

Incidence of infective endocarditis following surgical or transcatheter mitral valve repair or replacement: a systematic review and meta-analysis

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Received 4 December 2025; revised 16 February 2026; accepted after revision 27 February 2026; online publish-ahead-of-print 13 April 2026

Abstract

Aims

Infective endocarditis (IE) is a serious and potentially fatal complication of mitral valve (MV) intervention. There are limited data comparing the incidence of IE after MV repair compared with bioprosthetic MV replacement. The aim of this study was to analyse the incidence and timing of IE after MV repair compared with bioprosthetic valve replacement, in both surgical and transcatheter patient populations.

Methods and results

A literature search of Medline, Embase, and Cochrane Library (January 2000–September 2025) was conducted. Pooled IE incidence rates were derived using random-effects models. Eighty-two studies (80 939 patients, total follow-up 350 252 patient-years) were included. The overall incidence rate of IE was 0.97 per 100-patient-years (95% confidence interval [CI] 0.71–1.34). IE was more common after surgical MV replacement (SMVR) than surgical MV repair (SMVr): incidence rate 0.93 (95% CI 0.41–1.81) vs 0.39 (95% CI 0.25–0.62) per 100-patient-years, incidence rate ratio (IRR) 2.34 (95% CI 1.06–5.18), $P = .035$. The incidence of IE after transcatheter MV replacement (TMVR) was comparable to transcatheter MV repair (TMVr) (2.88 [95% CI 1.91–4.33] vs 1.70 [95% CI 0.84–3.43] per 100-patient-years), IRR 1.56 (95% CI 0.73–3.34), $P = .250$. The cumulative incidence of IE following SMVR was significantly higher than following SMVr at 1- and 2-years post-procedure, but not at 6 months.

Conclusions

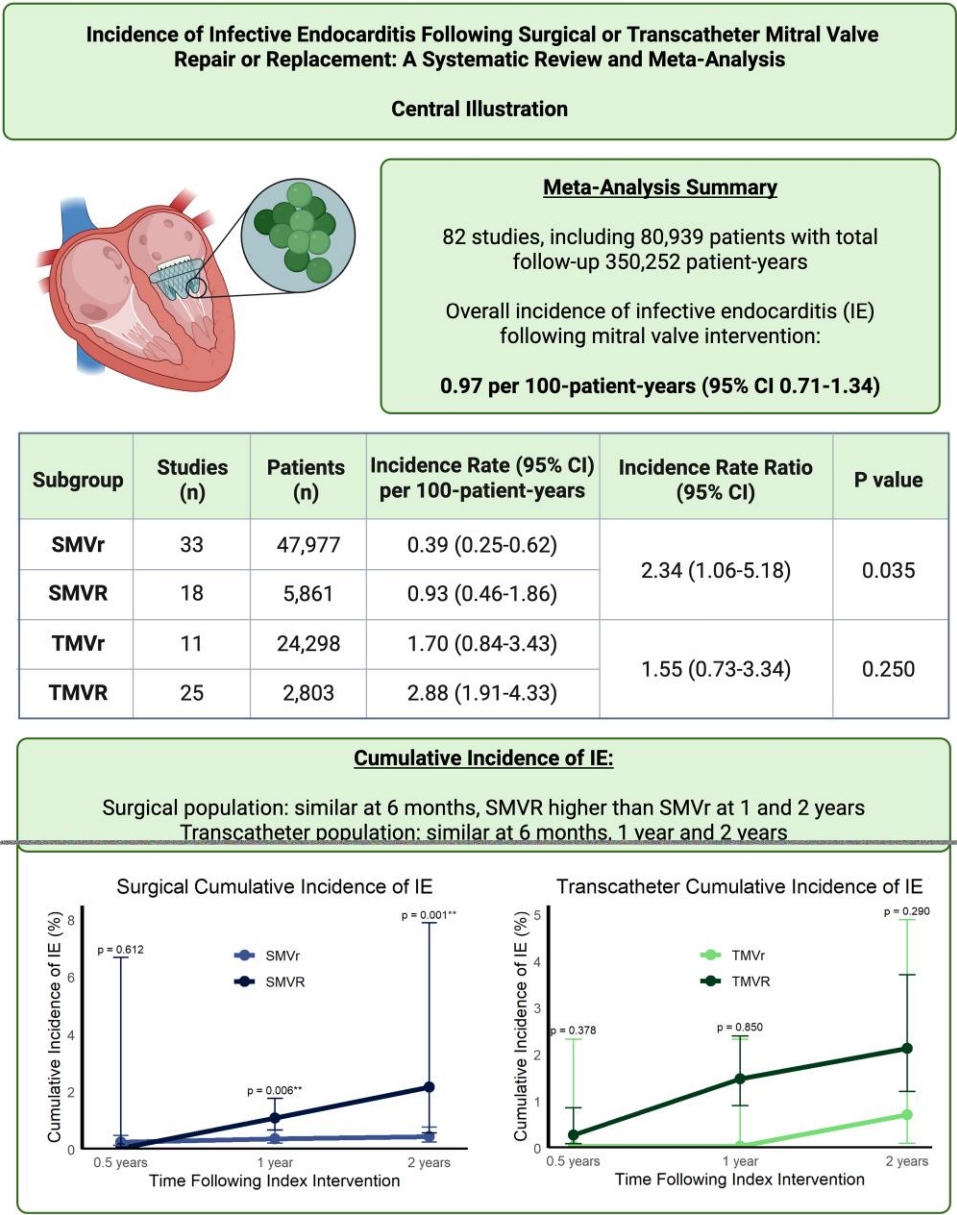
IE is an infrequent complication of mitral valve intervention. The incidence of IE following SMVR is significantly higher than following SMVr, while the incidence of IE following TMVR is numerically but not significantly higher than following TMVr. Reducing IE risk after mitral intervention is a clinical and research priority.

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Graphical abstract



Keywords Infective endocarditis • Surgical mitral valve repair • Surgical mitral valve replacement • Transcatheter mitral valve repair • Transcatheter mitral valve replacement • Post-procedural complications

Introduction

Infective endocarditis (IE), defined as infection of the endocardium or valvular apparatus, is a recognized complication following mitral valve repair (MVr) or replacement and is associated with high morbidity and mortality.¹⁻⁵ Patients with prosthetic valve replacement or prosthetic material used in valve repair have a 5-year risk of IE which is up to 70 times greater than those with native valves.⁶ Patients that develop prosthetic valve IE have a substantially higher risk of complication

(such as abscess or stroke) and mortality when compared with those with native IE.^{7,8}

For patients with mitral valve disease where the native valve can be repaired fully with a durable result, open surgical repair is the gold standard.³ In those where repair is not possible, surgical mitral valve replacement (MVR) (most commonly with a bioprosthesis) has excellent long-term outcomes.⁹⁻¹² In patients at high or prohibitive surgical risk, transcatheter repair and replacement options are increasingly utilized.^{13,14} Transcatheter repair predominantly includes mitral

transcatheter edge-to-edge repair (M-TEER), but in patients with unsuitable anatomy for TEER, several transcatheter replacement options now exist with similar early and mid-term outcomes to surgical replacement.^{15–17}

The relative incidence of IE after MVR or replacement is understudied. The aims of this study were (i) to determine the overall incidence of IE in patients after surgical or transcatheter MVR and bioprosthetic MVR, (ii) to compare the relative incidence of IE after surgical MVR (SMVR) with bioprosthetic surgical MVR (SMVR), (iii) to compare the relative incidence of IE after transcatheter MVR (TMVR) with transcatheter MVR (TMVR), (iv) to compare the relative incidence of IE after SMVR with TMVR, and (v) to compare the relative incidence of IE after SMVR with TMVR.

Methods

Search strategy

The protocol of this systematic review and meta-analysis has been registered in the International Prospective Register of Systematic Review (PROSPERO, CRD420251040530) and the reporting of this systematic review is informed by the meta-analysis of observational studies in epidemiology (MOOSE) reporting guidelines.¹⁸ The MOOSE reporting checklist is provided (supplementary material S1). Embase (Ovid), MEDLINE (Ovid), and Cochrane Central Register of Controlled Trials (CENTRAL) were searched with a date range 2000–2025 (date of the original search 2 July 2024; last repeated on 1 September 2025 to identify new publications). The search strategy is provided (supplementary material S2). No language restrictions were used. Abstracts were included. Covidence (Veritas Health Innovation, Melbourne, Australia) was used to deduplicate search results. The reference lists of prior systematic reviews and included publications were screened to identify additional potentially relevant studies.

