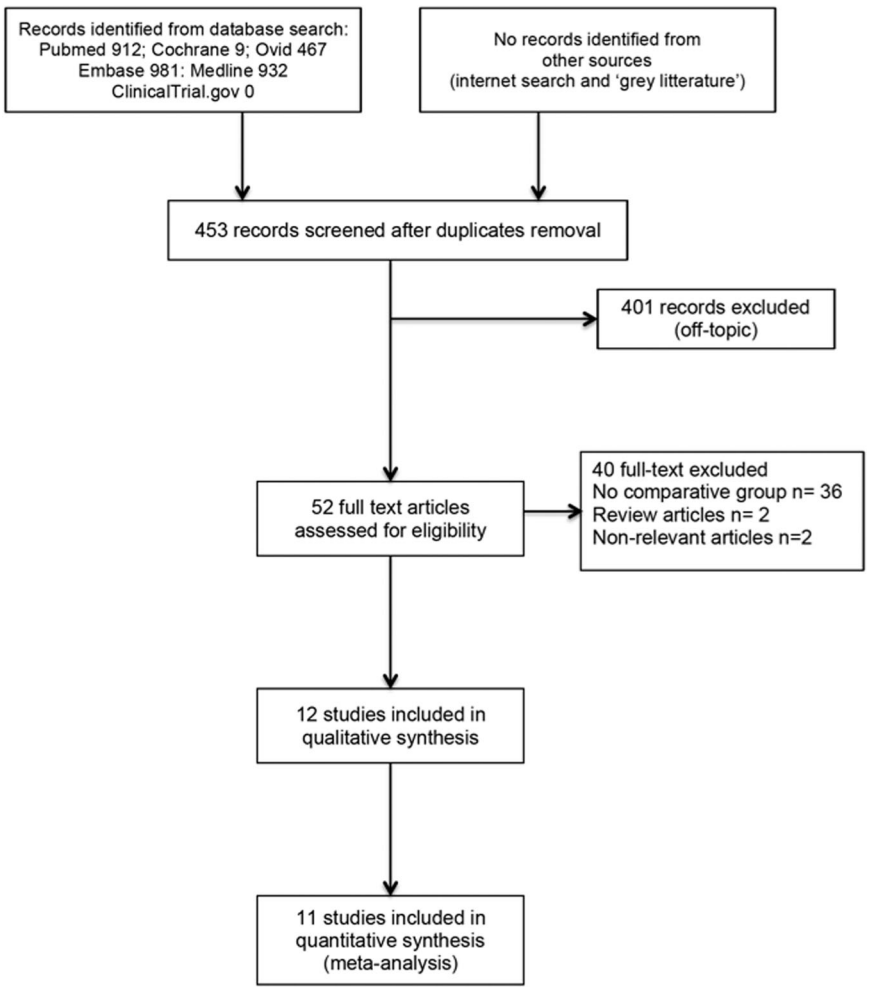

FIGURE 1 Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow chart

There was 100% concordance between reviewers equating to a Cohen's kappa coefficient of $\kappa = 1$. The mean sample size was 59.3 (median 38.5) patients (range, 5–250 patients) and the mean follow-up duration was 33.3 (median 40.3) months, (range, 3.7–56 months). All included studies were retrospective; six studies[10–14,16] included two homogeneous populations and were considered high-quality (median equal or above 10, Table 2); 601 cardiac masses were myxomas (92%) with most prevalent location at the level of the left atrium (Table 2).

3.2 | Definition of minimally invasive

Studies who were eligible for inclusion in the MI group included those reporting: minimally invasive approach as right mini-thoracotomy (4–6 cm) at the level of the third or fourth intercostal space with or without video assistance, with central and or peripheral cannulation, with external or internal aortic clamping; minimally invasive approach as upper or J-shape mini sternotomy; robotic minimally invasive series.

Given that atrial myxoma was the most frequent cardiac mass, right mini-thoracotomy was the most utilized minimally invasive access[10,11,14,15,17–19]; for aortic valve masses a parasternal incision (4–5 cm with rib resection and reattachment) was performed in some cases.[11] Robotic or robotic assisted approach was used in Shilling,[12] Yang,[13] and Moss.[16]

3.3 | Primary outcome

Results for primary and secondary endpoints in each study are summarized in Table 3. There was no difference in mortality at follow-up between patients who underwent MI and MS (IRR: 0.98; 95% CI: 0.25–3.82; $p = .98$) and the groups were homogeneous (χ^2 1.5, I^2 0%, $p = .91$). Similarly there was no difference in tumor recurrence (IRR: 1.13; CI: 0.26–4.88; $p = .87$) with low heterogeneity ($p = .9$) (Figure 2A,B). The overall mean follow-up duration was 33.31 months (range, 3.7–56 months).

