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Mechanical and bioprosthetic valves in young women: a systematic review and meta-analysis of cardiac, maternal, and fetal outcomes

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ABSTRACT

Valve replacement for the heart in young women, particularly those who are pregnant, is challenging. It requires finding the right balance between valve durability, managing anticoagulation, and ensuring positive reproductive outcomes. This systematic review and meta-analysis compared mechanical prosthetic (MP) and bioprosthetic valves (BP) across cardiac, maternal, and fetal outcomes. Nine studies were included following a comprehensive literature search. The analysis revealed MACE invol.

Keywords: bioprosthetic valve, heart valve replacement, mechanical prosthetic valve, pregnancy, young women.
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INTRODUCTION

When dealing with severe valvular illness, heart valve replacement is an essential operation, particularly in young women of childbearing age. For these women, the decision between bioprosthetic and mechanical valves is complex, with each option carrying unique considerations for both maternal and fetal outcomes. While mechanical valves offer superior durability and lower long-term reoperation rates, their reliance on lifelong anticoagulation introduces significant maternal risks, including thromboembolism, hemorrhage, and anticoagulation-related complications during pregnancy.[1] In contrast, while bioprosthetic valves reduce the need for anticoagulation, there is a higher chance of structural valve deterioration associated with them, which might result in reoperation being necessary for younger patients.[2]

The decision between valve types is further complicated because of changes in both physiology and hemodynamics, prosthetic valves are subject to greater strain during pregnancy.[3] Mechanical valves increase the risk of valve thrombosis and other maternal problems during pregnancy, while bioprosthetic valve recipients may face challenges related to valve degeneration over time.[4] Despite advancements in surgical techniques and valve technology, there remains considerable uncertainty regarding the optimal prosthetic valve choice for young women, particularly those planning pregnancies.

This investigation aims to compare cardiac, maternal, and fetal outcomes between bioprosthetic and mechanical valves in young women, with a focus on identifying the benefits and risks associated with each valve type. By addressing this knowledge gap, we seek to provide evidence-based insights to guide clinical decision-making and improve outcomes for this unique patient population.

METHODS

Study Design

We performed a comprehensive search on electronic databases: PubMed and ScienceDirect. The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines were followed to ensure high-quality and transparent reporting in this systematic review and meta-analysis.[5] The search strategy combined keywords and Boolean operators, using the terms: ((bioprosthetic valve) OR (biological valve) OR (mechanical) OR (mechanical valve)) AND ((young) OR (young age) OR (Women) OR (Pregnancy) OR (childbearing)). The search was conducted until August 2024. Additional manual searches of reference lists from relevant articles were performed.

Inclusion and exclusion criteria

The primary emphasis of the inclusion criteria was research about bioprosthetic or mechanical heart valve replacement in women who were either youth (≤ 50 years old) or of childbearing age. Eligible studies had to provide data on cardiac outcomes (major adverse cardiac events/MACE, thromboembolic events, structural valve deterioration/SVD, re-operation or redo surgery), maternal outcome (pregnancy loss), or fetal outcome (preterm delivery). Studies without sufficient data or those that did not differentiate between valve types were excluded. Case reports, editorials, and conference abstracts were also not included.

Outcomes of interest

Cardiac outcomes: MACE refers to a composite of severe cardiac complications, including cardiac death, MI, heart failure, and thromboembolic events.[6] Thromboembolic events involve blood clots or emboli obstructing blood flow, such as valve thrombosis, stroke, or systemic embolism.[7] Structural valve deterioration (SVD) describes the progressive degeneration or dysfunction of a bioprosthetic valve, characterized by calcification, leaflet tearing, or stenosis, often necessitating reoperation.[2] Re-operation or redo surgery refers to a surgical procedure performed to replace or repair a previously implanted prosthetic heart valve due to dysfunction or complications.

