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Left versus right ventricular pacing during TAVR and balloon aortic valvuloplasty: A systematic review and meta-analysis

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Abstract

Introduction: While right ventricular pacing (RVP) is the conventional temporary pacing modality used for transcatheter aortic valve replacement (TAVR), this approach possesses inherent risks and procedural challenges. We aim to assess and compare the safety and efficacy of left ventricular pacing (LVP) and RVP during TAVR and balloon aortic valvuloplasty (BAV).

Methods: Following PRISMA guidelines, a comprehensive literature search was conducted in four databases from inception to December 15th, 2023. We included observational studies and clinical trials comparing LVP with RVP during TAVR and BAV procedures. Primary outcomes included short-term mortality, mortality due to cardiac tamponade, and procedural complications including bleeding, vascular complications, and cardiac tamponade. Secondary outcomes comprised procedure duration and length of hospital stay.

Results: Five studies involving 830 patients with RVP and 1577 with LVP were included. Short-term mortality was significantly higher in the RVP group (RR 2.32, 95% CI: [1.37–3.93], $P = .002$), as was the incidence of cardiac tamponade (RR 2.19, 95% CI: [1.11–4.32], $P = .02$). LVP demonstrated shorter hospital stays (MD = 1.34 d, 95% CI: [0.90, 1.78], $P < .001$) and reduced procedure duration (MD = 7.75 min, 95% CI: [5.08, 10.41], $P < .00001$) compared to RVP. New pacemaker implantation was higher in the RVP group (RR 2.23, 95% CI: [1.14, 4.39], $P = .02$).

Conclusion: LVP during TAVR and BAV emerges a safer alternative to RVP, offering reduced mortality, hospital stays, and procedure durations.

KEYWORDS
cardiac pacing, left ventricular, right ventricular, transcatheter aortic valve replacement

Abbreviations: AMSTAR-2, assessing the methodological quality of systematic reviews 2; AVB, atrioventricular block; BAV, balloon aortic valvuloplasty; BMI, body mass index; CABG, coronary artery bypass graft; CI, confidence interval; I-V, inverse variance; LVEF, left ventricular ejection fraction; LVP, left ventricular pacing; MD, mean difference; M-H, Mantel–Haenszel method; NOS, Newcastle–Ottawa scale; PCI, percutaneous coronary intervention; PRISMA, preferred reporting items for systematic reviews and meta-analyses; RBBB, right bundle branch block; RoB, risk-of bias assessment; RVP, right ventricular pacing; SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement.

1 | INTRODUCTION

Transcatheter aortic valve replacement (TAVR) represents a minimally invasive substitute for surgical aortic valve replacement (SAVR) that is applicable across the entirety of the operative risk spectrum, particularly in elderly patient populations.[1–3] Over the past two decades, the evolution of TAVR has been characterized by advancements in patient selection, pre-procedural planning strategies, and the continuous refinement of device technologies. Consequently, TAVI has transitioned into a simplified intervention done under local anesthesia, with a reduction in the duration of hospitalization.[4] These enhancements have led to a decrease in procedural complication rates and better patient outcomes.[5,6]

Despite notable advancements, the use of intraprocedural rapid ventricular pacing remains imperative to ensure transient cardiac standstill during critical phases of valve positioning, deployment, as well as pre- and post-dilatation when applicable.[7] Typically accomplished through a transvenous temporary pacing lead advanced to the right ventricular (RV) apex under fluoroscopy, this method requires additional venous access, which exposes patients to inherent risks of vascular complications including bleeding, pseudoaneurysm, arteriovenous fistula, thrombosis, or infection. The use of a temporary pacing lead also carries the potential risk of RV perforation, leading to pericardial effusion or life-threatening cardiac tamponade. Additionally, the inclusion of a RV pacing lead contributes to prolonged procedural duration, increased fluoroscopy usage, and elevated procedural costs.[6,7] Also, the risk of lead instability in the RV introduces the possibility of loss of capture and valve embolization.[6]

Using left ventricular (LV) wire pacing has the potential to make the TAVI procedure shorter, simpler, and safer, with the advantages of reduced cost, procedure and fluoroscopy time. This approach, recognized for its safety and effectiveness, has been previously documented in interventions involving both Balloon Aortic Valvuloplasty (BAV) and TAVI.[6,8–11] Therefore, in this meta-analysis, we aimed to assess and compare the safety and efficacy of standard RV pacing with LV pacing, focusing on mortality and procedural complications.

2 | METHODS

We conducted a systematic review and meta-analysis according to the Cochrane Handbook for Systematic Reviews of Intervention and reported it according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). We also followed the AMSTAR-2 (Assessing the Methodological Quality of Systematic Reviews 2) Guidelines.[12,13] Because of the nature of our study, there was no need to obtain patient permission and ethical approval. We registered the study protocol in PROSPERO (CRD42024499467).

2.1 | Data sources and search strategy

A comprehensive systematic literature search of Cochrane Central Register of Controlled Trials (CENTRAL), SCOPUS, PubMed (MEDLINE), and Web of Science (WoS), was performed from inception to December 15th, 2023. The search was conducted without specific limitations on criteria. Further details about the search methodology, including keywords, search terms employed, and the obtained results can be found in Table 1.

2.2 | Eligibility criteria

We utilized the PICO framework to include studies based on the following inclusion criteria: (1) Population included patients undergoing TAVI or aortic valve valvuloplasty. (2) Intervention included the use of left ventricular rapid pacing during the procedure. (3) Comparator was right ventricular rapid pacing during the procedure. (4) Primary safety outcomes included short-term mortality, cardiac tamponade, and mortality due to cardiac tamponade. Primary efficacy outcomes included hospital length of stay and procedure duration. Secondary outcomes included major and minor vascular complications, bleeding, and cerebrovascular Events. Regarding the study design, clinical trials (randomized and non-randomized control trials) and observational studies (retrospective cohort, prospective cohort, and case-control studies) were included. Review articles, animal trials, letters to editors, commentaries, editorials, case reports, and conference abstracts, studies with overlapping data, and in vitro studies were excluded from the analysis.

2.3 | Study selection

The articles obtained through the systematic search were uploaded to Zotero Reference Library, where duplicates were determined and removed. After duplicates removal, the titles and abstracts of the search results were uploaded to the Rayyan website[28] and screened for relevance by two authors (B.B.K. and A.A.). Potentially eligible studies were then retrieved for full-text screening. The final list of included studies was agreed upon by discussion between all authors. Disagreement amongst reviewers was resolved through consensus. The reference lists of the retrieved studies were manually screened for any additional eligible studies.

2.4 | Data extraction

Data extraction forms were created using Excel Sheets. The data was extracted separately by three authors (B.B.K., M.A., and A.A.), and any differences were handled by a senior author (M.A.). For each study, the following information was extracted:

1. Summary of the included studies as study type, duration, country of origin, procedure indication, inclusion and exclusion criteria. Details provided in Table 2.
2. Procedural characteristics as valve types, approach of anesthesia, radiation dose and valve implantation approach (transfemoral/transapical). Details provided in Table 3.

TABLE 1 Details of search strategy.

