Review

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Surgical closure versus transcatheter closure for ventricular septal defect post-infarction: a meta-analysis

Mohamed A. S. Aramin, MD[a], Shadi Abuhashem, MD[a], Khalid Jamal Faris, MD[a], Belal M. M. Omar, MD[a], Mohd Burhanuddin, MD[b], Puli Sai Teja, MD[b], Mark Ibraheim, MD[c,*]

Background: Surgical correction of post-infarct ventricular septal defect (PIVSD) is associated with a significant incidence of morbidity and mortality. The authors aimed to evaluate the effectiveness and safety of surgical versus transcatheter approaches in the management of PIVSD.

Methods: A systematic review and meta-analysis of retrospective from five databases including the Cochrane Library, PubMed, Web of Science, Ovid, and Scopus) until 9 March 2024 was conducted. Risk ratio (RR) for dichotomous outcomes was used and data with a 95% CI are presented.

Results: A total of 7 retrospective observational studies with 603 patients were included in the analysis. Surgical closure was associated with a significantly lower short-term mortality and lower number of residual shunt or re-intervention rate compared to percutaneous closure, with a relative risk (RR) of 1.21 (95% CI:1:00–1.46, $P = 0.05$) and 2.68 (95% CI: 1.46–4.91, $P = 0.001$), respectively. Surgical closure was associated with a non-significantly lower long-term mortality rate compared to percutaneous closure, with a relative risk (RR) of 1.10 (95% CI: 0.82–1.48, $P = 0.52$). No difference is reported when time from acute myocardial infarction (AMI) or PIVSD to intervention is compared groups, with a relative risk (RR) of -0.24 (95% CI: -4.49 to 4.2, $P = 0.91$).

Conclusion: Our meta-analysis shied the light on the significance of surgical closure in terms of short-term mortality and the need for re-intervention. However, no significant difference was observed in terms of long-term mortality and time to intervention.

Keywords: cardiac surgery, post-infarct ventricular septal defect, transcatheter

Introduction

A rare but potentially fatal side effect of acute myocardial infarction is known as post-infarct ventricular septal defect (PIVSD). Although the overall death rate for medically managed PIVSD is still higher than 94%, the frequency of PIVSD has dropped from 1–2% to 0.25–0.31% with extensive thrombolytic therapy and revascularization therapy for myocardial infarction[1,2]. Even though the 2017 guidelines from the European Society of Cardiology recommend immediate surgery for PIVSD[3], surgical correction is still linked with a high rate of morbidity and death (between 25 and 60%) and might not be appropriate for individuals who are clinically unstable in the early stages[4]. Because transcatheter closure reduces shunting immediately and is less invasive than surgical closure, it has gained popularity as a potential improvement in early mortality[5]. However, there is limited evidence of comparison between transcatheter closure and surgical closure regarding outcomes such as short-term mortality and long-term. Thus, we conducted our meta-analysis to further assess the efficacy and safety of surgical vs transcatheter in the management of PIVSD.

HIGHLIGHTS

- Our meta-analysis shied the light on the significance of surgical closure in terms of short-term mortality and the need for re-intervention. However, no significant difference was observed in terms of long-term mortality and time to intervention.
- Surgical closure showed statistically significance lower risk in terms of short-term mortality and number of residual shunt or re-intervention with no difference in other outcomes.
- The literature does not, nevertheless, provide the intervention time, and the data that are accessible are based on sporadic cases. Therefore, more research on early versus late transcatheter closure is needed.

[a]Faculty of Medicine, Al-Quds University, Jerusalem, Palestine, [b]Department of Internal Medicine, Bhaskar Medical college, Telangana, India and [c]Department of Cardiothoracic Surgery, Alexandria University Hospitals, Alexandria, Egypt

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*Corresponding author. Address: Department of Cardiothoracic Surgery, Alexandria University Hospitals, Alexandria, Egypt. Tel.: +20 112 562 1963. E-mail: getyourpaper01@gmail.com (M. Ibraheim).

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Methods

We ensured that our methodology and results adhered to systematic review and meta-analysis guidelines, including PRISMA 2020[6] and Meta-Analysis of Observational Studies in Epidemiology (MOOSE)[7] To maintain transparency, we registered our protocol on open science framework (OSF) ID: 10.17605/OSF.IO/FRWJS.