Maternal outcome: Pregnancy loss encompasses any spontaneous or medically induced termination of pregnancy. This includes miscarriage (fetal death occurring after 20 weeks of gestation), stillbirth (fetal death occurring before 20 weeks of gestation), and elective termination.

Fetal outcome: Birth that takes place before 37 weeks of gestation is referred to as preterm delivery. This outcome is often associated with neonatal morbidity or mortality.

Data extraction and quality assessment

The data was retrieved separately by two reviewers (IKAPH, PFKP) using a uniform data collecting form. We collected data from studies including author, publication year, study design, valve types, patient demographics, and outcome metrics. These included maternal and fetal outcomes as well as cardiac outcomes. A well-known instrument for observational studies, the Newcastle-Ottawa Scale (NOS) was used to evaluate the included publications' systematic quality.[8] Studies were classified as low quality (<5 points), moderate quality (5-7 points), or high quality (>7 points). Discrepancies between reviewers discussed or consulted with other reviewers to resolve (KPY, IWS).

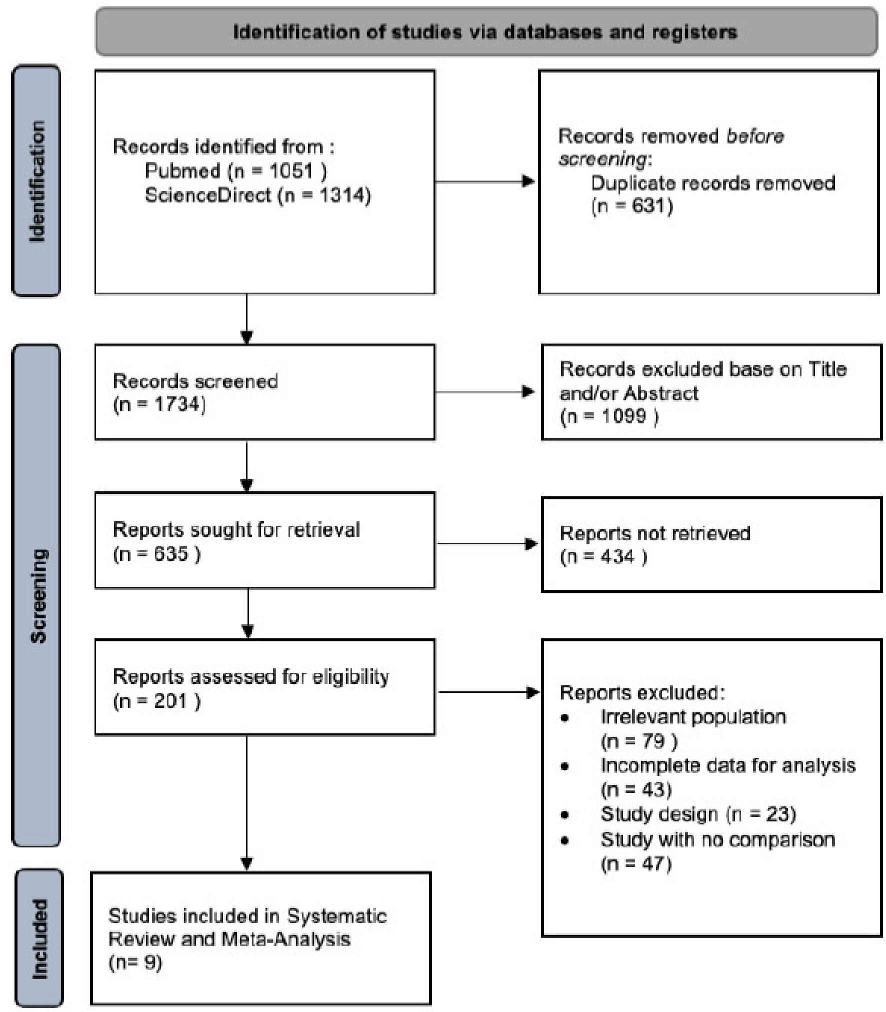

Figure 1. PRISMA flow diagram.

