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REVIEW ARTICLE

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Mini-sternotomy vs right anterior thoracotomy for aortic valve replacement

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Abstract

Background: While minimally invasive techniques for aortic valve replacement (AVR) have been shown to be safe, limited data exist comparing the varying approaches. This study aimed to compare the outcomes between two minimally invasive approaches for AVR: mini-sternotomy (MS) and right anterior thoracotomy (RAT).

Materials and Methods: A systematic search of MEDLINE, EMBASE, and OVID was conducted for the period 1990-2019. Nine observational studies (n = 2926 patients) met the inclusion criteria.

Results: There was no difference in operative mortality between MS and RAT (odds ratio [OR]: 0.87, 95% confidence interval [CI]: 0.41-1.85; $P = .709$). Meta-analyses favored MS over RAT in reoperation for bleeding (OR: 0.42, 95% CI: 0.28-0.63; $P < .001$), aortic cross-clamp time (standardized mean difference [SMD]: −0.12, 95% CI: −0.20 to 0.029; $P = .009$), and the rate of conversion to sternotomy (OR: 0.32, 95% CI: 0.11-0.93; $P = .036$). The rate of permanent pacemaker insertion approached borderline significance in favor of MS (OR: 0.54, 95% CI: 0.26-1.12; $P = .097$). In-hospital outcomes of stroke, atrial fibrillation, and surgical site infection were similar between the two groups. The length of hospital stay was shorter for RAT (SMD: 0.12, 95% CI: 0.027-0.22; $P = .012$) and the length of postoperative ventilation was borderline significant in favor of RAT (SMD: 0.16, 95% CI: −0.027 to 0.34; $P = .095$).

Mohammad Yousuf Salmasi and Hamish Hamilton contributed equally to this study.

Conclusions: This study highlights important differences in short-term outcomes between MS and RAT as approaches for AVR. This has important implications for patient selection, especially in the elderly, where such approaches are becoming more common-place.

KEYWORDS

meta-analysis, mini-sternotomy, right anterior thoracotomy, valve repair/replacement

1 | BACKGROUND

With the increasing prevalence of aortic stenosis in the elderly population,[1,2] the need for less traumatic approaches for treatment are becoming increasingly important. Minimally invasive aortic valve replacement (MIAVR) has been shown to achieve similar mortality rates to conventional aortic valve replacement, albeit with more technical demand.[3] MIAVR uses a smaller incision and avoids complete division of the sternum, conferring several benefits: lower ventilation time,[4-6] pain scores,[5,6] intensive care unit (ICU) stay,[5,7]

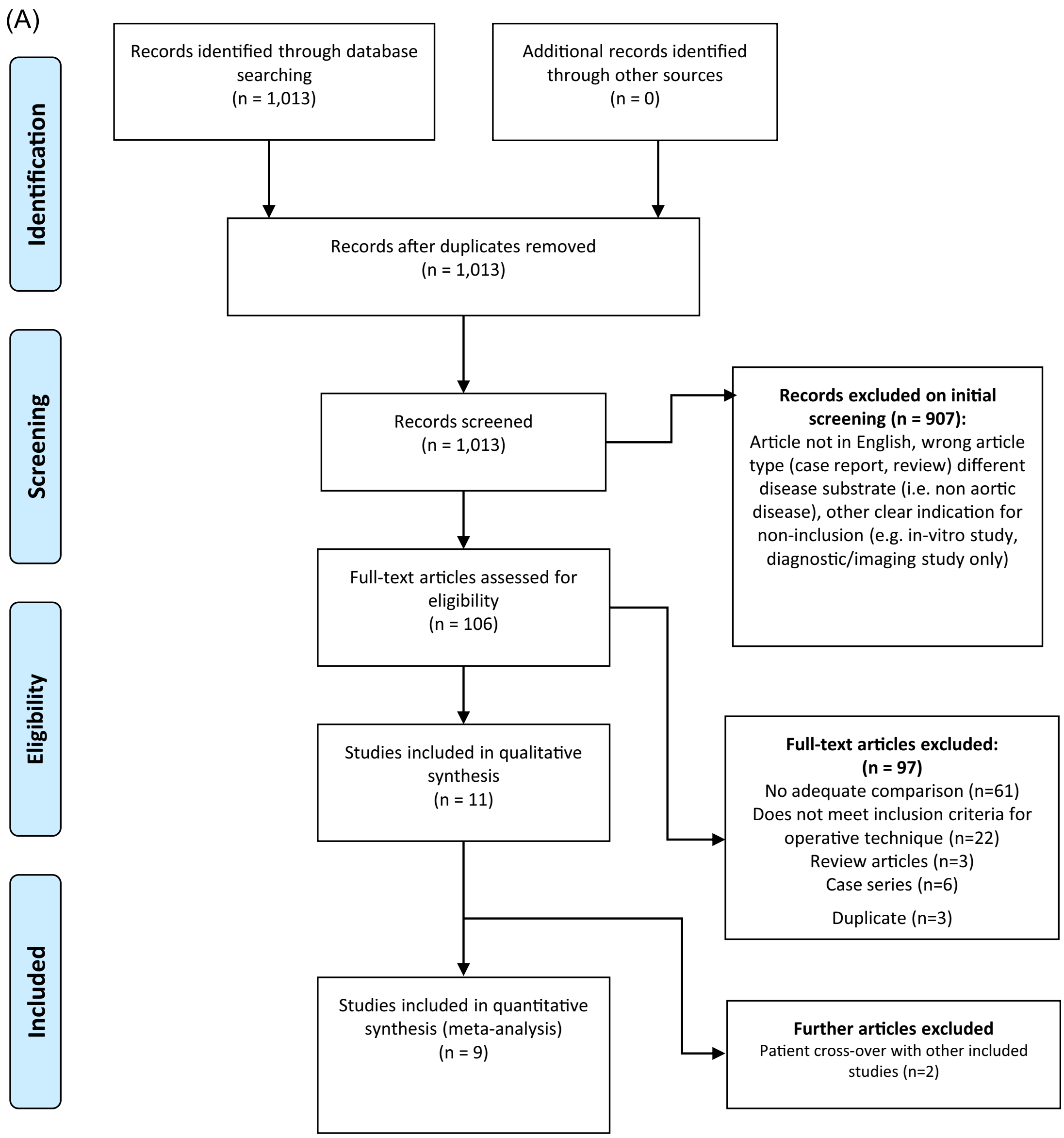

FIGURE 1 A, Study selection flow diagram. B, Risk of bias summary: green = 1 pt, yellow = 1 pt, red = 0 pt. C, Funnel plot analysis