Inclusion and exclusion criteria

Studies were included according to the following criteria: (i) adult patients (age ≥ 18 years) who underwent (ii) SMVR, (iii) bioprosthetic SMVR, (iv) TMVR, or (v) TMVR. The TMVR group included both M-TEER and other transcatheter repair methods. The TMVR group included all TMVR modalities: valve in native valve, valve-in-bioprosthetic valve, valve-in-ring, and valve-in-mitral-annular calcification. Studies were excluded if they met any of the following criteria: (i) paediatric patients (age < 18 years), (ii) mechanical SMVR, (iii) active IE, or IE within 6 weeks of the studied valve intervention, (iv) IE of the aortic, tricuspid and/or pulmonary valves, unless concurrent with IE of the repaired/replaced mitral valve, (v) Liebman-Sacks endocarditis, (vi) balloon valvuloplasties, (vii) pregnancy, (viii) studies with insufficient data to ascertain the incidence of IE (including cross-sectional studies, case reports, case series with < 3 patients, and surgical explant studies), or (ix) systematic reviews or meta-analyses. Study eligibility was independently assessed by two reviewers, with disagreements resolved by a third reviewer. In cases of studies reporting on the same patient cohort, we included data from the most recent comprehensive cohort. This study required no ethical approval.

Outcomes

The primary outcome was the incidence of IE, both overall and incidence per index intervention. The secondary outcome was the incidence of IE following index intervention at 6 months, 1 year, and 2 years post-procedure, both overall and incidence per index intervention. IE was defined as confirmed (by Duke Criteria) or suspected IE requiring medical management and/or surgical intervention.¹⁹

Data extraction

Study screening and data extraction phases of the review were completed using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia). Data from included studies were independently extracted by two investigators, with inconsistencies being resolved by a third, consistent reviewer. The extracted data included baseline characteristics,

sample size, the type of mitral valve intervention, number and timing of IE events, and follow-up time. In studies that contained two cohorts of patients that could have outcomes separated by index intervention, each cohort was treated as a separate study in figures.

Statistical analysis

The number of IE events and corresponding follow-up time were used to calculate study-specific incidence rates (IRs). To account for mortality and loss to follow-up, individual patient data or the number of patients remaining under observation at each follow-up interval were used when available. Log-transformed IRs were pooled using a random-effects meta-analysis model, with between-study variance estimated by the maximum-likelihood method. A continuity correction of 0.5 was applied to studies reporting zero events. Heterogeneity was evaluated using the Cochran Q statistic and I^2 values.²⁰ Meta-regression was used to identify significant covariates and evaluate their impact on the incidence of IE. Subgroup analyses were conducted to compare IE incidence between different mitral valve interventions. The results were reported as IRRs with 95% confidence intervals (CIs). To evaluate measurable confounding between subgroups, pooled analyses of patient baseline characteristics were performed using random-effects meta-analysis with maximum-likelihood estimation of between-study variance. Numbers of IE events reported at different follow-up intervals were used to derive pooled time-specific incidence estimates. Publication bias and small-study effects were assessed through visual inspection of funnel plots, trim-and-fill analysis, and Egger's regression test. Baujat plots were generated to explore each study's contribution to overall heterogeneity and influence on the pooled incidence estimates.²¹ Line plots were generated to explore timing data. Statistical significance was set at a P value $< .05$ (two-sided). All analyses were performed with R, version 4.4.0 (R Foundation for Statistical Computing), packages meta, and metafor.^{22–24} The central illustration was generated using BioRender.

Data availability

The data underlying this article are available from the corresponding author on reasonable request.

Results

Study inclusion

A total of 8800 studies identified by the literature search, of which 82 studies met the eligibility criteria for inclusion (Figure 1, Table 1). The studies included 80 939 patients with a total follow-up of 350 252 patient-years, with a mean weighted follow-up 4.3 years per patient (Table 2). This comprised of 309 202 patient-years following SMVR (mean weighted follow-up 6.4 years per patient), 30 595 patient-years following SMVR (mean weighted follow-up 5.2 years per patient), 7726 patient-years following TMVR (mean weighted follow-up 0.3 years per patient), and 2729 patient-years following TMVR (mean weighted follow-up 1.0 years per patient).

Patient characteristics

Patient characteristics from included studies are shown in Table 3. The overall pooled estimate of patient age was 63.1 years, and 46.9% were female. The pooled estimates of patient age for those undergoing SMVR and SMVR were 54.6 years and 58.7 years, respectively, while the pooled estimated of patient age for those undergoing TMVR and TMVR were 67.8 years and 74.4 years, respectively. Patient characteristics were compared across treatment strategy (repair vs replacement for surgical and transcatheter approaches) and treatment approach overall (surgery vs transcatheter). Compared with patients undergoing SMVR, those undergoing SMVR were more likely to be female (60.3% [95% CI 53.6–66.6] vs 42.5% [95% CI 43.3–50.6], $P < .001$) and had a higher rate of prior coronary artery bypass grafting (27.2 [95% CI 24.9–29.7] vs 5.0 [95% CI 4.2–6.1], $P < .001$; Table 3). Patients undergoing TMVR had a higher rate of atrial fibrillation than those undergoing

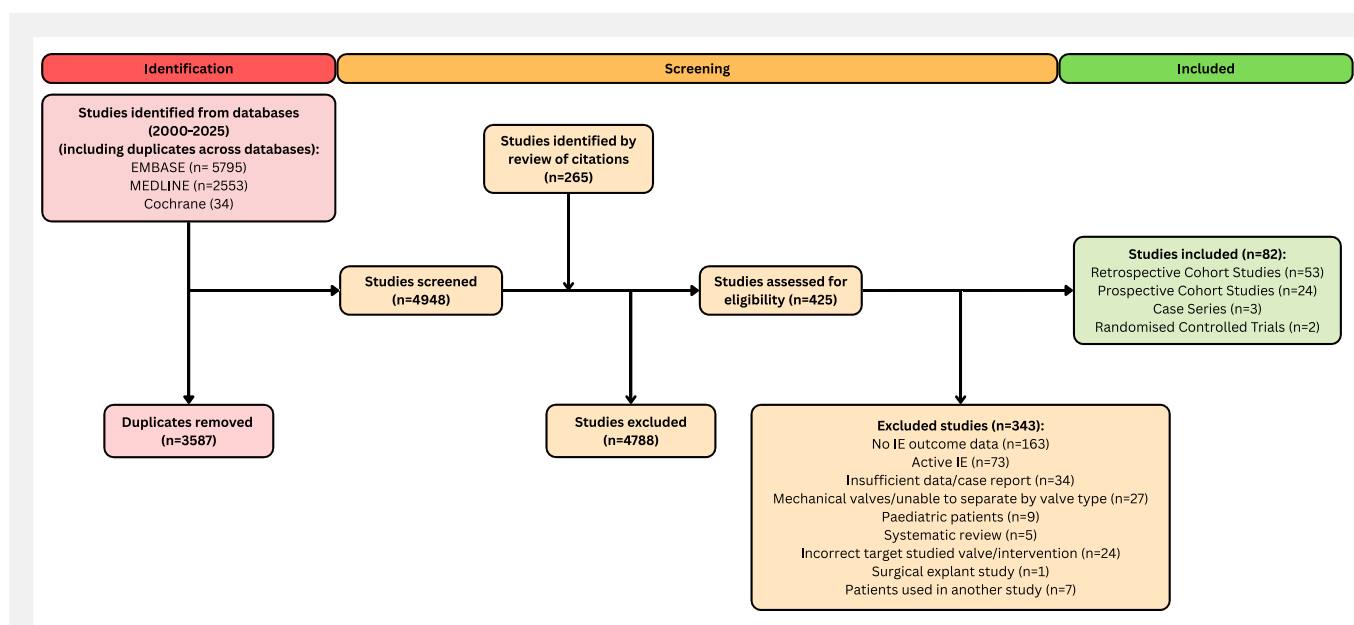


Figure 1 Flow diagram of the identification, screening, and inclusion process. IE, Infective Endocarditis

TMVR (61.4% [95% CI 57.3–65.3] vs 36.4% [95% CI 19.7–57.2], $P = .021$; [Table 3](#)), but were otherwise similar in characteristics. Next, we compared patients undergoing transcatheter MV repair or replacement to those undergoing surgical MV repair or replacement ([Supplementary table S3](#)): this analysis demonstrated that transcatheter patients were older (71.2 years [95% CI 69.4–75.0] vs 55.9 years [95% CI 52.2–59.6], $P < .001$), had a significantly higher EuroSCORE II (19.9% [95% CI 10.8–29.1] vs 9.6% [95% CI 3.6–15.7], $P = .04$), and a significantly greater burden of all baseline comorbidities than surgical patients.