Component 1		Component 2		Component 3		Component 4		Component 5
((TAVI) OR (TAVR) OR (transcatheter aortic valve implantation) OR (Transcatheter Aortic Valve Replacement*) OR (Balloon Valvuloplasty*))	AND	(Aortic valve stenosis*)	AND	((Cardiac Pacing) OR (pacing*))	AND	((left ventricular) OR (Left*))	AND	((right ventricular) OR (Right*))

3. Baseline characteristics as number of patients undergoing RV or LV pacing, gender, age, BMI, smoking history, hypertension, left ventricular ejection fraction (LVEF), Euroscore, Previous PCI, and previous CABG. Summary of baseline characteristics is delineated in detail in Table 4.
4. Outcomes: primary safety outcomes included short-term mortality, cardiac tamponade, and mortality due to cardiac tamponade. Primary efficacy outcomes included hospital length of stay and procedure duration. Secondary outcomes included major and minor vascular complications, bleeding, and cerebrovascular events.

2.5 | Risk of bias and certainty of evidence

The evaluation of quality of observational studies was carried out using the Newcastle-Ottawa Scale (NOS) risk of bias assessment tool.[26] The NOS assigns a maximum of nine points across three domains. A cumulative score on the NOS ranging from 0 to 3 indicates a high risk of bias, 4 to 6 suggests a moderate risk, and a score of ≥7 suggests a low risk of bias. Furthermore, the Cochrane RoB 2 risk-of bias assessment was utilized to assess the quality of randomized control trial.[27]

2.6 | Statistical analysis

We conducted the meta-analysis utilizing Review Manager software (RevMan Version 5.4).[14] Dichotomous outcomes were represented using risk ratio with a 95% confidence interval (CI), using Mantel–Haenszel method (M–H) and considering statistical significance as a *P-value* < .05. Continuous outcomes were assessed through mean difference (MD) and 95% CI, utilizing the inverse variance (I–V) method. To address heterogeneity among the included studies, we applied the random-effects model based on the DerSimonian-Laird method, setting the level of statistical significance at *P-value* < .05. Heterogeneity was assessed using Chi-square and I-square tests, following guidelines from the Cochrane Handbook,[10] where I-square values of 0%–40%, 30%–60%, and 50%–90% were interpreted as insignificant, moderate, and substantial heterogeneity, respectively. Significant heterogeneity was determined if the alpha level for the Chi-square test was below 0.1. In instances of significant heterogeneity, a leave-one-out sensitivity analysis was conducted. Due to the limited number of included studies, publication bias assessment using funnel plots was not feasible.

3 | RESULTS

3.1 | Search results and study selection

We retrieved 333 records after searching the databases and excluded 125 duplicates using Zotero, with 208 records eligible for title and abstract screening. Nine entered full-text screening, and finally, five studies were included[6,7,15,16,17] as shown in PRISMA in Figure 1.

3.2 | Characteristics of included studies

Five studies were included in the final analysis with a total of 830 patients in the right ventricular pacing (RVP) group and 1577 in the left ventricular pacing (LVP) group. Three of the included studies were prospective cohort studies, one was a retrospective cohort, and one was a randomized control trial. Two of these studies were conducted in Poland, one in the UK, one in the Netherlands, and one in France.[6,7,15–17] Detailed summary of the included studies is provided in Table 2.

3.3 | Primary safety outcomes

3.3.1 | Short-term mortality

The short-term mortality was reported in all the studies and was higher in the RVP group (RR 2.32, 95% CI: [1.37–3.93], *P-value* = .002) as shown in Figure 2. The pooled results displayed no heterogeneity ($I^2 = 0\%$, $P = .80$). Subgroup analysis of the TAVR studies only revealed similar trends with higher short-term mortality in the RVP group (RR 1.99, 95% CI: [1.13–3.51], *P-value* = .02, $I^2 = 0\%$, $P = .94$).

3.3.2 | Cardiac tamponade

The pooled analysis demonstrated a higher likelihood of developing cardiac tamponade in the RVP group compared with the LVP group (RR 2.19, 95% CI: [1.11–4.32], *P-value* = .02) as shown in Figure 3. The pooled results displayed no heterogeneity ($I^2 = 0\%$, $P = .58$). Subgroup analysis of TAVR studies was utilized and revealed comparable incidence of cardiac tamponade between both groups (RR 1.88, 95% CI: [0.92–3.82], *P-value* = .08, $I^2 = 0\%$, $P = .66$).

TABLE 2 Summary of studies comparing RV pacing and LV pacing in patients undergoing TAVR or BAV.

Study ID	Study design	Procedure indication (*n*)				Study duration	Country	Sample size		Population definition	Inclusion criteria	Study conclusion
		AS	AR	Mixed AS/AR	FBP			RV	LV			
Savvoulidis 2022	Single center retrospective cohort	1226	0	0	0	156 months	UK	470	756	1272 consecutive patients with severe symptomatic AS undergoing TAVR at Queen Elizabeth University Hospital Birmingham in the UK were enrolled in a prospective nationwide TAVR Registry	All TAVR patients were included except for those undergoing transapical or transaortic procedures. No patient exclusion was based on baseline conduction abnormalities, such as 1st degree AV block, RBBB, or LBBB.	LV rapid ventricular pacing for THV deployment is safe, efficacious and cost-effective compared with traditional RV pacing and may be a further step forward in the overall simplification of TAVR procedures.
Hokken 2021	Single center prospective cohort	1,294	10	18	22	30 months	Netherlands	45	488	All patients undergoing TAVR in the center	–	A restricted RV pacemaker strategy is safe and shortens procedure time. The majority of TAVR procedures do not require a temporary RV pacemaker lead.
Stapor 2020	Single center retrospective cohort	143	0	0	0	23 months	Poland	61	82	All consecutive patients with severe AS who underwent transfemoral TAVR were included.	–	Direct LV wire pacing during TAVR seems to be simple, reproducible, and safe. This technique provides reliable, sustained stimulation characterized by a low complication rate and showing a potential reduction in procedural time and cost.

(Continues)

TABLE 2 (Continued)

Study ID	Study design	Procedure indication (*n*)				Study duration	Country	Sample size		Population definition	Inclusion criteria	Study conclusion
		AS	AR	Mixed AS/AR	FBP			RV	LV			
Kleczynski 2020	Single center prospective cohort	202	0	0	0	52 months	Poland	102	100	Patients with severe symptomatic AS	Aortic valve area < 0.7 cm2 (indexed AVA < 0.5 cm2 /m2 body surface area) who underwent BAV between January 2015 and May 2019	Direct rapid LV guidewire pacing is a simple, safe and effective method during BAV, which allows for a shorter procedural time and a reduced complication rate compared to a temporary PM placed in the RV.
Faurie 2019	Multicenter RCT	–	–	–	–	12 months	France	152	151	TAVR with either LV or RV stimulation	Patients age more than 18 years of age undergoing TAVR implantation with planned transfemoral approach using the SAPIEN 3 or XT (Edwards Lifesciences, Irvine, California) valve were eligible for inclusion	For TAVR patients with a SAPIEN 3 valve, using rapid ventricular pacing in the LV significantly shortened procedure duration, fluoroscopy time, and cost compared to RV stimulation. This approach-maintained efficacy and safety while simplifying the TAVR procedure by eliminating the need for a transvenous temporary pacing lead or additional venous access in most cases.