Statistical analysis

A meta-analysis was conducted using RevMan 5.4.1. Odds Ratio (OR) with 95% CIs were calculated. When measuring heterogeneity using the I^2 statistic, a value of 25% was considered low, 50% moderate, and 75% high. To assess the possibility of publication bias, funnel plots were used.

RESULTS

Study Selection and Characteristics

We found 1,314 records in total from ScienceDirect and 1,051 from PubMed, yielding 1,734 total records after the elimination of duplicates. After the abstracts and titles were checked, 635 papers were examined, with 201 assessed for eligibility. The final tally for the studies included in the meta-analysis and systematic review was nine.[3,9–16] The flowchart of studies selection and identification are summarized in Figure 1. The included studies featured 4,874 patients with mechanical MP and 1,556 patients with BP, focusing on young women or women of childbearing age. Valve sites varied across studies, with mitral valve replacements predominating in both BP and MP groups. The details of the study characteristics as stated in Table 1.

Quality of Included Studies

The quality assessment using the Newcastle-Ottawa Scale (NOS) demonstrated all research was of moderate to first-rate, with ratings beginning at 7 to 8, as seen in Table 2. All studies were retrospective cohort studies.

Cardiac Outcomes

MACE was reported in six studies. The pooled analysis showed no statistically

Table 1. Characteristics of Included Studies

Study	Population	Patients (n)		Age, Mean (SD)		Pregnancies, n (%)		Valve Sites	
		MP	BP	MP	BP	MP	BP	MP	BP
North et al., 1999	Women aged 12-35 undergoing valve replacement	178	73	27.0 (5.7)	23.4 (6.0)	50 (28)	40 (55)	AVR: 25%, MVR: 72%, TVR: 3%	AVR: 14%, MVR: 75%, TVR: 11%
Sadler et al., 2000	Women aged 12–35 who conceived after valve surgery	50	33	23.7	20.6	50 (100)	33 (100)	MVR: 86%, MVR + AVR or TVR: 14%	MVR: 100%
Bozso et al., 2020	Non-pregnant women aged <50 undergoing AVR	57	57	38.2 (8.9)	39.8 (9.7)	NR	NR	AVR: 29.8, AVR + MVR: 19.3%	AVR: 40.4, AVR + MVR: 14%
Batra et al., 2018	People who are 50 years old or younger who have had a prosthetic heart valve placed and go on to get pregnant	217	241	25.6 (7.6)	26.4 (7.0)	217 (100)	241 (100)	AVR: 43%	AVR: 65%
Lameijer et al., 2018	Pregnant there was no discernible disparity between the MP and BP categories. h prosthetic heart valves	12	40	NR	NR	12 (100)	40 (100)	AVR: 75%	AVR: 47.5%
Lawley et al., 2014	Pregnant there was no discernible disparity between the MP and BP categories. h prosthetic heart valves	20	44	NR	NR	20 (100)	44 (100)	MVR:50%, AVR: 30%	MVR: 25%, AVR: 20%
Singab et al., 2020	There was no discernible disparity between the MP and BP categories. h mitral valve prostheses	181	174	46.5 (10)	47.6 (9.9)	132 (73)	134 (77)	MVR: 100%	MVR: 100%
Ng et al., 2023	Pregnant there was no discernible disparity between the MP and BP categories. h prosthetic valves	4152	874	29	30	4152 (100)	874 (100)	NR	NR
Bouhout et al., 2014	Pregnant there was no discernible disparity between the MP and BP categories. h aortic valve replacements	7	20	NR	NR	7 (100)	20 (100)	AVR: 100%	AVR: 100%

Abbreviations: NR= not reported, MP= mechanical prosthetic valve, BP= bioprosthetic valve, AVR= aortic valve replacement, MVR= mitral valve replacement, TVR= tricuspid valve replacement.