Overall incidence of IE after MV intervention

Across the 82 studies including 80 939 patients with 350 252 patient-years of follow-up, there were a total of 1246 IE events. This corresponded to an overall incidence of IE after bioprosthetic MVR or TMVr of 0.97 (95% CI 0.71–1.34) per 100 patient-years ([Figure 2](#)). In the setting of high heterogeneity ($I^2 = 94\%$), Egger's test suggested the presence of small study effects ($P = .015$). The overall incidence of IE after trim-and-fill sensitivity analysis was 0.39 (95% CI 0.26–0.58) per 100 patient-years, $I^2 = 96\%$ ([supplementary material S4](#)). Funnel plots, trim-and-fill analyses and Baujat plots are shown in [supplementary materials S4](#) and [S5](#).

Incidence of IE after surgical MV interventions

Across 49 studies including 53 838 patients with 339 797 patient-years of follow-up the incidence of IE following SMVR or SMVr was 0.53 (95% CI 0.36–0.79) per 100 patient-years, $I^2 = 89\%$ ([Figure 3](#)). When stratified by treatment strategy, the incidence of IE following SMVr was 0.39 (95% CI 0.25–0.62) per 100 patient-years, $I^2 = 89.3\%$ ([Figure 3](#)). The incidence of IE following SMVR was 0.93 (95% CI 0.46–1.86) per 100 patient-years, $I^2 = 81.4\%$ ([Figure 3](#)). The incidence of IE following SMVR was significantly higher than after SMVr, with an IRR of 2.34 (95% CI 1.06–5.18), $P = 0.035$.

Incidence of IE after transcatheter MV interventions

Across 36 studies including 27 101 patients with 10 455 patient-years of follow-up, the incidence of IE following TMVR or TMVr was 2.48 (95% CI 1.73–3.51) per 100 patient-years, $I^2 = 73.0\%$ ([Figure 4](#)). When stratified by treatment strategy, the incidence of IE following TMVr was 1.70 (95% CI 0.84–3.43) per 100 patient-years, $I^2 = 88.6\%$ ([Figure 4](#)). The incidence of IE following TMVR was 2.88 (95% CI 1.91–4.33) per 100 patient-years, $I^2 = 41.9\%$ ([Figure 4](#)). Although numerically higher, there was no statistically significant difference in the incidence of IE following TMVR compared with TMVr, with an IRR of 1.56 (95% CI 0.73–3.34), $P = .250$.

Incidence of IE after MV replacement

Across 43 studies including 8664 patients with 33 324 patient-years of follow-up the incidence of IE following SMVR or TMVR was 1.71 (95% CI 1.11–2.63) per 100 patient-years, $I^2 = 82.0\%$ ([supplementary material S6A](#)). Egger's test suggested the presence of small-study effects ($P = .04$). The overall incidence of IE following MVR after trim-and-fill sensitivity analysis was 0.72 (95% CI 0.42–1.21) per 100 patient-years, $I^2 = 88.0\%$.

When stratified by approach, the incidence of IE following SMVR was 0.93 (95% CI 0.46–1.86) per 100 patient-years, $I^2 = 81.4\%$. The incidence of IE following TMVR was 2.88 (95% CI 1.91–4.34) per 100 patient-years, $I^2 = 41.9\%$. The incidence of IE following TMVR was significantly higher than after SMVR, with an IRR of 3.26 (95% CI 1.51–7.03), $P = .003$.

Incidence of IE after MV repair

Across 44 studies including 72 275 patients with 316 298 patient-years of follow-up the incidence of IE following SMVr or TMVr was 0.55 (95% CI 0.36–0.86) per 100 patient-years, $I^2 = 96.0\%$ ([supplementary material S6B](#)). When stratified by approach, the incidence of IE following SMVr was 0.39 (95% CI 0.25–0.62) per 100 patient-years, $I^2 = 89.3\%$. The incidence of IE following TMVr was 1.70 (95% CI 0.84–3.43) per 100 patient-years, $I^2 = 88.6\%$. The incidence of IE following

Table 1 Study characteristics

First author, year	Study design	Study period	Intervention	N (patients)	Device/Valve
Akoodad (2023) ²⁵	Prospective Cohort	2008–2021	TMVR—VIV	119	Sapien XT/Sapien 3: 117 J-Valve: 2
Alhakak (2025) ²⁶	Retrospective Cohort	2000–2020	SMVr	3239	
Ali (2004) ²⁷	Retrospective Cohort	February 1993–July 2002	SMVR	80	Total homograft: 65 Partial homograft: 39
Alvarez-Covarrubias (2024) ²⁸	Retrospective Cohort	November 2011–April 2021	TMVR—VIV, ViR, ViMAC	77	Sapien XT: 10 Sapien 3: 51 Sapien 3 Ultra: 9 Lotus: 4 Direct Flow: 1 Tendyne: 2
Ararat (2023) ²⁹	Retrospective Cohort	March 2017–July 2019	TMVR—VIV, ViR	22	
Argenziano (2010) ³⁰	Retrospective Cohort	2005–2010	M-TEER	107	MitraClip 0: 11 1: 65 2: 31
Bapat (2024) ³¹	Prospective Cohort	2017–2021	TMVR—Native valve	252	Intrepid: 50
Besola (2021) ³²	Retrospective Cohort	July 2007–July 2020	TMVR—VIV	82	Gribier-Edwards: 1 Sapien: 11 Sapien XT: 46 Sapien 3: 24
Bouleti (2015) ³³	Prospective Cohort	March 2011–August 2013	TMVR—VIV, ViR	17	Sapien XT: 17
Budra (2022) ³⁴	Prospective Cohort	2011–2017	Mitral Transcatheter Neochord Implantation	88	DS1000: 94
Chen (2009) ³⁵	Prospective Cohort	April 2003–December 2007	SMVr	42	Carpentier Physio ring: 42
Chen (2024) ³⁶	Retrospective Cohort	January 2001–December 2018	SMVR	2707	
Cheng (2022) ³⁷	Retrospective Cohort	March 2016–November 2019	SMVr	89	
Chiang (2023) ³⁸	Retrospective Cohort	January 2017–December 2021	SMVr	164	Physio II ring: 80 Cosgrave ring: 21 Memo3D ring: 9
da Costa (2019) ³⁹	Prospective Cohort	May 2015–June 2018	TMVR—VIV	50	Braille Inovare: 50
Davarasand (2014) ⁴⁰	Retrospective Cohort	September 2003–October 2013	SMVR	6	Carpentier-Edwards or Hancock II