Abbreviations: AS, aortic stenosis; AR, aortic regurgitation; FBP, failed bioprosthetic valve; RV, right ventricle; LV, left ventricle; RCT, randomized controlled trial; TAVR, transcatheter aortic valve replacement; RBBB, right bundle branch block; LBBB, left bundle branch block; BAV, balloon aortic valvuloplasty; PM, pacemaker; AV, atrioventricular; AVA, aortic valve area.

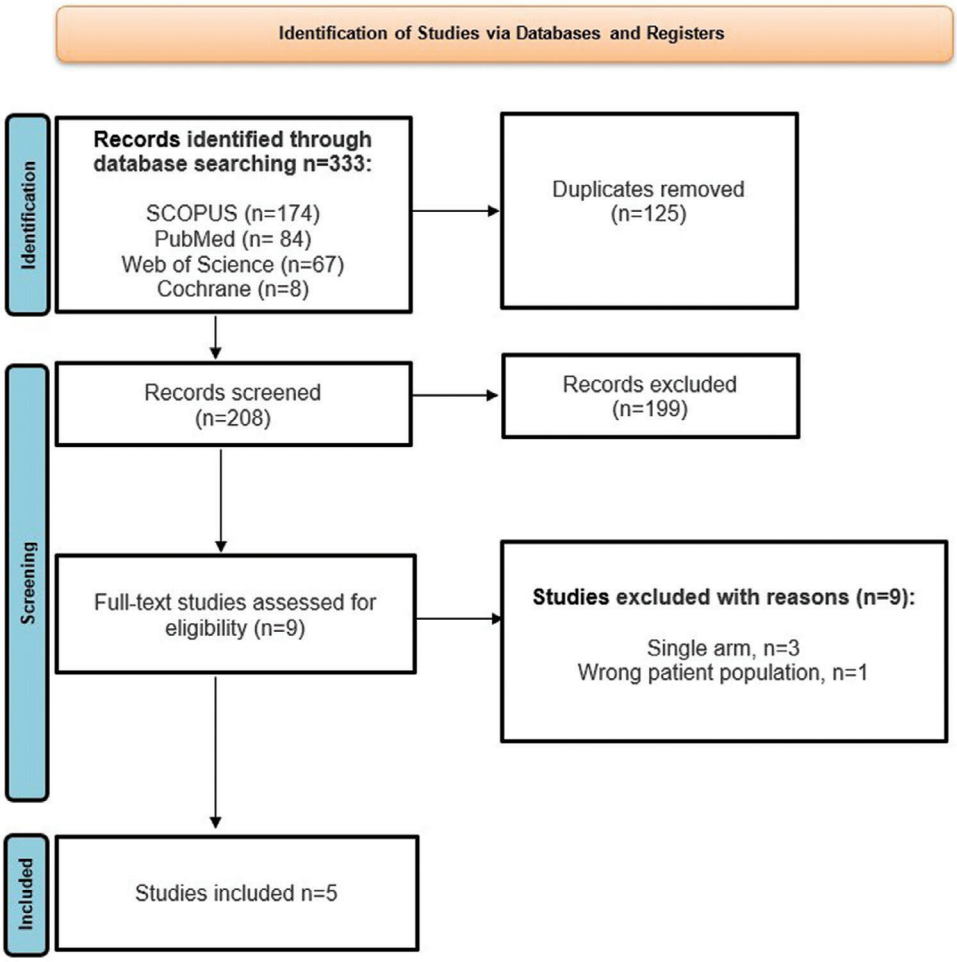

FIGURE 1 The PRISMA flow diagram of literature screening and selection. [Color figure can be viewed at wileyonlinelibrary.com]

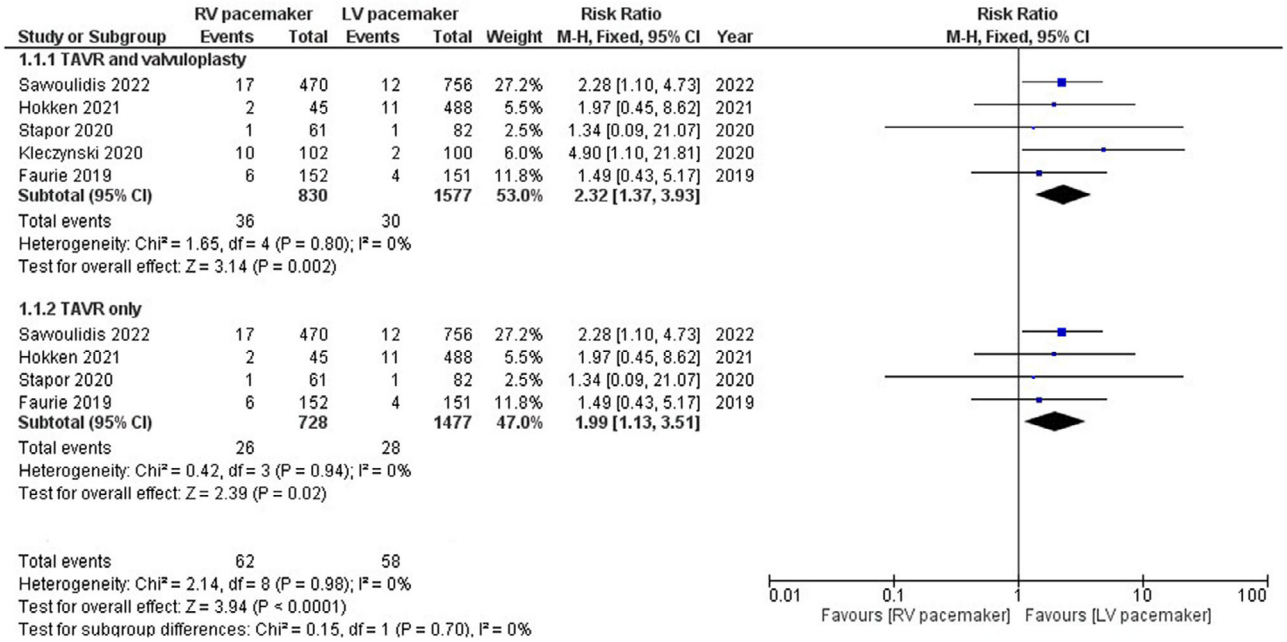

FIGURE 2 Forest plot of short-term mortality (RR risk ratio, CI confidence interval). [Color figure can be viewed at wileyonlinelibrary.com]