(B)

	Cohort representative of population	Identical community in both groups	Ascertainment of exposure	Outcome of interest not present at start of study	Comparability of cohorts		Assessment of outcomes	Adequate follow-up	Loss to follow-up	Total
Fattouch 2016	a	a	a	a	c	c	b	a	d	6
Hiraoka 2014	b	a	a	a	c	c	b	a	d	6
Klococovnik 2012	a	a	a	a	c	c	b	a	d	6
Miceli 2014a	a	a	a	a	c	c	b	a	b	7
Miceli 2014b	b	b	a	a	c	c	b	a	a	5
Semsroth 2017	a	a	a	a	a	c	b	a	a	8
Tokarek 2015	a	a	a	a	c	a	b	a	d	7
Wahlers 2015	b	a	a	a	c	c	b	a	b	7
Olds 2019	a	a	a	a	a	c	a	a	b	8

(C)

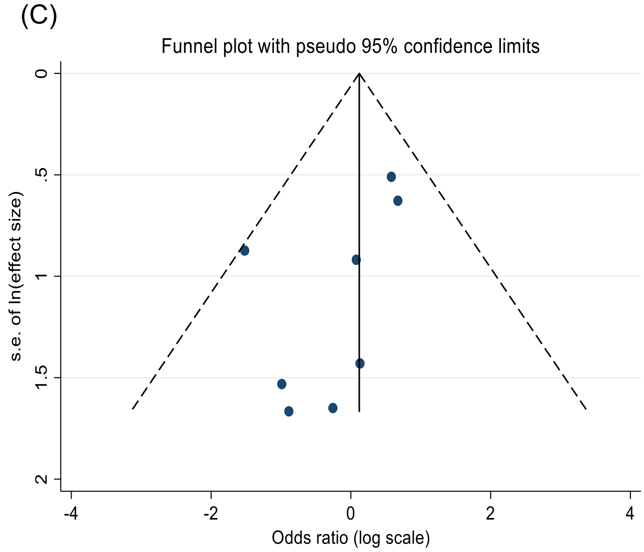

FIGURE 1 (Continued)

and hospital stay.[7,8] There is also evidence to suggest a lower transfusion requirement during surgery,[5] and a reduced volume of blood lost from chest drainage.[4,6]

Mini-sternotomy (MS) and right anterior thoracotomy (RAT) are widely reported as minimally invasive approaches for AVR. MS is performed via a 6- to 10-cm midline skin incision with J sternotomy at the third to fourth intercostal space, whereas RAT is performed via a 5- to 7-cm incision in the right second intercostal space.[9] RAT sacrifices the right internal thoracic artery and reduces the operative field more so than MS.[3]

Current US and European guidelines do not give preference to either procedure[10,11] and there are no randomized studies in the literature comparing the two approaches. With MIAVR centers set to keep increasing, guiding the choice between both minimally invasive approaches with the best available scientific evidence is crucial.

This study aims to systematically review and meta-analyze the data available from recent studies to provide a comparison of outcomes between RAT and MS as approaches for surgical AVR.

2 | MATERIALS AND METHODS

2.1 | Systematic review of the literature

This study used the framework provided by the prescribed reporting items in systematic reviews and meta-analyses.

We systematically searched OVID versions of MEDLINE and EMBASE (1990 to 2019) using the title keyword “mini sternotomy” and “right thoracotomy” combined with “Aortic valve stenosis” in humans. The folllowing were the inclusion criteria: we included all studies written in English comparing MS vs RAT in patients undergoing adult cardiac surgery that reported any of the prespecified perioperative clinical outcomes. Reference lists of important papers were searched for relevant studies missed by the search strategy.

2.2 | Study selection

Three review authors (LC, HH, and ID) independently assessed titles and abstracts of all the papers found in the electronic search. Potential studies were marked as “retrieve” and any differences between reviewers were discussed. The full text publications were retrieved and assessed, and were included if they[1] reported ≥1 of the predetermined outcomes of the review for both MS and RAT[2]; were human studies published in English. Abstracts were excluded as there was insufficient methodological reporting to allow for risk of bias assessment.

2.3 | Data extraction

A data collection form was used for study characteristics and outcome data. The following characteristics were extracted.

TABLE 1 Characteristics of included studies

Study name	Country	Study design	Intervention	n	Age	% Female	% NYHA class ≥3	Adjusted factors	Outcomes	Follow-up	NOS score
Fattouch[26]	Italy	Co, R	MS	854	72 ± 11.4	46.4	52.6	None	30 d mortality, CPB time, AoX time, stroke, reoperation for bleeding, new AF, RBCs	30 d	6
			RAT	276	72.2 ± 11.2	41.7	33.7				
Hiraoka[24]	Japan	Co, R	MS	26	71.8 ± 14.8	46		None	30 d mortality, CPB time, AoX time, stroke, reoperation for bleeding, RBCs	30 d	6
			RAT	62	56.3 ± 13.8	35					
Klokocovnik[22]	Slovenia	Co, R	MS	209	74 (64-83)	25	24	None	30 d mortality, CPB time, AoX time, stroke, reoperation for bleeding	30 d	6
			RAT	8	72 (33-78)	34	25				
Miceli[18]	Italy	Co, R	MS	155	68.5 ± 11.5	47.7	26.5	None	In-hospital mortality, CPB time, AoX time, stroke, reoperation for bleeding, new AF, RBCs	35 mo	7
			RAT	251	67.2 ± 12.8	34.3	25.9				
Miceli[20]	Italy	Co, R	MS	117	76.8 ± 6	61.9	47.70	None	CPB time, AoX time	8 mo	5
			RAT	164							
Semsroth[21]	Austria	Co, R	MS	118	72 (38-91)	49.2	54.6	Age, sex, BMI, creatinine clearance, preoperative AF, diabetes mellitus, NYHA III-IV, LVEF, aortic stenosis, COPD	AoX time, stroke, reoperation for bleeding, RBCs	5 y	8
			RAT	118	72 (34-89)	45.8	68.3				
Tokarek[16]	Poland	Co, R	MS	44	67 (57-77)	54.6	26.7	Surgical team	30 d mortality, stroke, new AF	2 y	7
			RAT	50	63 (54-73)	44	31.6				
Wahlers[25]	Austria	Co, P	MS	77	75.6 ± 6.6	50.6	57.1	None	In-hospital mortality, CPB time, AoX time, stroke, reoperation for bleeding	12 mo	6
			RAT	10	75.3 ± 13.5	60	20				
Olds[23]	USA	Co, R	MS	120	73.5 (66-80.5)	42.5		none	30 d mortality, CPB time, AoX time, stroke, reoperation for bleeding, new AF, ICU, LOS	30 d	
			RAT	267	75 (67-81)	42.7					