Continued

Table 1 Continued

First author, year	Study design	Study period	Intervention	N (patients)	Device/Valve
De Bonis (2014) ⁴¹	Retrospective Cohort	1991–2004	SMVr	139	St Jude Séguin ring: 92 Carpentier-Edwards Classic ring: 25 Flexible Duran ring: 6 Flexible Sovereign ring: 3 Flexible St Jude Tailor ring: 2 Autologous pericardium: 11
Deharo (2024) ⁴²	Retrospective Cohort	January 2012–June 2022	SMVr	1851	
			M-TEER	4741	MitraClip
Duncan (2017) ⁴³	Case Series	October 2014–March 2017	TMVR—Native valve	5	Tendyne: 5
Duncan (2024) ⁴⁴	Prospective Cohort	November 2014–June 2020	TMVR—Native valve	191	Tendyne: 191
Eggebrecht (2015) ⁴⁵	Prospective Cohort	August 2010–August 2013	M-TEER	7890	MitraClip
Elmously (2018) ⁴⁶	Prospective Cohort	December 2013–May 2017	TMVR—VIV	19	Sapien 3: 2 Sapien XT: 17
Feldman (2011) ⁴⁷	RCT	September 2005–November 2008	M-TEER	184	MitraClip
Galeone (2024) ⁴⁸	Retrospective Cohort	March 2015–April 2024	TMVR—Native valve, VIV, VIR	39	Sapien 3: 22 Sapien 3 Ultra: 13 Sapien XT: 4
Gerdisch (2014) ⁴⁹	Retrospective Cohort	September 2008–February 2013	SMVr	15	
Guerrero (2020) ⁵⁰	Retrospective Cohort	March 2013–June 2017	TMVR—VIV, VIR, VIMAC	903	Sapien: 36 Sapien XT: 364 Sapien 3: 468
Guerrero (2023) ⁵¹	Prospective Cohort	February 2015–December 2017	TMVR—VIV, VIR, VIMAC	91	
Gulbins (2002) ⁵²	Prospective Cohort	July 1996–January 1999	SMVR	7	Mitral homograft
Gutiérrez-Ortiz (2024) ⁵³	Prospective Cohort	December 2020–June 2022	TMVR—Native valve	40	Tendyne: 40
Han (2022) ⁵⁴	Retrospective Cohort	January 1996–July 2018	SMVR	388	Perimount Bovine: 143 Magna Mitral Ease Bovine: 74 Hancock II Porcine: 134 Epic Porcine: 8 Biocor Porcine: 29
Hell (2024) ⁵⁵	Prospective Cohort	January 2020–December 2021	TMVR—Native valve, VIMAC	195	Tendyne: 195
Iribarne (2024) ⁵⁶	Retrospective Cohort	January 2004–December 2019	SMVr	32 736	
Karavas (2002) ⁵⁷	Retrospective Cohort	June 1991–June 2000	SMVr	1273	
Kim (2010) ⁵⁸	Retrospective Cohort	July 1997–July 2007	SMVr	122	
					Continued

Table 1 Continued

First author, year	Study design	Study period	Intervention	N (patients)	Device/Valve
Kim (2017) ⁵⁹	Retrospective Cohort	January 1997–December 2015	SMVR	303	SMVr
			SMVr	294	
Kim (2021) ⁶⁰	Retrospective Cohort	January 1990–December 2015	SMVr	384	SMVr
Korkmaz (2011) ⁶¹	Prospective Cohort	July 2006–November 2009	SMVr	103	
Kulik (2006) ⁶²	Prospective Cohort	January 1977–July 2002	SMVR	2006	Medtronic Hancock: 42 Edwards Pericardial: 7
Laham (2023) ⁶³	Retrospective Cohort	June 2010–December 2016	SMVr	64	Gore-tex neochoordae
Lee (2015) ⁶⁴	Retrospective Cohort	August 2008–March 2013	SMVr	15	SMVr
Lee (2024) ⁶⁵	Retrospective Cohort	January 2001–December 2018	SMVr	3007	
Liu (2019) ⁶⁶	Retrospective Cohort	January 2007–September 2014	SMVr	110	
Ludwig (2023) ²³	Retrospective Cohort	May 2014–July 2022	TMVR—Native valve	400	
					Altavalue: 1 CardIAQ: 1 CardioValve: 2 Cephea: 5 Evoque: 5 Fortis: 1 Highlife: 7 Intrepid: 23 Sapien M3: 14 Tendyne: 310 Tiara: 28
Malaisrie (2024) ⁶⁷	Prospective Cohort	2018–2021	TMVR—ViV	50	Sapien 3: 50
Mandye (2022) ⁶⁸	Retrospective Cohort	January 2018–December 2021	SMVR	37	Hancock II: 37
Masters (2004) ⁶⁹	Retrospective Cohort	May 1991–December 1999	SMVR	138	Hancock II: 138
Miura (2009) ⁷⁰	Retrospective Cohort	April 1999–September 2007	SMVr	116	SMVr
Miura (2020) ⁷¹	Retrospective Cohort	April 1999–October 2009	SMVr	94	
Mohammed (2021) ⁷²	Retrospective Cohort	Unavailable	M-TEER	36	Mitraclip: 36
Muneretto (2015) ⁷³	Prospective Cohort	January 2009–March 2012	SMVr	50	Carpentier-Edwards Classic: 26 Physio: 24
Murzi (2017) ⁷⁴	Retrospective Cohort	September 2005–December 2015	SMVR	40	TMVR—Native valve, ViV
			TMVR—Native valve, ViV	21	

Continued

Table 1 Continued

First author, year	Study design	Study period	Intervention	N (patients)	Device/Valve
Myken (2005) ⁷⁵	Retrospective Cohort	January 1983–January 2000	SMVR	172	Biocor porcine: 172
Nakajima (2010) ⁷⁶	Retrospective Cohort	October 1997–May 2008	SMVr	45	Carpentier-Edwards Classic rigid ring: 43
Nasir (2024) ⁷⁷	Retrospective Cohort	2006–2020	SMVR	502	
Ng (2000) ⁷⁸	Prospective Cohort	April 1990–January 1998	SMVr	33	Carpentier-Edwards rigid ring: 6 Medtronic Sculptor semiflexible: 12 Cosgrove-Edward flexible: 7
Omay (2009) ⁷⁹	Prospective Cohort	2002–2007	SMVr	36	
Oxenham (2003) ⁸⁰	Prospective Cohort	1975–1979	SMVR	133	Hancock Carpentier-Edwards
Park (2025) ⁸¹	Retrospective Cohort	January 2000–December 2022	SMVr	1500	
Perier (2013) ⁸²	Retrospective Cohort	September 2006–December 2012	SMVR	6	
Pravda (2022) ⁸³	Prospective Cohort	October 2010–October 2019	TMVR—Native valve, ViV	836 49	Physio II ring: 836 Sapien 3: 32 Sapien XT: 17
Seguchi (2023) ⁸⁴	Retrospective Cohort	May 2015–March 2022	SMVr	124	
Shimokawa (2009) ⁸⁵	Retrospective Cohort	July 1991–December 2006	SMVr	619	
Sorajja (2019) ⁸⁶	Prospective Cohort	November 2014–November 2017	TMVR	9	Tendyne
Stone (2018) ⁸⁷	RCT	December 2012–June 2017	M-TEER	302	MitraClip
Szpytma (2024) ⁸⁸	Retrospective Cohort	July 2021–June 2023	SMVR	47	Mitris Resilia: 47
Taggarse (2017) ⁸⁹	Retrospective Cohort	January 2008–September 2016	SMVr	619	
Taramasso (2012) ⁹⁰	Retrospective Cohort	March 2000–April 2011	SMVr M-TEER	91 52	MitraClip: 52
Tomsic (2024) ⁹¹	Retrospective Cohort	January 2008–December 2020	SMVr	89	Physio ring: 22 Physio II ring: 59
Trumello (2020) ⁹²	Retrospective Cohort	2003–2017	SMVr	39	
Truong (2025) ⁹³	Retrospective Cohort	January 1996–December 2021	SMVR	1084	
Urena (2018) ⁹⁴	Prospective Cohort	July 2010–July 2017	TMVR—ViV, ViR, ViMAC	91	Sapien XT: 37 Sapien 3: 53
Ussia (2017) ⁹⁵	Case Series	March 2015–November 2015	TMVR—Native valve	4	CardiaQ Edwards
von Bardeleben (2019) ⁹⁶	Retrospective Cohort	2011–2015	M-TEER	13 575	MitraClip
Warner (2024) ⁹⁷	Retrospective Cohort	October 2015–December 2019	M-TEER	965	MitraClip
Continued					