significant difference between MP and BP groups (OR: 1.31, 95% CI: 0.82–2.09, p = 0.26), with moderate heterogeneity (I^2 = 42%). Thromboembolic events occurred at a significantly greater rate in the MP group compared to the BP group. (OR: 6.59, 95% CI: 3.41–12.74, p < 0.001), with no heterogeneity (I^2 = 0%). Structural valve deterioration (SVD) was significantly lower in the MP group compared to the BP group (OR: 0.01, 95% CI: 0.00–0.70, p = 0.03), but with substantial heterogeneity (I^2 = 79%). For re-operation or redo surgery, the MP group had lower risk and showed superior results than the BP group (OR: 0.06, 95% CI: 0.01–0.32, p = 0.001, I^2= 57%). The forest plots for cardiac outcomes are stated in Figure 2A-D.

Maternal Outcome

Pregnancy loss was reported in five studies (Figure 2E). Compared to the BP group, the MP group had a much greater risk of pregnancy loss, according to the pooled study (OR: 4.62, 95% CI: 1.87–11.40, p < 0.001), with high heterogeneity (I^2 = 75%).

Fetal Outcome

Preterm delivery was reported in six studies (Figure 2F). The pooled odds ratio favored the BP group (lower risk with BP compared to MP), whereas the disparity did not reach statistical significance. (OR: 2.20, 95% CI: 0.86–5.58, p = 0.10). A great deal of heterogeneity (I^2 = 83%).

Publication Bias

Funnel plots for all outcomes were visually inspected (Figure 3), showing some asymmetry, particularly for pregnancy loss and thromboembolic events. This suggests potential publication bias, which may influence the robustness of the results.

DISCUSSION

This systematic review and meta-analysis compared the outcomes of mechanical MP and BP in young women, with a focus on cardiac, maternal, and fetal outcomes. The findings provide important insights into the potential hazards and advantages linked to each valve type, highlighting key considerations for clinical decision-making in this unique patient population.

MACE was comparable between MP and BP, with no statistically significant difference observed. This suggests that the overall cardiac risk profile of the two valve types may be similar, although the individual components of MACE, such as thromboembolic events, showed clear differences. In the MP group, thromboembolic events occurred at a much higher rate, underscoring the need for meticulous anticoagulation management in these patients. Economy and Valente (2015) reinforce this finding, highlighting the prothrombotic state of pregnancy and the complexity of achieving adequate anticoagulation in women with mechanical heart valves. They reported

Table 2. The Newcastle-Ottawa Scale qualitative analysis of the included studies

Author	Study design	NOS Score			Total score
		Selection	Comparability	Outcome	
North et al., 1999	Retrospective	★★★	★★	★★	7
Sadler et al., 2000	Retrospective	★★★	★★	★★★	8
Bozso et al., 2020	Retrospective	★★★	★★	★★	7
Batra et al., 2018	Retrospective	★★★	★★	★★★	8
Lameijer et al., 2018	Retrospective	★★★	★★	★★★	8
Lawley et al., 2014	Retrospective	★★★	★★	★★★	8
Singab et al., 2020	Retrospective	★★★	★★	★★★	8
Ng et al., 2023	Retrospective	★★★	★★	★★	7
Bouhout et al., 2014	Retrospective	★★★	★★	★★★	8

a valve thrombosis rate of 4.7%, with half of these events occurring during the transition from VKAs to low molecular weight heparin (LMWH).[17]

This critical period aligns with our findings of heightened thromboembolic risks and further underscores the importance of vigilant anticoagulation management, particularly during pregnancy. Report from Suri et al. Regarding the management of anticoagulation throughout pregnancy, no significant difference was seen between the MP and BP groups. Using mechanical valve prostheses is difficult since no known treatment is completely safe for the mother and the unborn child. This investigation compared oral anticoagulants (acenocoumarol) and heparin, with oral anticoagulants increasing thrombotic risks and heparin causing more hemorrhagic complications. This investigation found 72.1% live births but higher spontaneous abortions with acenocoumarol and significant maternal risks, emphasizing the need for tailored care.[18]