3.4 | Secondary end-points

Cardiopulmonary bypass time and cross clamp time were significantly longer in the MI group (SMD: 0.73; 95% CI: 0.32–1.13; $p < .01$); (0.32; 95% CI: 0.08–0.56; $p < .1$) (Table 3), yet with no effect on postoperative clinical outcome. On the contrary the MI approach resulted in reduced LOS (SMD: −1.59; 95% CI: −2.35, −0.82; $p < .01$); however significant heterogeneity was observed ($p < .01$). There was no difference in term of reopening for bleeding (RD: −0.01; 95% CI: −0.03, 0.01; $p = .59$), TIA/stroke (RD: −0.01; 95% CI: −0.03, 0.01; $p = .22$), respiratory failure (RD: −0.00; 95% CI: −0.02, 0.01; $p = .6$) and renal failure (−0.00; 95% CI: −0.02, 0.01; $p = .62$), with no heterogeneity. Need for future re-do surgery was similar among the two groups;(IRR: 1.92; 95% CI: 0.39–9.53], $p = .42$), with low-heterogeneity ($p = .98$ and 1, respectively).

Tumor size did not differ significantly between MI and MS (SMD: −0.47; 95% CI: −1.29, 0.35; $p = .26$); average maximum diameter was 12.6 versus 13.6 mm for MI and MS, respectively.

There was no in-hospital or 30-day mortality. No conversions to sternotomy were reported (Table 3).

3.5 | High-quality studies

The overall quality of studies is summarized in Table S1. Of 11 included studies, 6 were rated as high-quality (≥10 points). Subgroup analysis of the high-quality studies revealed no significant between-group difference in terms of the primary outcomes late mortality and recurrence (IRR: 0.47; 95% CI: 0.07–3.07; $p = .43$ and IRR: 1.47; 95% CI: 0.09–25.5; $p = .78$, respectively) (Figures S1 and S2); CPB and CC time were significantly longer in the MI group yet no effect on postoperative outcome was noted (Table S2).

3.6 | Subgroup analysis: robotic

Three studies included robotic surgery. Similar to the overall population, the robotic approach was as safe as the MS approach with similar early postoperative outcomes (Table S3); LOS was significantly reduced in the robotic group (SMD: −0.91; 95% CI: −1.58, −0.24: $p < .01$), yet heterogeneity was detected ($p < .01$); given the limited robotic sample size, no analysis at follow-up could be carried out.

3.7 | Heterogeneity assessment: bias exploration

A risk of bias analysis was performed for all included studies as per the Cochrane guidelines. Overall, there was a high level of bias due to the fact that a majority of studies were not randomized or blinded. Moreover, we assigned scores for each of the domains D1–D7. No study fulfilled all of these criteria (Figure 3). Funnel plots were used to assess publication bias for all primary and secondary outcomes. There was no funnel plot asymmetry for the primary outcome late survival (Figure S3) and tumor relapse at follow-up (Figure S4).

3.8 | Meta-regression

In the multi-variable model (total sample size, age, sex, COPD, NYHA class, previous stroke/TIA, redo, CPB), no association with the primary outcome late survival/recurrence or perioperative mortality was observed. Table S4 provides a list of overall meta-regression coefficients.