Table 1 Continued

First author, year	Study design	Study period	Intervention	N (patients)	Device/Valve
Wilbring (2013) ⁹⁸	Retrospective Cohort	November 2008–January 2014	TMVR—VIV, VIV	13	Sapien THV: 10 Sapien XT: 2
Williams (2001) ⁹⁹	Retrospective Cohort	March 1994–June 2000	SMVR	8	Toronto SPY
Yao (2003) ¹⁰⁰	Retrospective Cohort	November 1973–December 1998	SMVR	154	Hancock porcine: 43 Carpentier-Edwards porcine: 26 Carpentier-Edwards bovine: 33 Ionescu-Shiley pericardial: 39 Hancock II porcine: 13
Ye (2015) ¹⁰¹	Retrospective Cohort	April 2007–December 2013	TMVR—VIV	31	Sapien, Sapien XT
Yeo (2019) ¹⁰²	Retrospective Cohort	January 2014–September 2015	M-TEER	3420	MitraClip
Zahr (2023) ¹⁰³	Prospective Cohort	February 2020–August 2022	TMVR—Native valve	33	Intrepid
Zegdi (2008) ¹⁰⁴	Case Series	January 1991–February 2004	SMVr	13	
Zhong (2020) ¹⁰⁵	Retrospective Cohort	January 2010–December 2012	SMVr	26	

TMVR, Transcatheter Mitral Valve Repair; VIV, Valve-in-valve; SMVr, Surgical Mitral Valve Repair; SMVR, Surgical Mitral Valve Replacement; VIV, Valve-in-Ring; VIMAC, Valve-in-Mitral-Annular-Calification; M-TEER, Mitral Transcatheter Edge-to-Edge Repair.

Table 2 Summary of the numbers of studies, numbers of patients, and follow-up duration

	All patients	SMVr	SMVR	TMVr	TMVR
n (patients)	80 939	47 977	5861	24 298	2803
n (studies)	87	33	18	11	25
Mean weighted follow-up (years)	4.3	6.4	5.2	0.3	1.0
Total follow-up (patient-years)	350 252	309 202	30 595	7726	2729

SMVr, Surgical Mitral Valve Repair; SMVR, Surgical Mitral Valve Replacement; TMVr, Transcatheter Mitral Valve Repair; TMVR, Transcatheter Mitral Valve Replacement.

TMVr was significantly higher than after SMVr, with an IRR of 4.19 (95% CI 1.75–10.01), $P = .001$.

Timing of IE after MV interventions

Forty-five studies including 8606 patients had data that allowed calculation of pooled estimates for the cumulative incidence of IE at 6 months, 1 year, and 2 years following surgical or transcatheter MV repair or replacement (Table 4). The overall cumulative incidence of IE was 0.17% (95% CI 0.08–0.37%) at 6 months, 0.57% (95% CI 0.33–0.98%) at 1 year, and 0.87% (95% CI 0.49–1.54%) at 2 years. Following surgical mitral valve intervention, there was no significant difference in cumulative incidence of IE at 6 months between SMVR and SMVr. There was a statistically significant higher cumulative incidence of IE after SMVR compared with SMVr at 1 year (1.09% [95% CI 0.67–1.77%] vs 0.37% [95% CI 0.21–0.67%], $P = .006$, Table 4) and 2 years (2.17% [95% CI 0.57–7.89%] vs 0.44% [95% CI 0.25–0.77%], $P = .001$, Table 4, Figure 5A). Following transcatheter mitral valve intervention, there was no significant difference in the cumulative incidence of IE after TMVR compared with TMVr at 6 months, 1 year, or 2 years (2.13% [95% CI 1.21–3.71%] vs 0.71% [95% CI 0.10–4.89%] at 2 years, $P = .290$, Table 4, Figure 5B). Following mitral valve replacement, there was no significant difference in the cumulative incidence of IE after SMVR compared with TMVR at 6 months, 1 year, or 2 years (2.17% [95% CI 0.57–7.89%] vs 2.13% [95% CI 1.21–3.71%] at 2 years, $P = .184$, Table 4). Following MVr, there was no significant difference in the cumulative incidence of IE after SMVr compared with TMVr at 6 months, 1 year, or 2 years (0.44% [95% CI 0.25–0.77%] vs 0.71% [95% CI 0.10–4.89%] at 2 years, $P = .184$, Table 4).

Discussion

This study is a systematic analysis of the incidence of IE after surgical or transcatheter mitral valve bioprosthetic replacement or repair. To our knowledge, this is the first systematic review to compare both surgical repair and replacement populations, and to compare transcatheter repair and replacement populations while incorporating population characteristics and the timing of IE occurrence after intervention. Our main findings are as follows: (i) the incidence of IE after MV repair or replacement is low at 0.97 per 100 patient-years; (ii) the incidence of IE after bioprosthetic SMVR is significantly higher than after SMVr; (iii) the incidence of IE after TMVR is numerically higher than after TMVr, but this does not reach statistical significance; (iv) the incidence of IE after TMVR is significantly higher than after SMVR; (v) the incidence of IE after TMVr is significantly higher than after SMVR; and (vi) the

Table 3 Pooled estimated of patient characteristics

Pooled estimates	Overall	SMVr	SMVR	P value (SMVr vs SMVR)	TMVr	TMVR	P value (TMVr vs TMVR)
Age (years)	63.1 (59.8–66.4)	54.6 (50.7–58.6)	58.7 (50–56.9)	.236	67.8 (60.6–74.0)	74.4 (72.3–76.5)	.0776
Sex (% female)	46.9 (43.3–50.6)	42.5 (36.6–48.6)	60.3 (53.6–66.6)	<.001*	38.0 (34.0–42.2)	52.3 (47.6–57.9)	.071
Hypertension (%)	59.0 (49.5–67.9)	39.6 (25.8–55.2)	44.9 (29.6–61.2)	.703	70.0 (57.7–80.0)	76.5 (67.7–83.5)	.351
Diabetes mellitus (%)	20.5 (17.3–24.1)	12.1 (10.0–17.0)	17.9 (12.4–25.2)	.258	21.4 (12.9–33.5)	27.8 (25.1–30.5)	.284
Prior PCI (%)	15.4 (10.0–23.1)	6.9 (2.6–17.1)	NA (1 study only)	NA	23.3 (17.7–30.0)	19.6 (11.8–30.7)	.528
Prior CABG (%)	21.1 (14.8–26.6)	5.0 (4.2–6.1)	27.2 (24.9–29.7)	<.001*	19.1 (10.0–33.5)	29.0 (23.0–35.8)	.191
Atrial fibrillation (%)	43.4 (35.8–51.2)	34.9 (23.7–48.0)	36.6 (16.0–63.6)	.871	36.4 (19.7–57.2)	61.4 (57.3–65.3)	.021*
Prior stroke/TIA (%)	8.9 (7.2–11.1)	5.5 (4.2–7.3)	6.7 (4.1–10.9)	.450	10.1 (6.7–14.8)	14.9 (11.9–18.6)	.084
CKD (%)	27.2 (14.7–44.7)	6.2 (3.0–12.2)	4.0 (0.9–16.6)	.735	70.5 (21.3–95.5)	47.2 (31.2–63.8)	.398
STS PROM Score (%)	10.6 (7.3–13.9)	NA (0 studies)	NA (0 studies)	NA	8.2 (7.3–9.1)	11.2 (7.1–15.3)	.161
EuroSCORE II (%)	16.0 (9.6–22.3)	6.5 (3.3–9.7)	NA (1 study only)	NA	16.7 (3.9–29.6)	21.5 (8.9–34.2)	.603

SMVr, Surgical Mitral Valve Repair; SMVR, Surgical Mitral Valve Replacement; TMVr, Transcatheter Mitral Valve Repair; TMVR, Transcatheter Mitral Valve Replacement; PCI, Percutaneous Coronary Intervention; CABG, Coronary Artery Bypass Graft; TIA, Transient Ischaemic Attack; CKD, Chronic Kidney Disease.

*P < .05.

cumulative incidence of IE after SMVr and SMVR is similar at 6 months but diverges thereafter, with higher rates after SMVR at 1 and 2 years.