Note: Co, R: retrospective cohort study; Co, P: prospective cohort study; median (IQR); mean ± standard deviation

Abbreviations: AF, atrial fibrillation; AoX, aortic cross-clamp; CPB, cardiopulmonary bypass; ICU, intensive care unit; LVEF, left ventricular ejection fraction; MS, mini-sternotomy; NOS, Newcastle–Ottawa scale; RAT, right anterior thoracotomy

1. Methods: study design, number of study centers, study setting, follow-up period, date of study, and adjustments for confounding.
2. Participants: n, mean age, age range, sex, and disease severity.
3. Outcomes: binary and continuous variables

Our primary outcome was 30-day or in-hospital mortality. Secondary outcomes were conversion to sternotomy, stroke, reoperation for bleeding, incidence of atrial fibrillation, permanent pacemaker (PPM) insertion, surgical site infection (SSI) ventilation time, transfusion rate, length of stay, cardiopulmonary bypass (CPB), and aortic cross-clamp (AoX) times.

2.4 | Statistical analysis

All analyses were performed using Stata 13.0 software (Stata Corp, College Station, TX). The Mantel–Haenszel[12] method was used to create weighted pooled averages and a random effects model, as described by DerSimonian and Laird,[13] to control for unseen heterogeneity.

Binary outcome variables were presented as odds ratios (ORs). Continuous data were analyzed as a difference in means with 95% confidence intervals (CIs). In cases where continuous variables were reported as a median with range (or interquartile range), results were

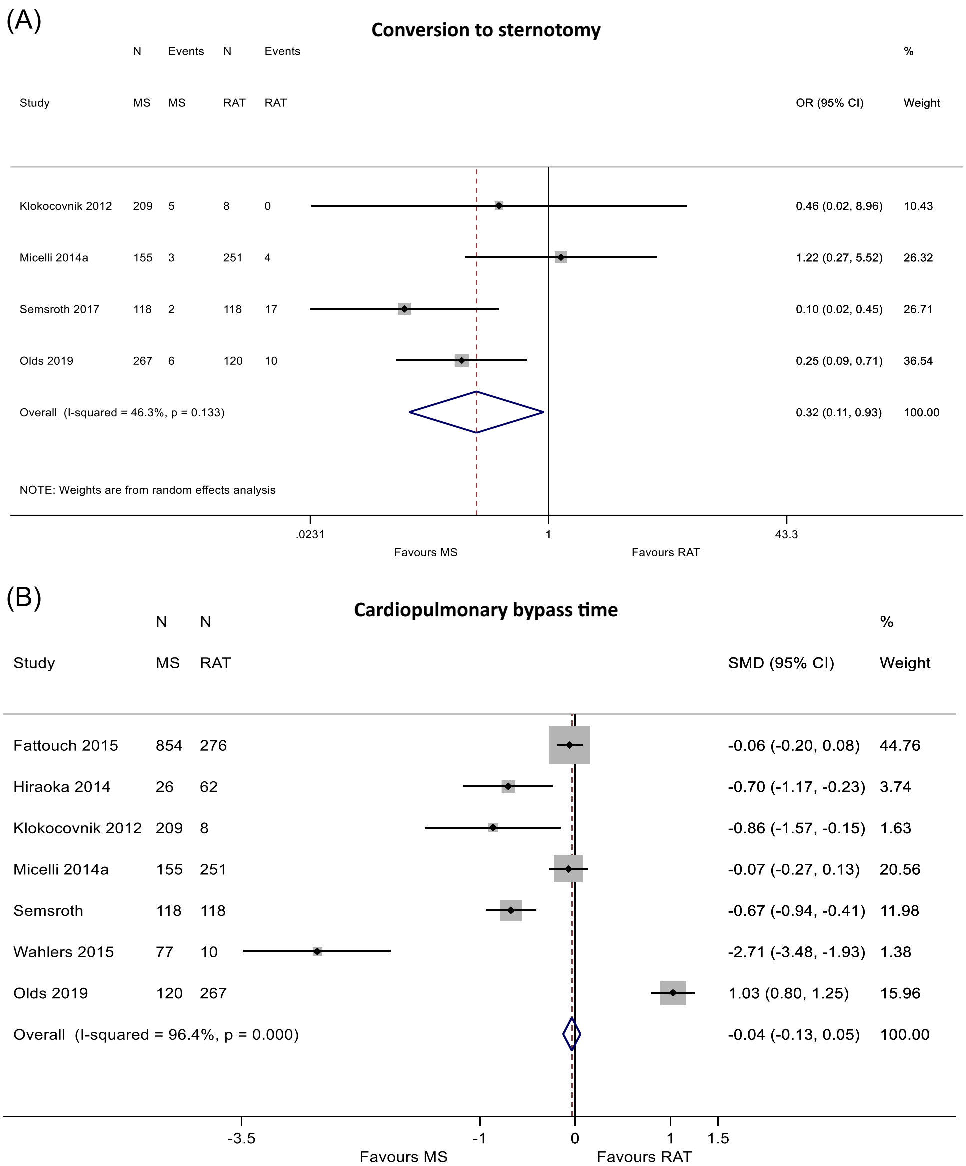

FIGURE 2 Forest plots demonstrating meta-analyses comparing operative parameters of aortic valve replacement between mini-sternotomy (MS) and right anterior thoracotomy (RAT) for: A, Rate of conversion to sternotomy; B, cardiopulmonary bypass time; C, aortic cross-clamp time