TABLE 2 Study characteristics

Author, year(total patients)study type	MI/ MS (*N*)	Age(year/old)		Sex(female) (no, %)		BSA (m^2),BMI (kg/m^2)		Tumor Size(max diameter, cm)		Tumor histology and location	
		MI	MS	MI	MS	MI	MS	MI	MS	MI	MS
Ravikumar, 2000 (*n* = 5) Retrospective	2/3	33.5	43.3	2 (100)	2 (66.3)	NA	NA	NA	NA	Myxoma 2 (100%)	Myxoma 2 (66.3%) Chondrosarcoma 1 (33.3%)
Iribarne, 2010 (*n* = 74) Retrospective	38/36	52.4 ± 2.8	59.9 ± 2.6	29 (76.3)	23 (63.8)	26.5 ± 1	26.7 ± 0.8	8.5 ± 1.7	13.2 ± 2.6	Left atrium 16 (44.4%) Right atrium 12 (33.3%) Aorta 4 (11.1%) Other 4 (11.1%) Myxoma 18 (50%) Papillary fibro. 8 (22.2%) Thrombus 3 (8.3%) Vascular malformation 4 (11.1%) Other 3 (8.3%)	Left atrium 30 (79%) Right atrium 4 (10.5%) Aorta 3 (7.9%) Other 1 (2.6%) Myxoma 26 (68.4%) Papillary fibro. 5 (13.2%) Thrombus 4 (2.6%) Vascular malformation 1 (2.6%) Other 2 (5.3%)
Pineda, 2014 (*n* = 39) Retrospective	22/17	62 ± 17	57 ± 12	18 (81.8)	12 (70.6)	NA	NA	7.5 (4-19.7)		Left atrium 22 (56.4%) Aortic valve 8 (20.5%) Right atrium 6 (15.4%) Left ventricle 2 (5.1%) Right ventricle 1 (2.6%) Myxoma 26 (66.7%) Papillary fibro. 9 (23.1%) Thrombus 4 (10.2%)	
Shilling, 2012 (*n* = 45) Retrospective	16/29	53.1 ± 15.2	58.8 ± 11.4	11 (69)	21 (72)	34.6 ± 6.8	28.6 ± 5.3	NA	NA	Left atrium 16 (100%) Myxoma 16 (100%)	Left atrium 29 (100%)Myxoma 29 (100%)
Yang, 2015 (*n* = 93) Retrospective	49/44	47.7 ± 13	51.2 ± 12.1	25 (51)	26 (59)	23.2 ± 3.6	23.5 ± 3.8	4.8	4.3	Left atrium 45 (91.8%) Right atrium 4 (8.1%) Myxoma 49 (100%)	Left atrium 39 (88.6%) Right atrium 5 (11.3%) Myxoma 44 (100%)
Sawaki, 2015 (*n* = 23) Retrospective	7/16	68.7 ± 7.8	62.6 ± 18.1	3 (43.3)	12 (75%)	23.4 ± 2.4	23.9 ± 4.1	16 ± 9	16.7 ± 8.9	Left atrium 6 (86%) Right atrium 1 (14%) Myxoma 7 (100%)	Left atrium 13 (81%) Right atrium 2 (13%) Other 1 (6%) Myxoma 12 (75%) Thrombus 2 (13%) Hemangioma 1 (6%) Hamartoma 1 (6%)

(Continues)

TABLE 2 (Continued)

Author, year(total patients)study type	MI/ MS (N)	Age(year/old)		Sex(female) (no, %)		BSA (m^2),BMI (kg/m^2)		Tumor Size(max diameter, cm)		Tumor histology and location	
		MI	MS	MI	MS	MI	MS	MI	MS	MI	MS
Lee, 2016 (*n* = 146) Retrospective	63/83	51.5 ± 14.6	54.8 ± 13.9	54 (86)	51 (61)	23 ± 2.9	23.1 ± 2.7	3.7 ± 1.8	3.5 ± 1.5	Left atrium 60 (95%) Right atrium 3 (5%) Myxoma 63 (100%)	Left atrium 75 (90%) Right atrium 5 (6%) Left ventricle 2 (3%) Right ventricle 1 (1%) Myxoma 83 (100%)
Moss, 2016 (*n* = 69) Retrospective	30/39	55.1 ± 13.1	59.5 ± 13.4	23 (76.7)	27 (69.2)	29 ± 7.5	28.6 ± 6.1	NA	NA	Left atrium 30 (100%)	Left atrium 39 (100%)
Dong, 2018 (*n* = 66) Retrospective	30/36	56 ± 6.5	53.9 ± 5.9	24 (80)	27 (75)	21.7 ± 1.8	22.6 ± 2.1	44.5 ± 2.7	45.9 ± 3.6	Left atrium 30 (100%) Myxoma 30 (100%)	Left atrium 36 (100%) Myxoma 36 (100%)
Ellouze, 2018 (*n* = 43) Retrospective	20/23	61 ± 12	56 ± 12	14 (70)	14 (61)	26 ± 4	25 ± 6	3.8 ± 1.8	4.1 ± 1.9	Left atrium 18 (90%) Right atrium 2 (10%)	Left atrium 19 (82%) Right atrium 4 (17.3%)
Lou, 2019 (*n* = 50) Retrospective	17/33	55.9 ± 18.2	54.4 ± 17.3	12 (70.6)	19 (57.6)	NA	NA	NA	NA	Left atrium 40 (80%) Right atrium 8 (16%) Left ventricle 1 (2%) Right ventricle 1 (2%) Myxoma 46 (92%) Lipoma 2 (4%) Rhabdomyoma 1 (2%) Fibroma 1 (2%)	

Note: Data are presented as mean ± *SD* or number.