Literature search

We searched across various databases, including the Cochrane Library, PubMed, Web of Science, Ovid, and Scopus until 9 March 2024. We used the following key words: "post-myocardial infarction ventricular septal defects (VSD)", "Transcatheter Closure", "Surgical Closure".

Study selection

Regarding the Population, Intervention, Comparison, Outcome, and Study design (PICOS) strategy, studies were considered eligible for inclusion if they fulfilled the following criteria: P: Pooled patients treated for post-infarction VSD, I: Patients treated with percutaneous closure, C: Patients treated with surgical closure, O: Included at least 1 gross clinical outcome, such as [mortality rates, number of residual shunt or re-intervention, and time from acute myocardial infarction (AMI) or PIVSD to intervention (days)], and S: The study design was comparative in nature and reported on humans (retrospective/prospective observational and randomized studies were all eligible).

We specifically excluded commentaries, conference, abstracts, review articles, and animal/basic science reports, case reports, editorials, and cross-sectional studies. Additionally, we excluded non-English studies and those with unreliable data from our analysis.

After eliminating 50 duplicate studies, two screeners (A.A. and B.M.M.O.) independently conducted the primary screening by evaluating the titles and brief abstracts of the remaining 214 studies. Any discrepancies encountered during this process were resolved by the senior author (P.S.T). Subsequently, two investigators (M.A.S.A and S.A) performed the secondary screening by assessing the full texts of the selected 20 studies. To ensure accuracy, a third reviewer (K.J.F) was involved in the screening process. Finally, we excluded for four studies for being irrelevant, two reviews, three protocols, three conference papers, and one non-English study.

Data curation and tabulation

Data extraction and tabulation were performed independently by two authors (M.A.S.A. and S.A.). Any discrepancies were verified by a third author (K.J.F.). The following information was extracted from each study whenever reported: author names/affiliation, year of publication, number of patients in each arm), duration of the study OR follow-up (month); and baseline demographics including mean age, sex, left ventricular ejection fraction (LVEF), and previous percutaneous coronary intervention were also extracted as presented in (Table 1).

Study quality assessment

The quality assessment of the included studies was conducted by two independent authors (M.B. and A.A.) using the Newcastle–Ottawa Scale (NOS)[14]. The NOS evaluates studies based on three domains: selection, comparability, and outcomes. A maximum score of 9 can be achieved, with a score of 7 or higher indicating high quality. Any discrepancies that arose during the assessment process were resolved through discussion between the two authors, and if needed, a third reviewer was consulted for resolution.

Outcome definition

Our study aimed to evaluate the prognosis of postinfarct ventricular septal defects from surgical to percutaneous approach. These measures encompassed: short-term mortality ($\leq$ 30-day mortality), long-term mortality (overall mortality during the follow-up period), number of residual shunt or re-intervention (the occurrence of either an incomplete closure of the VSD or the need for additional medical procedures or surgeries after an initial VSD closure), Time from AMI or PIVSD to intervention (the time between the diagnosis to the procedure).

Statistical analysis

This analysis was performed using RevMan software[15], specifically version 5.4.1. All outcomes were combined and analyzed using a random-effects model, which calculated risk ratios (RR), or mean differences (MD) along with their corresponding 95% CIs. We used the inverse variance method with a random-effects model for all outcomes. A p value less than 0.05 was considered significant, indicating that the results were unlikely to be due to chance. Additionally, a $\chi^2 p$ value less than 0.10 was considered significant and indicated significant heterogeneity among the included studies, suggesting substantial variability in the results beyond what would be expected by chance.

Results

Literature search results and study selection

We found a total of 264 studies. We removed duplicate studies and performed an initial screening, which narrowed down the selection to 27 articles that were thoroughly examined. From this group, seven studies matched our criteria and were combined for a pairwise meta-analysis. Further details can be found at (Fig. 1).

Characteristics of included studies

In our meta-analysis, we analyzed a total of 7 observational studies[8–13,16] involving 603 patients. All the studies were retrospective and were conducted in six different countries. The follow-up duration varied, ranging from 18.11 months in the study by Ma *et al.*[13] to ~20 years in the study by Sathananthan *et al.*[9]. Further details can be found in (Table 1).

Study quality assessment

The quality of the included studies, as assessed by the NOS, ranged from six to nine points, indicating good to fair quality and a low risk of bias. Only one study achieved a score of nine[13], the rest six studies scored seven and eight points. Further details can be found at (Supplementary Table 1, Supplemental Digital Content 1, http://links.lww.com/MS9/A552).