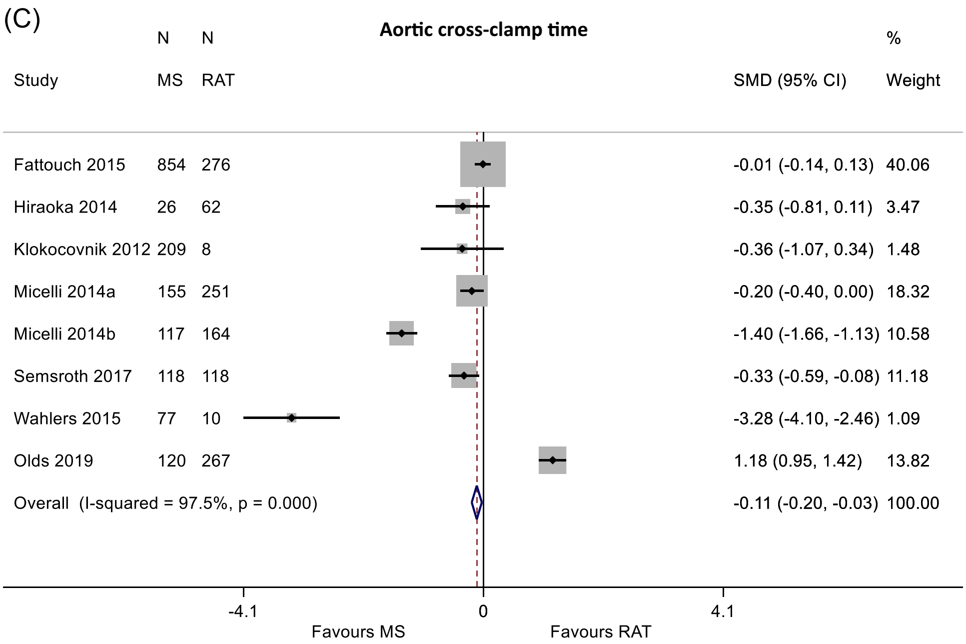

FIGURE 2 (Continued)

converted to mean and SD using the formula proposed by Wan et al.[14] This formula provides a near unbiased estimation of SD for normally distributed data and a 5% relative error for skewed data. Sensitivity analysis was then performed by removing these studies to determine if they had influenced the overall direction of the effect estimate.

2.5 | Sensitivity and heterogeneity

Sensitivity analysis was performed by removing studies that had a particularly high risk of confounding. Substantial heterogeneity was considered as a *P*-value of the χ^2 statistic of <0.10 or an I^2 statistic of greater than 50%.

2.6 | Assessment of in-study bias

Risk of bias was assessed independently by two reviewers (HH and PR) using the Newcastle–Ottawa scale (NOS).[15] The NOS is based on three components of study methodology: participant selection, comparability of cohorts, and measurement of outcomes. Funnel plot analysis assessed for publication bias.

3 | RESULTS

3.1 | Results of the search

In total, 1013 studies were retrieved through the electronic search of MEDLINE and EMBASE. Based on the titles and abstracts, 907 studies did not meet the inclusion criteria. Subsequently, 106 full texts were assessed for eligibility (Figure 1A).

From the final group of studies (11), two clusters of papers were produced by the same sets of authors, respectively, and study centers. The two published studies by Tokarek and colleagues[16,17] reported on the same cohort of patients receiving AVR: the study reporting a more complete set of variables of interest[16] was therefore included and the other excluded.

Another cluster of three studies also came from the same center using patients in similar time periods.[18-20] The study by Gilmanov[19] appeared to cross-over in its patients with the earlier Miceli study[18] and was therefore excluded.

3.2 | Included studies

Nine observational studies were identified that met the inclusion criteria; one prospective[21] and eight retrospective cohort studies.[16,18,20,22-26] These studies included 2926 patients undergoing elective, isolated MIAVR. MS was used in 1720 cases and RAT in 1206. The study by Semsroth et al[21] provided propensity matched data which was used rather than the raw data it included. Further information from included studies can be found in Table 1.

3.3 | Risk of bias in included studies

Risk of bias was assessed using the NOS (Figure 2), which has a maximum score of 9. Two studies scored 8,[21,23] three studies scored 7,[16,18,25] three studies scored 6,[22,24,26] and one study scored 5.[20] The "risk of bias summary" table provides a breakdown of the scoring (Figure 1B). Funnel plot analysis found little evidence of publication bias, while Egger's test found no small-study effects (*P* = .127) (Figure 1C).

3.4 | Intraoperative parameters

The rate of conversion to sternotomy was assessed in four studies.[18,21-23] Meta-analysis found it to be significantly lower in the MS group compared to RAT (OR: 0.32, 95% CI: 0.11-0.93; *P* = .036) (Figure 2A). CPB was shorter for MS compared with RAT (SMD: −0.36, 95% CI: −0.13 to 0.055; *P* = 0.436), being reported across seven studies (Figure 2B).

Analysis of AoX time (in minutes) demonstrated shorter times for MS compared to RAT (SMD: −0.12, 95% CI −0.20 to 0.029; *P* = .009) (Figure 2C). Wahlers et al[25] showed an abnormally large advantage for MS, which may result from RAT being performed by a single surgeon over a small number cases (n = 10). When this study was removed, the effect bordered significance (SMD: −0.080, 95% CI: −0.166 to 0.007; *P* = .071) (Figure 4). Further sensitivity analysis removing studies with converted results did not change the overall effect.[18,21,22]