Prior studies evaluating the incidence of IE after surgical mitral valve repair or replacement

The current study shows that the IRR of developing IE following bioprosthetic SMVR compared with following SMVr is 2.34. Two large recent cohort studies by Alhakak *et al.* (2025) and Lee *et al.* (2024) have compared the rates of IE following SMVr and SMVR.^{26,65} Alhakak *et al.* (2024) reported a significantly lower rate of IE after SMVr (1.6% at 10 years) compared with SMVR (6.1% at 10 years).²⁶ Lee *et al.* (2024) reported an incidence of 1.6% following SMVr, and 2.4% following SMVR over a variable length of follow-up.⁶⁵ Both studies combine outcomes for surgical mechanical and bioprosthetic valve replacement. Given the differing risks of IE between mechanical and bioprosthetic surgical valves, this is a limitation to making a direct comparison with surgical repair.^{106–108} For this reason, this study has been restricted to include only bioprosthetic valve replacement.

Prior studies evaluating the incidence of IE after transcatheter mitral valve repair or replacement

There are limited data comparing the incidence rates of IE following TMVr and TMVR. Separately, more recent studies such as Deharo *et al.* (2024) have given rates of 1.5 per 100 patient-years after M-TEER (which constitutes 99.6% of the patients in our TMVr population), while the Expanded Clinical Study of the Tendyne Mitral Valve System has given a rate of 6.1% of patients developing IE in the 3 years following TMVR, and studies with the Intrepid TA-MVR system have given a lower rate of 2.7% over 2 years.^{44,109} The current study shows that the IRR of developing IE following TMVR compared with following TMVr is 1.56, although this does not reach statistical significance. This may represent the same effect as seen in the comparison between

SMVR and SMVr, and may not reach significance due to a significantly smaller population size and shorter follow-up. Further research into the rates of IE following TMVR and TMVr, including comparative studies, is warranted.

Timing of IE following MV interventions

Our study indicates that the differences in IE incidence between SMVR and SMVr populations are borne out from 1-year post-intervention, suggesting the additional risk occurs over follow-up rather than at the time of the index procedure or the early post-procedural phase. Studies of comparable population sizes include the recent study of the Taiwanese national database, which estimated the incidence of IE of 1.4% and 2.0% at 1 and 2 years, respectively following bioprosthetic SMVR,¹⁰⁶ and the recent study of the Danish national registry, which estimated higher incidences of IE of 2.25% and 2.5% at 1 and 2 years, respectively, following bioprosthetic or mechanical SMVR.²⁶ Further research into the timing of IE following MV intervention is warranted.

Comparative rates of IE following replacement or repair between surgical and transcatheter populations

Recent studies have attempted to compare outcomes following surgical or transcatheter repair or replacement.^{42,90,110} Deharo *et al.* (2024) found no significant difference in rates of IE following SMVr and M-TEER, while Taramasso *et al.* (2012) were unable to compare the two.^{42,90} Similarly, Murzi *et al.* (2017) reported a single patient developing IE after TMVR and no patients developing IE after SMVR, but were unable to compare the two. Previous studies have highlighted significant differences between transcatheter and surgical populations, in both repair and replacement.^{15,29,42,111} This was confirmed in our analysis which demonstrated that patients undergoing transcatheter interventions are older, have a higher frailty, and have more comorbidities. Studies that have attempted to match for these differences in baseline characteristics have been varied in their results, with some reporting

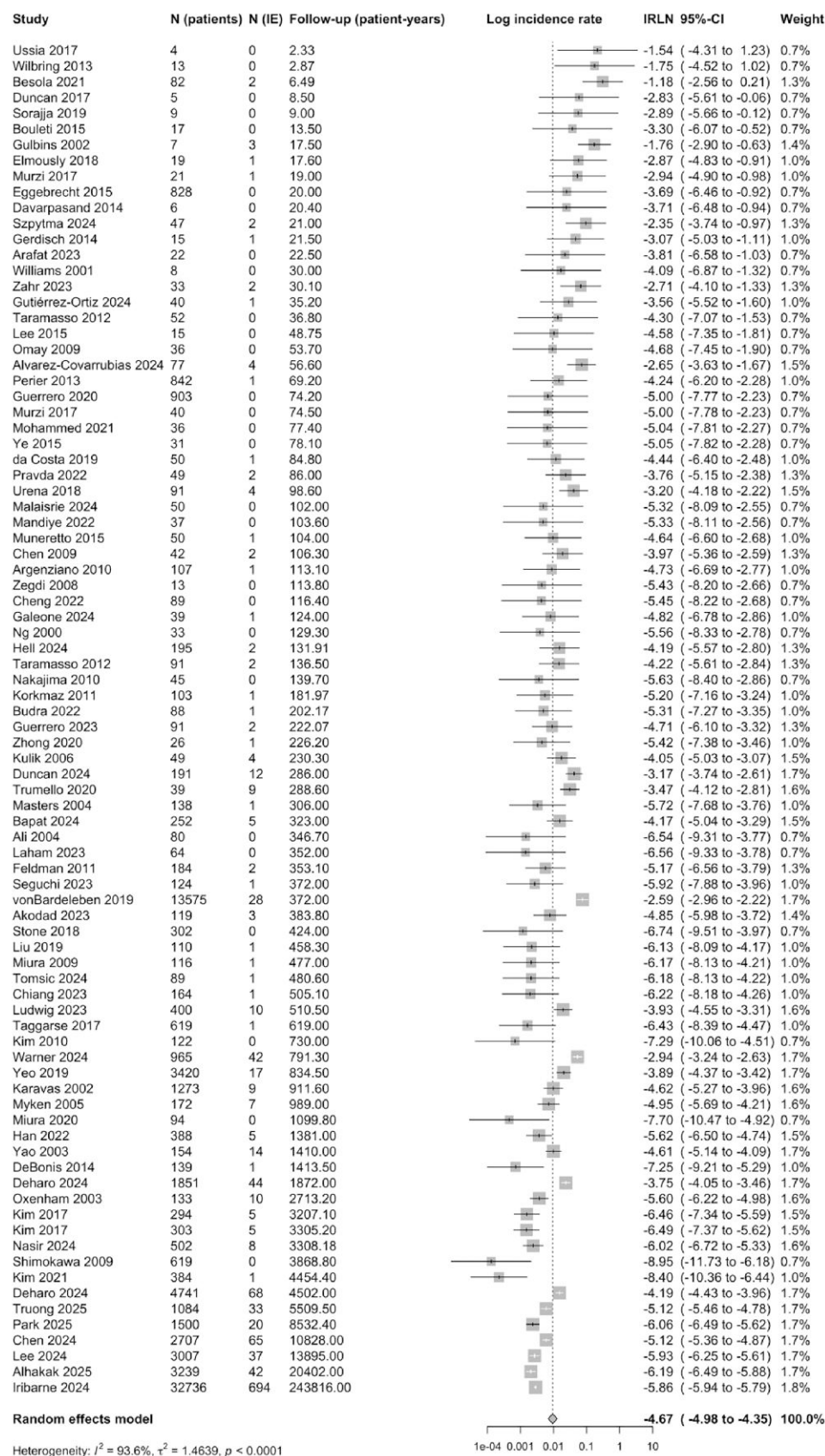


Figure 2 Forest plot showing all included studies. IE, Infective Endocarditis IRLN, Log-transformed Incidence Rate