Structural valve deterioration (SVD), on the other hand, was significantly more common in the BP group. This aligns with existing literature indicating that bioprosthetic valves, while advantageous in terms of reduced thromboembolic risk, are prone to degeneration, particularly in younger populations with higher cardiac output demands. SVD in bioprosthetic valves is common due to mechanical stress, calcification, immune responses to residual antigens, and atherosclerotic processes.[19] Sbarouni and Oakley also noted accelerated deterioration of bioprosthetic valves during pregnancy, necessitating reoperation in some cases.[20]

Our analysis also showed that re-operation was increased in the BP group compared to the MP group. Our study did not evaluate the long-term durability between MP and BP in young women or during pregnancy. But, the study by North et al. showed that the 10-year valve loss in young women was increased in BP (82%) compared to MP (29%), with a significant relative risk (RR) of valve loss (Bioprosthetic vs. Mechanical): 2.48 (95% CI, 1.35–4.57).[9] This finding also strengthens our results that the durability of the MP group is undoubtful.

Pregnancy loss considerably increased in MP compared to BP. This finding highlights the challenges associated with managing mechanical valves during pregnancy, particularly the risks associated with anticoagulation therapy. The teratogenic effects of warfarin, along with the potential for anticoagulation-related hemorrhage or valve thrombosis, likely contribute to MP patients being at a higher risk of miscarriage.[21] In contrast, BP valves, which often do not require anticoagulation, may offer a safer alternative for women planning pregnancies, despite their shorter durability.

Although preterm delivery was more common in women with MP, the difference was not statistically significant. High heterogeneity in this analysis suggests that outcomes may vary depending on factors such as anticoagulation protocols, patient comorbidities, and the timing of valve implantation relative to pregnancy. Nevertheless, the trend toward better fetal outcomes with BP supports their use in young women who prioritize pregnancy outcomes over long-term valve durability.

The findings of this analysis highlight the complex trade-offs between valve durability, anticoagulation-related risks, and pregnancy outcomes. Mechanical valves offer superior long-term durability but at the cost of increased thromboembolic risk and poorer maternal outcomes during pregnancy. Bioprosthetic valves, while associated with better pregnancy outcomes, may necessitate earlier reoperation due to structural deterioration. The significance of considering patient preferences, reproductive goals, and the hazards linked to each valve type in making personalized decisions is highlighted by these results.

This investigation is strengthened by the inclusion of multiple high-quality studies and a rigorous methodological approach. However, limitations include considering past events of most included studies and the high heterogeneity observed in some analyses, particularly for preterm delivery. Publication bias was evident in some funnel plots, potentially influencing the robustness of the findings. Future research should focus on prospective studies and standardized reporting of outcomes to better inform clinical guidelines.

CONCLUSION

In conclusion, although mechanical valves are more long-lasting, they come with a greater risk of thromboembolic events and miscarriage. Although bioprosthetic valves improve outcomes for both the mother and the fetus, they do have some drawbacks, such as a higher risk of structural valve degeneration and the need for repeat or re-operational surgery. These results emphasize the importance of tailored treatment plans and provide crucial evidence to help young women choose replacement valves.