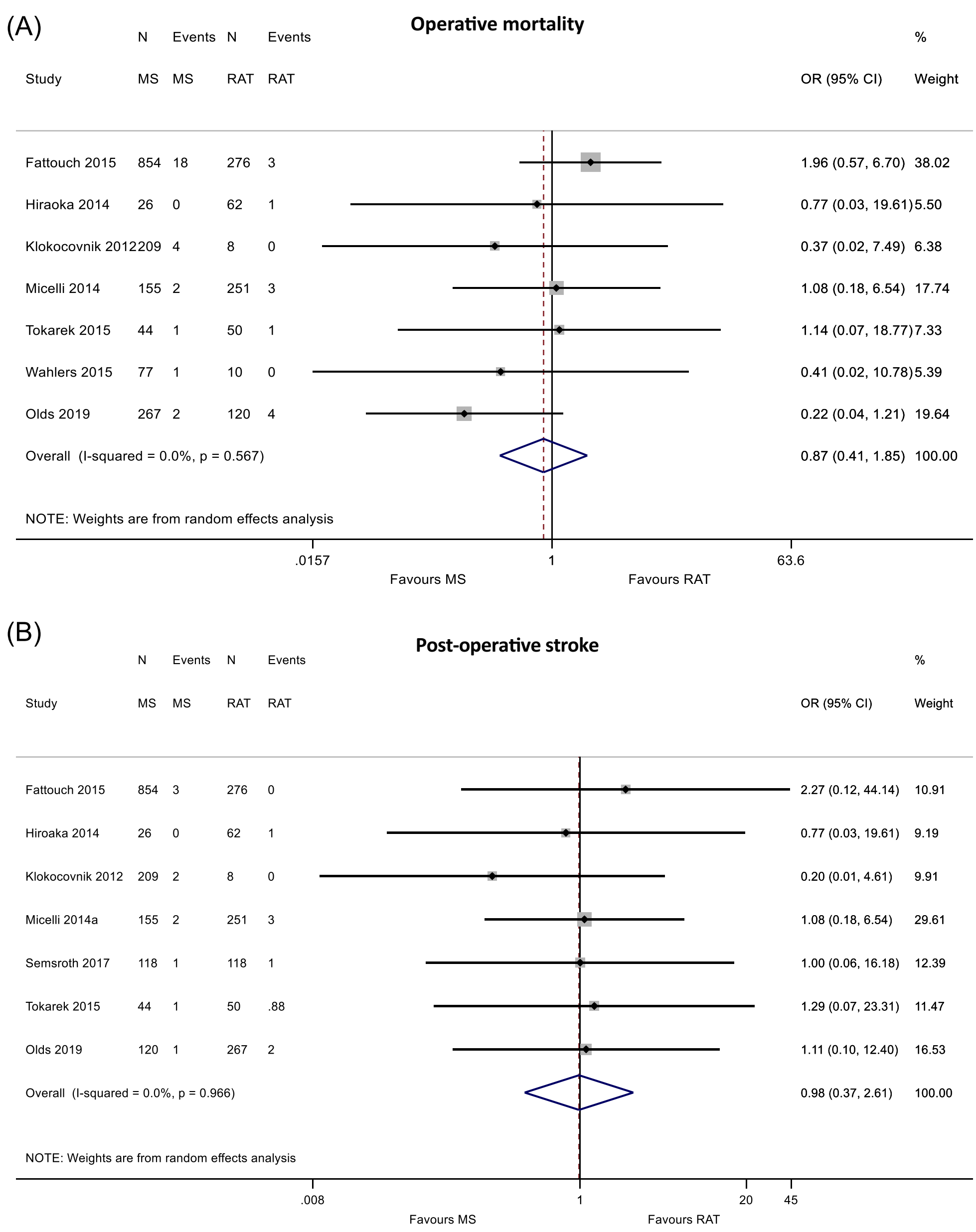

FIGURE 3 Forest plots demonstrating meta-analyses comparing outcomes of aortic valve replacement between MS and RAT for: A, operative mortality; B, stroke; C, reoperation for bleeding. MS, mini-sternotomy; RAT, right anterior thoracotomy

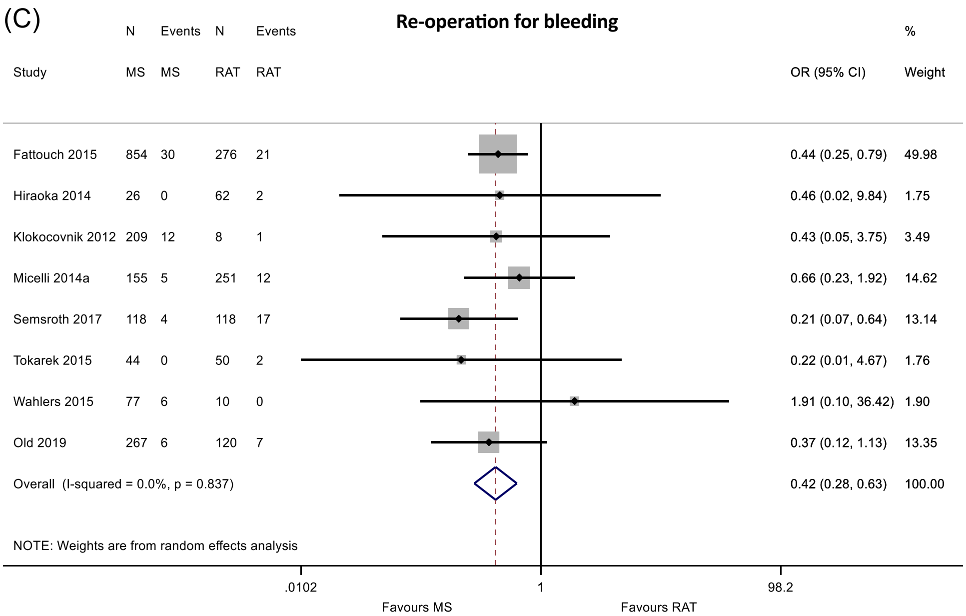

FIGURE 3 (Continued)

3.5 | Primary outcome: operative mortality

There was no difference between MS and RAT for 30-day or in-hospital mortality (OR: 0.87, 95% CI: 0.41-1.85; $P = .709$) (Figure 3A). Early mortality was reported across seven studies.[16,18,22-26] Semsroth et al[21] reported mortality at 90 days, so was not included.

3.6 | Secondary outcomes

There was no difference in the incidence of stroke between MS and RAT (OR: 0.98, 95% CI: 0.37-2.61; $P = .966$) (Figure 3B). Incidence of postoperative stroke was reported for 2558 patients across seven studies.