Table 1

Summary and baseline characteristics of the included studies.

Study ID	Country	Study design	Total sample size	Sample size (N)		Duration of the study or follow-up (month)	Outcomes	Age (years) mean (SD)		Gender (male) (%)		LVEF (%)		Previous PCI (%)	
				Percutaneous closure	Surgical closure			Percutaneous closure	Surgical closure	Percutaneous closure	Surgical closure	Percutaneous closure	Surgical closure	Percutaneous closure	Surgical closure
Maltais *et al.*[8], 2008	Canada	Retrospective study	51	12	39	60	Overall mortality, Residual VSD, time from myocardial infarction to VSD diagnosis, and time from VSD diagnosis to treatment.	71.3 ± 7.7	66.6 ± 8.9	NA	NA	44	46	NA	NA
Sathananthan *et al.*[9], 2013	New Zealand	Retrospective study	25	9	16	240	Mortality rates	NA	NA	NA	NA	NA	NA	NA	NA
Heiberg *et al.*[10], 2014	Denmark	Retrospective study	37	9	28	96.3	Mortality rates, time from VSR to closure, Mean time of postprocedural survival	75.1 ± 8.4	68.2 ± 9.5	44.4	71.4	NA	NA	11.1	14.3
Trivedi *et al.*[11], 2015	France	Retrospective study	20	6	14	36	Rates of residual shunt and mortality, time to first surgical or percutaneous closure, time from myocardial infarction to VSD	75.66 ± 17.16	65.66 ± 18.94	NA	NA	47.6	47.6	NA	NA
Duan *et al.*[12], 2022	China	Retrospective study	85	34	51	123.4	Mortality rates	66.2 ± 9.1	51.6	49.2	4.3				
Giblett *et al.*[1], 2022	UK	Retrospective study	362	131	231	60	Mortality rates, t. times from AMI to treatment, and number of vessels with coronary artery disease	71 ± 9.74	67 ± 8.95	34.9	27.9	43.8	54.1	41.5	38.7
Ma *et al.*[13], 2022	China	Retrospective study	23	6	17	18.11	Mortality rates, postoperative residual shunt	66.00 ± 7.82	63.88 ± 7.61	33.3	52.9	45.33	47.76	16.7	35.3

LVEF; left ventricular ejection fraction, NA, not applicable; PCI; percutaneous coronary intervention, VSD; ventricular septal defect; VSR, Ventricular septal rupture.