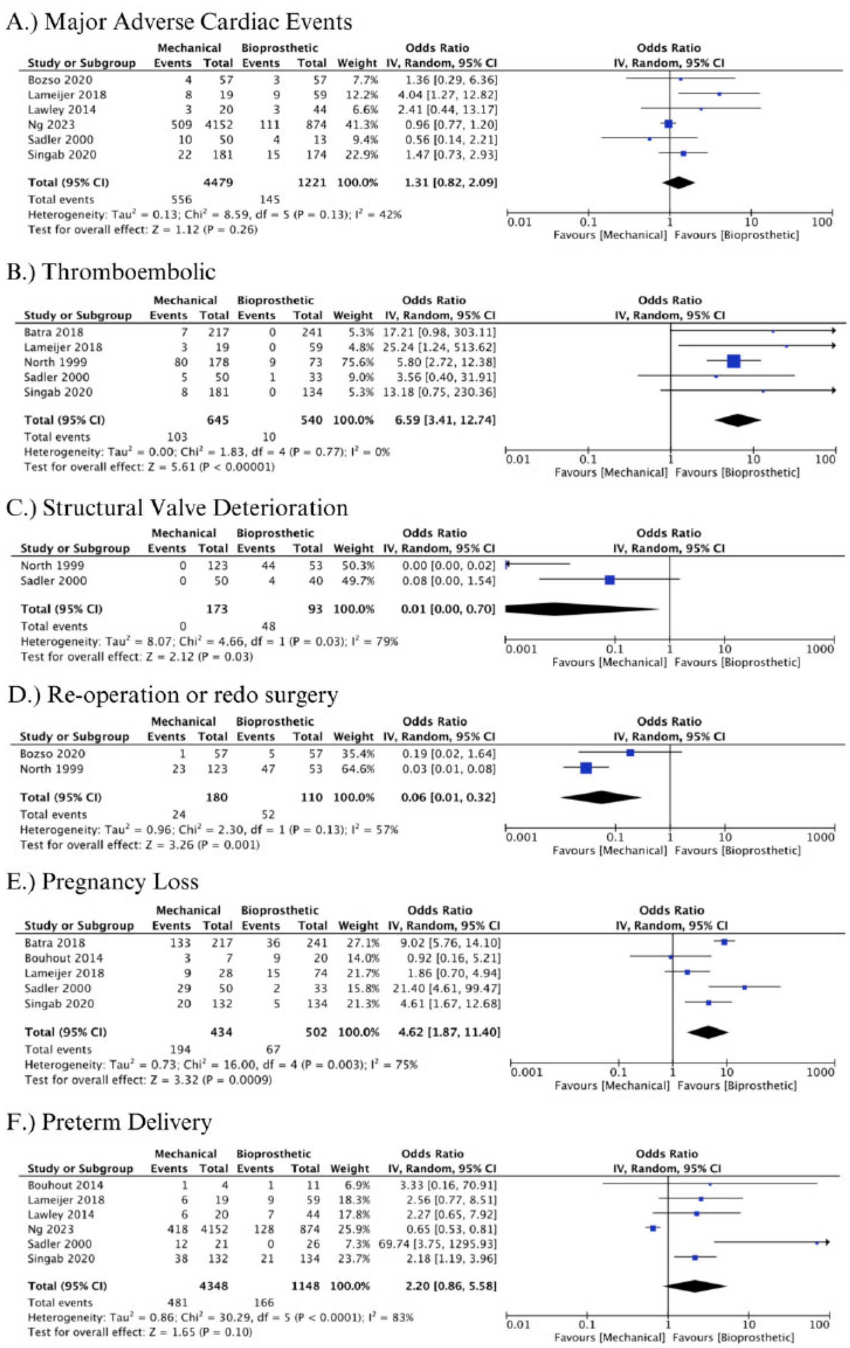

Figure 2. Forest Plots Comparing Mechanical and Bioprosthetic Valves for Cardiac, Maternal, and Fetal Outcomes. A) MACE, B) Thromboembolic Events, C) Structural Valve Deterioration (SVD), D) Re-operation or redo surgery, E) Pregnancy Loss, and F) Preterm Delivery. Odds ratios are calculated as mechanical prosthetic (MP) over BP.

CONFLICT OF INTEREST

The authors have nothing to declare and no relationship with any industries.

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DISCLOSURES

We have nothing to declare and no relationship with any industries.