MS demonstrated a lower rate of re-exploration for bleeding compared with RAT (OR: 0.42, 95% CI: 0.28-0.63; $P < .001$) (Figure 3C). Reoperation for bleeding was reported for 2645 patients across eight.[16,18,21-26] Sensitivity analysis, removing a study with high levels of bias from surgeon ability and learning curve,[25] did not change the overall effect.

MS and RAT had a comparable incidence of new onset postoperative atrial fibrillation (OR: 0.68, 95% CI: 0.23-2.06; $P = .496$) (Figure 4A). Heterogeneity was significantly high in this analysis ($I^2 = 93.4\%$, $P < .001$).

The incidence of PPM insertion was not different between the two groups although meta-analysis approached significance, finding a borderline lower incidence of PPM insertion in MS compared to RAT (OR: 0.54, 95% CI: 0.26-1.12; $P = .097$) (Figure 4B). The incidence of SSI was reported in six studies,[21-26] and found to be similar between MS and RAT groups (OR: 0.65, 95% CI: 0.34-1.27; $P = .209$) (Figure 4C).

3.7 | ICU requirements and hospital stay

Postoperative ventilation time was only reported in two studies,[18,24] meta-analysis for which found no difference between MS and RAT approaches (SMD: 0.16, 95% CI: −0.027 to 0.34; $P = .095$) (Figure 5A), although the result approached borderline significance toward a lower ventilation time in the RAT group.

The length of stay in the ICU was not different between the groups (SMD: 0.002, 95% CI: −0.086 to 0.09; $P = .965$) (Figure 5B), whereas the length of total hospital stay was significantly lower in the RAT group (SMD: 0.12, 95% CI: 0.027-0.22; $P = .012$) (Figure 5C).

4 | DISCUSSION

Minimally invasive aortic valve procedures have for years demonstrated comparable safety and efficacy with conventional approaches, showing acceptable outcomes and complication rates. The benefit of enhanced recovery and patient satisfaction is becoming increasingly important in all aspects of surgical care, which is the posited main advantage of minimally invasive surgery. This must be off-set against the increased technical demand and potential complications in the post-operative period.

It is widely agreed that AVR via RAT is a more technically demanding procedure, with a more limited operating field, and this has been reflected in our analysis: surgeons were more likely to convert to a full sternotomy in RAT patients compared to MS patients, undoubtedly to improve the access in demanding cases where the surgeon deemed minimal access as a hindrance operative progress.

Our analysis found increased AoX times in RAT patients, reflecting the challenge this access poses to timely performance of the various steps of the AVR procedure. Despite this, surgical experience is likely to vary among the studies we have reported. As with most minimally invasive procedures, a recognized learning curve exists. Studies have shown that and cautious management of the learning curve in surgical procedures can lead to improved outcomes.[27,28] Variability in experience and proficiency among surgeons affects the number of cases required to overcome the learning curve.[29] While most reports in our analysis emerge from specialized centers, the overall recommendation is for the operative approach to be selected according to surgeon's technical expertise, which in turn may affect the observed outcomes.