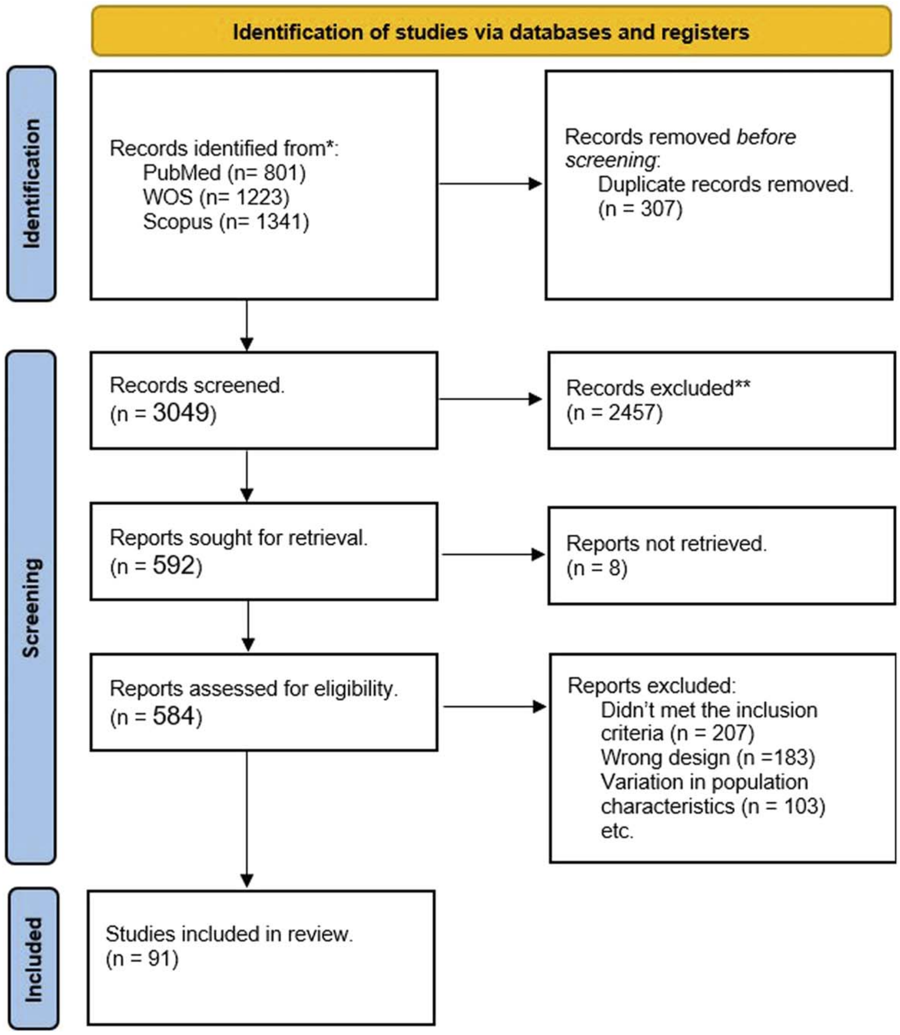

Figure 1. PRISMA flow chart of our study.

Short-term mortality

We conducted an analysis of short-term mortality, focusing on 7 studies that involved a total of 207 patients in the percutaneous closure group and 396 patients in the surgical closure group. Our findings revealed that surgical closure was associated with a significantly lower short-term mortality rate compared to percutaneous closure, with a relative risk (RR) of 1.21 (95% CI: 1:00–1.46, $P = 0.05$). The analysis indicated no heterogeneity among the studies, with an I^2 value of 0% (Fig. 2A).

Long-term mortality

We conducted an analysis of long-term mortality, focusing on 6 studies that involved a total of 195 patients in the percutaneous closure group and 357 patients in the surgical closure group. Our findings revealed that surgical closure was associated with a non-significantly lower long-term mortality rate compared to percutaneous closure, with a relative risk (RR) of 1.10 (95% CI: 0.82–1.48, $P = 0.52$). The analysis indicated low heterogeneity among the studies, with an I^2 value of 36% (Fig. 2B).

Number of residual shunt or re-intervention

We conducted an analysis of long-term mortality, focusing on 7 studies that involved a total of 198 patients in the percutaneous closure group and 341 patients in the surgical closure group. Our findings revealed that surgical closure was associated with a significantly lower number of residual shunt or re-intervention compared to percutaneous closure, with a relative risk (RR) of 2.68 (95% CI: 1.46–4.91, $P = 0.001$). The analysis indicated moderate heterogeneity among the studies, with an I^2 value of 52% (Fig. 3A).

Time from AMI or PIVSD to intervention (days)

We conducted an analysis of Time from AMI or PIVSD to intervention (days), focusing on 4 studies that involved a total of 158 patients in the percutaneous closure group and 303 patients in the surgical closure group. Our findings revealed approximately no difference between both groups, with a relative risk (RR) of – 0.24 (95% CI: – 4.49 to 4.2, $P = 0.91$). The analysis indicated high heterogeneity among the studies, with an I^2 value of 75% (Fig. 3B).