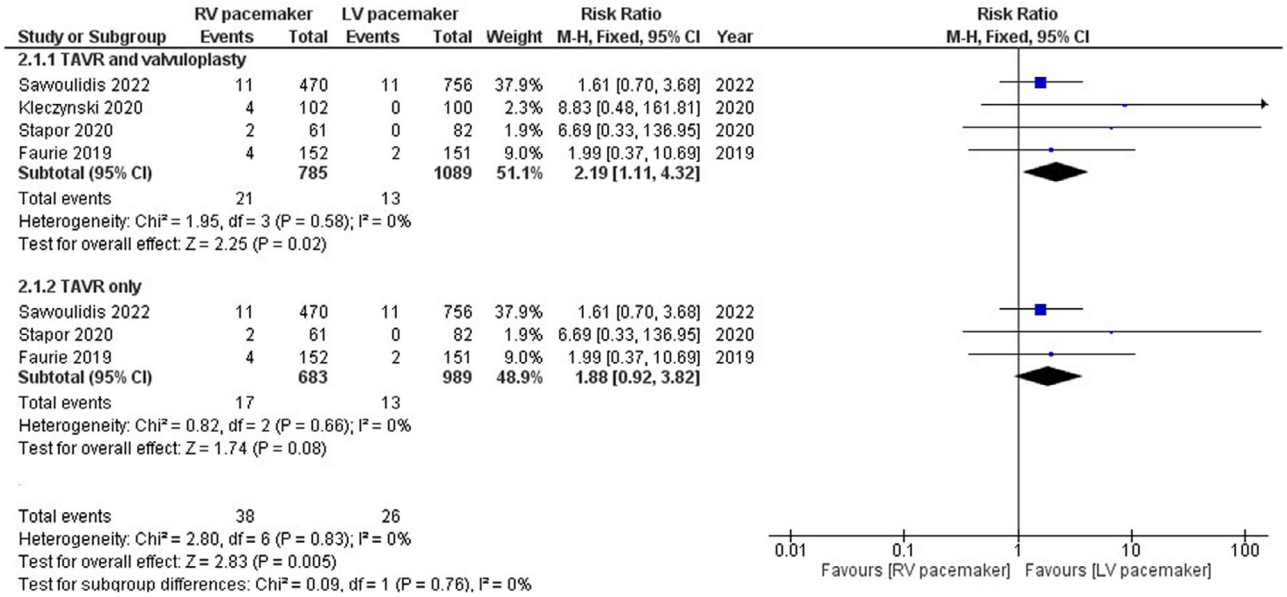

FIGURE 3 Forest plot of cardiac tamponade (RR risk ratio, CI confidence interval). [Color figure can be viewed at wileyonlinelibrary.com]

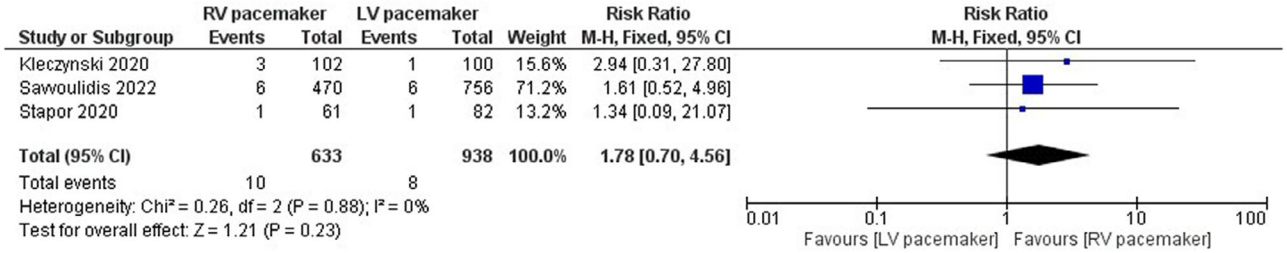

FIGURE 4 Forest plot of mortality due to cardiac tamponade (RR risk ratio, CI confidence interval). [Color figure can be viewed at wileyonlinelibrary.com]

3.3.3 | Mortality due to cardiac tamponade

Mortality due to cardiac tamponade was comparable between RVP and LVP groups (RR 1.78, 95% CI: [0.7–4.56], *P-value* = .23) as shown in Figure 4. The pooled results displayed no heterogeneity (I^2 = 0%, *P* = .88).

3.4 | Secondary safety outcomes

3.4.1 | Major and minor vascular complications and bleeding

Major vascular complications were comparable between RVP and LVP groups (RR 1.78, 95% CI: [0.86–3.70], *P-value* = .12) as shown in Figure 5. The pooled results displayed no heterogeneity (I^2 = 32%, *P* = .22). Similarly, minor vascular complications were comparable between both groups (RR 0.73, 95% CI: [0.43–1.24], *P-value* = .25) as shown in Figure 6. The pooled results displayed no heterogeneity (I^2 = 0%, *P* = .25). No significant heterogeneity was reported in any of these outcomes. Furthermore, bleeding was comparable between both cohorts (RR 0.95, 95% CI: [0.51–1.76], *P-value* = .86, I^2 = 15%, *P* = .31) as shown in Figure 7.

3.4.2 | Cerebrovascular accidents

Cerebrovascular accidents were comparable between the RVP and LVP groups (RR 1.67, 95% CI: [0.78–3.57], *P-value* = .18) as shown in Figure 8. The pooled results displayed no heterogeneity (I^2 = 0%, *P* = .44). Subgroup analysis of studies with only TAVR intervention revealed similar results with no significant difference between both cohorts (RR 1.64, 95% CI: [0.74–3.64], *P-value* = .23, I^2 = 26%, *P* = .26).

3.4.3 | New pacemaker implantation

New pacemaker implantation was higher in the RVP group compared with LVP (RR 2.23, 95% CI [1.14, 4.39], *P-value* = .02). The pooled results exhibited significant heterogeneity (I^2 = 86%, *P* = .02).

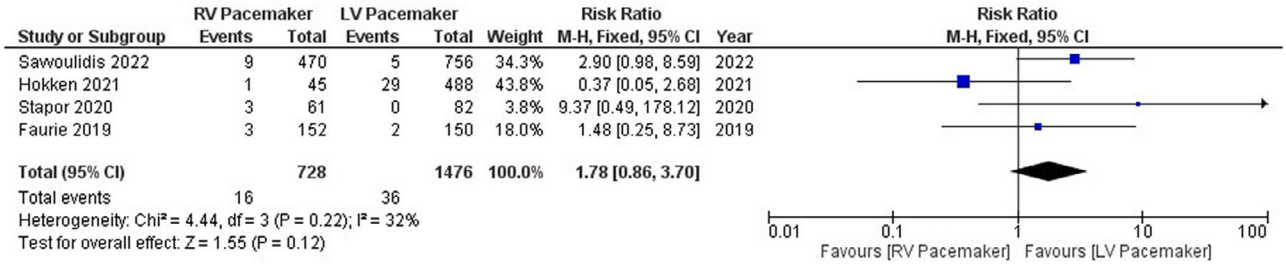

FIGURE 5 Forest plot of major vascular complications (RR risk ratio, CI confidence interval). [Color figure can be viewed at wileyonlinelibrary.com]

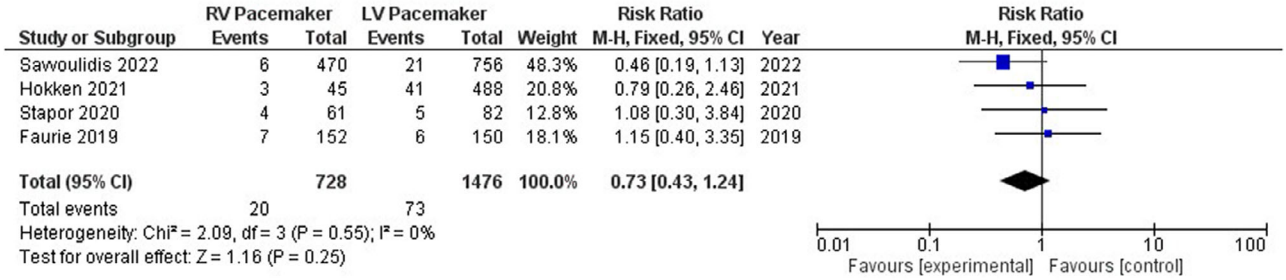

FIGURE 6 Forest plot of minor vascular complications (RR risk ratio, CI confidence interval). [Color figure can be viewed at wileyonlinelibrary.com]