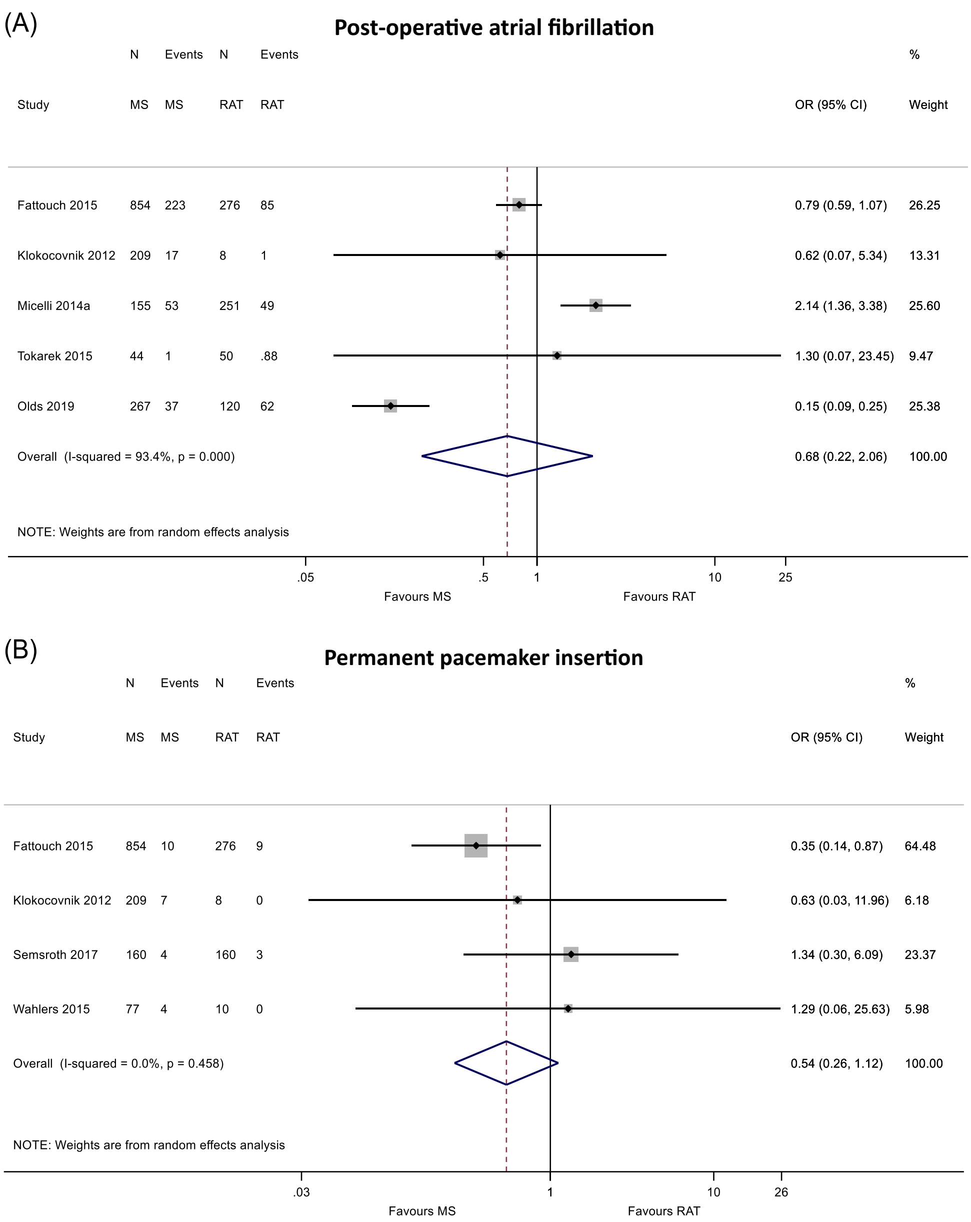

FIGURE 4 Forest plots demonstrating meta-analyses comparing the incidence of postoperative complications in aortic valve replacement patients, between MS and RAT groups, for: A, postoperative atrial fibrillation; B, permanent pacemaker insertion; C, surgical site infection. MS, mini-sternotomy; RAT, right anterior thoracotomy

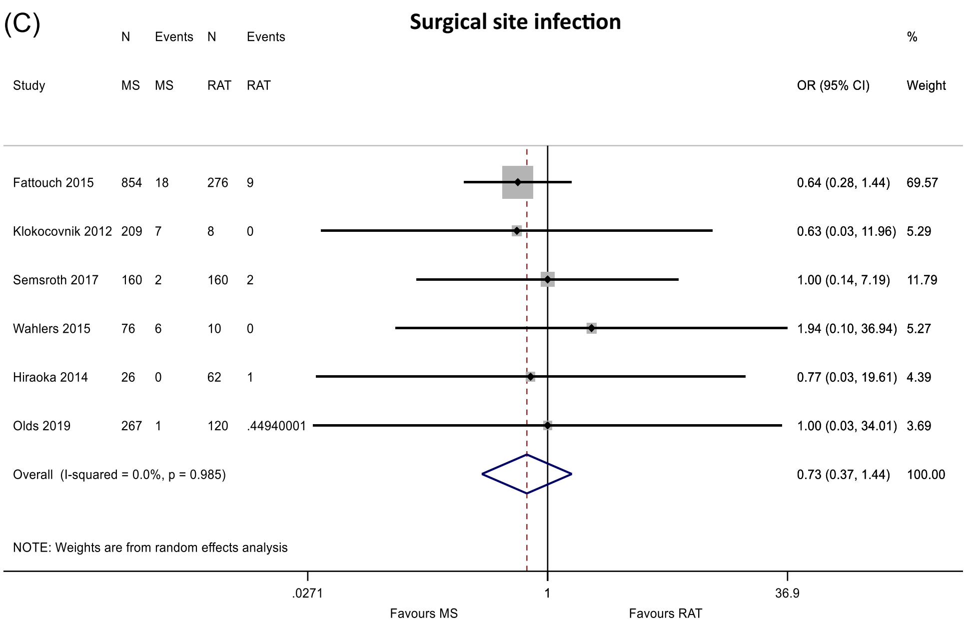

FIGURE 4 (Continued)

Compared to conventional sternotomy, MIAVR poses a theoretical reduction in bleeding, due to reduced trauma to the sternum and pericardial structures.[4] Our meta-analysis is the first to draw attention to the higher incidence of reoperation for bleeding with RAT compared to MS. Reoperation carries serious clinical risks for patients and incurs significant additional financial costs for hospitals.[30] An observational study of 566 propensity matched pairs undergoing cardiac surgery found that "reoperation for bleeding" led to a significantly increased postoperative mortality, major complications, reoperations for valve dysfunction, and longer hospital stay.[31]

The higher rate of reoperation may be a surrogate marker of bleeding rates or an indication of the technical challenges associated with the RAT approach. Possible reasons for increased bleeding may be associated with (a) injury to the right internal mammary artery, (b) injury to intercostal vessels, and (c) increased AoX and CPB times. However, varying protocols for return to theater also exist among institutions, potentially confounding reported results. Future studies may benefit from identifying more specific metrics for comparison, including (a) chest tube drainage rates and (b) transfusion requirements (packed red blood cells, fresh frozen plasma, and platelets).

Several studies have described a potentially shorter recovery following RAT compared to other types of access, mainly due to improved postoperative ventilation and reduced pain, offered by the smaller incision and avoidance of sternal access altogether.[32] This was confirmed by our study which found a significantly shorter hospital stay in RAT patients compared to MS. Our analysis of ventilation time was unfortunately limited by low statistical power (only two studies analyzed), although the result of this analysis was borderline in favor of RAT. These benefits have important advantages for higher risk patients, including older patients.[33]

Postoperative complications found to be similar between both access routes were several: operative mortality, stroke, atrial fibrillation, SSI, and PPM insertion (although the latter complication was borderline in favor of MS). Similar findings in short-term major clinical outcomes have been corroborated in other recent data synthesis studies. Chang et al conducted a meta-analysis (>10 000 patients) comparing the two minimally invasive approaches (MS and thoracotomy), and both approaches with conventional AVR. The minimally invasive approaches had comparable mortality and stroke rates to conventional AVR as well reduced hospital stay of 0.8 days on average. Compared to MS, thoracotomy had comparable early mortality and stroke rates but had lower atrial fibrillation incidence, shorter hospital stay, and longer CPB times.[34]

4.1 | Strengths and limitations

The analysis offered by this study provides an improved comparison for two viable methods of approaching the aortic valve with increasing acceptability. The overall quality of evidence, however, is limited by the inherent biases for which observational studies are susceptible to. Key areas of potential bias are: failure to control for pretreatment confounders and surgeon experience, and inadequate reporting of follow-up losses. Inconsistency between studies limits confidence in findings; this was seen in the heterogeneity of CPB times, which may be due to a number of confounding factors: surgeon selection bias, variability in experience, mix of traditional and sutureless valves.