AUTHORS CONTRIBUTION

I.K.A.P.H. conceptualized the study, designed the methodology, and led the systematic review and data analysis. P.F.K.P. played a role in data extraction, performed the statistical analysis, and contributed to interpreting the results. K.P.Y. provided valuable input during the study design, offered critical feedback, and ensured the intellectual quality of the manuscript. I.W.S. guided the overall direction of the study, supported methodological decisions, and carefully reviewed the manuscript for clarity and rigor. All authors worked collaboratively, accepted responsibility for the work's correctness and integrity, and signed off on the final draft.

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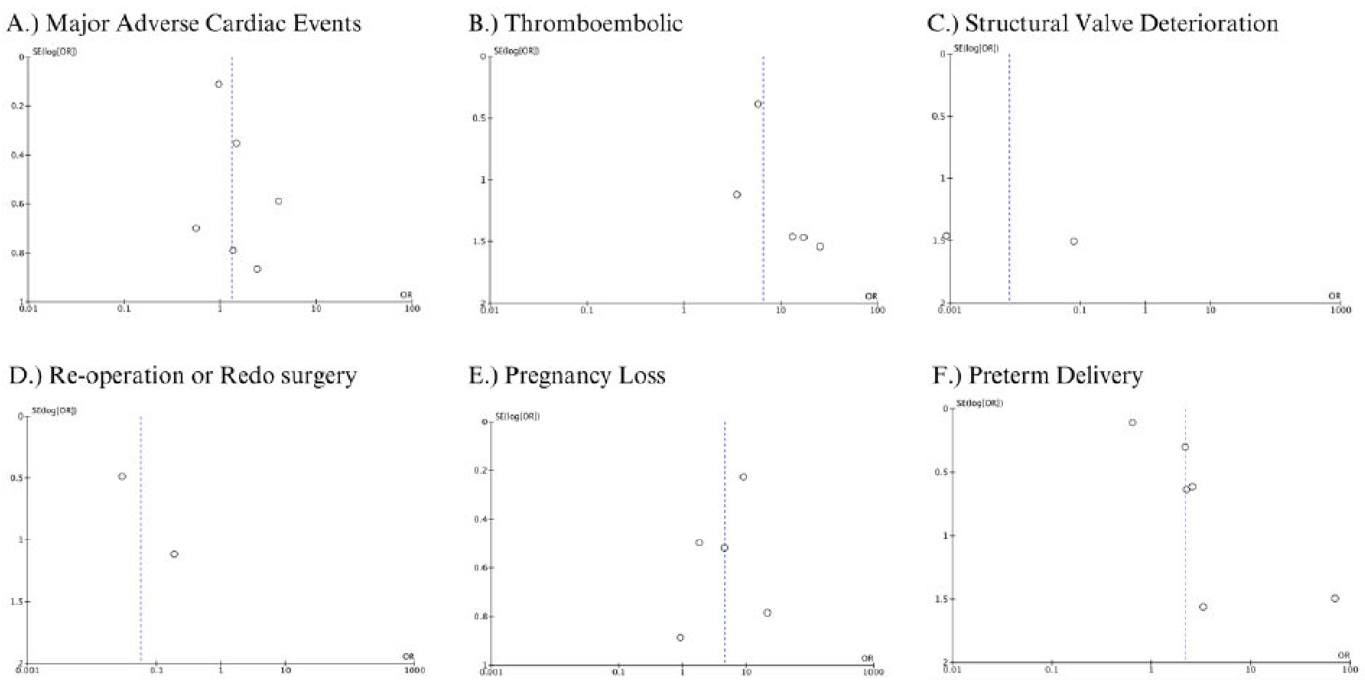

Figure 3. Funnel Plots Assessing Publication Bias for Cardiac, Maternal, and Fetal Outcomes. A) MACE, B) Thromboembolic Events, C) Structural Valve Deterioration (SVD), D) Re-operation or redo surgery, E) Pregnancy Loss, and F) Preterm Delivery.

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