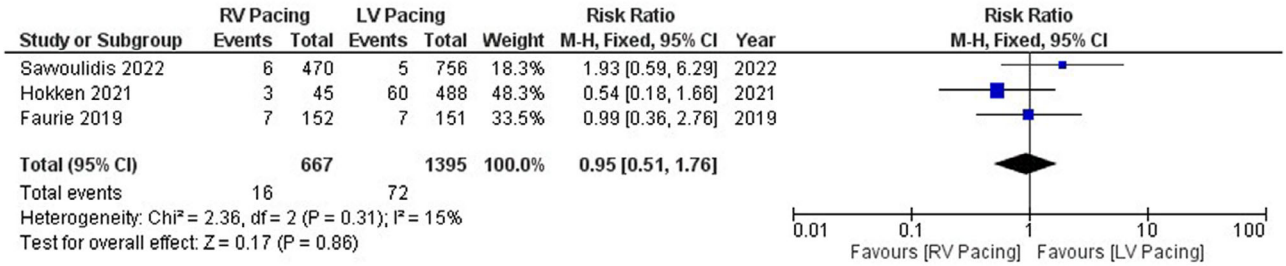

FIGURE 7 Forest plot of all bleeding (RR risk ratio, CI confidence interval). [Color figure can be viewed at wileyonlinelibrary.com]

Sensitivity analysis was conducted with exclusion of Hokken *et al.* leading to resolution of heterogeneity (I^2 = 8%, P = .34). After sensitivity analysis, the results remained significant with higher incidence of pacemaker implantation in the RVP group compared with LVP group (RR 1.51, 95% CI [1.10, 2.07], *P-value* = .01) (Figure 9).

3.4.4 | Radiation dose (mGy)

No significant differences in radiation dose were found between RVP and LVP groups (MD = 3.91; %; 95% CI: [−134.38, 142.20], *P-value* = .96). The pooled analysis displayed significant heterogeneity (I^2 = 93%, P < .00001) (Figure 10).

3.5 | Healthcare utilization outcomes

3.5.1 | Length of hospital stay

The length of hospital stay was significantly higher in the RVP group compared with the LVP group (MD = 1.34 day; %; 95% CI: [0.90, 1.78], *P-value* < .00001) as shown in Figure 11. The pooled analysis displayed significant heterogeneity (I^2 = 57%, P = .07). Subgroup analysis of TAVR only studies was displayed similar findings with longer length of hospital stay in the RVP group (MD = 1.26, 95% CI: [1.07–1.44], *P-value* < .00001, I^2 = 0%, P = .51).

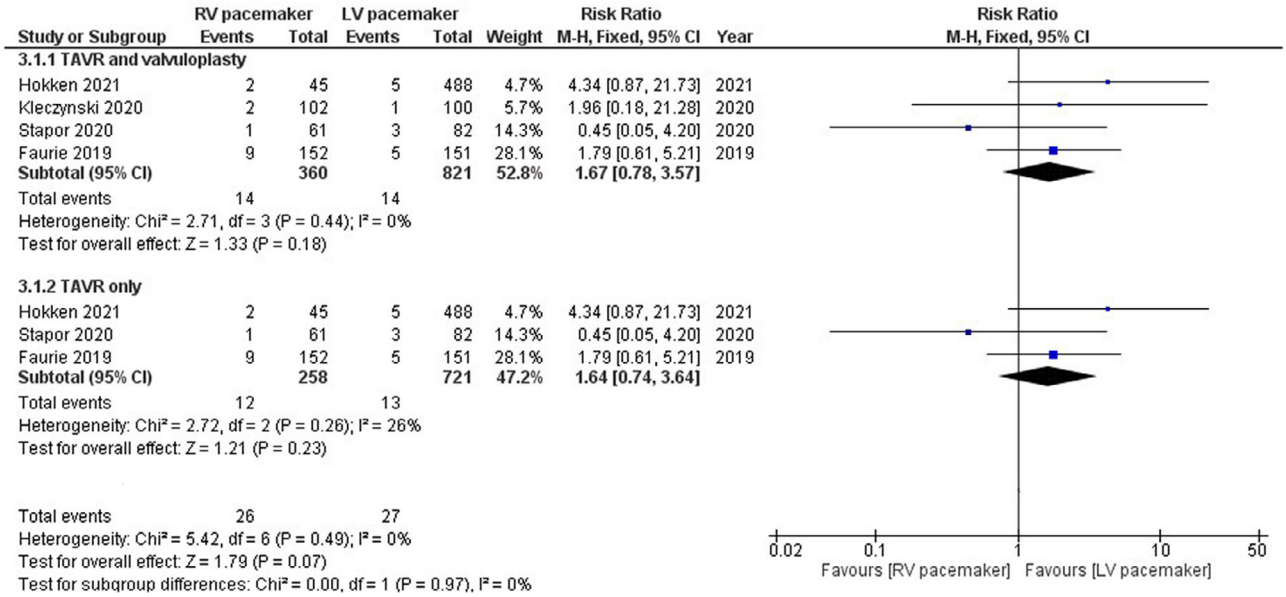

FIGURE 8 Forest plot of cerebrovascular accidents (RR risk ratio, CI confidence interval). [Color figure can be viewed at wileyonlinelibrary.com]

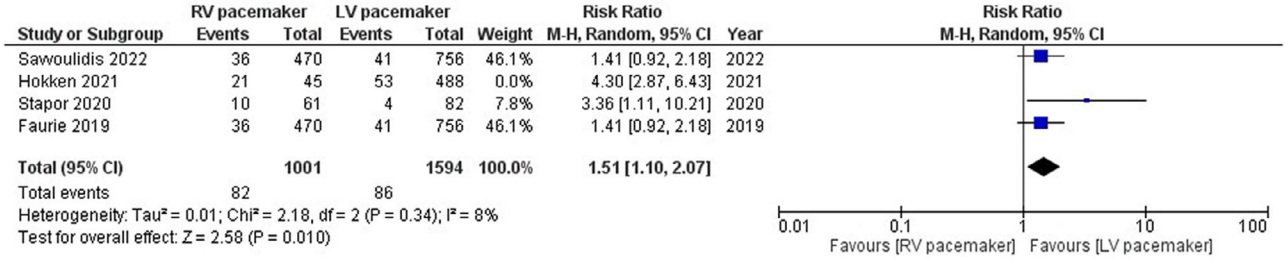

FIGURE 9 Forest plot of permanent pacemaker implantation (RR risk ratio, CI confidence interval). [Color figure can be viewed at wileyonlinelibrary.com]