5 | CONCLUSION

The technical challenges posed by surgical approach may affect operative times and short-term complications associated with difficult access: namely conversion to sternotomy and reoperation for bleeding. Despite the reduced hospital stay offered by RAT, this review suggests that attention to training may be important to ensure that potential complications following MIAVR are kept to a

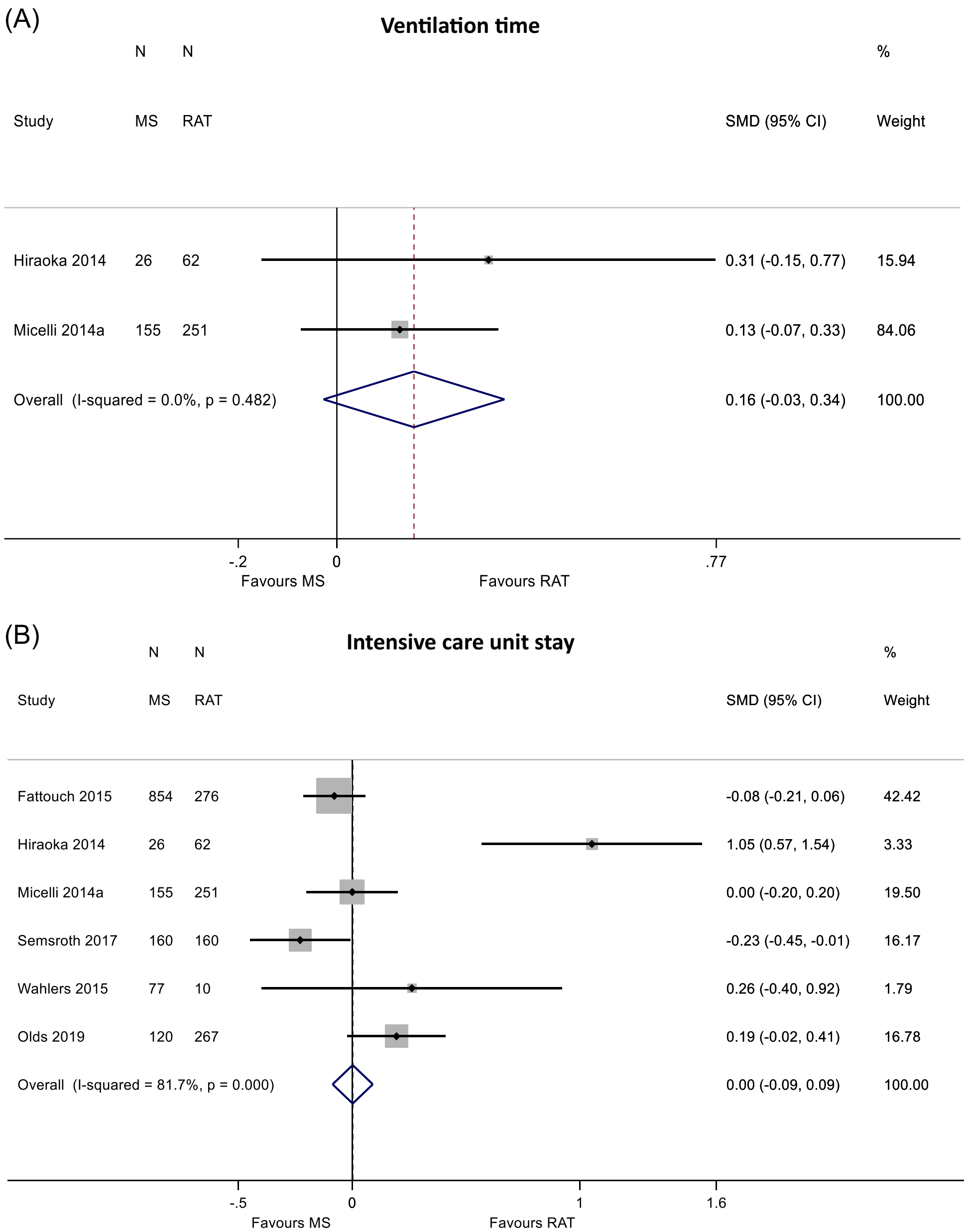

FIGURE 5 Forest plots demonstrating meta-analyses comparing postoperative metrics in aortic valve replacement patients, between MS and RAT groups, namely: A, ventilation time; B, intensive care unit stay; C, hospital length of stay. MS, mini-sternotomy; RAT, right anterior thoracotomy

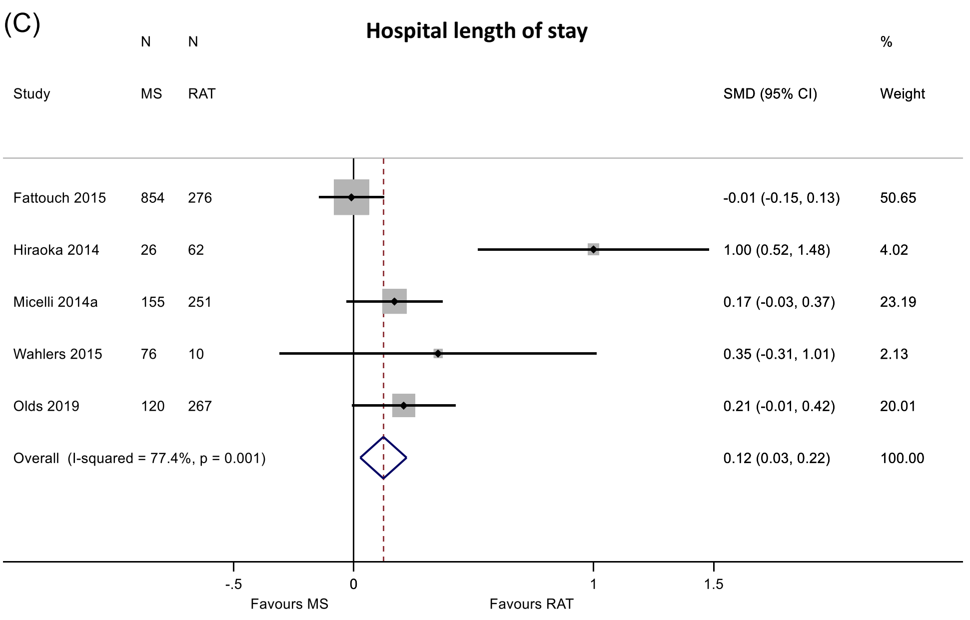

FIGURE 5 (Continued)

minimum, compared to MS which is likely to be less technically challenging.

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