Abbreciations: BMI, body mass index; BSA, body surface area; MI, minimally invasive; MS, median sternotomy.

TABLE 3 Overall results of meta-analysis

Outcome	N Studies	MI	MS	Overall effect IRR	SMD	RD	95% CI	p	Heterogeneity χ^2	p	I^2
Primary outcome											
Late mortality	6			0.98			0.25; 3.82	.98	1.5	.91	0%
Late relapse	6			1.13			0.26; 4.88	.87	0.68	1	0%
Secondary outcome											
Early mortality[b]	11	294	359			0	−0.02; 0.02	1	0	1	0%
Bleeding	11	294	359			−0.01	−0.03; 0.01	.59	1.88	1	0%
Respiratory failure	11	294	359			−0.00	−0.02; 0.01	.6	1.98	1	0%
Renal failure	11	294	359			−0.00	−0.02; 0.01	.62	3.39	.97	0%
Neuro complication	11	294	359			−0.01	−0.03; 0.01	.22	8.34	.60	0%
Length of stay[a]	10	292	356		−1.59		−2.35; −0.82	<.01	152.42	<.01	94%
CPB time[a]	10	292	356		0.73		0.32; 1.13	<.01	49.86	<.01	82%
Cross clamp time[a]	10	292	356		0.32		0.08; 0.56	.03	18.97	<.01	53%
Late redo-surgery	6			1.92			0.39; 9.53	.42	0.41	1	0%
Tumor size	7	229	255		−0.47		−1.29; 0.35	.26	100.3	<.01	94%

Abbreviations: CI, confidence interval; CPB, cardiopulmonary bypass; IRR, incidence rate ratio; MI, minimally invasive; MS, median sternotomy; RD, risk difference; SMD, standardized mean difference.

[a]Denotes significance.

[b]Include in-hospital and 30-days mortality.