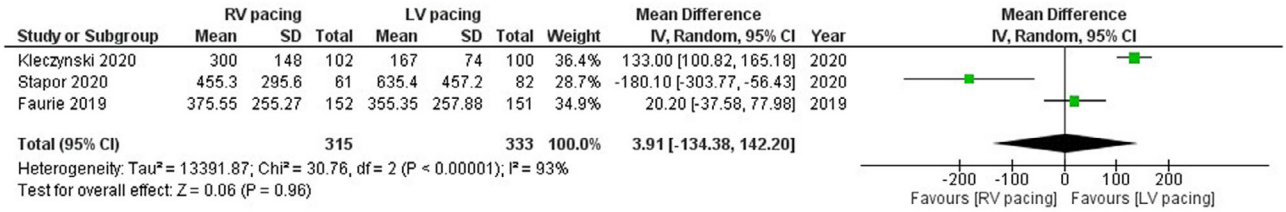

FIGURE 10 Forest plot of radiation dose (MD mean difference, CI confidence interval). [Color figure can be viewed at wileyonlinelibrary.com]

3.5.2 | Procedure duration (minutes)

The RVP group had significantly higher procedure duration compared with the LVP group (MD = 7.75 min; %; 95% CI: [5.08, 10.41], *P-value* < .00001) as shown in Figure 12. The pooled analysis displayed significant heterogeneity (I^2 = 65%, P = .02). Subgroup analysis of the studies were only TAVR was utilized revealed similar trends with higher procedure duration in the RVP group (MD = 8.09, 95% CI: [4.42–11.77], *P-value* < .00001, I^2 = 65%, P = .04).

Summary of all previous results is provided in Table 5.

3.6 | Quality of the included studies

According to the Newcastle-Ottawa Scale (NOS), the evaluated four observational studies demonstrated a low risk of bias in the domains of selection, comparability, and outcome assessment. However, the involved clinical trial demonstrated a high risk of bias according to

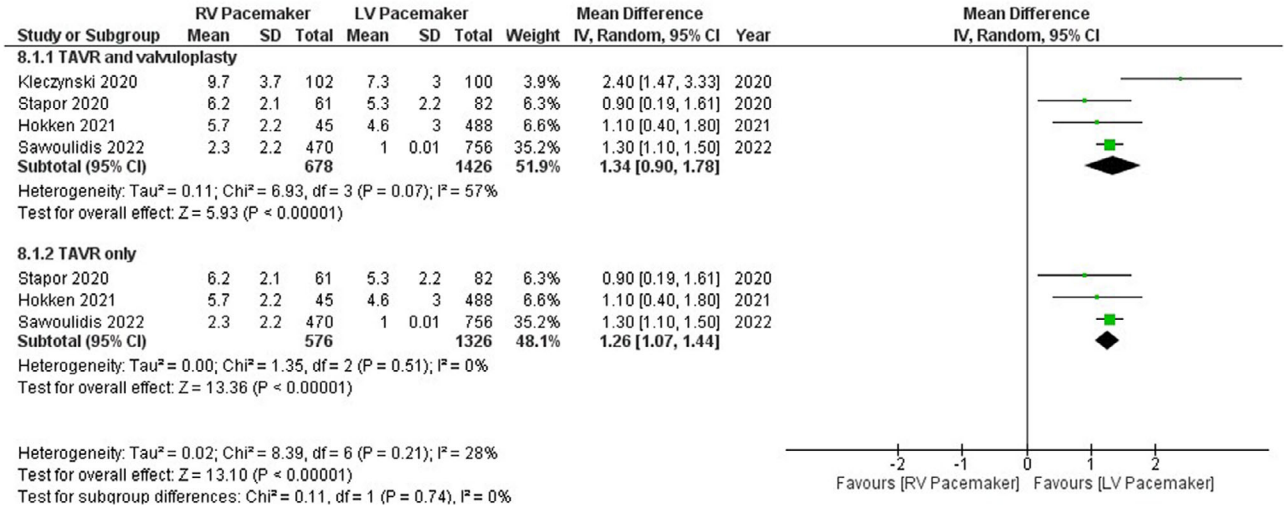

FIGURE 11 Forest plot of length of hospital stay (MD mean difference, CI confidence interval). [Color figure can be viewed at wileyonlinelibrary.com]

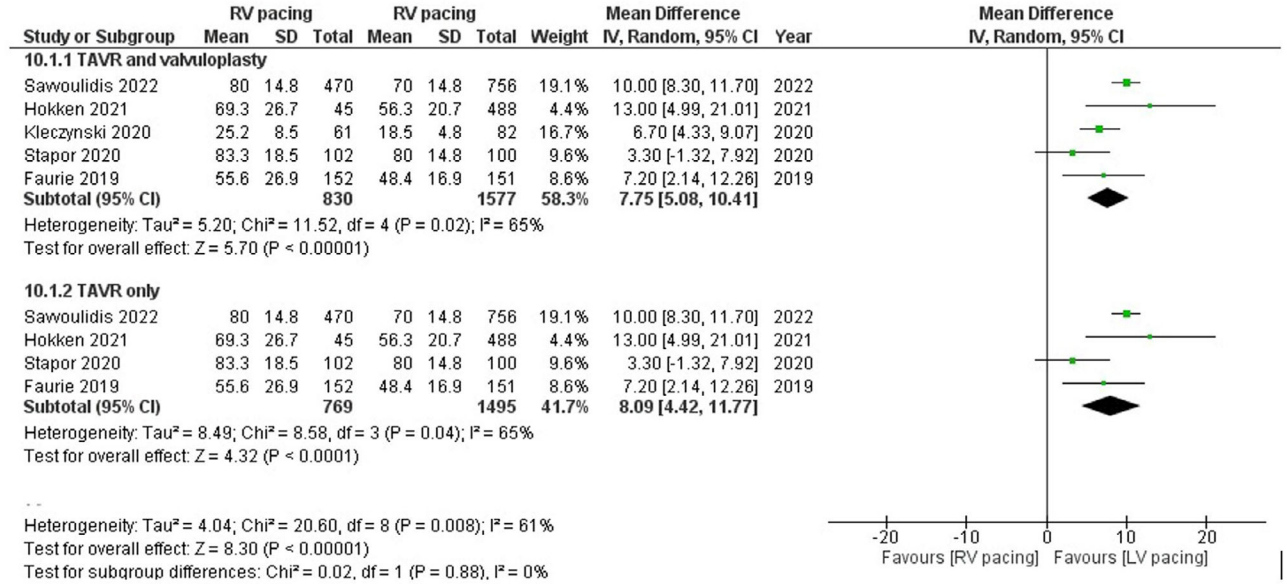

FIGURE 12 Forest plot of procedure duration (MD mean difference, CI confidence interval). [Color figure can be viewed at wileyonlinelibrary.com]

the Cochrane RoB2 tool. Comprehensive details regarding the quality assessment domains of the included studies are delineated in Table 6.

4 | DISCUSSION

4.1 | Summary of the key findings

Our systematic-review and meta-analysis aimed to compare the safety and efficacy outcomes of left ventricular pacing (LVP) and right ventricular pacing (RVP) during TAVR and valvuloplasty procedures. The analysis of five studies including 2407 patients revealed crucial findings regarding mortality rates, procedural complications, and healthcare system utilization. This work signifies that left ventricular stimulation allows more simplification of the TAVR procedure using a less invasive technique. LVP was associated with lower short-term mortality and permanent pacemaker implantation, as well as shorter hospital stay and procedural duration. LVP was associated with lower rate of post-procedural cardiac tamponade, but when assessing studies of TAVR only, this effect has disappeared.

4.2 | Explanation of the study findings

Short-term mortality was found to be lower in the LVP group. This finding may be attributed to the lower rate of life-threatening

TABLE 3 Procedural characteristics.