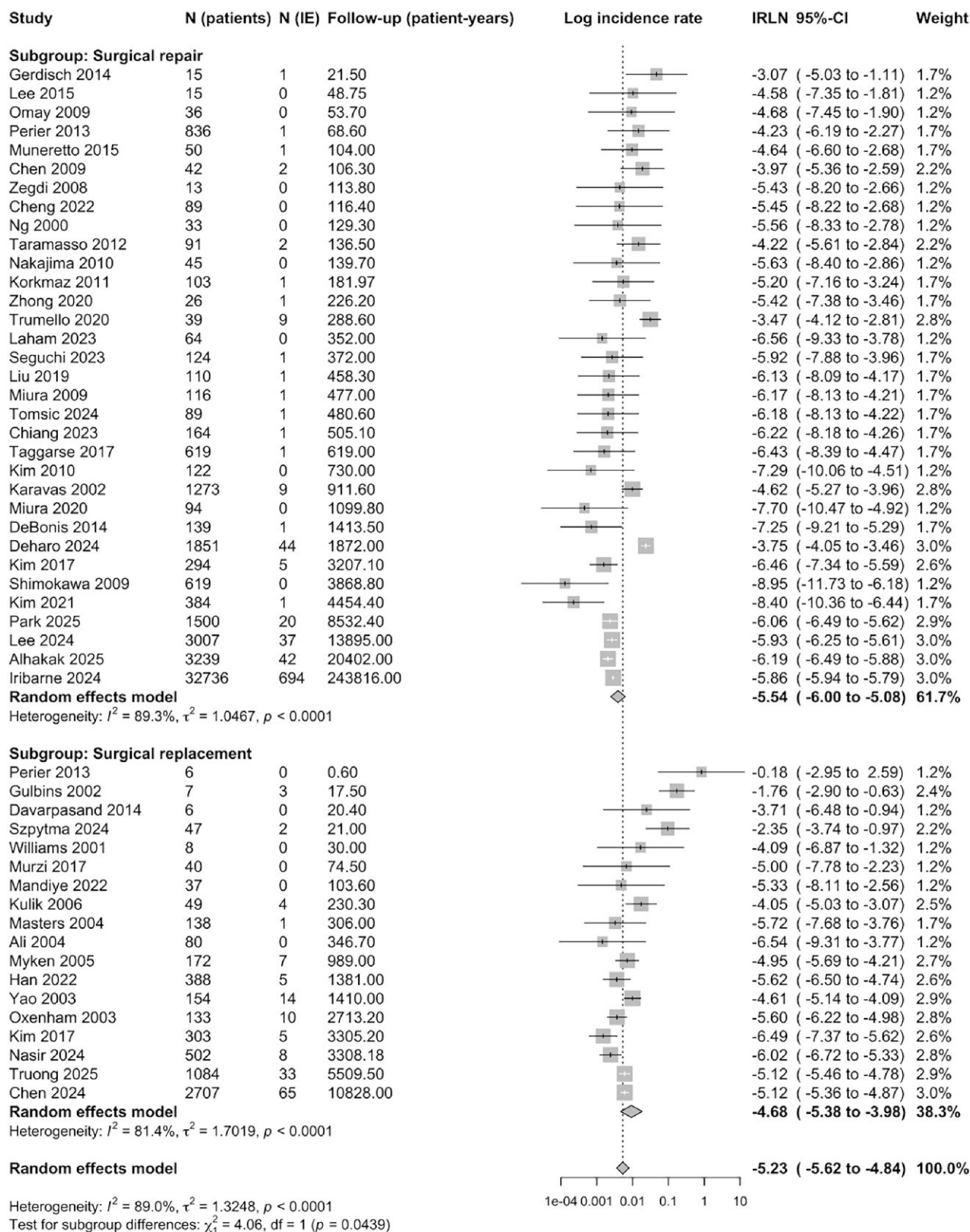


Figure 3 Forest plot showing studies reporting outcomes following surgical mitral valve repair, and surgical mitral valve replacement, separated by index intervention. IE, Infective Endocarditis IRLN: Log-transformed Incidence Rate

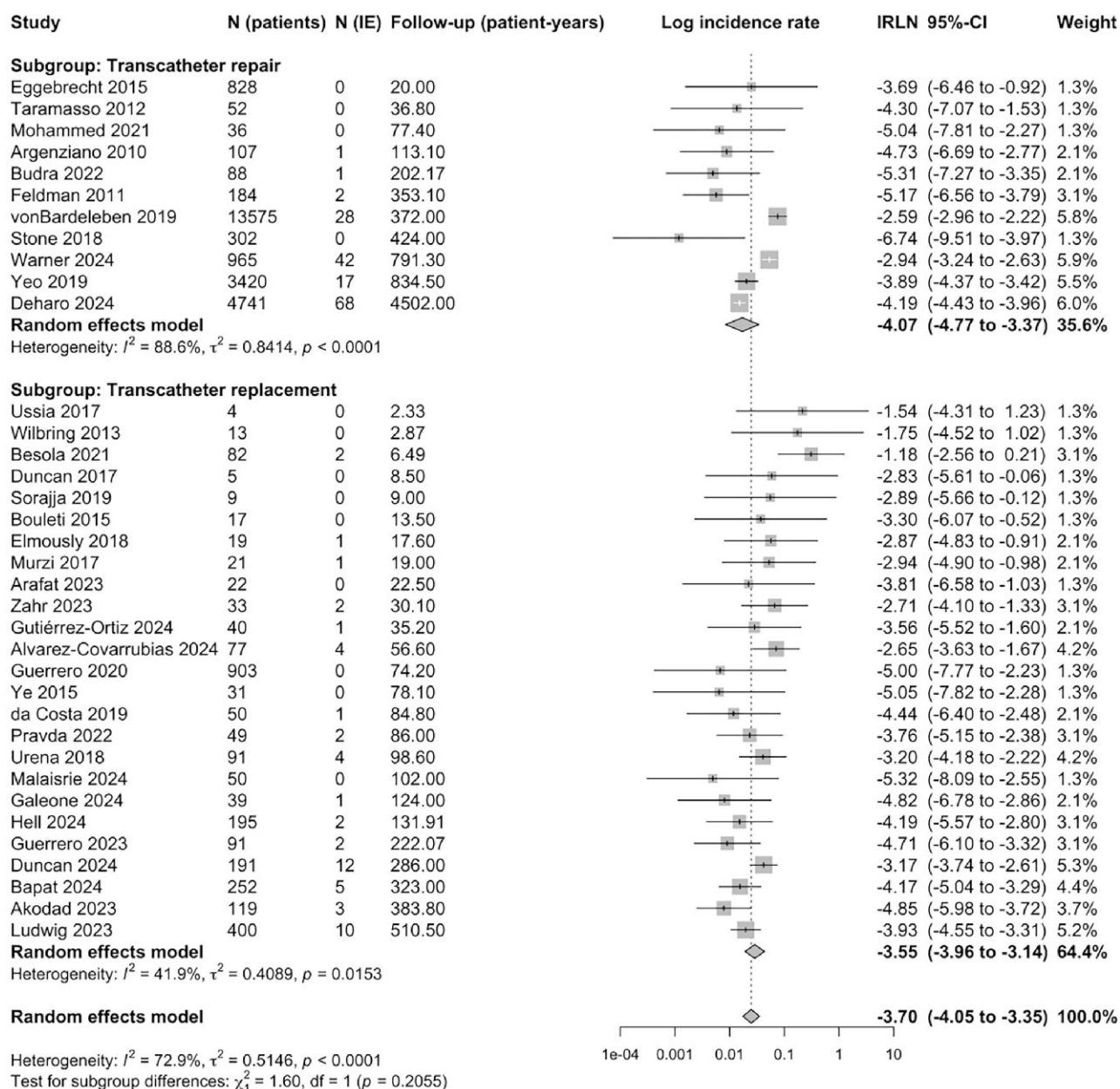


Figure 4 Forest plot showing studies reporting outcomes transcatheter mitral valve repair, and transcatheter mitral valve replacement, separated by index intervention. IE, Infective Endocarditis IRLN, Log-transformed Incidence Rate

either no or reduced significant differences in measured outcomes, while others reported persistently worse outcomes for transcatheter populations.^{15,112,113} While we have identified significantly higher rates of IE following transcatheter replacement compared with following surgical replacement and following transcatheter repair compared with following surgical repair, the extent of the differences in the transcatheter and surgical populations significantly undermines the validity of our comparison between the groups. Future randomized controlled trials, such as the currently ongoing REPAIR MR Trial (NCT04198870), are required to meaningfully compare these populations, and thus validly compare rates of IE following these interventions when not confounded by baseline characteristics.¹¹⁴

Mechanisms of IE after MV repair or replacement

Alhakak *et al.* (2025) have postulated that the reduced risk of IE after SMVr is due to less prosthetic material exposed to blood flow compared with after SMVR.²⁶ Another (interacting) possibility is that SMVr results in less residual turbulence and disturbance of normal blood flow, and a lower likelihood of endothelial injury. While the decision to repair or replace a valve that is amenable to repair is multifactorial, in populations at moderate or high-risk of developing IE, the results of this study suggest that further weight should be given in favour of performing SMVr compared with SMVR where technically feasible.^{3,4}