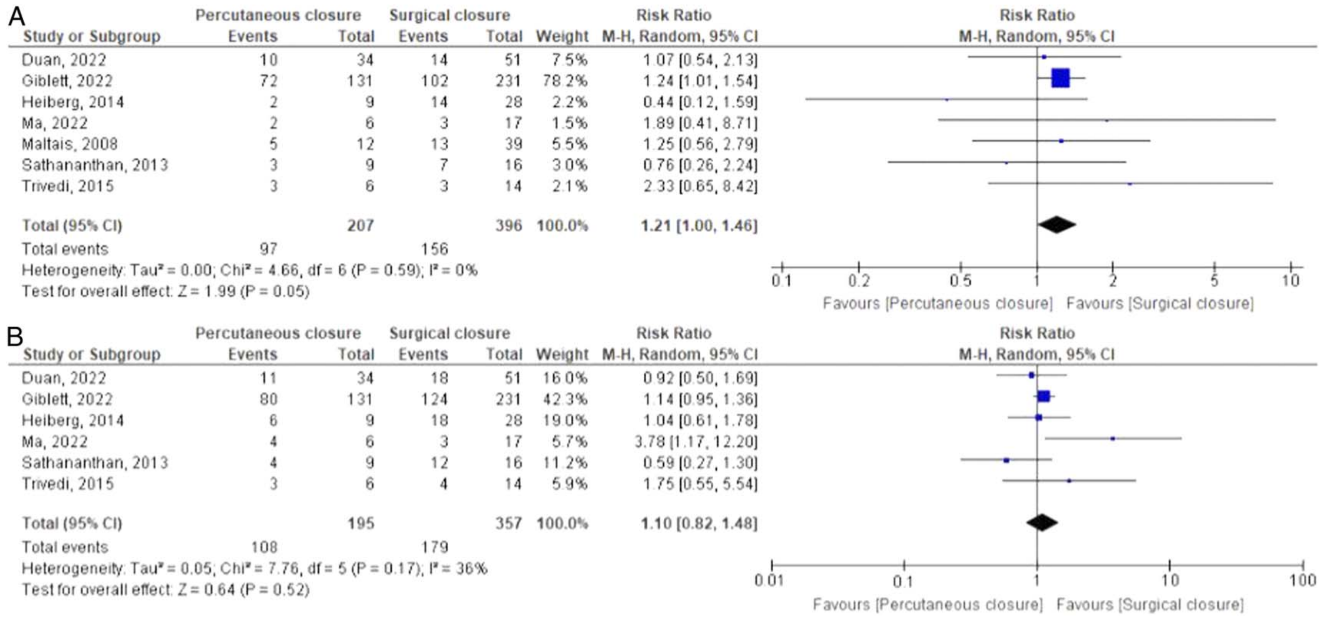

Figure 2. (A) Short-term mortality. (B): Long-term mortality.

Discussion

Our meta-analysis is the first to investigate the usage of surgical versus percutaneous/transcatheter closure of ventricular septal defect as a complication post-MI. We included seven studies in which surgical closure showed statistically significance lower risk in term of short-term mortality and number of residual shunt or re-intervention with no difference in other outcomes.

PIVSD is a dangerous illness that, if left untreated, can cause a sudden left-to-right shunt and deteriorating heart function[11]. Although it is best to close the wound as soon as possible, delaying surgery permits scarring tissue to grow, which facilitates healing. Large studies have demonstrated that surgery postponed by at least one week after PIVSD considerably decreases mortality compared to surgery during the first week following PIVSD, even if the best time to delay surgery is still up for debate[17,18]. Individuals who frequently exhibit cardiogenic shock may not be good candidates for surgery, which can complicate the clinical decision-making process about the appropriateness and scheduling of operation.

Lock and colleagues reported the first case of transcatheter intervention for PIVSD[19]. Because of its quick shunt reduction and little invasiveness, it was later suggested as a bridging therapy to surgical intervention, with the potential to be a successful early-phase treatment even for patients in cardiogenic shock. According to Calvert *et al.*[20], it is beneficial for survival to reduce the shunt volume by at least two-thirds. A pooled event