Study ID	Valve type						Procedure				Access					
	Balloon-expandable		Self-expanding		Mechanically-expandable		Pre-dilatation		Post-dilatation		Transfemoral		Transaxillary		Other (e.g., transcaval)	
	RV	LV	RV	LV	RV	LV	RV	LV	RV	LV	RV	LV	RV	LV	RV	LV
Savvoulidis 2022	410/470	672/756	60/470	84/756	–	–	207/470	98/756	126/470	197/756	441/470	739/756	29/470	16/756	0/470	1/756
Hokken 2021	22/45	262/488	19/45	201/488	4/45	25/488	15/45	181/488	12/45	188/488	42/45	472/488	3/45	16/488	0/45	0/488
Stapor 2020	17/61	9/82	41/61	73/82	3/61	0/82	41/61	71/82	37/61	59/82	–	–	–	–	–	–
Faurie 2019	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Abbreviations: RV, right ventricle; LV, left ventricle.

complications such as cardiac tamponade in the LVP group. Indeed, our analysis revealed a lower rate of cardiac tamponade in the LVP group. This is clinically relevant as central venous access and insertion of a temporary pacemaker in the right ventricular apex can lead to access site complications, such as bleeding or cardiac injury, which leads to pericardial effusion and tamponade.[17] A study conducted by Rezq and colleagues presumed that more than half of the pericardial tamponade cases following TAVR were linked to right ventricular perforation as a result of placing a temporary pacemaker. Other causes of tamponade in this study included annular rupture, aortic dissection, or a rupture in the left ventricular free wall.[18] In a multivariate analysis, pericardial tamponade complicating transient pacemaker insertion was associated with a five-fold increased risk of in-hospital mortality.[19] Furthermore, a large study on European registry of emergency cardiac surgery complicating TAVR found that right ventricular perforation caused by transient pacing was associated with a 43% risk of in-hospital mortality.[20] Stapor et al. found that tamponade was more frequently observed in the RVP group (3.3% vs. 0%). However, this did not reach statistical significance ($P = .34$).[7] Similarly, cardiac tamponade was more frequent in the RVP group compared to the LVP group in the EASY TAVI trial. However, this result did not reach significance possibly due to small sample size (1.3% vs. 2.6%; $P = .68$).[6]

There were no cases of cardiac tamponade due to the guidewire in the LVP group, but two of the four cases in the RVP group were due to the temporary pacing lead.[20] Another large-scale national TAVR registry recently reported a significant increase in tamponade rates over time from 1.3% in the period of 2010 to 2012 to 2.0% in the period of 2013 to 2015, with no difference according to valve type (Edwards SAPIEN or CoreValve). But there was no available data on the proportion of cases that occurred due to the temporary pacing lead.[21]

Contrary to these findings, our analysis revealed a similar rate of mortality due to cardiac tamponade in both LVP and RVP groups. This may well highlight the nature of the included studies, which mostly relied on selection of patients for guidewire pacing group and exclusion of patients with conduction disturbances from the LVP group.

Complications, such as bleeding, major and minor vascular complications, and cerebrovascular accidents, were also similar between both pacing groups

Regarding efficacy of LVP, safety and efficacy of LVP during TAVI procedures was reported in two single arm studies.[9,22] It was more explained in small, single arm registries and case series with low rates of procedural complications.[10,11,23] However, many of these studies have excluded patients with baseline conduction abnormalities or pacemakers.[9–11]

Despite the proved efficacy of LVP, the use of the LVP technique has diminished due to the fact that early TAVR protocols required a PM insertion into the right ventricle to provide appropriate rapid pacing and protection from arrhythmias and heart blocks, which were observed more frequently in early generation valves.[24] In the past, many institutions would leave the RVP wire in situ for 24 h, especially in patients receiving self-expandable valves due to the risk of late complete atrioventricular block (AVB). This approach is no longer needed due to reduced occurrence of AVB by using the new generation of

TABLE 4 Summary of baseline patient characteristics and risk factors in studies comparing outcomes in patients undergoing TAVR with right ventricular rapid pacing versus left ventricular pacing.

Study ID	Savvoulidis 2022	Hokken 2021	Stapor 2020	Kleczynski 2020	Faurie 2019
RV pacing (*n*)	470 (38.3)	45 (6.7)	61 (42.7)	102 (50.5)	152 (50.2)
LV pacing (*n*)	756 (61.7)	488 (72.6)	82 (57.3)	100 (49.5)	151 (49.8)
Age (Mean ± SD)					
RV pacing	81.8 ± 6.7	81.7 ± 6.1	81 ± 5.3	85.6 ± 5.4	83.18 ± 5.52
LV pacing	81.3 ± 7.4	78.7 ± 8.2	80.6 ± 5.3	85.9 ± 4.6	82.70 ± 5.71
Male *n* (%)					
RV pacing	265 (56)	32 (71.1)	20 (32.8)	49 (48.0)	82 (53.9)
LV pacing	432 (57.2)	271 (55.5)	35 (42.7)	51 (51.0)	71 (47)
BMI (kg/m^2) (Mean ± SD)					
RV pacing	_	26.4 ± 4.7	28 ± 4.9	25.2 ± 3.6	26.3 ± 4.3
LV pacing	_	27.1 ± 4.8	28.3 ± 4.7	25.53 ± 3.7	26.1 ± 5.2
Hypertension *n* (%)					
RV pacing	_	33 (73.3)	_	99 (97.0)	121 (79.6)
LV pacing	_	342 (70.1)	_	93 (93.0)	121 (80.1)
Diabetes *n* (%)					
RV pacing	141 (30)	16 (35.6)	_	53 (51.9)	30 (19.7)
LV pacing	199 (26.3)	144 (29.5)	_	47 (47.0)	38 (25.2)
Current smoker *n* (%)					
RV pacing	275 (58.5)	_	_	_	11 (7.2)
LV pacing	444 (58.7)	_	_	_	13 (8.6)
LVEF (%) (mean ± SD)					
RV pacing	_	_	59.1 ± 9.5	49.16 ± 11.7	60.25 ± 11.35
LV pacing	_	_	58.3 ± 11.3	48.83 ± 7.9	57.91 ± 13.38
Euroscore (%) (mean ± SD)					
RV pacing	16.06 ± 10.2	_	3.6 ± 2.9	9.4 ± 6.1	13.25 ± 10.14
LV pacing	12.26 ± 7.8	_	3.2 ± 2.3	10.43 ± 6.1	12.72 ± 9.96
Previous CABG *n* (%)					
RV pacing	72 (15)	7 (15.6)	8 (13.1%)	16 (15.6)	12 (7.9)
LV pacing	66 (8.7)	51 (10.5)	12 (14.6%)	18 (18.0)	5 (3.3)
Previous PCI (*n*)					
RV pacing	108 (23)	15 (33.3)	22 (36.1%)	32 (31.3)	54 (35.5)
LV pacing	129 (17.1)	124 (25.4)	26 (31.7%)	35 (35.0)	47 (31.1)
Peripheral arterial disease *n* (%)					
RV pacing	_	19 (42.2)	7 (11.5%)	17 (16.6)	25 (16.4)
LV pacing	_	114 (23.4)	9 (11%)	15 (15.0)	18 (11.9)
Prior MI *n* (%)					
RV pacing	111 (23.6)	13 (28.9)	_	26 (25.4)	_
LV pacing	131 (17.3)	63 (12.9)	_	22 (22.0)	_
Prior pacemaker placement *n* (%)					
RV pacing	_	0	_	9 (8.8)	8 (5.3)
LV pacing	_	84 (17.2)	_	7 (7.0)	12 (7.9)
COPD *n* (%)					
RV pacing	_	5 (11.1)	8 (13.1)	16 (15.6)	_
LV pacing	_	69 (14.1)	16 (19.5)	14 (14.0)	_