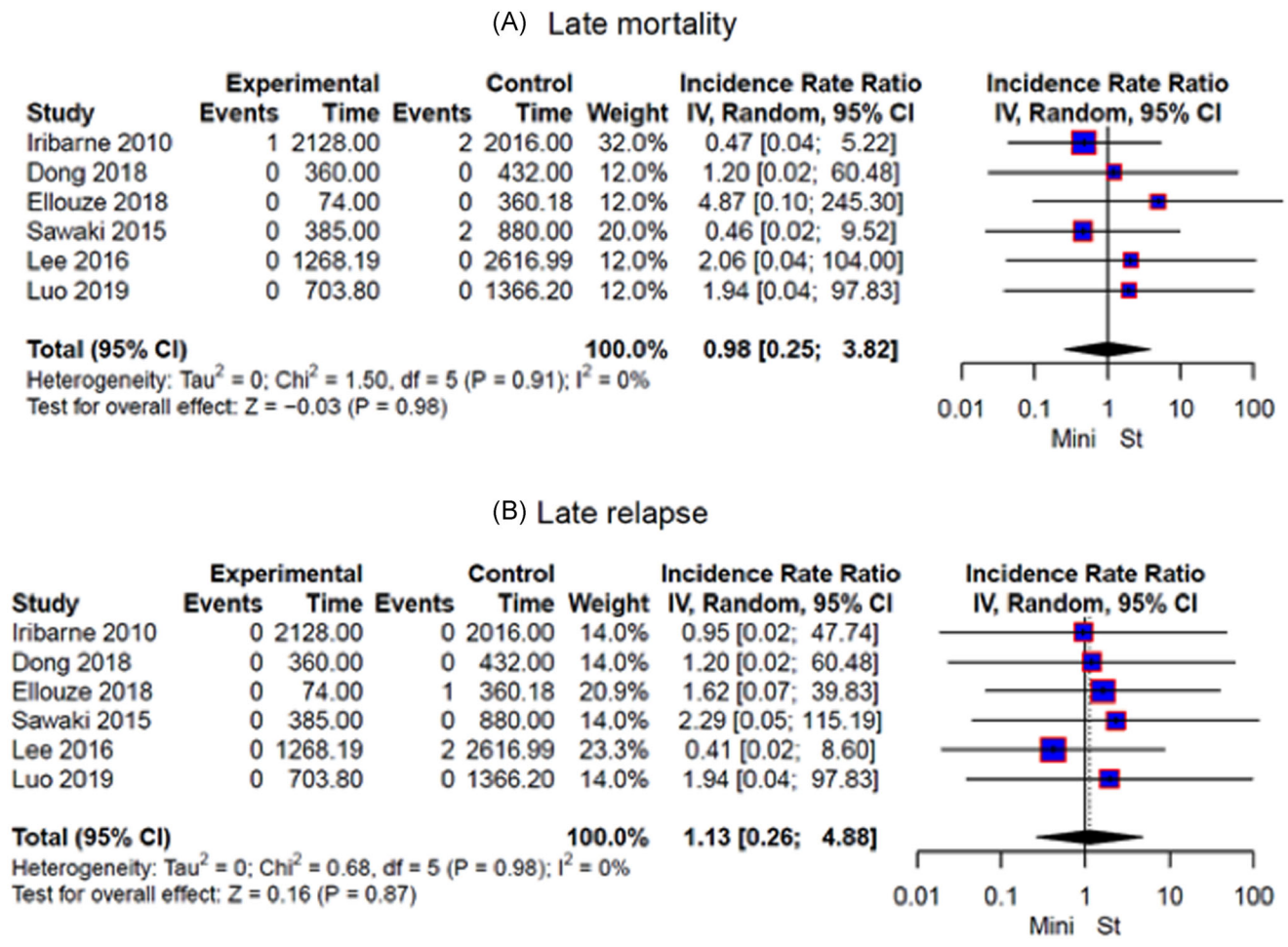

FIGURE 2 (A) Forest plot of the primary outcome late survival. (B) Forest plot of the primary outcome tumor relapse. CI, confidence interval

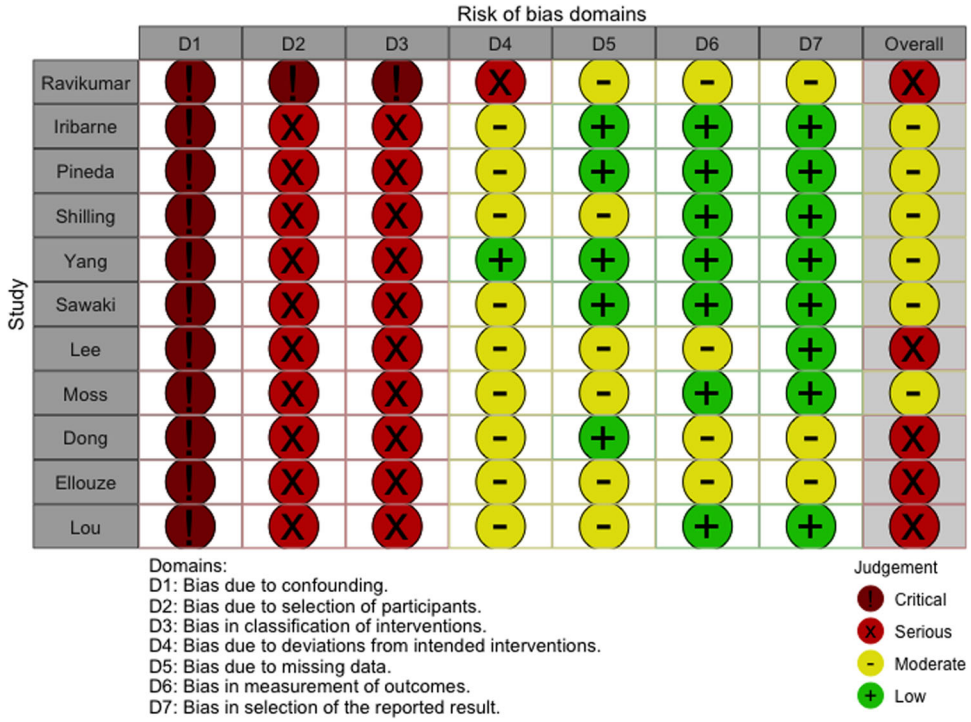

FIGURE 3 Risk of bias analysis

4 | DISCUSSION

Minimally invasive cardiac surgery has been reported since the 1990s.[14] Described benefits includes: reduced blood loss and pain, shorter LOS, and generally, superior patient satisfaction.[20] MI was also found beneficial in high-risk patients to reduce surgical trauma.[7]

Due to the rarity of intra cardiac masses few studies comparing the outcomes of MI and MS surgery have been published. The present meta-analysis, by aggregating data from 11 studies, confirms that the MI approach for cardiac tumor resection is as safe as MS, with excellent early and late outcomes, very low recurrence rates, and rare need for reoperation at follow-up.