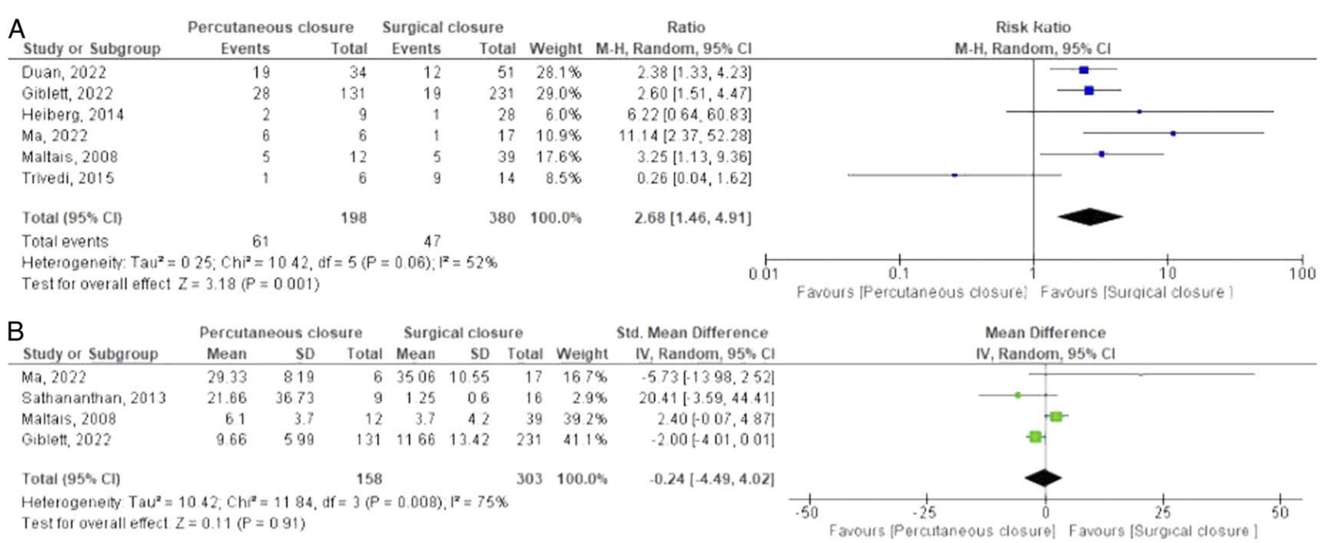

Figure 3. (A) Number of residual shunt or re-intervention. (B) Acute myocardial infarction or post-infarct ventricular septal defect to intervention (days).

rate above eighty percentage was observed in terms of need for shunt reduction in a recent single-arm meta-analysis on transcatheter closure [21]. Transcatheter closure for PIVSD is anticipated to quickly improve hemodynamics with minimal invasiveness and may provide a chance to stabilize critical conditions until definitive treatments, such as surgical closure or additional transcatheter closure, are implemented. This is because shunt reduction has a satisfactory success rate. Multiple therapies have been shown to reduce in-hospital mortality[12]. A considerable proportion of patients in our pooled trials received more than one treatment, which could account for the equal short- and long-term death rates between transcatheter closure and surgical closure[12,16].

According to our meta-analysis, there was a noteworthy difference between our groups' incidence of residual shunt or re-intervention. Left ventricular rupture and subsequent infectious endocarditis were considered risks associated with residual shunt. For patients with a sizable residual shunt, interventions may persist. It is possible that some of the medications given to patients who had residual shunts were bridging therapies, which could have counteracted the effects of the residual shunt. In our investigations, some authors[8,9] provided a strategy for initial intervention; however, the residual shunt therapy course is not well-studied. However, there was no discernible difference in the duration between the two groups between the diagnosis of AMI or PIVSD and the intervention. According to our meta-analysis, both groups' intervention timing was comparable, which produced comparable rates of morbidity and death. It is advised to postpone surgery; the exact timing of transcatheter closure should remain unclear. Trivedi *et al.*[11]. favored late transcatheter closure; however, Calvert *et al.*[20]. demonstrated superior early closure results. Tang and colleagues suggested postponing this surgery till the clinical circumstances permit, which should be feasible in more than one week[20]. The literature does not, nevertheless, provide the intervention time, and the data that is accessible is based on sporadic cases. Therefore, more research on early versus late transcatheter closure is needed.

Limitations

Our study has many limitations as any meta-analysis from the lack of individual patients' data, which hinders us from investigating several important outcomes, as well as the observational nature of the included studies with differences in baseline characteristics, which may affect the ability to generalize our data, which as well affected and increased our heterogeneity percentage per outcome. Moreover, other data is still missing to properly answer our study question such as location of VSD and the time of intervention, which are still questionable and without definitive identification in any of the included studies, which we think are important prognostic values as for example early closure can't be compared to late closure. Therefore, we call for randomized controlled trials to be conducted on such a pivotal debate in terms of patients suffering from post-MI VSD to provide the proper evidence-based clinical management.

Conclusion

Our meta-analysis shied the light on the significance of surgical closure in terms of short-term mortality and the need for re-intervention. However, no significant difference was observed in terms of long-term mortality and time to intervention.

Ethical approval

Not applicable.

Consent

All authors reviewed and agreed on the final version of the manuscript.

Human ethics and consent to participate statement

Our manuscript was not applied on human beings and thus requires no ethical approval.

Source of funding

Not applicable.

Author contribution

M.B. and M.I. formulated the research idea and prepared the search strategy. A.A., M.A.S.A., S.A., and K.J.F. performed the screening and data extraction, M.A.S.A. and B.M.M.O. did the analysis, and K.J.F., P.S.T., and S.A. wrote the primary draft, which was further edited and modified by M.I. and B.M.M.O. All authors reviewed and agreed to the final version of the manuscript.

Conflicts of interest disclosure

The authors declare no conflicts of interest.

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Guarantor

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Availability of data and materials

All data are available and attached.

Provenance and peer review

Not commissioned, externally peer-reviewed.

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