(Continues)

TABLE 4 (Continued)

Study ID	Savvoulidis 2022	Hokken 2021	Stapor 2020	Kleczynski 2020	Faurie 2019
Dyslipidemia *n* (%)					
RV pacing	_	26 (57.8)	_	_	77 (50.7)
LV pacing	_	256 (52.5)	_	_	66 (43.7)
Stroke *n* (%)					
RV pacing	_	9 (20.0)	7 (11.5)	12 (11.7)	10 (6.6)
LV pacing	_	99 (20.4)	5 (6.1)	10 (10.0)	19 (12.6)

Abbreviations: RV, right ventricular; LV, left ventricular; BMI, body mass index; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease.

valves, improved implantation technique, and frequent late (after over 24 h) AVB development.[7]

Our analysis showed higher rate of permanent pacemaker implantation in the RVP group, which is consistent with what was reported by Auffret and colleagues. The need for permanent pacemaker was higher in the RVP cohort because of the risk profile of patients. In this cohort, new permanent pacemakers were required particularly in patients with right bundle branch block (RBBB) at baseline (59%).[17] RBBB is an established risk factor with new pacemaker rates of up to 40%.[25] Some of the included studies in our analysis considered using LVP when no risk factors of AVB were present as (first-degree AVB, Mobitz I block, RBBB, or left anterior hemiblock).[7,17]

The pooled analysis showed that procedure duration was shorter in the LVP group, which can be attributed to procedure simplification and improvements in operator expertise over time.

Also, length of hospital stay was shorter in the LVP group, which is similar with what is reported in the literature.[16,17] This can be attributed to higher rate of cardiac tamponade and permanent pacemaker implantation in the RVP group or higher baseline conduction abnormalities in the RVP group.[7,17]

5 | LIMITATIONS

This study has some limitations. Firstly, all of the included studies were observational studies, with the exception of one randomized clinical trial. Secondly, valve selection and choice of the pacing wire were based on the operator's choice and expertise. Thirdly, two[7,17] of the included studies have eliminated patients with high risk of developing AVB from the LVP group, which could introduce selection bias. Moreover, the lack of individual patient data hinders our assessment of some potential cofounding factors such as need for pacemaker, which might affect our hospital stay outcome as well as the lack of clear evidence about decision process of pacing.

All these factors could hinder the generalizability of the results to the target population. Finally, there were differences in baseline characteristics between both groups as history of percutaneous coronary intervention, myocardial infarction and coronary artery bypass surgeries.

6 | FUTURE RECOMMENDATIONS

Further randomized controlled trials are required to assess the safety and efficacy of LVP, particularly in comparison with RVP in patients undergoing TAVR or valvuloplasty. These trials must include patients with risk factors for AVB at baseline as RBBB or AVB of any degree.

7 | CONCLUSION

Left ventricular pacing (LVP) is a plausible alternative to right ventricular pacing (RVP) in patients undergoing transcatheter aortic valve replacement or valvuloplasty, particularly in the absence of high-grade conduction disturbances. LVP has demonstrated superior outcomes with lower short-term mortality rates, lower incidence of cardiac tamponade, and pacemaker implantation. On the other hand, RVP could be the preferred modality of treatment if baseline conduction abnormalities are present.

AUTHOR CONTRIBUTIONS

Basma B. Khalefa: Conceptualization; literature searching; data extraction and risk of bias assessment reviewing; project administration; first draft writing, and final manuscript editing. **Mohammed Ayyad**: Conceptualization; data extraction; first draft writing, and final manuscript reviewing. **Mohammed Ayyad**: Conceptualization; data extraction; risk of bias assessment, and final manuscript reviewing. **Alaa Ayyad**: Conceptualization; first draft writing, and final manuscript editing. **Mazen N. A. Yassin**: Data extraction and final draft reviewing. **Ahmed K. Awad**: Conceptualization; project management; data collection; data extraction reviewing, and first draft writing.

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CONFLICT OF INTEREST STATEMENT

None to declare.

DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study are presented in this article. On request, all additional raw data is available from the corresponding author.

TABLE 5 Pooled analysis of studies comparing outcomes in patients undergoing TAVR with RV rapid pacing versus patients with LV pacing.

Outcome	No. of studies	No. of patients	Statistical method	Effect estimate	*P* value for ES	Heterogeneity	
						I^2 (%)	*P* value for ES
Short-term mortality	5	2407	RR (M-H, Fixed, 95% CI)	2.32 [1.37–3.93]	.002[a]	0	.80
Cardiac tamponade	4	1874	RR (M-H, Fixed, 95% CI)	2.19 [1.11–4.32]	.02[a]	0	.58
Death due to cardiac tamponade	3	1571	RR (M-H, Fixed, 95% CI)	1.78 [0.7–4.56]	.23	0	.88
Major vascular complication	4	2204	RR (M-H, Fixed, 95% CI)	1.78 [0.86–3.70]	.12	32	.22
Minor vascular complication	4	2204	RR (M-H, Fixed, 95% CI)	0.73 [0.43–1.24]	.25	0	.25
Bleeding	3	2062	RR (M-H, Fixed, 95% CI)	0.95 [0.51–1.76]	.86	15	.31
Cerebrovascular accidents	4	1181	RR (M-H, Fixed, 95% CI)	1.67 [0.78–3.57]	.18	0	.44
New pacemaker implantation	4	2595	RR (M-H, Random, 95% CI)	2.23 [1.14, 4.39]	.02[a]	86	.02*
Radiation dose	3	648	MD (I-V, Random, 95% CI)	3.91 [−134.38, 142.20]	.96	93	<.00001*
Length of Hospital Stay	3	2104	MD (I-V, Random, 95% CI)	1.34 [0.90, 1.78]	<.00001[a]	57	.07
Procedure duration	3	2407	MD (I-V, Random, 95% CI)	7.75 [5.08, 10.41]	<.00001[a]	65	.02*

Abbreviations: RR, risk ratio; ES, effect size; M-H, Mantel–Haenszel method; CI, confidence interval; IV, inverse variance; MD, mean difference.
[a]Statistically significant.

TABLE 6 Summary of risk of bias.

A. Summary of risk of bias in observational studies using the Newcastle-Ottawa Scale.									
	Selection				Comparability	Outcome			
Study ID	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts	Overall Score
Savvoulidis 2022	*	*	*	*	*	*	*	*	8
Hokken 2021	*	*	*	*	*	*	*	*	8
Stapor 2020	*	*	*	*	*	*	*	*	8
Kleczynski 2020	*	*	*	*	*	*	*	*	8

B. Summary of risk of bias in randomized control trial using the RoB 2 tool.						
Assessment domain	Randomisation process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall bias
Faurie 2019	Low	Low	Low	High	Low	High

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