Table 4 Cumulative incidence of infective endocarditis following index procedure

Time	Overall cumulative incidence of IE (%)	SMVr	SMVR	P value (SMVr vs SMVR)	TMVr	TMVR	P value (TMVr vs TMVR)	P value (SMVR vs TMVR)	P value (SMVr vs. TMVr)
6 months	0.17 (0.08–0.37)	0.25 (0.13–0.48)	0.04 (0.00–6.69)	.612	0.04 (0.00–2.33)	0.28 (0.09–0.86)	.378	.651	.289
1 year	0.57 (0.33–0.98)	0.37 (0.21–0.67)	1.09 (0.67–1.77)	.006*	0.04 (0.00–2.33)	1.48 (0.91–2.40)	.085	.380	.116
2 years	0.87 (0.49–1.54)	0.44 (0.25–0.77)	2.17 (0.57–7.89)	.001*	0.71 (0.10–4.89)	2.13 (1.21–3.71)	.290	.184	.640

SMVr, Surgical Mitral Valve Replacement; SMVR, Surgical Mitral Valve Repair; TMVr, Transcatheter Mitral Valve Replacement; TMVR, Transcatheter Mitral Valve Replacement.
* $P < .05$.

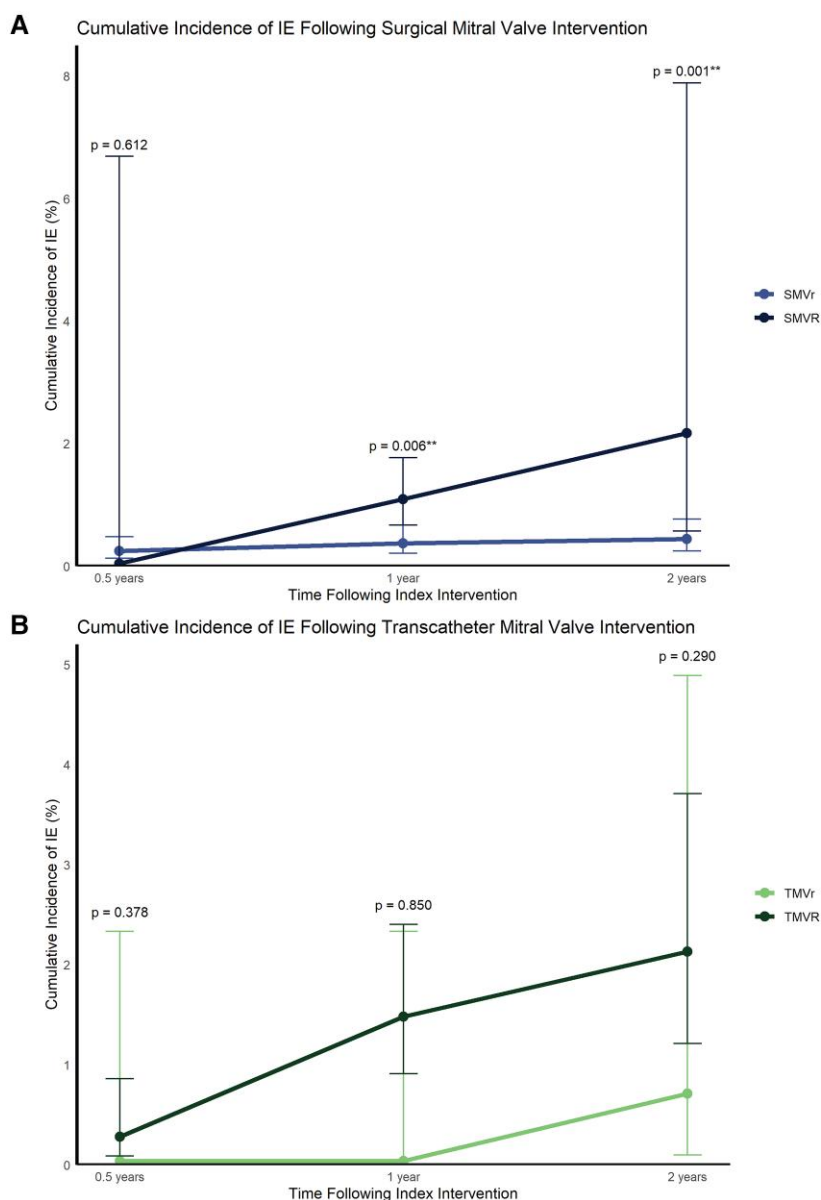


Figure 5 A) Cumulative incidence of infective endocarditis (IE) at specific time points following surgical mitral valve intervention. SMVr, surgical mitral valve repair; SMVR, Surgical Mitral Valve Replacement. $P < .01$ denoted with '**'. B) Cumulative incidence of IE at specific time points following transcatheter mitral valve intervention. TMVr, Transcatheter Mitral Valve Repair; TMVR, Transcatheter Mitral Valve Replacement

Limitations

The analysis is based on heterogeneous, primarily observational, data, with variability in and lack of reporting of patient background characteristics, timings and type of follow-up, and timings of IE. Where possible, meta-regression and meta-analysis tools have been used to account for confounding with respect to IE and baseline characteristics, but unmeasured confounding and selection bias in observational data cannot be excluded. Significant differences in the age, comorbidity burden, and frailty preclude meaningful comparisons between surgical and transcatheter populations. There was additionally variability in and lack of standardization of definitions of IE, and variability in reporting of timing of incidence. Duration of follow-up for transcatheter intervention was notably short, with mean weighted follow-up of 0.3 years and 1.0 years for TMVr and TMVR respectively, undermining incidence and timing calculations. In addition, patients with active IE were excluded from the analysis, but incomplete reporting is a possibility. The findings of this study are descriptive, and describe hypotheses that require validation in prospective, ideally randomized studies.

Conclusions

IE is an uncommon but important complication of MVR or replacement. The rates of IE following SMVR are significantly higher than following SMVr over long-term follow-up, while the rates of IE following TMVR are numerically but not significantly higher than following TMVr over long-term follow-up. The increased risk of IE in patients undergoing SMVR occurs late and therefore does not appear to be related to factors at the time of procedure. The rates of IE following TMVR are significantly higher than following SMVR, and following TMVr are significantly higher than following SMVr, over long-term follow-up; however, inherent differences in the baseline characteristics of surgical and transcatheter populations undermines meaningful direct comparison of the relative rates of IE following these different approaches. Pooled analyses of randomized controlled trials that account for these differences are required to meaningfully compare the rates of IE following surgical and transcatheter interventions.

Acknowledgements

Many thanks to Katerina Dangas (Oxford Heart Centre, UK), Danuzia Silva (Mayo Clinic, USA), and Parth Patel (Mayo Clinic, USA) for their contribution to study screening, and to Matthew Henry (Health Care Libraries, University of Oxford) for his assistance with performing literature searching.

Author contributions

Jonathan Vibhishanan (Conceptualization [supporting], Data curation, Investigation, Project administration, Writing—original draft [lead], Methodology, Visualization, Writing—review & editing [equal]), Mark Zorman (Conceptualization, Investigation [supporting], Formal analysis, Software, Visualization [lead], Methodology, Writing—review & editing [equal]), Basimah Malik (Data curation, Investigation, Writing—review & editing [supporting]), Marco Coronelli (Investigation [supporting]), Akshaya Kumar (Investigation [supporting]), Jonathan Hampshire (Investigation [supporting]), Katherine Heylen (Investigation [supporting]), Anurag Choksey (Investigation [supporting]), Kate Eastwick-Jones (Investigation [supporting]), Sam Dawkins (Supervision [supporting]), James D. Newton (Investigation [supporting]), Bernard D. Prendergast (Supervision [supporting]), and Thomas J. Cahill (Conceptualization, Supervision [lead], Writing—review & editing [equal]).

Supplementary data

Supplementary data are available at *European Heart Journal – Valvular and Structural Heart Disease* online.

Declarations

Data Availability

No data were generated or analysed for this manuscript.

Disclosure of Interest

The authors have no conflicts of interest to declare.

Funding

The authors received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical Approval

Ethical Approval was not required.

Pre-registered Clinical Trial Number

None supplied.

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