Among the total number of 653 tumors described, 601 (92%) were myxomas, 22 (3.3%) papillary fibroelastoma, 13 (1.9%) thrombus, 6 (0.9%) vascular malformation, 2 (0.3%) lipoma, 1 (0.1%) fibroma, 1 (0.1%) rhabdomyoma, 1 (0.1%) chondrosarcoma, 1 (0.1%) hamartoma, and 5 (0.7%) classified as "other." Only Ravikumar[9] included a case of secondary atrial chondrosarcoma.

This study confirms that the MI approach requires prolonged operative time due to longer CPB and CC time. However, there was no demonstrable effect on clinical outcomes and MI had similar rates of postoperative complications as the MS approach. In line with previous studies, LOS was significantly shorter in the MI group.[20] The same results were observed in the subgroup analysis of the high-quality studies.[10–14,16]

Notably, we did not find significant differences in terms of tumor size between groups. We may speculate that large masses may preclude the MI approach. Nevertheless, even in cases of large size of the tumor, the MI approach may be still feasible.[21]

Regarding the incidence of recurrences, our results are in line with previously published literature. A retrospective study from the Mayo Clinic spanning over 50 years reported a recurrence rate of 5.6% with a MS approach.[22] Similarly, Keeling et al.[23] reported a rate of 2% and in a prospective single cohort series of patients treated with a minimally invasive approach, Bianchi et al.[24] reported an incidence of recurrence of 3.3%.

With cardiac myxoma, while a stalk base resection is generally indicated to avoid tumor recurrence, its superiority over endocardial resection is under debate. The Mayo Clinic[22] study demonstrated that there were no differences in tumor recurrence based in resection margin.

In our meta-analysis, there were no conversions to sternotomy and the rate of reopening for bleeding was similar between the two groups (safety end-point). The presence of a right atrial tumor has been reported as possible contraindication for a minimally invasive approach due to fragmentation during cannulation procedures.[25] Importantly, there was no difference in the occurrence of postoperative neurological events and no clinically relevant embolization events were observed in the MI group.

While a majority of patients included in this study had benign cardiac tumors, it worth noting that the use of MI has been described in literature in the context of primary malignant tumors.[26] The MI approach has largely been utilized with benign tumors rather than malignant tumors probably due to the greater ease of resection, the less invasive nature of benign tumors, and the lack of need for very

complex cardiac reconstructions, which would be difficult with MI access.

5 | LIMITATIONS

A main limitation inherent to the study design stems from the use of retrospective cohort studies in our pooled analyses; hence possible biases due to treatment allocation and other confounders could not be rule out. There was a certain degree of clinical heterogeneity; while most of the studies included exclusively myxoma at the level of the left or right atrium, others have included masses at the level of the aortic valve or ventricles. Follow-up times in this analysis were short with respect to tumor recurrence or survival and long-term follow-up was not always availableWe could not analyze the impact of different surgical techniques (e.g. resection with patch, endocardial resection, single vs. double atrial approach) on late recurrences. Also, all series included in the analysis were low-medium volume, likely due to the rarity of cardiac tumors. With this in mind, we could not evaluate the effect of the surgical cumulative volume on clinical outcomes. Sensitivity analysis of the robotic studies was undermined by the limited sample size; no analysis in terms of survival and relapse at follow-up could be carried out; while we may conclude that the robotic approach may be as safe as MS, we cannot validate the long-term results.

Finally, no cost-analysis could be performed.

6 | CONCLUSION

To our knowledge, the present study is the first pairwise meta-analysis comparing the early and late performance of minimally invasive versus sternotomy approaches in the context of cardiac tumors. Minimally invasive surgery was associated with excellent early and late outcomes, comparable to the MS approach. Our analysis showed that the risk of primary tumor recurrence might be independent of surgical access; this strengthens the effectiveness of MI surgery.

Further research with longer follow-up is needed to compare long-term variables, such as tumor recurrence.

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CONFLICT OF INTERESTS

The authors declare that there are no conflcit of interests.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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